# REVISION RECORD

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CHAPTER 1 OVERVIEW OF THE DTX DESIGN CRITERIA

1.1 Purpose and Extent

The DTX Design Criteria establishes the engineering requirements for the Downtown Rail Extension (DTX) project of the Transbay Program in San Francisco, California.

The DTX design criteria apply to the design of all DTX facilities, unless otherwise directed by the specific facility owner. The criteria provide a uniform basis and framework for the DTX design that meet the requirements of the Transbay Joint Powers Authority (TJPA) and the rail operators—Caltrain and the California High-Speed Rail Authority.

1.2 DTX Project Description

The DTX will connect Caltrain’s regional rail system and the statewide high-speed rail system to the Salesforce Transit Center in downtown San Francisco. The Salesforce Transit Center is owned and operated by the TJPA and is referred to throughout this manual as the Transit Center. The rail alignment will be constructed principally below grade to provide a critical link for Peninsula commuters and travelers on the state’s future high-speed rail system.

The DTX alignment begins in the below-grade Transit Center rail station at First and Mission streets. At the west end of the station, the station’s six tracks transition to two tracks through a cut-and-cover throat structure and continue in a mined tunnel southward under Second Street and westward under Townsend Street to a new underground station at Fourth and Townsend streets. West of the station, near Seventh and Townsend streets, the tracks ascend to grade via a u-shaped retained cut (referred to as the “u-wall”), and the alignment continues southward at-grade to Sixteenth Street, south of the existing Caltrain terminal station and 4th and King Railyards. A tunnel stub box extends side-by-side with the u-wall to allow for a connection to the future Pennsylvania Avenue Extension—a tunnel being developed by the San Francisco County Transportation Authority that will grade-separate the rail alignment from surface streets. Including revenue and non-revenue at-grade trackwork and stations, the total construction length of the DTX is approximately 2.2 miles. The main elements of the DTX project are as follows:

Transit Center train box extension. The train box extension will extend the existing below-grade structural box of the Transit Center eastward from the east side of Beale Street to the TJPA’s property line to extend the platform lengths and provide ventilation and emergency exiting from the east end of the train box. A standalone structure, a pedestrian entrance and exit, will be located on Beale Street on the northern side of the train box extension. The train box extension, inclusive of the pedestrian entrance/exiting structure, will be constructed under TJPA property with an open-cut method.

Transit Center fit-out. The fit-out of the two-level below-grade rail station at the Transit Center will include facilities for rail operations, customer service, and ancillary support. The lower concourse, one level below the grand hall, will house ticketing, passenger waiting, and support spaces for Caltrain and the California High-Speed Rail Authority—the primary tenants—as well as leasable retail space. On the level below, six tracks and three center platforms will serve commuter and high-speed trains. Back-of-house support spaces will also be built on this level to support rail service.
Cut-and-cover structures. Cut-and-cover construction will be used along Second Street, Townsend Street, and in portions of the 4th and King Railyards for the following structures:

- Throat structure located at Second and Howard streets at the northern end of the DTX alignment where the two-track alignment widens to six tracks at the west end of the Transit Center
- Tunnel east of the Fourth and Townsend Street Station along Townsend Street
- Fourth and Townsend Street Station
- Tunnel west of the Fourth and Townsend Street Station along Townsend Street
- U-wall and tunnel stub box along Townsend Street west of Sixth Street to bring the tracks to grade and allow for a connection to the Pennsylvania Avenue Extension, a planned grade separation tunnel project being led by the San Francisco County Transportation Authority

Mined tunnel. Sequential excavation method mining is being considered for the tunnel along portions of Townsend Street and Second Street. The mined tunnel extends from the west side of Third and Townsend streets to Clementina and Second streets. The tunnel is primarily two tracks but expands to three tracks as it approaches the throat structure. The length of the mined portion of the tunnel is approximately 0.65 miles.

Fourth and Townsend Street Station. The Fourth and Townsend Street Station will serve Caltrain and high-speed rail passengers with destinations in the South of Market area or transferring to the San Francisco Municipal Railway (Muni) Central Subway. The street level station entrances and exits along Townsend Street will lead to two levels below grade: a concourse and a train platform level. The concourse level will accommodate passenger amenities such as restrooms, ticketing machines, maps, and schedule information. This level will also house mechanical and electrical rooms and staff areas. The platform level will have two tracks, an 875-foot center platform for Caltrain passengers, and two 800-foot side platforms for high-speed rail passengers. The underground station will be constructed using cut-and-cover techniques.

Ventilation and emergency egress. Ventilation and emergency egress structures will house equipment for the ventilation of the tunnel and include emergency egress to allow passengers to evacuate safely from the tunnels to grade in the event of an incident. Ventilation shafts will be located at either end of the Fourth and Townsend Street Station and the underground station at the Transit Center. Two standalone ventilation and emergency egress structures will be located along the tunnel alignment; these will be constructed on parcels next to the DTX tunnel outside of the street right-of-way, one at Third and Townsend streets and the other at Second and Harrison streets.

Trackwork. Trackwork includes the mainline tracks through the tunnel and stations as well as 0.4 miles of at-grade maintenance-of-way and turnback tracks within the existing Caltrain right-of-way.

Systems. Systems include rail systems such as traction power, overhead contact, train control, signaling, radio, and network systems; mechanical, electrical, plumbing, fire-life safety, and security systems for the tunnel, stations, and ventilation and emergency egress structures; and other support systems, such as closed-circuit television, fare collection, and passenger display information systems.

1.3 DTX Project Goals

As identified in the Transbay Program’s environmental documents, the principal goals of the DTX project are to:

- Improve Caltrain service by providing direct access to downtown San Francisco
Enhance connectivity between Caltrain and other major transit systems
Provide direct access to downtown San Francisco for future high-speed rail service
Reduce traffic congestion on U.S. Highway 101 and Interstate 280
Improve regional air quality through reduced auto emissions
Promote opportunities to develop land uses in conjunction with the proposed transportation facilities in a manner consistent with the City of San Francisco’s land use goals and supportive of transit use

1.4 Operational Objectives

The DTX design must meet the following operational objectives:
• Provide safe and reliable movement of passengers and employees throughout the DTX system
• Minimize disruption to existing rail service
• Minimize project costs (i.e., capital, operating, and maintenance costs)
• Avoid adverse environmental impacts
• Minimize construction and operational impacts to neighboring communities
• Accommodate staged construction and provide capacity for system expansion, including future tunnel connections
• Modify the train box and advance construction of other rail-related infrastructure to respond to design specifications issued by the California High-Speed Rail Authority to accommodate future high-speed train service and Caltrain
• Locating sites for and constructing ventilation shafts/emergency tunnel exit structures and underground facilities to meet emergency response needs of system operations

1.5 Interface Coordination

The DTX designer must identify and coordinate interfaces with projects, plans, and infrastructure that may affect design, construction, or operation of the DTX; examples include:
• 4th and King Railyards – Prologis
• Future BART (Bay Area Rapid Transit)/Muni Pedestrian Connector – TJPA
• Central Subway – San Francisco Municipal Transportation Agency
• Future rail crossing to the East Bay – Link21
• Peninsula Corridor Electrification Project – Caltrain
• Pennsylvania Avenue Extension – San Francisco County Transportation Authority
• Private developments near the DTX alignment
• Public and private utilities, including San Francisco Public Utilities Commission’s combined sewer system improvements
1.6 Design Criteria Organization

The design criteria are organized into chapters corresponding the principal disciplines of the DTX design. Where disciplines overlap, such as communications, fire-life safety, and security, the criteria are appropriately cross-referenced. Each chapter is summarized as follows:

Chapter 1: Overview of the DTX Design Criteria. Introduction and overview of the project’s objectives and requirements and limited design criteria applicable to all or a number of project disciplines.

Chapter 2: Owner’s Requirements. Specific owner’s requirements relative to the functional and operational performance of the DTX.

Chapter 3: System Safety and Security. System safety management, reliability assurance, and safety certification requirements and specific design criteria for project security; project security features are also contained in other chapters.

Chapter 4: Environmental Requirements. General climatic setting and natural and existing built environment, which is used in conjunction with the specific design criteria presented in other chapters.

Chapter 5: Civil Design. General civil design, including survey control, roadways, and storm drainage, and requirements for maintenance and protection of traffic during project construction.


Chapter 7: Guideway Geometrics. Track geometry (horizontal and vertical alignment) and required clearances and track spacing, including physical and operational clearances for rolling stock.

Chapter 8: Trackwork. Track, including track structure, track components, other track materials, and special trackwork.

Chapter 9: Geotechnical Requirements. Geotechnical exploration, testing, and analysis as well as seismic and ground motions performance criteria.

Chapter 10: Seismic Design. Seismic design of permanent structures, including mined tunnel final linings, cut-and-cover structures, retaining structures, slopes, bridges, buildings and surface facilities, and temporary structures, including the mined tunnel initial support and the cut-and-cover excavation support structure.

Chapter 11: Protection of Existing Infrastructure. Protection through temporary support or underpinning of existing facilities, including buildings, highway structures, utilities, and other infrastructure near to or affected by the DTX construction.

Chapter 12: Structures. Temporary and permanent structures including support of excavation, retaining walls, retained cut structures (boat sections), cut-and-cover structures, passenger stations, bridges, buildings, and miscellaneous structures; the design criteria include material properties and structure loading and durability requirements.

Chapter 13: Tunnels. Temporary and permanent structures including initial support, initial lining, and final lining for mined tunnels; the design criteria include material properties and structure loading requirements.
Chapter 14: Architecture and Vertical Conveyance. Architectural and site development design criteria for project facilities including the Fourth and Townsend Street and Transit Center stations. The design criteria include platform geometry, passenger circulation criteria, sizing of public and non-public spaces, employee equipment and office room layouts, materials and finishes, vertical conveyance, and site development requirements.

Chapter 15: Fire-Life Safety. Fire-life safety systems, including fire detection, alarm, and suppression systems; emergency lighting and tunnel ventilation systems, and fire fighters’ air systems. The design criteria also include requirements for emergency egress and exit signage.

Chapter 16: Mechanical Systems. Mechanical design for DTX facilities, including station and ancillary facility ventilation and temperature control, elevators, and escalators, and plumbing and drainage systems.

Chapter 17: Electrical Systems. Electrical design for all DTX facilities, including requirements for materials and performance standards, electrical equipment and wiring, lighting, grounding, and power for tunnel operating systems, with the exception of traction electrification and high voltage services.

Chapter 18: Rail Systems. Supplemental criteria for train systems design including traction power electrification system, comprising an overhead contact system and power distribution, voice and train control communication systems, and signals and train control systems.

Chapter 19: Communications. Communications systems, including the communication backbone network requirements and project systems requirements for passenger amenities, security, and supervisory control and data acquisition.

Chapter 20: Stray Current and Corrosion Control. Corrosion control, including stray current, soil and water, and atmospheric corrosion control, including protective requirements and material selection.

1.7 DTX Projectwide Codes, Standards and Guidelines

The DTX design must comply with the requirements of government, operator, and industry codes, regulations, and standards. Specific codes, standards, and guidelines relevant to each discipline are listed in the chapter for that discipline. The lists of codes, standards, and guidelines in each chapter should not be considered exhaustive. See also Appendix B for a compiled listing.

The precedence for the application of codes and standards for each discipline is based on the specific requirements of that discipline. The code with highest precedence is listed first, as indicated in the following list:

1. Federal regulations
2. Statewide regulations
3. City and County of San Francisco codes (as applicable)
4. Operator criteria, requirements, and technical memoranda
5. Specific industry code or standard
6. California Building Code
In cases where there is no order of precedence, codes and standards are listed alphabetically, and the most stringent of the applicable code, standard, or guideline governs by default. In the case of a conflict between applicable codes and standards, the designer will propose a best practice for the particular purpose and confirm it with the TJPA.

1.7.1 Regulations

The current edition of the regulation at the time of notice to proceed for Final Design applies. Any exceptions to the requirements of the regulations will require the approval of the governing authority.

1.7.2 Operator Criteria

- Caltrain Engineering Standards, which include:
  - Design Criteria
  - Standard Drawings
  - Standard Specifications
  - Standards for Design and Maintenance of Structures
  - Standards for Excavation Support Systems
  - CADD Manual
- CHSRA Design Criteria Manual and Technical Memoranda

1.7.3 Codes and Standards

The current edition of codes and standards at the time of notice to proceed for Final Design will be applicable. Any exceptions to the requirements of the codes and standards will require the approval of the governing authority.

1.8 Variances and Changes to Design Criteria

1.8.1 Variance Request

A proposed departure from these criteria must be documented on the TJPA’s design criteria variance request form. Variance requests should be accompanied by calculations, sketches, examples of precedents, or other supporting documentation.

The TJPA’s approval of a variance request does not grant a design variance from applicable regulatory codes and standards, which are outside the scope of this manual and must be obtained through the administrative procedures governed by the agency having jurisdiction.
1.8.2 Change Control

At the conclusion of DTX Preliminary Engineering and prior to the initiation of Final Design, the DTX Design Criteria Manual will become a controlled document, and a list of controlled document holders will be appended to the manual. See the TJPA’s document control procedures for more on controlled documents.

Any proposed changes to the criteria resulting from a designer-initiated variance request, technological advances, amendments to operator design criteria, or any other reason will be reviewed by the project’s Configuration Management Working Group, and if approved, recorded in a design criteria change history document, which will contain a unique identification number for each change, the date of implementation of the change, and a description of the change.

The Configuration Management Working Group and the TJPA will approve the distribution of updated design criteria, in accordance with its document control procedures.

1.8.3 Changes to Operator Criteria

The DTX design criteria incorporate design criteria for both Caltrain and high-speed rail, with the governing criteria for each element defined by the operators. For several disciplines, the DTX design criteria supplement or amend operator criteria, as approved by the operator through a variance process.

Each of these documents is a living document and will be subject to change over the lifetime of the DTX.
CHAPTER 2 OWNER’S REQUIREMENTS

This chapter defines the TJPA’s requirements for the operation and performance of the Downtown Rail Extension (DTX) project. Conflicts between these operational and functional criteria and specific design criteria provided in subsequent chapters should be brought to the attention of the TJPA for resolution. See Chapter 1, section 1.8, Variances and Changes to Design Criteria.

The DTX design must not affect the operators’ projected levels of service as described in their respective business plans.

2.1 Operations Control

Train movements throughout the DTX track network will be governed by a centralized traffic control system or similar type system.

The primary train control facility for the DTX will be located within Caltrain’s Central Control Facility (CCF), which is not part of the DTX project. Any modifications to the CCF resulting from integrating the DTX must also be made to Caltrain’s backup facility in San Jose.

A mimic train control facility will be located in the Transit Center. The mimic facility is intended primarily for use in emergencies.

2.2 Train Operations

DTX operation will support Caltrain commuter and California High-Speed Rail Authority (CHSRA) high-speed service on dedicated platforms in the Transit Center and the Fourth and Townsend Street Station.

Normal revenue operating hours for the DTX and Transit Center will be between 4:30 a.m. and 1:30 a.m., Monday through Friday, and between 6:00 a.m. and 1:30 a.m. on weekends. However, the design must assume a 24-hour-per-day operation.

The morning peak period for the DTX will be between 6:00 a.m. and 9:00 a.m., Monday through Friday. The evening peak period for the DTX will be between 4:00 p.m. and 7:00 p.m., Monday through Friday.

Track and signal layout must accommodate a minimum capacity of 2-minute 45-second headways for combined Caltrain and high-speed rail service on each track in each direction during the peak period.

Station dwell time is defined as the period from wheel stop to wheel start and is governed by the operators, Caltrain and CHSRA, at the Transit Center. See Table 2-1.

The Fourth and Townsend Street Station must accommodate both Caltrain commuter and high-speed rail service. The minimum dwell time at the Fourth and Townsend Street Station will be 2 minutes.
Table 2-1: Transit Center Dwell Times

<table>
<thead>
<tr>
<th>Service</th>
<th>Scheduled Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caltrain</td>
<td>20</td>
</tr>
<tr>
<td>CHSRA</td>
<td>20</td>
</tr>
</tbody>
</table>

### 2.3 Ridership

Ridership levels are subject to change based on operator and stakeholder analysis. The designer must verify ridership levels with the TJPA before proceeding with design efforts that require ridership information.

### 2.4 Design Life

The minimum design life for the DTX infrastructure is shown in Table 2-2. The specified design life will be achieved through programmed maintenance.

Table 2-2: DTX Infrastructure Minimum Design Life

<table>
<thead>
<tr>
<th>Infrastructure Element</th>
<th>Minimum Design Life (in years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underground structures</td>
<td>100</td>
</tr>
<tr>
<td>Above-grade facilities, including bridges, passenger station buildings, ventilation</td>
<td>100</td>
</tr>
<tr>
<td>buildings, and other ancillary facilities</td>
<td></td>
</tr>
<tr>
<td>Traction power facilities including overhead contact system</td>
<td>50</td>
</tr>
<tr>
<td>Track systems (rail, fastening system, ties, ballast, subballast, and subgrade)</td>
<td>50</td>
</tr>
<tr>
<td>Train control system</td>
<td>25*</td>
</tr>
<tr>
<td>Communications systems</td>
<td>20*</td>
</tr>
<tr>
<td>Supervisory control and data acquisition system</td>
<td>25*</td>
</tr>
<tr>
<td>Civil design works - site improvements and storm drainage</td>
<td>50</td>
</tr>
<tr>
<td>Civil design works - roadways and pavement</td>
<td>25</td>
</tr>
<tr>
<td>Ventilation system</td>
<td>50</td>
</tr>
<tr>
<td>Mechanical, electrical, plumbing systems</td>
<td>50</td>
</tr>
<tr>
<td>Temporary facilities including shoofly (temporary tracks), temporary station facilities, traffic decking</td>
<td>5</td>
</tr>
<tr>
<td>Movement joints</td>
<td>25</td>
</tr>
<tr>
<td>Bearings</td>
<td>25</td>
</tr>
<tr>
<td>Architectural wall and floor finishes (accounting for regular cleaning, and minor repair every 10 years)</td>
<td>50</td>
</tr>
<tr>
<td>Elevators and escalators</td>
<td>25*</td>
</tr>
</tbody>
</table>

* Notwithstanding equipment upgrades, replacement, and enhancement consistent with manufacturers product service and support.
2.5 Rolling Stock

The DTX design must accommodate the rolling stock of both Caltrain and CHSRA and allow for the most restrictive requirements of the possible trainsets as described in this section.

Use the rail loads described in Section 12.2.1, Loads and Forces, in the design of DTX structures.

2.5.1 Commuter Trains

Caltrain’s electrified commuter trains will consist of bi-level electric multiple unit (EMU) trainsets. Caltrain has selected the KISS double-decker EMU manufactured by Stadler US Inc. for use on the DTX.

Trainsets comprise a maximum of ten cars, or measure 875 feet in total length, during peak service and will be configured to allow level boarding at the Transit Center and the Fourth and Townsend Street Station at their respective platform heights.

Caltrain’s EMU design parameters are shown in Table 2-3. Because seating capacity and available standing area may vary depending on the configurations of the specific vehicles procured by Caltrain, measurements for weight, length, power consumption, etc., are presented as average values for a single EMU.

Table 2-3: Caltrain EMU Design Parameters

<table>
<thead>
<tr>
<th>Length (ft)</th>
<th>Width (ft)</th>
<th>Height (ft)</th>
<th>Tare Weight AW0 (lbs)</th>
<th>Average Number of Seats</th>
<th>Available Standing Space (ft²)</th>
<th>Auxiliary Power (kW)</th>
<th>Max. Output Power at the Wheels (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90.26</td>
<td>10.61</td>
<td>15.88</td>
<td>165,000</td>
<td>110</td>
<td>350</td>
<td>65</td>
<td>6000</td>
</tr>
</tbody>
</table>

Use the values in Table 2-3 for the tare weight of the EMU (AW0). To calculate parameters AW1 through AW3, assume an average passenger weight of 195 pounds.

Include the weights of seated and standing passengers in calculations for the design of the following:

- Traction power systems: Use an average weight of train car with fully seated passenger load plus standing passengers at an intensity of 1 per 1.8 ft² of standing space—194 standing passengers, 304 total passengers (59,280 lbs) (AW3 = 224,280 lbs).

- Propulsion and braking characteristics (acceleration/deceleration and time to reach various speeds): Use the tare weight of the train car with a fully seated passenger load plus standing passengers at an intensity of 1 per 2.7 ft² of standing space—129 standing passengers, 239 total passengers (44,215 lbs) (AW2 = 209,215 lbs).

- National Fire Protection Association (NFPA) 130 station platform capacity and exiting requirements: Use an average weight of the train car with fully seated passenger load plus standing passengers at an intensity of 1 per 1.8 ft² of standing space—194 standing passengers, 304 total passengers (59,280 lbs) (AW3 = 224,280 lbs).

Use a maximum of 1.5 mph/s for the deceleration rate for the EMU. Do not assume that regenerative braking will be used.
2.5.2 High-speed Trains

The CHSRA has not yet selected the rolling stock it will use on the DTX. The design parameters presented in Table 2-4 are based on candidate wide-body high-speed trainsets. These criteria assume the following requirements for high-speed trains:

- Trainsets comprise eight-car consists of distributed-power units measuring 672 feet in length; however, CHSRA reserves the right to use double consists (sixteen cars) with a total length of approximately 1,345 feet. The station platform lengths will be limited to that of a single consist and operational means will be employed to allow passenger access to the other half of the double consist. Trackwork must be designed to avoid the fouling of crossovers by a double consist.

- Passenger capacity of high-speed trains is limited to the available number of seats. There will be no standees.

Table 2-4: High-speed Train Double-Consist Design Parameters

<table>
<thead>
<tr>
<th>Length (ft)</th>
<th>Width (ft)</th>
<th>Height (ft)</th>
<th>Tare Weight (lbs)</th>
<th>Average Number of Seats</th>
<th>Auxiliary Power (kW)</th>
<th>Max. Output Power at the Wheels (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,345</td>
<td>11.08</td>
<td>15.68</td>
<td>1,920,000</td>
<td>900-1,000</td>
<td>3,200</td>
<td>22,000</td>
</tr>
</tbody>
</table>

Table 2-4 provides the tare weight of the rolling stock (AW0). Use the actual weight of the train car with fully seated passenger load (AW1) as the basis for the design of traction power load flow simulations to define propulsion and braking characteristics (acceleration/ deceleration and time to reach various speeds) and to define NFPA 130, (Standard for Fixed Guideway Transit and Passenger Rail Systems) station platform capacity and exiting requirements.

To calculate AW1, use an average passenger weight of 210 pounds (this assumes 15 pounds of luggage).

Use a maximum deceleration rate of 1.7 mph/s for full service at speeds of 100-0 mph and a minimum of 2.0 mph/s for emergency service on level tangent dry track. Do not assume that regenerative braking will be used. The acceleration rate for the high-speed train is 1.3 mph/s from 0 to 60 mph.

2.5.3 Maintenance Equipment and Work Trains

Rolling stock for normal maintenance and servicing in the underground portions of the DTX will be diesel-powered. Diesel-powered locomotives will be used for maintenance and servicing in the event of a power failure or when traction power must be turned off.

All maintenance equipment and emergency locomotives must be configured to correspond with the minimum clearances provided in CHAPTER 7 GUIDEWAY GEOMETRICS, for passenger service. The designer is responsible for writing operating procedures and obtaining approval for the procedures from the operators and accepted by the TJPA to ensure adequate ventilation and the safe operation of diesel-powered locomotives in the DTX tunnel.
2.6 Reliable, Available, Maintainable and Safe

The design documents for DTX facilities must define minimum criteria for materials and construction processes. The materials and construction processes selected for the project must meet current standards of high-quality and be reliable, available, maintainable, and safe.

2.7 Operations during Construction

The DTX project includes the modification of the existing Caltrain mainline trackwork approach to the Fourth and King Street Station area. These tracks must be designed to Caltrain standards. Deviations from these criteria must be approved by the TJPA through a design variance request. See Chapter 1, section 1.8, Variances and Changes to Design Criteria.

As the construction of the new trackwork has the potential to adversely affect Caltrain and CHSRA operations (should CHSRA be operational at an interim station at the Fourth and King Street Station at the time of DTX construction), all efforts must be made to maintain an acceptable level of service for all rail operations through the DTX project area.

The staging and implementation of the mainline DTX construction in city streets must be coordinated with the San Francisco Department of Public Works and the San Francisco Municipal Transportation Agency, including its Municipal Railway light rail operations, to minimize disruption to surface traffic and communities.

2.7.1 Guideway Inspection and Maintenance

Ease of inspecting and maintaining the infrastructure must be a primary consideration in the design of the DTX.

The design of infrastructure requiring periodic inspection and maintenance must provide adequate access for both personnel to perform required inspection and maintenance, and for equipment removal and replacement.

Infrastructure must be provided with the initial protection necessary to maintain minimum standards of maintenance.

2.7.2 System Expansion

The design of the DTX must not preclude a future standard gauge rail connection to the East Bay, as mandated by California Senate Bill No. 916, October 2003.

Other potential accommodations for future system expansion must be incorporated into the DTX design, as directed by the TJPA.
CHAPTER 3 SYSTEM SAFETY AND SECURITY

SCOPE

System safety and security criteria will be established and confirmed through a systematic process of evaluating the safety and security needs of the Downtown Rail Extension (DTX) project, as defined in the Transbay Program’s Safety and Security Management Plan (SSMP).

In accordance with the United States Department of Transportation, Federal Transit Administration’s Circular 5800.1, the SSMP specifically identifies how Programwide issues of safety and security will be addressed and certified from initial project planning through the start of revenue service.

Safety and security criteria arising from the SSMP will be integrated into chapters of these criteria, including the following:
- Chapter 15: Fire-Life Safety
- Chapter 16: Mechanical Systems
- Chapter 17: Electrical Systems
- Chapter 18: Rail Systems
- Chapter 19: Communications

CODES, STANDARDS AND GUIDELINES

The following guidelines and references will guide the preparation of the SSMP and the development of the specific design criteria requirements:
- American Public Transportation Association (APTA), Manual for the Development of System Safety Program Plans for Commuter Railroads
- California Building Code
- California Occupational Safety and Health Administration regulations (Cal/OSHA)
- FTA Hazard Analysis Guidelines for Transit Projects
- FTA Transit Security Design Considerations
- National Fire Protection Association—NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems
- U.S. Department of Transportation, Federal Railroad Administration Code of Federal Regulations (CFR)
- U.S. Department of Transportation, Federal Transit Administration (FTA), Circular 5800.1, Safety and Security Management Guidance for Major Capital Projects

Safety and security infrastructure must conform to relevant industry codes and standards.
3.1 Safety-Critical Systems

Systems for signaling, traction power, communications, fire-life safety, and security are deemed critical to the life-safety of DTX system users. Components of these safety-critical systems must be designed according to fail-safe and checked-redundancy principles and incorporate high-reliability parts, selective redundancy, and warning and protective devices, as required, to help achieve the specified requirements. Safety-critical systems must be capable of safe and correct operation under the extremes of the governing environmental conditions identified in CHAPTER 4, ENVIRONMENTAL REQUIREMENTS, and elsewhere.

3.1.1 Safety Principles

The principles governing the design of safety-critical system components are as follows:

Fail-Safe. The fail-safe principle applies to both hardware and software configurations and states that the occurrence of any failure of safety-critical hardware or software, or any combination thereof, must not result in a condition known to be unsafe.

Checked Redundancy. The checked-redundancy principle applies to both safety-critical hardware and software configurations and states that the probability of any failure or combination of failures must not result in a condition known to be unsafe or pose a greater risk than that associated with fail-safe design.

Alternate safety principles will be permitted, provided that they have been demonstrated through analysis, experience in service, and a rigorous safety certification process to provide a level of safety equal to that of the stated principles. Alternate principles must also be in accordance with recognized North American standards.

3.1.2 Special Criteria

The following special criteria govern the design of safety-critical systems:

♦ Safety-critical systems under normal conditions must prevent the use of inadvertent or incorrect actions or procedures by operating personnel.

♦ The design must not assume that procedures can be substituted to accomplish any safety functions provided by specific aspects, components, subsystems, or equipment.

♦ The design must assume that operating personnel will follow correct actions and procedures.

♦ If a hazard analysis demonstrates a conflict between human safety and equipment safety, the design must favor human safety.
3.2 Safety and Security Certification

The TJPA’s safety and security certification process will be consistent with the requirements of CPUC General Orders and industry practice.

The goals of the safety certification process are to (a) ensure that all critical system elements have been monitored for safety and security from development through implementation, (b) verify that the DTX will be safe for full operation of Caltrain and the CHSRA before the commencement of revenue service, and (c) provide documentary evidence and verification showing achievement of the required level of safety, as defined in the SSMP.

The documentation will comprise a series of certificates attesting to conformance with safety and security requirements of the individual system elements, procedures, and training programs.
CHAPTER 4 ENVIRONMENTAL REQUIREMENTS

SCOPE

The Downtown Rail Extension (DTX) design must comply with federal, state, and local environmental regulations, guidelines, criteria, and approvals. The project is subject to National Environmental Policy Act and California Environmental Quality Act regulations.

The conditions indicated herein represent minimum design requirements. More stringent environmental criteria may be contained in other chapters or in related documents. In such cases, the more stringent criteria apply.

The Transbay Program’s Final Supplemental Environmental Impact Statement/Environmental Impact Report (SEIS/EIR) identifies specific environmental impacts from the construction and operation of the DTX and offers mitigation measures in each case. Volume 2, Appendix D.2, contains all mitigation measures and other environmental commitments related to the design, construction, and operation of the DTX, which are incorporated by reference into these design criteria. The Final SEIS/EIR incorporates by reference, and for some environmental analyses, refines information in the Draft SEIS/EIR. In some cases, no changes to the potential impacts or mitigation measures were made in the Final SEIS/EIR. For these particular instances, the Draft SEIS/EIR is identified as the source document for further information on environmental conditions. The design and specification of DTX infrastructure must incorporate the appropriate mitigation measures and other environmental commitments specified for the DTX.

REFERENCES

Ackerly, David and Andrew Jones, Mark Stacey, and Bruce Riordan. 2018. California’s Fourth Climate Change Assessment, San Francisco Bay Area Region Report. Publication number: CCCA4-SUM-2018-005


California Building Code

California Code of Regulations (CCR). Title 22, Social Security.


4.1 Elevation

The project’s critical flood inundation elevation discussed in section 4.5 is based on FEMA’s Flood Insurance Rate Maps, SFPUC’s 100-Year Storm Flood Risk map, and inundation maps prepared for the Port of San Francisco. The Port of San Francisco maps are included in the countywide Sea Level Rise Action Plan and are supporting evidence that sea level rise mitigation planning should be taken into consideration during DTX project development. A 2022 technical memorandum produced for the project, Justification on Estimating the Critical Inundation Elevation at the DTX Station Entrances and Tunnel Portal, details the methodology used to establish the critical flood inundation elevation. The ground surface elevation over the extent of the DTX alignment varies from a minimum of 6 feet to a maximum of 61 feet, approximately, based on NAVD 88 (North American Vertical Datum of 1988).

4.2 Temperature and Relative Humidity

Typical ambient temperatures San Francisco, California, range from approximately 40°F to 80°F, with recorded extremes of 28°F and 103°F. California’s Fourth Climate Change Assessment, San Francisco Bay Area Region Report projects the average hottest day of year to increase by a minimum of 6.3°F along the coast.

Use the following temperature and humidity ranges for the at-grade portions of the DTX, unless otherwise specified in other chapters of this DTX Design Criteria Manual:

- Atmospheric ambient temperature ranges between 25°F and 109°F, accounting for projected warming resulting from climate change
- Relative humidity ranges between 5 percent and 95 percent
4.3 Wind Conditions

Use the following wind conditions:

- Maximum sustained 2-minute wind: 58 mph
- Maximum sustained 5-second wind: 59 mph
- Peak recorded gust: 74 mph
- Design gust: 85–100 mph pending building type/application, in conformance with section 1609A.3 of the California Building Code

4.4 Rainfall

Precipitation is seasonal. May through October is considered the dry season, and November through April is considered the rainy season. Use the following rainfall amounts and intensities:

- Normal annual rainfall: 15 to 22 inches
- Maximum rainfall in 24-hour period: 2 inches
- Maximum rainfall in 1-hour period: 1.5 inches
- Fewer than 10 days of thunderstorm days per year

4.5 Sea Level Rise and Floods

The project’s critical flood inundation elevation of +13.32 feet (NAVD88) factors in sea-level rise over the 100-year life cycle of the project or 2 feet above the 100-year floodplain elevation, whichever is greater. See References.

Critical facilities, such as the Transit Center and Fourth and Townsend Street station entrances, tunnel portal, tunnel portal, and vent structures, must be designed so that the finish floor elevation or top-of-slab foundation are compliant with the criteria. Where the designer demonstrates that this requirement is not feasible, reasonable flood mitigations must be implemented. Deviations from these criteria must be approved by the TJPA through a design variance request. See Chapter 1, section 1.8, Variances and Changes to Design Criteria.

Where portions of the project are within the 100-year floodplain or may be affected by other portions of the project within the 100-year flood plain, the drainage facilities must be designed for the 100-year flood condition.

4.6 Snowfall, Ice Pellets and Icing

Snow and ice are rare; do not consider them in the design beyond typical building code considerations for San Francisco.
4.7 Fog

Heavy fog is common to San Francisco and must be considered in the design of above-grade sections of the alignment.

4.8 Soils

4.8.1 Geotechnical Data

The following reports must be referenced for soils, geologic, and seismic data for the DTX alignment. See CHAPTER 9, Geotechnical Requirements.

- Final Geotechnical Data Report, April 22, 2022
- Final Geotechnical Interpretive Report, May 6, 2022

4.8.2 Seismicity

The DTX will be located in an area of high seismic risk. The design must comply with applicable codes and standards governing the design of facilities capable of withstanding the forces and displacements associated with the maximum credible earthquake in the project area. Seismic design criteria are discussed in detail in CHAPTER 10 SEISMIC DESIGN.

4.8.3 Groundwater

The DTX must conform to the requirements of the San Francisco Bay Regional Water Quality Control Board. A San Francisco Public Utilities Commission discharge permit may be applicable depending on the amount of discharge.

Dewatering discharges to the City of San Francisco sewer system will require a permit in accordance with Article 4.1 of the San Francisco Department of Public Works Code.

4.8.4 Resistivity

Criteria in abeyance.

4.8.5 Atmospheric Pollution and Contamination

Section 2.16 of the Final SEIS/EIR Volume 1 contains information pertaining to existing atmospheric pollutants and contaminants along the DTX alignment.

Requirements for mitigating air quality impacts of the DTX are specified in Appendix D.2 of the Final SEIS/EIR.
4.9 Hazards and Hazardous Materials

Section 3.10.3, of the Draft SEIS/EIR contains information pertaining to potential hazardous material impacts along the DTX alignment.

Sampling for hazardous materials must comply with Article 22A of the San Francisco Health Code and provide the data needed to achieve the overall objectives for the project. Samples must be analyzed for 22 CCR metals, with an emphasis on total and soluble lead concentrations for fill samples. Targeted analyses for organic compounds must be performed at source-specific boring locations, where contaminant releases are known or suspected to have occurred.

If hazardous wastes as defined in San Francisco Health Code Article 22A are identified during environmental site investigations, the designer must prepare a site mitigation plan in accordance with Article 22A. The site mitigation plan must include procedures to ensure that excavated material is managed in accordance with hazardous materials laws and regulations.

Groundwater samples must be analyzed for compounds listed in Article 4.1 of the San Francisco Public Works Code for Industrial Wastes.

A site-specific health and safety plan (HASP), prepared by a qualified environmental professional, is required for all construction work along the project alignment where hazardous materials may be encountered. Specific measures to be included in the HASP to protect construction workers and the general public will depend on the extent and magnitude of hazardous materials in soils and groundwater, but must include engineering controls, monitoring, and security measures as necessary.

4.10 Noise and Vibration

Section 2.12 of the Final SEIS/EIR Volume 1 contains information pertaining to noise and vibration impacts along the DTX alignment.

Requirements for mitigating noise and vibration during construction of the DTX are specified in Appendix D.2 of the Final SEIS/EIR.
CHAPTER 5  CIVIL DESIGN

SCOPE

This chapter establishes the requirements for the general civil design for the Downtown Rail Extension (DTX) project, including survey control; roads and streets; landscaping; fencing; drainage; and traffic control, including the maintenance and protection of traffic during construction. Civil design criteria are applicable to all project infrastructure, both above and below ground.

CODES, STANDARDS AND GUIDELINES

Civil design for the DTX must conform to the latest editions of the following standards, codes, specifications, and regulations, unless otherwise specified in these criteria:

♦ American Association of State Highway and Transportation Officials
  A Policy on Geometric Design of Highways and Streets (AASHTO Green Book)

♦ American Public Works Association (APWA) Standard Plans for Public Works Construction

♦ American Railway Engineering and Maintenance-of-Way Association (AREMA)
  Manual for Railway Engineering

♦ Americans with Disabilities Act (ADA) Standards for Accessible Design

♦ San Francisco Municipal Transportation Agency, Department of Parking and Traffic Regulations for Working in San Francisco Streets (Blue Book)

♦ California Building Code

♦ California Department of Transportation (Caltrans)
  ● Caltrans Highway Design Manual
  ● Caltrans Standard Plans and Standard Specifications
  ● Caltrans Surveys Manual
  ● California Manual of Uniform Traffic Control Devices

♦ Caltrain Engineering Standards

♦ California Public Utilities Commission (CPUC) General Orders (GO):
  ● GO 36-E, In the Matter of the Establishment or Abolition of Agencies, Non-Agencies, Sidings, Spur Tracks and Other Station Facilities, and the Curtailment of Agency Service of Common Carriers
  ● GO 72-B, Rules Governing the Construction and Maintenance of Crossings at Grade of Railroads with Public Streets, Roads and Highways in the State of California
  ● GO 75-D, Regulations Governing Standards for Warning Devices for At-Grade Highway-Rail Crossings in the State of California
  ● GO 88-B, Rules for Altering Public Highway-Rail Crossings
  ● GO 135, Regulations Governing the Occupancy of Public Grade Crossings by Railroads
Facilities within Caltrain property must conform to Caltrain standards, the AREMA Manual for Railway Engineering, and other codes and standards, as applicable.

Facilities outside Caltrain property must conform to the standards of the appropriate authority having jurisdiction, such as the City and County of San Francisco (City) and Caltrans.

5.1 Survey Control

5.1.1 Horizontal Datum and Control

The horizontal datum for the project is the North American Datum of 1983 (NAD 83), as defined by the National Geodetic Survey. Coordinates will be based on the California Coordinate System (CCS) of 1983, Zone 3, Epoch 1991.35. The physical reference network for the coordinates will be the California High-Precision Geodetic Network.

Project plans or other documents must indicate the basis of the coordinates used, including the CCS zone, physical reference network, and epoch used to establish the coordinates.

The primary horizontal control points shown in Table 5.1 must be used in conjunction with the project.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Approximate Location</th>
<th>Northing (Lat.)</th>
<th>Easting (Long.)</th>
<th>Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB7679</td>
<td>Highway 101 near Candlestick Point</td>
<td>37 42 22.13446</td>
<td>122 23 36.88949</td>
<td>12.14</td>
</tr>
<tr>
<td>AB 7677</td>
<td>San Francisco Zoo</td>
<td>37 44 00.31877</td>
<td>122 29 49.01603</td>
<td>77.72</td>
</tr>
<tr>
<td>HT 0814</td>
<td>Yerba Buena Island</td>
<td>37 48 35.82913</td>
<td>122 21 58.10100</td>
<td>341.24</td>
</tr>
</tbody>
</table>

5.1.2 Vertical Datum and Control

The vertical datum for the project is the California state datum, i.e., the North American Vertical Datum of 1988 (NAVD 88), as defined by the National Geodetic Survey. Project plans or other documents must indicate the vertical datum. The primary vertical control points in Table 5.2 must be used in conjunction with the DTX design.
Table 5-2: Primary Vertical Control Points (NAVD 88)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Approximate Location</th>
<th>Northing (Lat.)</th>
<th>Easting (Long.)</th>
<th>Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HT0759</td>
<td>Embarcadero SFFD Engine House #9</td>
<td>37 47 25</td>
<td>122 23 19</td>
<td>11.50</td>
</tr>
<tr>
<td>HT0758</td>
<td>SE Corner Intersection of Main &amp; Harrison streets</td>
<td>37 47 17</td>
<td>122 23 25</td>
<td>31.74</td>
</tr>
<tr>
<td>HT0684</td>
<td>BART Transbay Tube ventilation building</td>
<td>37 47 43</td>
<td>122 23 34</td>
<td>4.79</td>
</tr>
<tr>
<td>HT0685</td>
<td>Embarcadero, between Market &amp; Mission St.</td>
<td>37 47 39</td>
<td>122 23 33</td>
<td>10.17</td>
</tr>
<tr>
<td>HT0687</td>
<td>Southern Pacific Co. building, intersection of Market &amp; Steuart streets</td>
<td>37 47 44</td>
<td>122 23 39</td>
<td>12.40</td>
</tr>
<tr>
<td>HT0787</td>
<td>Embarcadero, Bay Bridge Pier adjacent to Pier 26</td>
<td>37 47 17</td>
<td>122 23 18</td>
<td>14.79</td>
</tr>
<tr>
<td>HT0788</td>
<td>Embarcadero, Bay Bridge Pier adjacent to Pier 26</td>
<td>37 47 17</td>
<td>122 23 18</td>
<td>14.26</td>
</tr>
</tbody>
</table>

To convert elevations in National Geodetic Vertical Datum of 1929 (NGVD 29) or San Francisco Department of Public Works format to NAVD 88:
- Add 2.75 feet to original NGVD 29 elevations
- Add 11.35 feet to original San Francisco Department of Public Works elevations

5.2 Streets, Sidewalks Curbs, Ramps and Gutters

Existing streets, sidewalks, curbs, curb returns, driveway curb cuts, ADA ramps, and gutters disturbed by construction must be restored to their original function. The design of streets, sidewalks, curbs, curb returns, driveway curb cuts, ADA ramps, gutters, and striping must conform to DPW Standard Plans and Specifications. At a minimum, replacements must match the existing type and dimensions.

Improvements to sidewalks, curbs, ramps, and gutters must conform to the DPW Standard Plans and Specifications, APWA Standard Plans for Public Works Construction, and ADA Standards for Accessible Design.

5.2.1 Streets

The alignment, profile, cross slopes, and clearances of restored streets must match the preconstruction condition, unless otherwise agreed between the San Francisco Department of Public Works and the TJPA.

Geometric Design

The geometric design of streets must conform to the Caltrans Highway Design Manual and the AASHTO Green Book.

All major streets in the project area must be classified as urban minor arterials and designed for the greater of the currently posted operating speed or 35 mph.
Roadways and intersections must conform to AASHTO Green Book requirements to accommodate turning radii for standard design vehicles SU-30, WB-40, and BUS-40.

Design of at-grade crossings must conform to CPUC GO 36-E, 72-B, 75-D, 88-B, and 135.

Pavement Design

Pavement design must conform to DPW Standard Plans and Standard Specifications or the Caltrans Highway Design Manual, whichever governs, based on the traffic index and soil characteristics.

If the vertical clearance between road surface and top of utilities is limited, the design must include provisions for armoring the utility or backfilling with a lean concrete mix or controlled density fill material, or both. Chapter 6, UTILITIES, for applicable codes, standards, and requirements.

5.2.2 Grading

The existing terrain in the project area includes land with flat slopes to gradual slopes. Grading must be designed to maintain consistency with existing topographic conditions.

5.3 Landscaping and Streetscaping

The TJPA and San Francisco Department of Public Works will establish the requirements for landscaping and streetscaping as part of the reconstruction of City streets affected by the project. Pending an agreement with the Department of Public Works, the removal and replacement of trees in the public right-of-way must conform to San Francisco Department of Public Works regulations, and landscaping and streetscaping must be replaced in kind.

5.4 Permanent Fencing

Perimeter fencing to provide security and ensure the safety of the general public and employees of Caltrain, the California High-Speed Rail Authority (CHSRA), and the Transbay Joint Powers Authority (TJPA) will be required in specific locations, including:

- Caltrain station at Fourth 4th and King streets and 4th and King Railyards perimeter
- DTX portal and open cut-structures
- Ventilation structures
- Substations
- Other locations as agreed with the TJPA and San Francisco Department of Public Works

The TJPA and Caltrain will establish and agree on requirements for perimeter fencing for the Fourth and King Street Station and 4th and King Railyards and the DTX open-cut structures. Pending an agreement with Caltrain, perimeter fencing removed by the project must be replaced in kind.

Fence locations are subject to railroad clearance requirements, and must be coordinated with property lines, as necessary.
Fencing must be designed to
- withstand the wind speeds described in section 1609A.3, Basic Design Wind Speed, of the California Building Code.
- restrict thrown projectiles from impacting or hitting the sides and windshields of the trainsets.
- mitigate the effects of vandalism and graffiti during and after construction.

5.4.1 Low-Security Fencing

Low-security fencing must be 8-foot-high chain link fencing with 1-inch aluminum-coated steel fabric and support bars at the top and bottom of the fabric.

5.4.2 High-Security Fencing

Permanent steel high-security fencing must be made of one continuous sheet of diamond mesh that cannot unravel.

Gate locations must conform to the requirements established and agreed to by Caltrain, San Francisco Department of Public Works, and the San Francisco Fire Department (SFFD). Gates must include locking devices with separate keying for Caltrain and SFFD access.

5.5 Drainage

Base the design of drainage waterways, culverts, and structures on streets affected by DTX construction and within the affected Caltrain right-of-way on sound hydraulic principles to achieve an optimal combination of efficiency and economy. These criteria are relevant to the design of surface drainage only, including:
- At-grade guideway, consisting of the DTX mainline and associated tracks within Caltrain right-of-way
- Caltrain station at 4th and King streets and the 4th and King Railyards
- Storm drains and combined sewers in streets affected by construction

See CHAPTER 16, Mechanical Systems, for drainage design criteria for below-grade structures.

5.5.1 General Requirements

Drainage facilities requiring relocation or modification because of DTX construction must be replaced in kind or reconstructed to previous standards unless conditions of flow, loading, or operation are altered. If such conditions are altered, designs must conform to the design criteria and the standards of the facility owner. Do not include betterments in the design unless they are specifically agreed to between the drainage facility owner and the TJPA.

The design of drainage facilities in the Caltrain right-of-way including hydrologic and hydraulic design must conform to the Caltrain Design Criteria and CHSRA Design Criteria.

The design of drainage facilities in City right-of-way must conform to San Francisco Public Utilities Commission and San Francisco Department of Public Works requirements.
The design of drainage facilities owned by others that are relocated or modified because of DTX construction must conform to the design criteria and standards of the drainage facility owner. See CHAPTER 6, Utilities.

### 5.5.2 Hydrology

The hydrologic design of surface drainage facilities outside of the Caltrain right-of-way must conform to DPW Standard Specifications and Plans.

#### Design Storm

Drainage facilities in streets, parking lots, and other project areas outside of the Caltrain right-of-way must be designed for the runoff rate generated by the peak 5-minute duration precipitation during a 10-year storm.

#### Computation of Runoff

Compute the maximum expected discharge from drainage areas as follows:

- Drainage areas less than 0.5 square miles: Use the Rational Method and the values for the runoff coefficient (C) from the Caltrans Highway Design Manual. Coefficients prescribed by agencies with adjacent facilities that contribute flow must be used if these agencies have higher runoff coefficient criteria.
- Drainage areas greater than 0.5 square miles: Use standard, approved hydrologic design software packages such as the United States Army Corps of Engineers’ (USACE) hydrologic engineering center (HEC) Hydrologic Modeling System or HEC-1.

The design must incorporate interception points at the tunnel portal location to collect flow during the design storm event.

See CHAPTER 4, Environmental Requirements, for the requirements related to sea level rise and floods.

#### Time of Concentration

The time of concentration for a drainage area must be equal to the time required for overland flow, plus the time of conduit or channel flow from the most remote point of the drainage area to the point under consideration. The time of concentration of overland flow must be limited to a maximum travel distance of 150 feet.

### 5.5.3 Hydraulics

The hydraulic design of surface drainage facilities outside of the Caltrain right-of-way must conform to San Francisco Department of Public Works design criteria.
Hydraulic Design

The San Francisco Department of Public Works intensity-duration-frequency curves may be used for the hydraulic design. Alternatively, standard software packages specifically designed for hydraulic design, such as the USACE computer programs HEC-2 or HEC-RAS or other software approved by the TJPA, may be used instead of tabular methods.

Hydraulic Design Considerations

The hydraulic design must meet the following requirements:

♦ The height of water surfaces resulting from design storm discharges at each structure and along the waterways must not encroach on the superstructure of bridge-type structures.

♦ Full flow-through culvert-type structures are acceptable, provided that the ratio of the headwater depth to the height of the culvert is 1.5 or less.

♦ Improvements at locations where an established FEMA floodway exists must comply with the requirements of the National Flood Insurance Program.

♦ Where drainage is picked up by means of a headwall and inlet or outlet conditions control, the pipe must be designed as a culvert.

♦ The capacity of existing drainage infrastructure downstream from drainage facilities constructed or modified as part of the DTX design must not be exceeded.

Velocity and Freeboard

The following requirements for normal depth and velocities must be satisfied.

♦ Storm drains must have a minimum velocity of 3 fps when flowing full (5-year storm event). Combined sewers must be designed for a minimum velocity of 2 fps flowing full.

♦ Minimum peak flow velocities in pipe culverts and concrete-lined channels must be 2 fps when flowing two-thirds full. Maximum flow velocities in pipes, culverts, and concrete-lined channels must be 10 fps when flowing two-thirds full.

♦ The hydraulic grade line (5-year storm event) of storm drains and combined sewers must be 4 feet below pavement or ground surface and never less than 2 feet.

♦ The maximum encroachment of water on roadway pavements must not exceed half of a through-traffic lane or 1 inch less than the depth of curb during a 10-year storm of 5-minute duration. Inlets must be provided to control the encroachment of water on the pavement.

♦ Where the anticipated outlet velocity for a waterway exceeds the maximum permissible velocity for the bed material of the receiving channel, an acceptable means of energy dissipation must be used to reduce the velocity to safe limits. Discharge onto a fill slope is not permitted unless provisions are made to protect the slope from scour. Trainsets are prohibited from operating if water is over 2 inches above top of rail.

Debris Control

Do not use static inlet head in determining the size of the opening of drainage structures receiving flow from open channels and areas that may contribute debris.
Do not provide trash racks or screens for culvert-inlet protection.

Where culvert headroom is required for debris, headwater and tailwater depths must not exceed 0.8 of the culvert diameter or height. Drawdown at the entrance to this depth must not be construed as meeting this requirement unless it can be shown that the drawdown allows free passage of all debris.

If the drainage structure is protected from debris by existing conditions upstream or if the structure is part of an enclosed storm drain system with all inlets grated or protected, static head may be considered in computing the capacity. The static head on the entrance to the culvert and the water-surface elevation in the system at peak conditions must not be higher than can safely be contained by headwalls, ditch banks, and tributary drainage systems.

### 5.5.4 Drainage Infrastructure

The design of drainage infrastructure, including inlets, manholes, pipelines, and underdrains in the Caltrain right-of-way must conform to Caltrain Design Criteria. Within City streets, the design of drainage infrastructure must conform to DPW Standard Plans and Standard Specifications.

#### Inlets and Manholes

Space clean-out boxes and manholes at a maximum of 400 feet apart for ease of maintenance.

Where abrupt changes in the direction or slope of a pipeline are required, place an inlet or a manhole at the point of change in conformance with Caltrain Design Criteria.

#### Pipelines

Use the following minimum pipeline diameters:

- Combined storm-sewer drainpipes: 12 inches
- Storm drains, including connections to inlets: 18 inches
- Culverts under roadways: 18 inches

Where headroom is restricted, equivalent pipe arches may be used instead of circular pipe.

#### Filter Material

Use the findings of the soils engineering investigation as the basis for the design of filter material gradations for fine and coarse aggregates and the inclusion of filter fabric.

### 5.6 Maintenance and Protection of Traffic

A Traffic Management Plan (TMP) must be developed in accordance with the applicable portions of the California Manual of Uniform Traffic Control Devices, California Temporary Traffic Control Handbook (CATTCH), Caltrans Highway Design Manual, and San Francisco Municipal Transportation Agency (SFMTA) regulations. The TMP will include a temporary traffic control plan to address traffic safety and control needs.
through the work zones, including the details and locations of temporary infrastructure for detours and closures.

5.6.1 General Requirements

The TMP must include appropriate plans for the road closures and detours deemed necessary to support construction staging and to provide for safe operations during construction while minimizing and mitigating disruption of traffic and impacts to the community. Traffic within the limits of construction may be subject to speed reductions, altered traffic patterns, and reduced levels of service, as necessary.

Road closures and detours may be required during specific construction activities, such as the installation of girders over and next to active roadways and temporary street decking for cut-and-cover structures. Road closures will occur on weekday nights and weekends only.

Transit routes in the area may also be affected by construction. Detours may be provided for transit routes that run on the surface streets above the DTX alignment and may require the protection or decommissioning of the San Francisco Municipal Railway (Muni) overhead contact system (OCS). Procedures for OCS protection or decommissioning will be provided by others.

Routes for pedestrians and cyclists must have sufficient clearances and protections. Pedestrian detour routes must comply with ADA requirements.

5.6.2 Access

Access must be maintained within construction zones for:

- Emergency services and emergency vehicles
- Local businesses and residences

Temporary interruptions to local access to businesses and residences must be coordinated and agreed with the respective owners. A permit will also need to be acquired from San Francisco Department of Public Works if street space and sidewalks outside of the building property line or project limits are used for building or project construction, respectively. Special Traffic Permits (STPs) may be needed if a street, alley, or sidewalk needs to be closed during construction; STPs are issued by the SFMTA.

5.6.3 Temporary Infrastructure

Temporary infrastructure, including traffic control devices, traffic lanes, striping, and signage, will be used to implement detour routes and roadway closures. The design of temporary infrastructure must conform to the California Manual of Uniform Traffic Control Devices.

5.6.4 Temporary Traffic Lanes

The width of temporary traffic lanes must be no less than 10 feet and must provide enough transition before the lane begins and after the lane ends. The width of temporary turn lanes must also be no less than 10 feet. Parking lanes may be used as temporary traffic lanes. Temporary lane widths must be shown on the temporary traffic control plan.
5.6.5 Signage

City-owned signs to be removed and salvaged must be shown on the temporary traffic control plan.
CHAPTER 6 UTILITIES

SCOPE

This chapter establishes the requirements for the design of underground and overhead utility work, including the support, maintenance, relocation, abandonment, restoration, and new construction of utilities beyond 5 feet from building lines affected by construction of the Downtown Rail Extension (DTX) project.

CODES STANDARDS AND GUIDELINES

All utility work must comply with the standards, criteria, and guidelines of the utility owner. If the utility owner has no published standards, use the latest edition of the following codes, standards, and guidelines:

♦ American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering

♦ American Society of Mechanical Engineers (ASME) Guide for Gas Transmission and Distribution Piping Systems of the ASME Gas Piping Standards Committee

♦ California Public Utilities Commission (CPUC) General Orders (GO):
  ● GO 95, Rules for Overhead Electric Line Construction

♦ Caltrain Engineering Standards

♦ Code of Federal Regulations (CFR) Title 49, Part 192, Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards

♦ Institute of Electrical and Electronics Engineers National Electric Safety Code

♦ National Fire Protection Association (NFPA)
  ● NFPA 54, National Fuel Gas Code
  ● NFPA 70, National Electric Code

♦ San Francisco Department of Public Works (DPW) Order No: 187005, Regulations for Excavating and Restoring Streets in San Francisco

♦ San Francisco Department of Public Works (DPW) Standards Specifications and Plans

♦ San Francisco Municipal Transportation Agency, Department of Parking and Traffic Regulations for Working in San Francisco Streets (Blue Book)

♦ San Francisco Public Utilities Commission Asset Protection Standards

♦ San Francisco Public Utilities Commission Design Guidelines & Standards

The design of utilities within railroad right-of-way must conform to Caltrain standards, the AREMA Manual for Railway Engineering, and other codes and standards as applicable.
6.1  Design and Design Responsibility

Utility relocation design must indicate the utility infrastructure to be supported in place, temporarily or permanently relocated, or abandoned.

Coordinate utility work with public and private utility agencies to minimize conflicts and interruptions during construction. Private utilities may design new facilities or relocate existing facilities, or both.

It is anticipated that investor-owned utilities, including PG&E (Pacific Gas and Electric) and AT&T (American Telephone and Telegraph Company), will perform their own relocation engineering. The designer is responsible for coordinating the designs of all investor-owned utility relocations and incorporating these designs into the contract documents. Additionally, private utilities may design their new infrastructure or relocate their infrastructure. All work by private utilities to relocate their facilities will be coordinated with the Transbay Joint Powers Authority (TJPA) to ensure that the work conforms with the project requirements and the project schedule and budget is maintained.

Unless otherwise indicated, the designer must complete the design of the utility maintenance concepts and submit them to the respective utility owners for review and approval. Where these criteria indicate that the utility owner will complete the design of the utility maintenance concepts, the designer must review the concepts for compatibility and consistency with the DTX design.

6.2  Level of Service and Service Interruption

A level of service equivalent to the existing service for adjacent properties, residences, and businesses must be maintained throughout construction by supporting utilities in place, diverting utilities, or providing alternative temporary facilities.

Minimize interruption of existing utility services. Service must not be interrupted without the prior written consent of utility owners.

6.3  Relocation and Replacement

If temporarily relocated, existing utilities must be restored upon completion of work. If permanently relocated, the new utility must be operational before or coincident with the termination of the existing service.

Utilities requiring relocation or modification to allow for DTX construction must be replaced in kind or reconstructed to previous standards unless conditions of flow, loading, or operation are altered. If such conditions are altered, designs must conform to the design criteria and the standards of the utility owner. No betterments will be included unless specifically agreed to by the utility owner and the TJPA.

6.4  Corrosion Control

Corrosion control measures must be provided in accordance with CHAPTER 20, STRAY CURRENT AND CORROSION CONTROL.
6.5 Excavations

Excavations for utilities in City and County of San Francisco right-of-way must comply DPW Order No: 187005, San Francisco Municipal Transportation Agency’s (SFMTA) Blue Book, and San Francisco Public Utilities Commission’s (SFPUC) Asset Protection Standards.

6.6 Service Utilities

All design for the maintenance of service utilities, connections, and supporting infrastructure, including support-in-place, relocation and restoration, permanent relocation, and abandonment, must comply with the codes and standards indicated in Table 6.1. The minimum required clearance between pavement and top of utility is owner-specific based on the utility.

Table 6-1: Governing Codes & Standards for Service Utilities

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Applicable Code, Standard &amp; Guideline</th>
<th>Maintenance Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanitary, Storm and Combined Sewers</td>
<td>SFPUC Design Guidelines &amp; Standards, DPW Standard Specifications and Plans, DPW Orders</td>
<td>CHAPTER 5, CIVIL DESIGN, for maintenance requirements</td>
</tr>
<tr>
<td>Domestic Water Lines and Hydrants</td>
<td>SFPUC Design Guidelines &amp; Standards</td>
<td>Service will be maintained at all times; interruptions must be authorized by the SFPUC and the San Francisco Fire Department</td>
</tr>
<tr>
<td>Auxiliary Water Supply System (AWSS)</td>
<td>DPW Standard Specifications and Plans</td>
<td>Service will be maintained at all times; interruptions must be authorized by the SFPUC and the San Francisco Fire Department</td>
</tr>
<tr>
<td>Gas Lines</td>
<td>PG&amp;E standards, Codes and standards listed under Codes, Standards and Guidelines at the beginning of this chapter</td>
<td></td>
</tr>
<tr>
<td>Steam Lines</td>
<td>Clearway Energy’s requirements</td>
<td></td>
</tr>
<tr>
<td>Electrical Power Lines</td>
<td>PG&amp;E standards, SFPUC Design Guidelines &amp; Standards, SFMTA Blue Book</td>
<td></td>
</tr>
<tr>
<td>Street Lighting</td>
<td>SFPUC Design Guidelines &amp; Standards</td>
<td></td>
</tr>
<tr>
<td>Traffic Signals</td>
<td>SFMTA Blue Book</td>
<td>See CHAPTER 5, Civil Design, for requirements for temporary traffic lights and supporting infrastructure for the routing and detouring of traffic during construction</td>
</tr>
<tr>
<td>Muni Overhead Contact System</td>
<td>SFMTA Blue Book, CPUC General Order 95</td>
<td></td>
</tr>
<tr>
<td>Telecommunications</td>
<td>Utility owner’s requirements</td>
<td></td>
</tr>
</tbody>
</table>
6.7 Basement Vaults of Adjacent Buildings

The basement vaults of buildings surrounding the project area that do not encroach on the DTX footprint must be protected in place. Vaults that conflict with the DTX construction will be subject to demolition and reconstruction prior to tunnel construction; demolition of unpermitted vaults/basements within the public right-of-way will be at the property owner’s expense. The occupation of basement vaults by the TJPA’s contractors for construction of the DTX must be coordinated with both property and utility owners and conform to CHAPTER 11, PROTECTION OF EXISTING INFRASTRUCTURE.
CHAPTER 7  GUIDEWAY GEOMETRICS

SCOPE

This chapter establishes the requirements for track geometry and clearances for the Downtown Rail Extension (DTX), including the track in the train platform levels of the Transit Center and Fourth and Townsend Street stations, and the requirements for design speeds and track geometry, the horizontal and vertical alignment of the DTX tracks, proposed clearances, and maintenance and construction tolerances for track and structures. These criteria are primarily governed by the Caltrain Design Criteria and incorporate approved design variances from Caltrain.

Situations that do not conform to these criteria must be evaluated to confirm that vehicle performance and operations, including the lateral movements of vehicle diaphragms, are acceptable.

CODES, STANDARDS AND GUIDELINES

Unless otherwise stated in this chapter, use the latest edition of the following codes, standards, and guidelines to develop the DTX guideway geometrics:

- American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering
- California High-Speed Rail Authority (CHSRA) Design Criteria Manual
- California Public Utilities Commission (CPUC) General Orders (GO):
  - GO 26-D, Regulations Governing Clearances on Railroads and Street Railroads with Reference to Side and Overhead Structures, Parallel Tracks, Crossings of Public Roads, Highways and Streets
  - GO 118-A, Regulations Governing the Construction, Reconstruction, and Maintenance of Walkways Adjacent to Railroad Trackage and the Control of Vegetation Adjacent Thereto
  - GO 164-E, Rules and Regulations Governing State Safety Oversight of Rail Fixed Guideway Systems
  - GO 176, Rules for Overhead 25 kV AC Railroad Electrification Systems for a High-Speed Rail System
- Caltrain Engineering Standards
- Code of Federal Regulations (CFR) Title 49, Part 213, Track Safety Standards
- National Fire Protection Association (NFPA), Code NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems
7.1 Design Speeds

Round down calculated design speeds to the nearest increment of 5 mph.

7.1.1 Maximum Authorized Speed

The maximum authorized speed for passenger trains within the limits of the project for at-grade and below-grade tracks varies between 20 mph and 40 mph. The maximum authorized speed for trains approaching the Fourth and King Street Station between Caltrain mileposts 0.2 and 0.7 currently varies between 20 mph and 40 mph.

7.1.2 Maximum Speeds on Curves

Calculate the maximum speeds on curves using the formula in Equation 7.1:

Equation 7.1: Maximum Speeds on Curves

\[ V = \left(\frac{(E_a + E_u)}{0.0007D_c}\right)^{\frac{1}{2}} \]

Where:

- \( V \) is the train speed in miles per hour.
- \( E_a \) is the actual track superelevation in inches.
- \( E_u \) is the maximum unbalanced superelevation in inches.
- \( D_c \) is the degree of curvature in degrees, minutes, and seconds.

Maximum values for actual superelevation are shown in Table 7-3: Table. The maximum speed on curves must also be based on a maximum of 3 inches of unbalanced superelevation.

7.1.3 Maximum Speeds through Turnouts

The design speeds for passenger trains through turnouts are based on tangent point geometry and a maximum unbalanced superelevation of 3 inches. See the Caltrain Design Criteria, Chapter 2 – Track – Track, Part D – Special Trackwork for maximum operating speed through turnouts.

7.2 Track Geometry

The track geometry of the DTX must maximize system safety and maintain the riding comfort of passengers. These criteria typically contain two values for alignment design parameters: a desirable value (minimum or maximum) and an absolute value. The intent of the design is to meet the desirable values. In cases where the desirable values cannot be met, notify the TJPA but proceed with the design unless direction is received otherwise. Any deviations from these criteria must be approved by the TJPA through a design variance request. See Chapter 1, section 1.8, Variances and Changes to Design Criteria.
7.2.1 Horizontal Alignment

The horizontal alignment must be developed along track centerlines and consist of tangents and circular curves generally connected by spiral curves.

7.2.1.1 Minimum Tangent Length

Calculate the desirable minimum tangent length between ends of spiral curves using the formula in Equation 7.2:

Equation 7.2: Minimum Tangent Length

\[ LT = 3V \]

Where:

\[ LT \] is the minimum tangent length, measured in feet.
\[ V \] is the train speed in miles per hour.

The absolute minimum tangent length between the ends of spiral curves is 100 feet.

The desirable minimum length of track extension beyond the end of vehicle spot at stub-end tracks (platform or tail tracks) is 40 feet (distance between bumping post and bumper of trainset). The absolute minimum length of track extension beyond the end of vehicle spot at stub-end tracks is 20 feet.

Track Spacing

Track Spacing on Tangent Track. Values for the minimum distances between the centerlines of adjacent tracks are shown in Table 7-1.

<table>
<thead>
<tr>
<th>Item</th>
<th>Desirable Value</th>
<th>Absolute Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainline track to mainline track</td>
<td>15 ft 0 in.</td>
<td>14 ft 6 in.</td>
</tr>
<tr>
<td>Mainline to storage track</td>
<td>20 ft 6 in.</td>
<td>14 ft 6 in.</td>
</tr>
<tr>
<td>Storage track to storage track</td>
<td>15 ft 0 in.</td>
<td>14 ft 6 in.</td>
</tr>
</tbody>
</table>

The desirable value for spacing between storage tracks shown in Table 7-1 applies to tracks where no equipment will be serviced.

Track Spacing on Curves. On curves, to provide clearance between cars and locomotives equivalent to that obtained on adjacent tangent track, increase the distance between track centers:

- a minimum of 1 inch for every 30 minutes of curvature where the amount of superelevation is the same on adjacent tracks or the superelevation of the inner track is greater than that of the outer track.
- a minimum of 1 inch for every 30 minutes of curvature, plus 3.5 inches for every inch of difference in elevation between the two tracks where the superelevation of the outer track is greater than that of the inner track.
Track Spacing on Superelevated Curves. If an outside track on a curve has greater superelevation than an inside track, adjust the track center spacing to account for the effects of the differential superelevation. For every inch of differential superelevation, increase the track center spacing by 3.5 inches.

7.2.2 Horizontal Curves

Horizontal curves must conform to the Caltrain Design Criteria, Chapter 2: Track, Part C – Track Geometry, subsection 3.3, Horizontal Curves unless otherwise stipulated in this chapter.

Minimum Length of Circular Curve

The absolute minimum length of circular curve is 100 feet.

Minimum Radius of Curvature

Calculate the desirable minimum radius of curvature using the formula in Equation 7.3:

Equation 7.3. Minimum Radius of Curvature

\[ R = \frac{4V^2}{e} \]

\[ D_c = 2\sin^{-1}(\frac{50}{R}) \]

Where:

\( R \) is the radius of curvature in feet.
\( V \) is the train speed in miles per hour.
\( e \) is the total superelevation required for equilibrium in inches.
\( D_c \) is the degree of curvature in degrees, minutes, and seconds.

The absolute minimum radius of curvature must be 650 feet for mainline tracks, and 500 feet for Caltrain-only tracks, including curved crossovers.

Circular curves for track geometry will be defined by radius and equivalent degree of curvature (\( D_c \)).

7.2.3 Spiral Curves

Use spiral, easement, or transition curves between horizontal tangents and circular curves and between compound curves. Spiral curves, and the application of spirals, must be clothoids and conform to Caltrain Design Criteria Chapter 2: Track, Part C – Track Geometry, Section 5.0: Spirals.

The desirable minimum spiral length is the largest of the values determined by the formulas shown in Table 7-2. Round calculated lengths of spiral curves up to the nearest 5 feet.
Table 7-2  Minimum Length of Spiral Curve

<table>
<thead>
<tr>
<th>Spiral Design Factor</th>
<th>Desirable</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superelevation</td>
<td>$L_s = 1.47EaV$</td>
<td>$L_s = 1.17EaV$</td>
</tr>
<tr>
<td>Unbalance</td>
<td>$L_s = 1.63EuV$</td>
<td>$L_s = 1.22EuV$</td>
</tr>
<tr>
<td>Twist</td>
<td>$L_s = 82Ea$</td>
<td>$L_s = 82Ea$</td>
</tr>
<tr>
<td>Minimum Segment</td>
<td>$L_s = 2.64V$</td>
<td>$L_s = 2.20V$</td>
</tr>
</tbody>
</table>

Where:

$L_s$ is the length of the spiral curve in feet.
$E_a$ is the actual track superelevation in inches.
$E_u$ is the unbalanced superelevation in inches.
$V$ is the train speed in miles per hour.

Use design speeds with the maximum superelevation values shown in Table 7-2 to calculate spiral curve lengths. Round calculated lengths of spiral curves up to the nearest 5 feet.

Spiral curves must have a minimum length of 100 feet.

7.2.4  Reverse Curves

Avoid the use of reverse curves. Where reverse curves are unavoidable, the minimum tangent length between reverse curves must conform to the requirement in section 7.2.1, Horizontal Alignment. The use of reverse curves must be approved by the TJPA through a design variance request. See Chapter 1, section 1.8, Variances and Changes to Design Criteria.

7.2.5  Compound Curves

Compound circular curves may be used, provided they are connected by an adequate spiral, based on the difference between the required superelevation of the curves. The same speed must be used to determine the spiral lengths and superelevation for compound curves. The spiral lengths for compound curves must conform to the criteria in Section 7.2.3, Spiral Curves.

The minimum length of spiral between compound curves must be 62 feet.

7.2.6  Superelevation

Tracks must be superelevated to maximize the speed on curves, consistent with the performance of the trains. Superelevation is applied by raising the outside rail and must be varied uniformly along the length of the spiral curve.

Tracks must not have superelevation in the following conditions:

- Station platform tracks
- Yard, storage, tail, and maintenance tracks
- Tracks through turnouts and crossovers
**Calculation of Superelevation**

Superelevation is measured in inches and calculated to the nearest 0.25-inch using the following formulas:

Equation 7.4. Superelevation

\[ e = 0.0007 D_c V^2 \]

Where:

- \( e \) is the total or equilibrium superelevation in inches.
- \( D_c \) is the degree of curvature in degrees, minutes, and seconds.
- \( V \) is the maximum train design speed in miles per hour.

The total superelevation \( e \) is expressed as follows:

Equation 7.5. Total Superelevation

\[ e = E_a + E_u \]

Where:

- \( E_a \) is actual superelevation that is applied to the curve in inches.
- \( E_u \) is unbalanced superelevation (amount of superelevation not applied to the curve) in inches.

Round up to the nearest 0.25-inch the actual superelevation calculated in Equation 7.4 and Equation 7.5. For any curve, a minimum of 0.5 inches of superelevation must be specified.

**Maximum Superelevation**

Maximum track superelevation must conform to the values shown in Table 7-3.

Table 7-3: Table Maximum Superelevation

<table>
<thead>
<tr>
<th>Item</th>
<th>Desirable Value</th>
<th>Absolute Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual superelevation (( E_a ))</td>
<td>4 in.</td>
<td>5 in.</td>
</tr>
<tr>
<td>Unbalanced superelevation (( E_u ))</td>
<td>3 in.</td>
<td>3 in.</td>
</tr>
</tbody>
</table>

Avoid negative unbalance.

Base spiral curve lengths on a maximum unbalanced superelevation of 3 inches.

Check superelevation against the range of operating speeds to ensure that the maximum allowable value for negative unbalance is not exceeded.
Minimum Superelevation

The actual superelevation must be a minimum of 0.5 inches.

The minimum unbalanced superelevation must be 1 inch, except in cases where the actual superelevation and the unbalanced superelevation total less than 2 inches. If the equilibrium superelevation is less than 2 inches, the actual superelevation and unbalanced superelevation must be approximately equal.

Specify the minimum superelevation for any mainline curve calculation that yields less than the minimum required superelevation.

7.2.7 Vertical Profile

The vertical alignment or profile must consist of vertical tangents connected by parabolic vertical curves having a constant rate of grade change. The vertical profile must be developed for the top of rail, which is the low or inside rail on a superelevated curve.

Grades are calculated as percentages, rounded to the nearest 0.01 percent.

Maximum Gradient

Maximum track gradient must conform to the values shown in Error! Reference source not found.

Table 7-4: Maximum Track Profile Gradient

<table>
<thead>
<tr>
<th>Track Type and Condition</th>
<th>Desirable Value</th>
<th>Absolute Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainline tracks</td>
<td>1.0%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Station tracks</td>
<td>0.0%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Storage tracks</td>
<td>0.00%</td>
<td>0.20%</td>
</tr>
</tbody>
</table>

The maximum design gradient, with curve compensation at 0.04 percent per degree of curve, if applicable, for grade up to maximum gradient ($G_c$) is as follows:

Equation 7.6. Maximum Design Gradient

$$G_c = G - 0.04D_{vc}$$

Where:

- $G_c$ is the maximum gradient as a percentage.
- $G$ is the gradient before as a percentage.
- $D_{vc}$ is the degree of vertical curvature in decimal degrees.

Vertical curves are not allowed where car coupling and uncoupling tasks would normally be performed. Car coupling and uncoupling must be performed on track with constant vertical gradient.
Minimum Gradient

A minimum gradient must be maintained in the DTX tunnel to promote drainage of the track bed. The desirable minimum grade in tunnels must be greater than or equal to 0.3 percent. The absolute minimum grade in tunnels will be 0.25 percent. If a grade of 0.25 percent is not practical, a drainage system in addition to the normal trackside facilities must be provided.

Minimum Length of Gradient

Calculate the desirable minimum length of vertical gradient between vertical curves using the following formula:

Equation 7.7. Minimum length of vertical gradient

\[ L_g = 3V \]

Where:

- \( L_g \) is the minimum length of gradient between vertical curves in feet.
- \( V \) is the train speed in miles per hour.

The absolute minimum length of vertical gradient between vertical curves must be 100 feet.

7.2.8 Vertical Curvature

All changes in gradient must be connected by parabolic vertical curves with a constant rate of grade change per 100-foot station.

Minimum Length of Vertical Curve

The desirable minimum length of the vertical curve for both sags and summits is the largest of the values calculated by the following formulas:

Equation 7.8. Minimum Length of Vertical Curve

\[ L_{vc} = \frac{2.15D V^2}{A} \]
\[ L_{vc} = 4.55V \]
\[ L_{vc} = 400D \]

Where:

- \( L_{vc} \) is the length of vertical curve in feet.
- \( D \) is the absolute value of the difference in rates of grades expressed as a decimal.
- \( V \) is the train speed in miles per hour.
- \( A \) is the vertical acceleration, equal to 0.6 feet/sec/sec (ft/sec²).

The absolute minimum length of a vertical curve for both sags and summits is 100 feet.
Minimum Radius of Vertical Curvature

Vertical curves must conform to the requirements for high-speed mainline tracks and shooflies, as recommended in the AREMA Manual for Railway Engineering and shown in the following formula:

Equation 7.9. Minimum Radius of Vertical Curvature

\[ L_{vc} = \frac{(D \times K \times V^2)}{A} \]

Where:

- \( L_{vc} \) is the length of vertical curve, in feet.
- \( D \) is the absolute value of the difference in rates of grades expressed in decimal.
- \( K \) is the conversion factor (2.15) to give \( L \) in feet.
- \( V \) is the train speed in miles per hour.
- \( A \) is the vertical acceleration, equal to 0.6 ft/sec².

The recommended vertical accelerations (A) for passenger trains must be 0.60 ft/sec² (0.019 g). Under no circumstances will the length of vertical curve be less than 100 feet. Station platform and special trackwork will not be located inside of vertical curves.

7.2.9 Reverse Curves

Avoid reverse curves. Minimum tangent distances between reverse curves must conform to Chapter 7, subsection Minimum Tangent Length.

Compound Curves

Compound or unsymmetrical vertical curves will not be used on mainline tracks.

Combined Horizontal and Vertical Curvature

Avoid overlapping horizontal and vertical curves where feasible. The desirable minimum distance between end of spiral and beginning of vertical curve or end of vertical curve and beginning of spiral is 160 feet. The absolute minimum distance is 100 feet.

The use of overlap between vertical curves and horizontal spirals must be approved by the TJPA through a design variance request. See Chapter 1, section 1.8, Variances and Changes to Design Criteria. Where the overlap of horizontal and vertical curves cannot be avoided, the following conditions must be met:

- The minimum length of vertical curve, as calculated by all parameters, must be increased by a minimum of 50 percent.
- The speed on the horizontal curve must be adjusted as necessary to produce a desirable maximum unbalanced superelevation of 2 inches, and an absolute maximum unbalanced superelevation of 3 inches.
The design speed, horizontal alignment, and vertical profile must be adjusted so that the combined or equivalent curvature does not become excessive. The combination of vertical and spiral curvature must be checked to verify that the equivalent vertical curvature of the high rail is within allowable limits.

Combined horizontal and vertical curves are not allowed where car coupling and uncoupling tasks would normally be performed. Car coupling and uncoupling must be performed on track with a constant vertical gradient.

7.2.10 Turnouts

The alignment of turnout tracks must be along the turnout track curve and begin at the point of switch.

All turnouts and crossovers must be on a horizontal or vertical tangent alignment. Minimum lengths of tangent track at turnouts and crossovers must be within the limits specified in Table 7-5. Avoid placing turnouts and crossovers on horizontal and vertical curves within the geometric constraints of the DTX. Placement of any turnout or crossover on a horizontal or vertical curve must be approved by the TJPA through a design variance request. See Chapter 1, section 1.8, Variances and Changes to Design Criteria.

### Table 7-5: Minimum Tangent Length at Turnouts

<table>
<thead>
<tr>
<th>Item</th>
<th>Desirable value</th>
<th>Absolute value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between point of switch of turnout</td>
<td>50 ft</td>
<td>20 ft (tangent length will not be less than the length of stock rail projection)</td>
</tr>
<tr>
<td>Between point of switch and curve</td>
<td>100 ft</td>
<td>15 ft (tangent length will not be less than the length of stock rail projection)</td>
</tr>
<tr>
<td>Between point of switch and platform</td>
<td>100 ft</td>
<td>60 ft</td>
</tr>
<tr>
<td>Between point of switch and grade crossing</td>
<td>100 ft</td>
<td>50 ft</td>
</tr>
<tr>
<td>Between point of switch and last long tie of turnout</td>
<td>60 ft</td>
<td>15 ft (tangent length will not be less than the length of stock rail projection)</td>
</tr>
</tbody>
</table>

7.3 Clearances

Clearances between rail vehicles and fixed objects including structures and equipment must conform to the requirements in this section. The DTX design must conform to CPUC GO 26-D and 118-A and the clearance requirements established in this section.

The clearance envelope is based on requirements for commuter, high-speed, and maintenance and work trains. Maintenance and work trains proposed for use in the DTX tunnel must conform to the clearance requirements established for the passenger trains.

7.3.1 Definition of Clearance Envelope

The clearance envelope represents dedicated space for the rail vehicles into which no other part of the DTX system—structure or equipment—will encroach. The clearance envelope must be referenced from a working origin point located at the intersection of the centerline of track and the top of the running rail.
Caltrain and the California High-Speed Rail Authority have provided the data to establish the vehicle static envelope and the vehicle dynamic envelope for their respective rolling stock on tangent track. The California High-Speed Rail Authority vehicle dynamic envelope will be used as the DTX clearance envelope. The size and shape of DTX clearance envelope must be adjusted for non-tangent track and must consider vehicle roll and lateral shift, construction tolerances, and inswing/outswing resulting from track curvature and superelevation. The clearance envelope is derived from the worst-case composite vehicle dynamic envelope outlines provided by the operators.

Horizontal and vertical clearances on curved portions of the DTX must allow for changes in superelevation as identified in the following criteria:

- A minimum of 1 inch for every 30 minutes of curvature where the amount of superelevation is the same on adjacent tracks or the superelevation of the inner track is greater than that of the outer track
- A minimum of 1 inch for every 30 minutes of curvature, plus 3.5 inches for every inch of difference in elevation between the two tracks where the superelevation of the outer track is greater than that of the inner track

Vertical running clearances are governed by the overhead electrification requirements established by the Peninsula Corridor Joint Powers Board’s Peninsula Corridor Electrification Project. Vertical clearances must be measured along track centerline.

The clearances calculated from the combination of VDE and horizontal and vertical running clearances must not be less than the minimum values specified in Section 7.3.4.

**Vehicle Static Envelope**

The Caltrain vehicle static envelope is based on the Caltrain electric multiple unit—the Stadler KISS double-decker. The high-speed train vehicle static envelope is based on a combination of in-service high-speed passenger equipment, Association of American Railroads Plate C, and International Union of Railways CG Gauge.

**Vehicle Dynamic Envelope**

“Vehicle dynamic envelope” is defined as the extreme car body displacement caused by rotational, lateral, or vertical car body movements, or any combination of rotational, lateral, and vertical car body movements, that occur when the vehicle is operating at speed on level, tangent track. Car body movements are due to allowable wheel and rail wear, truck suspension movements, spring action, and permitted tolerances in vehicle and track construction. The car body movements included in the vehicle dynamic envelope are defined in Table 7-6
Table 7-6: Vehicle Dynamic Envelope – Car Body Movements

<table>
<thead>
<tr>
<th>Item</th>
<th>Magnitude*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle roll</td>
<td></td>
</tr>
<tr>
<td>Track cross level deviation</td>
<td>1 in.</td>
</tr>
<tr>
<td>Gauge variation</td>
<td>1 in.</td>
</tr>
<tr>
<td>Alignment deviation</td>
<td>0.75 in.</td>
</tr>
<tr>
<td>Wheel flange wear</td>
<td>0.625 in.</td>
</tr>
<tr>
<td>Wheel-rail clearance</td>
<td>0.25 in.</td>
</tr>
<tr>
<td>Suspension movement</td>
<td>2 in.</td>
</tr>
</tbody>
</table>

* The values presented for magnitude in Table 7.6 are subject to change once the California High-Speed Rail Authority has selected its train manufacturer.

At any single location, 50 percent of the calculated total car body movement must be applied.

The VDE for vehicles operating on level, tangent track is shown in Figure 7.1. The coordinates of the points indicated in Figure 7.1 are tabulated in Table 7-7.

![Figure 7.1: Vehicle Dynamic Envelope](image-url)
Table 7-7: DTX Composite Vehicle Dynamic Envelope

<table>
<thead>
<tr>
<th>Point Identification</th>
<th>Offset from Centerline of Track (ft)</th>
<th>Elevation above TOR (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>0.000</td>
<td>0.229</td>
</tr>
<tr>
<td>b, t</td>
<td>4.232</td>
<td>0.249</td>
</tr>
<tr>
<td>c, s</td>
<td>4.760</td>
<td>1.044</td>
</tr>
<tr>
<td>d, r</td>
<td>5.224</td>
<td>1.153</td>
</tr>
<tr>
<td>e, q</td>
<td>5.697</td>
<td>2.804</td>
</tr>
<tr>
<td>f, p</td>
<td>6.055</td>
<td>13.047</td>
</tr>
<tr>
<td>g, o</td>
<td>5.846</td>
<td>14.222</td>
</tr>
<tr>
<td>h, n</td>
<td>5.340</td>
<td>15.241</td>
</tr>
<tr>
<td>i, m</td>
<td>4.058</td>
<td>15.536</td>
</tr>
<tr>
<td>j, l</td>
<td>3.558</td>
<td>15.553</td>
</tr>
<tr>
<td>k</td>
<td>0.000</td>
<td>15.679</td>
</tr>
</tbody>
</table>

The effects of horizontal curvature resulting in mid-car inswing and end-of-car outswing of the composite vehicle must be considered. See subsection 7.3.4, Adjustments to Clearances for Horizontal Curvature and Superelevation, for calculating the amount of mid-car inswing and end-of-car outswing.

7.3.2 Horizontal Running Clearances

Horizontal running clearances provide for emergency egress and accommodate signals, switch machines, electrical disconnects, and other system equipment. Horizontal running clearances to fixed objects are measured from the centerline of track or from the composite VDE.

The minimum horizontal running clearance from the composite VDE to a fixed object must be 42 inches.

Locomotive and cab car mirrors, as well as other portions of the vehicle, must not protrude into emergency walkway space, as defined in CHAPTER 15FIRE-LIFE SAFETY, but they may project over the top of the walkway envelope.

7.3.3 Vertical Running Clearances

Vertical running clearances are defined by overhead contact system (OCS) requirements for minimum contact wire height. The criteria for OCS design requirements are provided in CHAPTER 18Rail Systems. See Table 18-3 in subsection 18.2.6, Electrical Clearances, for overhead, live-to-ground electrification clearance requirements.

7.3.4 Adjustments to Clearances for Horizontal Curvature and Superelevation

Horizontal running clearances to fixed objects must be increased to account for the effects of curvature and superelevation. Horizontal clearance must be measured perpendicular to the centerline of track.

Use the formula in Equation 7.10 to calculate the minimum increase to horizontal running clearances to account for curvature on the inside of curves:
Equation 7.10. Midpoint Offset Adjustment in Curves

\[ MO = 1.5'' D_c \]

Use the formula in Equation 7.11 to calculate the minimum increase to horizontal running clearances to account for curvature on outside of curves:

Equation 7.11 End of Car Offset Adjustment in Curves

\[ EO = 1.125'' D_c \]

Where:

- \( MO \) is the mid car offset in inches.
- \( EO \) is the end car offset in inches.
- \( D_c \) is the degree of curve

Check the horizontal clearance at the beginning and end of a horizontal curve to verify that adequate clearance is maintained on the tangent portions where the vehicle will be partially on the curve. Instead of a calculation based on the actual vehicle geometry, the full compensated clearance on the curve will begin 25 feet before the curve, be maintained at the beginning of the curve, and tapered to the tangent clearance over a distance equal to the length of the rail car.

Clearances on the inside of horizontal curves must be increased to account for the effects of superelevation. Calculate the width of the clearance to account for the horizontal curvature before adding the effects of superelevation.

Use the formula in Equation 7.12 to calculate the angle of rotation from the applied superelevation:

Equation 7.12. Angle of Rotation Adjustment in Curves and Spirals

\[ \Theta_{\text{rotated}} = \sin \left( \frac{E_a}{59.5} \right) \]

Where:

- \( \Theta_{\text{rotated}} \) is the angle of rotation in degrees.
- \( E_a \) is the actual superelevation in inches.

The point of rotation for superelevation for both the static envelope and the dynamic envelope is the top inside corner of the inside rail of the curve, located at the track profile elevation and 28.25 inches offset from the track centerline.

7.3.5 Tolerances

The clearance envelope must accommodate appropriate tolerances for construction and maintenance of the track and structures.
Track Tolerances

Track construction tolerances are shown in Table 7-8. For track in cut-and-cover and mined tunnel sections, maintenance allowances must be provided to account for long-term deformations of the structure invert slab arising from groundwater and soil loading. Base the maintenance allowances on the outcome of the respective analysis of the structure types.

Table 7-8: Track Construction Tolerances

<table>
<thead>
<tr>
<th>Item</th>
<th>Ballasted Track</th>
<th>Direct Fixation Track</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal track construction tolerance</td>
<td>± 0.5 in.</td>
<td>± 0.25 in.</td>
</tr>
<tr>
<td>Vertical track construction tolerance</td>
<td>± 0.5 in.</td>
<td>± 0.25 in.</td>
</tr>
</tbody>
</table>

Structure Tolerances

Tolerances for structures that support or house the DTX trackwork are shown in Table 7-9. Structure openings must be increased by the amounts shown, where applicable, to allow for construction tolerances.

Table 7-9: Structure Tolerances

<table>
<thead>
<tr>
<th>Structure</th>
<th>Horizontal</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut-and-cover tunnels (per cell)</td>
<td>2 in.</td>
<td>2 in.</td>
</tr>
<tr>
<td>Mined tunnel</td>
<td>2 in.</td>
<td>2 in.</td>
</tr>
<tr>
<td>Retaining walls</td>
<td>2 in.</td>
<td>N/A</td>
</tr>
<tr>
<td>Chorded construction (Based on 25-ft-long chords)</td>
<td>78/R (ft)</td>
<td>N/A</td>
</tr>
<tr>
<td>High-level platforms</td>
<td>+0/-0.5 in.</td>
<td>+/- 0.5 in.</td>
</tr>
<tr>
<td>Low-level platforms</td>
<td>+0/-0.5 in.</td>
<td>+/- 0.5 in.</td>
</tr>
<tr>
<td>Raised walkways</td>
<td>+0/-0.5 in.</td>
<td>+/- 0.5 in.</td>
</tr>
<tr>
<td>OCS poles</td>
<td>TBD</td>
<td>N/A</td>
</tr>
<tr>
<td>Signal poles</td>
<td>TBD</td>
<td>N/A</td>
</tr>
<tr>
<td>Signal bridges</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

7.3.6 Minimum Horizontal and Vertical Clearances

Minimum tangential horizontal clearances are shown in Table 7-10. The minimum horizontal clearance must be increased on non-tangent tracks and conform to the criteria in subsection 7.3.1, Definition of Clearance Envelope.
Table 7-10: Minimum Horizontal Clearance

<table>
<thead>
<tr>
<th>Infrastructure Asset</th>
<th>Minimum Horizontal Clearance</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Caltrain</td>
<td>CHSRA</td>
</tr>
<tr>
<td>Track centerline to face of tunnel partition wall</td>
<td>8 ft 7 in.*</td>
<td>8 ft 7 in.*</td>
</tr>
<tr>
<td>Track centerline to face of fixed equipment</td>
<td>8 ft 7 in.*</td>
<td>8 ft 7 in.*</td>
</tr>
<tr>
<td>Track centerline to face of station wall (condition where no walkway exists at the Transit Center)</td>
<td>7 ft 3 in.</td>
<td>7 ft 3 in</td>
</tr>
<tr>
<td>Track centerline to edge of level platform</td>
<td>5 ft 8 in.</td>
<td>6 ft 0 in.</td>
</tr>
<tr>
<td>At-grade track centerline to face of permanent structure</td>
<td>25 ft</td>
<td>25 ft</td>
</tr>
<tr>
<td>At-grade track centerline to fixed equipment</td>
<td>8 ft 7 in.</td>
<td>8 ft 7 in.</td>
</tr>
</tbody>
</table>

* Conformance with CPUC GO 26-D must be verified once CHSRA rolling stock is identified.

Minimum vertical clearances above top of rail are shown in Table 7-11. Minimum contact wire height is specified in CHAPTER 18, Rail Systems.

Table 7-11: Minimum Vertical Clearance

<table>
<thead>
<tr>
<th>Item</th>
<th>Desirable value</th>
<th>Absolute value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearance from top of rail to overhead structure (structural beam, ventilation plenum, etc.) in DTX tunnel</td>
<td>24 ft 6 in.</td>
<td>21 ft 6 in.</td>
</tr>
<tr>
<td>At-grade clearance from top of rail to overhead structure soffit</td>
<td>27 ft</td>
<td>24 ft 6 in.</td>
</tr>
</tbody>
</table>
CHAPTER 8 TRACKWORK

SCOPE

This chapter establishes the requirements for design and construction of the Downtown Rail Extension (DTX) trackwork including track structure and track components, such as rail, ties, fasteners, ballast, subballast, special trackwork (turnouts and crossovers), track appurtenances, and at-grade crossings.

CODES, STANDARDS AND GUIDELINES

Trackwork design must conform to the latest edition of the following standards, codes, and guidelines in the following order of precedence, unless otherwise specified in these design criteria.

◆ American Railway Engineering and Maintenance of Way Association (AREMA) Manual for Railway Engineering
◆ California High-Speed Rail Authority (CHSRA) Design Criteria Manual
◆ California Public Utilities Commission (CPUC) applicable General Orders (GO):
  ● GO 26-D, Regulations Governing Clearances on Railroads and Street Railroads with Reference to Side and Overhead Structures, Parallel Tracks, Crossing of Public Roads, Highways and Streets
  ● GO 36-E, In the Matter of the Establishment or Abolition of Agencies, Non-Agencies, Sidings, Spur Tracks and Other Station Facilities, and the Curtailment of Agency Service of Common Carriers
  ● GO 72-B, Rules Governing the Construction and Maintenance of Crossings at Grade of Railroads with Public Streets, Roads and Highways in the State of California
  ● GO 75-D, Regulations Governing Standards for Warning Devices for At-Grade Highway-Rail Crossings in the State of California
  ● GO 88-B, Rules for Altering Public Highway-Rail Crossings
  ● GO 118-A, Regulations Governing the Construction, Reconstruction, and Maintenance of Walkways Adjacent to Railroad Trackage and the Control of Vegetation Adjacent Thereto
  ● GO 135, Regulations Governing the Occupancy of Public Grade Crossings by Railroads
  ● GO 164-E, Rules and Regulations Governing State Safety Oversight of Rail Fixed Guideway Systems
  ● GO 176, Rules for Overhead 25 kV AC Railroad Electrification Systems for a High-Speed Rail System
◆ Caltrain Engineering Standards
◆ Code of Federal Regulations (CFR), Title 49, Part 213, Track Safety Standards
8.1 Track Requirements

8.1.1 Track Gauge

Track gauge will be 4 feet 8.5 inches, measured at 0.625 inch below the head of the rail on the gauge side on all tracks except on tight radius curves where gauge widening may be required.

8.1.2 Ballasted Track

Ballasted track will be composed of a well-compacted subgrade, subballast, ballast, ties (including elastic fastening system), running rail, and other track materials.

Ballasted track must be used for all at-grade mainline and non-revenue tracks including at-grade crossings.

8.1.3 Direct Fixation Track

Direct fixation track will be a low vibration track composed of concrete track bed, booted concrete block rail seats embedded in reinforced plinths or reinforced infill slabs, rail fastenings, special trackwork (turnouts and crossovers), guard rail, and running rail. Other track system types may be proposed as the supplier technologies evolve.

Direct fixation track must be used on all below-grade tracks, including station, tunnel, and open-cut/u-wall sections of the DTX alignment.

8.1.4 At-grade Crossing Track

The design of at-grade crossing track must conform to the Caltrain Design Criteria. See CHAPTER 8, subsection 8.2.7 and section 8.7.

8.2 Track Components

The design of track components and other track material must conform to the criteria described in subsection 8.2.1, Running Rail, through 8.2.9, Track Material Performance Requirements.

8.2.1 Running Rail

Running rail for permanent tracks and special trackwork must be new. Temporary tracks to support staged construction that will not be in service more than two years may be previously used but must be pretested for internal defects. Running rail will be 136 RE rail section and must conform to Caltrain Engineering Standards.

High-strength rail with a Brinell Hardness Number of 370 must be used in all special trackwork and new tracks.

Rail must be manufactured, and plant welded into continuously welded rail with a minimum section length of 1440 feet. Within project limits, 80-foot-long rail sections may be welded by electric flash butt method.
8.2.2 Concrete Ties

Concrete ties must be used for all permanent at-grade mainline running tracks, yard running tracks, and non-revenue running tracks. Concrete ties must conform to Caltrain Standards and the AREMA Manual for Railway Engineering.

Concrete ties must come complete with embedded rail shoulders, insulated rail seat pads, elastic rail clips, and rail clip insulators. Concrete ties must be between 8 feet 3 inches (minimum) and 8 feet 6 inches (maximum) in length and be installed at 24-inch spacing on center.

Concrete ties for at-grade crossings must be 10 feet in length, suitable for a moisture-prone environment, and installed to accommodate crossing panels and enhanced load distribution for additional vehicular traffic.

Concrete ties with a fastening system must be tested as a unit and meet all test recommendations in the AREMA Manual for Railway Engineering. Concrete tie fastening system must be galvanized or applied with a moisture and rust resistant paint. Concrete tie design must not be factored and conform to AREMA Manual for Railway Engineering, Chapter 30, Part 4.

8.2.3 Timber Ties

Timber ties with 16-inch Pandrol plates, e-clip, and screw spikes may be used for temporary trackwork, including special trackwork on ballasted track as part of the staged construction. Timber ties must measure 7 inches x 9 inches x 8 feet 6 inches in length and be installed at 19.5-inch spacing on center.

Timber ties may be used for temporary conditions only and must conform to the requirements of the AREMA Manual for Railway Engineering.

8.2.4 Transitions

Tracks must be designed to provide smooth transitions between different types track and changing track modulus. Reinforced concrete bridging slabs must be provided at transitions between direct fixation and ballasted track. Longer ties must be used in areas of ballasted track and conform to the Caltrain Standard Drawings to transition between standard tie zones and high modulus special trackwork or at-grade crossing zones. Direct fixation block spacing must be adjusted between areas of standard fasteners and high-resilience fasteners.

8.2.5 Ballast

Ballast design must conform to Caltrain Design Criteria Chapter 2 – Track, Section B – Track Structure, Subsection 5.0 – Ballast.

8.2.6 Subballast

Subballast design must conform to Caltrain Design Criteria Chapter 2 – Track, Section B – Track Structure, Subsection 3.0 – Subballast.

8.2.7 Geotextile Fabric

Geotextile fabrics must conform to the Caltrain Design Criteria.
8.2.8 Hot-Mix Asphalt Concrete Underlayment

Hot-mix asphalt concrete underlayment must conform to Caltrain Design Criteria Chapter 2 – Track, Part B – Track Structure, Section 4.0 – Hot-Mixed Asphalt Concrete Underlayment.

8.2.9 Track Material Performance Requirements

System Safety and Reliability

Track materials, including cut spikes, rail clips or pads, screw spikes, fastening systems, track bolts, nuts, spring washers, tie plates, rail anchors, insulated joints, standard joint bars, and compromise bars must be designed to resist corrosion in wet and dry climate to maximize system safety and reliability.

Noise and Vibration Mitigation

Resilient direct fixation fasteners must be used to minimize noise and vibration in accordance with commitments in the 2018 Final Supplemental Environmental Impact Statement/Environmental Impact Report. If direct fixation fasteners alone will not provide the required mitigation, then the design must incorporate other options for noise and vibration reduction, including the use of floating track slab in conjunction with elastomeric mats or discrete elastomeric bearings.

Fire Resistance

Track components including rail ties and direct fixation fasteners in tunnel sections must be non-combustible and have minimum smoke generation and toxicity characteristics.

8.3 Special Trackwork (Turnouts and Crossovers)

Special trackwork must conform to the Caltrain Engineering Standards. Where turnout sizes are not referenced within the Caltrain Engineering Standards, turnout sizes as specified in the AREMA Manual for Railway Engineering must be used. Where non-standard special trackwork is required, a design variance request must be submitted to Caltrain for approval.

The following turnouts and crossovers will be used:

♦ No. 8 and No. 9 lateral turnouts may be used in yard and non-revenue tracks where only Caltrain rolling stock will operate.
♦ No. 10, No. 14, and No. 20 lateral turnouts must be used in mainline tracks.
♦ No. 8 and No. 9 turnouts must have straight switch points and railbound manganese steel frogs. No. 10, No. 14, and No. 20 turnouts must have spring frogs.

8.4 Bonded Insulated Joints

Insulated joints must be prefabricated, factory assembled, epoxy-bonded, 36-inch, six-hole bar design assemblies conforming to the AREMA Manual for Railway Engineering and Caltrain Engineering Standards.
8.5 Track Appurtenances

8.5.1 Rail Lubrication

Train-activated rail lubricators must conform to the AREMA Manual for Railway Engineering (Volume 1 – Track, Chapter 5, Part 5, section 5.9 Wayside Lubrication of Rail on Curves and the manufacturer’s recommendations. The design and location of lubricators must include an analysis to ensure the following locations are provided with sufficient lubrication to prevent excessive rail wear and provide noise abatement:

- Curved approach to the DTX between Seventh and Townsend streets
- Curved transition between Townsend and Second streets
- Throat structure approach to the Transit Center

Rail lubricators located below grade must be designed to support remote monitoring, electronic type functioning system, and provide containment of the lubricant in case of malfunction or rupture of a hydraulic hose or valve.

8.5.2 Bumping Posts

A bumping post must be provided at the end of each stub-end track. Hydraulic bumping posts must be installed before the end of the track and conform to manufacturer’s recommendations and be compatible with Caltrain’s new rail fleet and the California High-Speed Rail Authority’s (CHSRA) fleet. Bumping posts must be designed to protect passengers and crew on the train, adjacent trains, and the platforms in the event of an over-run. The design must consider the track configuration, maximum likely speed, and rolling stock characteristics. See Chapter 7, subsection 7.2.1.1, Maximum Authorized Speed, for the minimum tangent lengths required between vehicle stop spot and face of trainset bumper.

8.6 Derailment Containment and Derails

8.6.1 Guard Rails

Guard rails are typically installed 10 inches from running rails to control movement of a derailed train and are typically positioned at raised portions of track or at approaches to tunnels or structural elements that require protection. Guard rails must be provided where a derailment could significantly damage adjacent structures, including the following locations: approaches to abutments and piers of overhead bridges, tunnel internal walls, and ends of high (CHSRA) passenger platforms. Guard rails must also be provided at curved track sections where derailments could pose an immediate risk to adjacent streets.

Guard rails will extend 25 feet beyond the length of track requiring guarding in both directions.

8.6.2 Restraining Rails

Restraining rails provide a narrow flangeway (1-5/8 inches) to avoid the derailment of a train navigating a curve with a radius of less than 500 feet. Restraining rails must be designed for curves of 500 feet or less.
8.6.3 Derails

The design and application derails must conform to the Caltrain Design Criteria, Chapter 2:–Track, Part D – Special Trackwork, 8.6.2 – Derails.

8.7 At-Grade Crossings

The design of temporary or permanent reconfigurations to existing at-grade crossings at Sixteenth Street and Mission Bay Drive must conform to CPUC GO 36-E, 72-B, 75-D, 88-B, and 135 as well as the latest edition of the Caltrain Design Criteria - Chapter 7, Grade Crossings, as modified by the requirements of the Caltrain Peninsula Electrification Program.
CHAPTER 9 GEOTECHNICAL REQUIREMENTS

SCOPE

This chapter establishes the following geotechnical requirements for the Downtown Rail Extension (DTX) project:

♦ Subsurface exploration and field and laboratory testing
♦ Reporting
♦ Ground improvement methods
♦ Excavation base stability
♦ Groundwater control
♦ Instrumentation and monitoring

This chapter does not provide specific design parameters. Because of the variability in ground conditions along the DTX alignment, the design parameters have been developed from site-specific subsurface investigations and laboratory testing programs. The geotechnical data and design parameters are presented in the geotechnical reports referenced herein. These geotechnical reports may only be relied on for design and bidding if they are indicated to be contractually reliable in the order of precedence set forth in the contract. Reference herein does not alone make these documents contractually reliable.

Additional provisions for geotechnical seismic design are identified in CHAPTER 13 Tunnels, Tunnels, and other areas of these design criteria.

The subsections that follow specify the appropriate application of these codes, standards, guidelines, and references. Geotechnical investigations and analysis must be sufficient to obtain permits for the work.

CODES, STANDARDS AND GUIDELINES

Geotechnical design for the DTX must conform to the latest edition of the following standards, codes, and guidelines unless otherwise specified in these criteria.

♦ American Railway Engineering and Maintenance-of-Way Association Manual for Railway Engineering
♦ ASTM International:
  • Annual Book of ASTM Standards, Section 4, Construction:
    – Volume 04.08: Soil and Rock (I): D420 – D5876/D5876M
    – Volume 04.09, Soil and Rock (II) D5878 - Latest
  • ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
  • ASTM D4623, Standard Test Method for Determination of In Situ Stress in Rock Mass by Overcoring Method—Three Component Borehole Deformation Gauge
  • ASTM D4729, Standard Test Method for In Situ Stress and Modulus of Deformation Using the Flat Jack Method
♦ Caltrain Engineering Standards
- Caltrans Highway Design Manual
- Caltrans Trenching and Shoring Manual
- Federal Highway Administration (FHWA), Geotechnical Technical Guidance Manual (GTGM)
- International Society of Rock Mechanics and Rock Engineering (ISRM)
- San Francisco Building Code (SFBC), which includes San Francisco Code Amendments (SF Amendments)
- San Francisco Department of Public Health requirements
- San Francisco Municipal Transportation Agency (SFMTA) Regulations for Working in San Francisco Streets (Blue Book)
- San Francisco Public Works Order No. 187005, Regulations for Excavating and Restoring Streets in San Francisco (or current superseding edition)
- State of California, Department of Water Resources, California Well Standards, Monitoring Well Standards (Bulletin 74-90)
- United States Army Corps of Engineers (USACE), Engineer Manual EM 1110-1-1804, Geotechnical Investigations
- United States Department of the Interior, Bureau of Reclamation (USBR):
  - USBR Earth Manual
  - USBR Ground Water Manual

REFERENCES

The following references may also be used in the geotechnical design of the DTX.


Federal Highway Administration Publication Number NHI-16-072, Geotechnical Site Characterization (Geotechnical Engineering Circular No.5).

Federal Highway Administration (FHWA), Publication Number NHI-97-021, Training Course in Geotechnical and Foundation Engineering: Subsurface Investigation.


**PROJECT-SPECIFIC REFERENCE DOCUMENTS**

The following reports and memoranda have been prepared for the Transbay Program. The geotechnical reports may be updated if additional investigations are warranted when work on the Geotechnical Baseline Report begins.


9.1 Subsurface Exploration and Testing

The following subsurface explorations and tests must be carried out to identify the subsurface stratigraphy and its variations and groundwater conditions along the DTX alignment:

- Boreholes, using Standard Penetration Testing (SPT) and other sampling methods
- Cone Penetration Test
- In situ tests—field vane shear and pressure meter
- In situ downhole geophysical tests
- Installation of piezometers and pumping wells
- In situ permeability tests
- Packer tests

The number and locations of the exploratory borings and the location of all field testing must suit the anticipated conditions, consistent with project objectives and design requirements. A work plan for all exploration and testing work that details the locations, drilling depths, and methods to be used must be prepared and submitted to the Transbay Joint Powers Authority (TJPA) for review and approval before the exploration and testing work begins.

Field explorations and tests must conform to the most recent applicable standards included in the Annual Book of ASTM Standards, Section 4, Construction, Volumes 04.08 and 04.09, Soil and Rock; United States Army Corps of Engineers Engineer Manual EM 1110-1-1804, Geotechnical Investigations; and other applicable industry codes and standards. Work must also conform to the Blue Book, other applicable City and County of San Francisco codes, and San Francisco Department of Public Works orders.

Deviations from ASTM International, International Society of Rock Mechanics, United States Army Corps of Engineers, and other specified standards must be approved by the TJPA through a design variance request. See Chapter 1, section 1.8, Variances and Changes to Design Criteria. Field permeability tests must follow the methods outlined in the USBR Earth Manual and the USBR Ground Water Manual, unless otherwise approved by the TJPA.

All tested and untested soil and rock samples recovered from the geotechnical and geological field exploration program must be maintained in a readily accessible storage facility within 20 miles of the project site until the completion of construction. These samples must be made available for viewing by the TJPA or its designees within one business day of a request. The TJPA may elect to allow prospective bidders to view the samples. Upon completion of construction, the TJPA will have the option to take possession of the samples and will have at least 30 days to exercise that option. If the TJPA elects not to take possession of the samples, the designer will be responsible for sample disposal. Untested samples must not be disposed of or released to any other party at any time without the written authorization of the TJPA.

9.1.1 Soil Explorations

Explorations within soil units must include an appropriate selection from the following methods:

- Rotary wash boring:
  - Soil sampling should generally be once every 5 feet and at layer changes, with continuous sampling performed on an as-needed basis. Sampling frequency may be reduced generally to once every 10
feet and at layer changes outside of the tunnel horizon, defined as the tunnel section, and one
diameter above and below the tunnel. Soil must be logged in accordance with the Caltrans Soil and

- For undisturbed and relatively undisturbed sampling of cohesive materials, where possible, use
  Dames & Moore piston sampler instead of Shelby tube sampling for soft to stiff cohesive materials.

Seismic field testing. Seismic field testing is used to determine dynamic properties of the soil
including downhole -S suspension logging (OYO Method or similar) and Seismic Cone Penetration
Test such that each design or idealized soil column can be represented by a measured shear wave
velocity profile. Shear wave and P-wave velocity information must be collected to adequate depth to
establish a reference horizon.

- Vibracore (rotasonic) drilling
- Cone Penetration Tests

During rotary wash drilling, always keep the drilling fluid in boreholes above the groundwater level and
avoid rapid fluctuations in the level of drilling fluids. Thoroughly clean the boreholes prior to taking samples.
Collect the drill cuttings in drums and dispose of them in accordance with applicable regulations.

### 9.1.2 Rock Explorations

If bedrock is encountered in boreholes within the planned depth of drilling, continuous rock coring
must conform to the following procedures:

- Rock coring will use a triple tube HQ coring system or a larger diameter triple tube coring system.
The HQ system produces cores measuring 2.4 inches in diameter. The advantage of the triple tube
system is that a split liner is used to contain the core, which results in less disturbance to the core.

- Where weak rock zones are encountered, alternative soil sampling techniques must be used instead
  of coring to recover samples that would be relatively undisturbed and suitable for testing. These
techniques include the use of samplers such as the Pitcher, Dames & Moore, or Modified California
samplers. The potential difficulty with these samplers is that they can be easily damaged by hard,
gravel-size particles that are often mixed with the softer clay-like matrix of the weathered shale.
These difficulties must be considered in the planning of the exploration program.

As part of the above-described explorations, an appropriate number of the following tests should be
performed to adequately characterize the bedrock:

- In hole permeability/packer tests
- Rock deformability (dilatometer and/or pressure-meter tests)
- Seismic tests: downhole P-S log by OYO method or equivalent to collect shear wave and p-wave
  velocities in the rock
- Acoustic televiewer and/or optical logging
- Horizontal in situ stress evaluations such as double packer test method (ISRM 40, 2003), over
coring (ASTM D4623), and/or flat jack testing (ASTM D4729)
9.1.3 Core Logging in Soil and Rock

A California-licensed geotechnical engineer or certified engineering geologist, as approved by the TJPA, must continuously monitor the drilling and coring procedures, visually classify the rock core, or soil samples obtained, and prepare a field borehole log. There must be at least one geotechnical engineer or engineering geologist for each drilling rig. In the case of rock core, logs must include a characterization of joints and texture and determination of rock-quality designation. Soil logs must include percent recovery for each sample in addition to the Unified Soil Classification System as adopted by ASTM D2487, soil description, and other descriptive terms required by the relevant ASTM standards. An experienced certified engineering geologist must also be on site to verify the classification of recovered rock and soil materials and aid on-site engineers, geologists, or other personnel.

At the end of each day, rock cores must be placed in plastic core bags or double-wrapped in plastic wrap, placed in wooden core boxes labeled with the horizontal and vertical locations where the cores were taken and the date, and transported to a storage facility. An adequate number of core boxes must be maintained on site at all times during field exploration activities. The cores must be photographed, taking at least one photo for each core box and closeups of special features such as shear zones or other features of special interest. The photo must clearly show the core box label. An experienced engineering geologist must study the core and edit the borehole log based on the geologist’s observations. Core boxes must be maintained in the San Francisco Bay Area throughout the design process and through bidding, with cores that have been removed for testing duly indicated in the appropriate locations in each box.

9.1.4 Cone Penetration Tests

Cone Penetration Tests must conform to the applicable ASTM standards, and the equipment must be capable of simultaneously measuring tip resistance, side sleeve, and pore pressures.

The testing equipment must be capable of performing downhole seismic surveys when required.

Pore pressure dissipation tests must be performed at selected depths to evaluate the consolidation characteristics of the soils and/or verify the hydrostatic water pressures.

Interpretation of the test results must follow the procedures described in the Guide to Cone Penetration Testing for Geotechnical Engineering (Robertson and Cabal 2015).

Cone Penetration Tests must not be terminated in loose or medium dense cohesionless material or soft to stiff cohesive material. The geotechnical investigation work plan must include the test’s target depth and criteria for termination including practical refusal.

9.1.5 Field Vane Shear Tests

Field vane shear tests must conform to the most recent applicable ASTM standards in soft soils to measure their in situ undrained shear strength. Test should usually be performed at small intervals ranging in depth from 1 foot to 3 feet. Near the top of the layer, tests must be performed at 1-foot intervals to determine the variation in strength with depth. At the bottom of the layer, tests must be performed at intervals of 1 foot to 2 feet.
9.1.6 Groundwater Monitoring

Recurrent monitoring must be performed in the project area, as defined and approved by the TJPA, to characterize seasonal fluctuations in groundwater level. Where possible, the groundwater levels must be monitored in each borehole. If accurate groundwater levels cannot be measured at the time of drilling because the use of drilling mud obscures groundwater levels, it may be appropriate to drill a secondary shallow hole next to the (primary) borehole where sampling is being performed and the groundwater levels in the secondary borehole may be monitored during the course of the primary borehole drilling. Upon completion of drilling and sampling of the primary borehole, both boreholes must be backfilled with cement grout in accordance with the requirements of the San Francisco Department of Public Health, unless piezometers are provided for recurrent water level monitoring.

Piezometers, multilevel piezometers, monitoring wells, and pumping wells must be installed at selected locations along the alignment to monitor groundwater levels and conduct permeability testing. Groundwater monitoring capability must be installed at all boreholes unless there is already a groundwater monitoring device available within 100 feet horizontally and 25 feet vertically. Consideration must be given to the installation of two or more multilevel piezometers at each area being monitored to allow for a thorough evaluation of groundwater flow characteristics. Regardless of the monitoring techniques used, both vertical and horizontal flow characteristics must be evaluated at locations where groundwater characterization is desired.

The installation of all groundwater monitoring facilities and groundwater monitoring must conform to the most recent applicable ASTM standards or other procedures approved by the TJPA. The necessary permits must be maintained during the life of these facilities and wells in accordance with the requirements of the San Francisco Department of Public Health.

For environmental groundwater investigation requirements. See CHAPTER 4, Environmental Requirements.

9.1.7 Downhole Geophysical Tests for Modulus Determination

Downhole geophysical testing must conform to the most recent applicable ASTM standards or other methods approved by the TJPA. Shear wave and P-wave velocity information must be collected to adequate depth to establish a reference the depth to a reference horizon.

9.1.8 In Situ Permeability Tests

Standpipe piezometers must be installed to isolate specific zones of rock or soil and to perform permeability tests. Appropriate test methods may include piezometer and pumping well test set-ups. The test methods and evaluation of the results must be in accordance with the USBR Earth Manual. The TJPA must approve any deviations from the procedures in the manuals.

9.1.9 Laboratory Testing

To the extent possible, laboratory testing must conform to the most recent applicable standards included in the Annual Book of ASTM Standards, Section 4, Construction, Volumes 04.08 and 04.09, Soil and Rock, or ISRM standards. Exceptions to the standard methods must be approved by the TJPA.

As a minimum, the following tests must be conducted in soil to establish the classification and engineering properties of each soil unit: laboratory visual classification, moisture content, unit weight, specific gravity, and sieve analysis. For fine-grained soils or fine-grained fractions of coarse-grained soils, hydrometer analysis and
Atterberg limits tests must be conducted to assist with soil classification and the evaluation of engineering characteristics.

One or more of the following tests—consolidation tests, drained triaxial tests, direct simple shear tests, consolidated undrained triaxial compression tests, or extension tests—must be conducted to evaluate other soil characteristics depending on the type of soil encountered. Soil abrasion testing must also be conducted in units that classify as sands or gravels and conform to the procedures developed by SINTEF in Trondheim, Norway (SINTEF 1998).

As a minimum, the following tests must be conducted in rock: unit weight, permeability, hardness, petrography, and strength. Strength testing depends on the type and condition of rock recovered and includes point load, Brazilian (splitting tension), triaxial compression, and unconfined compressive strength testing. Direct shear tests must be performed on rock discontinuities to conform to the most recent applicable ASTM standards.

As a minimum, testing must be conducted to establish design values for Poisson’s ratio and the friction angle of each type of rock expected to be encountered in the tunnel heading and at least one tunnel diameter above and below the heading. Rock abrasion testing using the AVS test and rock hardness using the Sievers’ J-value SJ test must be conducted as described by SINTEF. Rock abrasion testing using the CERCHAR abrasivity index test also be conducted. Mineralogy and petrographic analysis must be performed for each rock type. Representative samples of rock identified as containing asbestiform must be submitted for X-ray diffraction testing to evaluate for the presence of asbestos fibers.

The designer is responsible for proposing for the TJPA’s approval the number of each type of test necessary to adequately characterize each soil or rock unit encountered. The designer is responsible for obtaining enough testable samples of rock and soil to complete the agreed-upon laboratory testing program. Therefore, additional subsurface exploration and sampling may be necessary to obtain the adequate number of samples for subsurface characterization.

Regardless of whether soil or rock is encountered, corrosion testing must also be conducted, as necessary, to characterize the corrosion potential of materials encountered along the alignment.

If the designer wishes to use tests not covered in the current ASTM or ISRM standards, the designer must propose test methods to the TJPA for approval.

9.2 Geotechnical Reporting

Present the results of the geotechnical studies in the following geotechnical documents:

Geotechnical Data Report (GDR). All geotechnical data obtained for the project must be compiled in a GDR to be made available to bidding contractors or included as construction contract documents, or both. The GDR must include the following:

- Results of all geotechnical explorations, such as boreholes, Cone Penetration Tests, geophysical tests, vane shear tests, and any other tests that might be included in the investigation
- Results of all laboratory tests performed on soil samples and rock cores
- Evaluation of the effects of groundwater drawdown
Summaries of relevant site data from other investigation sources like Caltrans and previous projects at or next to the project site

Detailed results and tabulated summaries of the data and appropriate graphical presentations of the data to facilitate efficient and easy use of the data by designers and contractors alike

Alignment profile showing boring stick logs with offset from profile centerline

Calibration data for all installed instruments, such as piezometers or other monitoring devices, and hammer energy measurements for drilling rig SPT hammers.

A signature and stamp of the California-registered geotechnical engineer responsible for compiling the GDR

A digital transmittal of the gINT database (or equivalent) used to develop the log of test borings

All laboratory test results in MS Excel format or other digitally tabulated format

All Cone Penetration Tests and Seismic Cone Penetration Test data

All other field data collected in digital format (e.g., geophysical data, groundwater measurements both manual and digital, and site photographs)

Do not include any interpretation of the data in the GDR.

**Geotechnical Reference Materials (GRM).** The GRM is a compilation of geotechnical reports procured by the TJPA and project geotechnical engineering consultants, including reports from the San Francisco Department of Building Inspection archives, that provides contextual geotechnical conditions near the project. The GRM is for reference only and must not be relied on for design.

**Geotechnical Interpretive Report (GIR).** The GIR includes design parameters for the project and may be organized as a collection of design memoranda. The GIR must include the following discussions:

- Interpretation of the results of the geotechnical explorations
- Detailed subsurface profiles
- Appropriate design parameters for the major soil strata and rock units
- Recommendations for design groundwater levels
- Results of engineering analyses
- Construction considerations
- Recommendations for excavation, shoring, and dewatering
- Instrumentation and monitoring during construction
- Deep and shallow foundation design for vertical and lateral loading as well as estimates of settlements for all structures including the tunnel and ancillary items like overhead contact system (OCS) poles, equipment pads, and operations and maintenance facilities
- Evaluation of ground deformations that may be caused by excavations, and the impacts of this on existing adjacent structures
- Hydraulic design inputs received for geotechnical consideration, such as flood elevation, tidal variation, and sea level rise
- Design parameters for rock and rock discontinuities, such as joint spacing, dip angle, and dip directions
- Seismic design parameters, such as shear wave velocity and dynamic strength parameters of soil and rock units and stiffness reduction curves for dynamic loading

A preliminary engineering phase GIR must be prepared and submitted to the TJPA for approval. The preliminary GIR is a reference document and must not be relied on for Final Design in a design-build procurement. In a design-build procurement, the GIR must include the design-builder’s interpretations of the soil conditions to be encountered during construction. Completion of the GIR will be a hold point prior to commencement of tunnel excavation.

**Memoranda.** Memoranda consist of geotechnical calculations submitted with a register showing a list of the calculations and the latest version of each calculation. Superseded versions of the calculations must be maintained on the register and clearly indicated as superseded, with the current version of the calculation clearly referenced.

A basis-of-estimate memorandum must be prepared describing the basis for selection of geotechnical and geological design and construction parameters as well as recommended parameters to be used in the construction cost estimate. For example, a basis-of-estimate document will be prepared for ground improvement, describing the layout of ground improvement columns or zones and anticipated takes of cement, grout, or other materials that may be injected into the ground.

**Geotechnical Baseline Report (GBR).** A GBR must be prepared for the mined tunnel portion of the project only, in accordance with the recommendations and list of required content from the Underground Technology Research Council (ASCE 2007). The GBR serves as a summary of the GDR and GIR and is the contractual document included in the contract procurement. The GBR must focus on the geotechnical and groundwater conditions to be encountered during tunnel construction and must not include design parameters.

### 9.3 Ground Improvement Methods

Geotechnical studies must consider the applicability of ground improvement methods to improve the performance of the structures, reduce project cost, or accelerate the construction schedule, or a combination of these.

Ground improvement methods may be used to mitigate liquefaction, improve the base stability of excavations, control groundwater, reduce excavation-induced deformations, improve the stability of tunnel excavation, and strengthen the foundations of adjacent structures. Proposed analytical and design methods for these specialized techniques must be submitted to the TJPA for approval.

Specifications for techniques such as permeation grouting, jet grouting, compaction grouting, soil-cement mixing, ground freezing, compensation grouting, and other stabilization measures must be developed in accordance with geotechnical recommendations.

Strength improvements to native soil provided by ground improvement techniques will be considered temporary unless demonstrated to be capable of performing throughout the project design life and accepted by the TJPA.
9.4 Excavation Base Stability

Basal heave and hydrostatic analysis must be conducted for excavations for temporary and permanent facilities.

9.4.1 Basal Heave

The evaluation of excavation stability against basal heave must follow generally accepted soil mechanics principles to address the risk of base failure due to heave. The strength parameters used in the analysis must reflect the zone where the soil is subjected to shear deformations and recognize anisotropic effects on the shear strengths of soft soils. Factors of safety against basal heave must not be less than 1.5 (Clough and O'Rourke 1990), unless detailed analyses demonstrate that the ground deformations that may be used are within acceptable tolerances, as recommended by the geotechnical engineer and approved by the TJPA. The minimum factor of safety against hydrostatic uplift will be 1.3 (Bowles 2001).

9.4.2 Hydrostatic Uplift

The stability of the base of the excavation against hydrostatic uplift forces must be evaluated, both at maximum excavation depth and at intermediate stages. The minimum factor of safety against hydrostatic uplift will be 1.3. Achieving this factor of safety may require groundwater lowering by dewatering, use of relief wells, or ground improvement below the excavation subgrade to increase the soil strength and resistance against uplift, or a combination of these methods.

Basal heave and hydrostatic analysis must be conducted for excavations for temporary and permanent facilities.

9.5 Groundwater Control

Design analyses criteria must be developed for lowering the groundwater, where necessary, for construction. The analyses must evaluate the potential for settlements caused by dewatering and the likely impacts of these settlements on adjacent structures. The potential extent of groundwater drawdown around the site caused by dewatering of the site must be evaluated by pump tests and hydrogeologic evaluations. The analyses must develop limits for groundwater lowering or mitigation measures where the groundwater lowering exceeds the limits set by the results of the analyses. The analyses of ground movements resulting from groundwater control must be incorporated into the analyses of potential damage to adjacent properties (including buildings, utilities, and infrastructure), as discussed in CHAPTER 11PROTECTION OF EXISTING INFRASTRUCTURE.

The necessary tests must be performed to evaluate the anticipated quality and quantity of groundwater to verify that the discharge will meet the San Francisco Public Utilities Commission’s (SFPUC) Requirements Manual’s criteria for disposal of groundwater from dewatering into the sewer system. If necessary, on-site treatment must be designed to improve the quality of the discharge to meet SFPUC’s criteria for disposal in the sewer system.

Design and implementation of groundwater control during construction must achieve the requirements stipulated in the Final SEIS/EIR.
9.6 Instrumentation and Monitoring

Effective instrumentation and monitoring of ground movements and the movement of existing structures within and surrounding the zone of influence of the project work, structures under construction, and other facilities is required to manage and document the extent of construction impacts. The purpose of the instrumentation is to:

♦ monitor (a) the effectiveness of the contractor’s operations including dewatering and excavation and (b) indications of unacceptable conditions, such as excessive vibration and ground or structural movement, in and next to the project area as defined and approved by the TJPA.

♦ confirm lining shape using convergence monitoring and absolute survey.

♦ facilitate control of the impacts of construction operations on existing structures, utilities, and other facilities within or next to the project area as defined and approved by the TJPA.

♦ confirm design assumptions and design adequacy by verifying that the actual measurements, tolerances, deformations, and other parameters are within the limits assumed during design.

♦ monitor post-construction performance.

Instrumentation must be installed near the tunnel, braced excavations, vent shafts, and other facilities to accomplish these objectives.

Instruments to be used, as needed, are divided into two types: those that provide information concerning groundwater levels and pressures and those that provide information concerning ground, rail, and building and structure movements.

An instrumentation and monitoring program must be developed to address tunnel wall displacements, vibrations, and other issues related to construction. For buildings, utilities, and other infrastructure identified in the Final SEIS/EIR or addenda as being sensitive or historically significant, the instrumentation and monitoring system must be designed to employ at least two independent measurements, such as inclinometers coupled with surface survey markers, or combinations of tiltmeters, crack gauges, and arrays of survey prisms to monitor displacement and rotation of building facades.

A specification detailing information regarding the designing, furnishing, installing, monitoring, reading, recording, maintaining, and protecting of these devices must be developed for the TJPA’s review.

Subsections 9.6.1, Groundwater/Ground Movement Measuring Devices and subsection 9.6.2, Monitoring Schedules, describe the groundwater and ground movement measuring devices to be used in the instrumentation and monitoring program. See also CHAPTER 10, Seismic Design.

9.6.1 Groundwater/Ground Movement Measuring Devices

Groundwater measuring devices may consist of monitoring wells of the open standpipe type, wellpoint piezometers, and other devices as established by the geotechnical engineer in design memoranda. The primary functions of these instruments are to:

♦ permit monitoring of the groundwater level for compliance with limitations on the permissible amount of drawdown established for environmental or other reasons.
ascertain that the groundwater level has been adequately lowered prior to commencement of excavation, as it is essential to (a) exclude water from tunnel headings insofar as possible and (b) minimize the potential for excessive water leakage and detrimental soil movement into braced excavations.

Groundwater measuring devices may also be used to (a) give an overall indication of the water level in selected areas where grouting may be used; (b) reveal the presence of local pockets of ground that may not have been dewatered, and (c) to monitor changes in pore pressure during construction.

**Ground Movement Measuring Devices.** Ground movement measuring devices may consist of a combination of the devices described in this section and other devices as established by the geotechnical engineer in design memoranda and as approved by the TJPA.

**Building Settlement Markers.** Settlement markers are used, as needed, on walls and columns of structures both parallel and perpendicular to the alignment. Certain types of these markers, in addition to being used to monitor settlement, can also be used together with an extensometer tape to check for lateral separation of building walls perpendicular to the alignment. Data from these instruments is used to assess the need for changes in construction procedures should movements resulting from construction be excessive.

**Surface Movement Markers.** Two types of surface movement markers are used, as needed. One type, which is set directly at ground surface, reflects the movement (settlement or heaving caused by grouting or other causes) of the surface itself and other facilities next to it. The second, which is set into the ground directly beneath the pavement, is used to detect settlements that may be masked by the bridging.

**Subsurface Movement Markers.** These markers are used, as needed, to detect movements above tunnel excavations to assess the need for changes in construction procedures to limit ground movement should movements exceed tolerable amounts.

**Inclinometers.** Inclinometers are used, as needed, at critical locations to evaluate ground movements and assess the adequacy of the contractor's operations and temporary ground support systems in preventing movement of the adjacent ground and structures. Inclinometers may be attached to boreholes, the reinforcing cages of walls, or the soldier beams.

**Multiple Position Borehole Extensometers.** Multiple position borehole extensometers are used where deemed essential to monitoring ground settlement at various depths, over and next to tunnels and shaft walls at various distances from the face of the excavation.

**Optical Surveys.** Optical surveys are used to monitor the vertical and horizontal movement of building and ground settlement markers.

**Automatic Total Station.** Robotic total station is used for real-time settlement and horizontal movement monitoring of displacement-sensitive facilities.

**In-Place or Portable Seismographs.** Seismographs are used to monitor movements and vibrations resulting from the dynamic actions of operations or construction activities.

**Crack Gauges.** Crack gauges are used to monitor the changes of surface and building crack widths.
**Tiltmeters.** Tiltmeters are used in concert with surface movement markers, crack gauges, and optical surveys to monitor the tilt of building walls or other structures.

**Manometers/Floor Level Sensors.** Within buildings, floor level sensors are used on a periodic or continuous basis to monitor the level of the floor and changes in the level. This is especially important for structures with slabs-on-grade that could be subject to cracking resulting from differential settlement or differential horizontal strain.

### 9.6.2 Monitoring Schedules

Monitoring schedules for each type of instrument installed must be established. The data must be submitted bi-weekly (during design) and in real-time (during construction) to the TJPA for assessment to allow time for corrective action, if necessary. Because data collection is largely automatable, in-tunnel convergence monitoring devices and groundwater readings from automated sensors, such as dataloggers with remote communication capabilities, must be collected no less frequently than once per hour.

### 9.6.3 Deformation Trigger Levels

Values of measurements that will trigger the need for corrective action, referred to as trigger levels, must be specified in the contract documents and provided to field staff taking the measurements as well as to those responsible for evaluating the data. Monitoring data obtained from instruments during construction must be compared to the trigger levels included in the specifications on an ongoing basis.

The geotechnical engineer must establish allowable trigger levels by engineering analysis that models the construction process and estimates the anticipated or allowable deformations. Based on these evaluations, a multi-level observation system must be established that identifies threshold action, and possible shut-down levels. These levels must be established for individual instruments or instrument groups. The values used for threshold and action levels will depend on the physical asset (e.g., surface structure, subsurface structure, utility) to be monitored and the anticipated tunneling performance (i.e., ground response to tunnel excavation and support) and must be provided on a case-by-case basis by the engineer in the contract documents and approved by the TJPA.
CHAPTER 10 SEISMIC DESIGN

SCOPE

This chapter establishes the requirements for the seismic design of permanent structures for the Downtown Rail Extension (DTX) project including mined tunnel final linings, cut-and-cover structures, retaining structures, slopes, bridges, and buildings and surface facilities. In addition, criteria for temporary structures, including the mined tunnel initial support and the cut-and-cover excavation support structure, are provided.

The seismic design criteria are divided into categories by structure type—permanent underground structures, retaining structures, temporary underground structures, bridges, buildings and surface facilities, and non-structural components. The design requirements for each of these categories differ.

The design approach for permanent underground structures is based on a dual seismic criterion for two design earthquake levels, consistent with the American Association of State Highway and Transportation Officials Load and Resistance Factor Design Road Tunnel Design and Construction Guide Specifications (AASHTO LRFD Road Tunnel). The lower-level event is referred to as the Functionality Evaluation Earthquake (FEE), during and after which the designed structures must respond in an elastic manner and the facility is to remain operational. The structure must also be designed to withstand a high-level event with no collapse and no inundation for the protection of life safety; this is referred to as the Safety Evaluation Earthquake (SEE). The structures subject to the SEE may be designed to respond in an inelastic manner, but any structural damage must be limited to the minimal level that is repairable within a specific period of time. The seismic performance criteria for each earthquake level are referred to in Section 10.4.1 of AASHTO LRFD Road Tunnel. The FEE and SEE must be defined in the form of 5 percent damped horizontal and vertical response spectra, as follows:

FEE is defined by the larger of a probabilistic response spectrum based on a 10 percent probability of exceedance in 50 years (i.e., a return period of approximately 475 years) and a 67th percentile deterministic response spectrum.

SEE is defined by the larger of a probabilistic response spectrum based on a 5 percent probability of exceedance in 50 years (i.e., a return period of approximately 975 years) and an 84th percentile deterministic response spectrum.

CODES, STANDARDS AND GUIDELINES

Seismic design of the DTX must confirm to the latest edition of the following codes, standards, and guidelines unless otherwise specified in these criteria:


♦ American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering

♦ American Society of Civil Engineers/Structural Engineering Institute – ASCE/SEI 7, Minimum Design Loads for Buildings and Other Structures
ASTM International standards, Code ASTM A706, Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement

California Building Code (CBC)

California Department of Transportation (Caltrans) Memo to Designers 20-1, Seismic Design Methodology

California Department of Transportation (Caltrans) Memo to Designers 20-16, Seismic Safety Peer Review

Caltrans Seismic Design Criteria (SDC)

Caltrans Trenching and Shoring Manual

Peninsula Corridor Joint Powers Board - Caltrain Standards for Design and Maintenance of Structures

Peninsula Corridor Joint Powers Board – Caltrain Standards for Excavation Support Systems

San Francisco Building Code(SFBC), San Francisco Department of Building Inspection, Administrative Bulletin-082 Guidelines and Procedures for Structural Design Review

San Francisco Building Code (SFBC), which includes San Francisco Code Amendments (SF Amendments)

REFERENCES

The following references may also be used in support of the analysis and design of permanent underground structures for the DTX:


The geotechnical reports and memoranda prepared for the DTX project must also be consulted. These reports may be updated if additional investigations are warranted when work on the Geotechnical Baseline Report begins. See CHAPTER 9 Geotechnical Requirements.
10.1 Seismic Hazard

The project area is located within a high-seismicity region characterized by the San Andreas Fault system, which is the principal tectonic element of the North American/Pacific plate boundary in California. In the San Francisco Bay Area, seismic slip is partitioned onto subsidiary structures, such as the San Andreas, Hayward, and Calaveras faults, that are distributed across the Coast Ranges province. The San Andreas and Hayward faults have the highest slip rates and are the most active of any faults in the Bay Area. Other important earthquake sources that are capable of producing large-magnitude earthquakes include the San Gregorio, Calaveras, Rodgers Creek, and Greenville fault zones.

Both probabilistic and deterministic seismic hazard assessments, probabilistic seismic hazard assessment or assessments (PSHA) and deterministic seismic hazard assessment (DSHA), respectively, must be performed by developing seismic hazard models accounting for the regional tectonic setting, seismicity, and geology. The hazard models must capture the expected recurrence rate and maximum magnitudes of active faults and seismic source zones, the characteristics of the ground motion attenuation from source to site, and the effects of local site conditions including their uncertainties. The seismic hazard models must be consistent with the National Seismic Hazard Model by the United States Geological Survey adopted by the latest design standards (e.g., ASCE/SEI 7) at the time of design. The controlling earthquakes (i.e., pairs of magnitude and distance) must be determined based on the hazard deaggregation from PSHA for the design level hazards and spectral periods of interest.

The seismic hazard assessments must be conducted for reference horizon conditions. A reference horizon must be defined at the depth of the top of a competent material or rock unit, which must be sufficiently deep below the entire underground structures of interest. Also, the upper 30-meter time-averaged shear wave velocity (Vs30) must be defined for the reference horizon. The reference horizon must be used as the elastic half-space in seismic-site response analyses, where outcrop input ground motions are applied. See subsection 10.2.2, Site Response Analysis.

As the project covers a large area, the variation of seismic hazards along the project alignment must be estimated and reflected in developing design ground motions.

For near-fault sites, the rupture directivity effects on ground motions must be assessed for both FEE and SEE spectra. Near-fault sites are defined as follows, in accordance with section 11.4.1. of ASCE/SEI 7.

- Within 9.5 miles of the surface projection of a known hazardous fault capable of producing earthquake magnitude 7 or larger events

Or

- Within 6.25 miles of the surface projection of a known hazardous fault capable of producing earthquake magnitude 6 or larger events.

Multiple directivity models are available. PEER Center Report No. 2019/03, Ground-Motion Directivity Modeling for Seismic Hazard Applications, summarizes five directivity models developed in the Next Generation Attenuation – Western U.S. (NGA-West2) and presents five approaches for the implementation of the directivity models (Donahue et al. 2019). One of the five approaches must be used in the assessment of directivity effects. Other directivity models and application approaches may be considered and must be approved by the Transbay Joint Powers Authority (TJPA).

The seismic hazard assessments for all structure types included in the DTX project must be peer-reviewed in accordance with Section 10.10 and approved by the TJPA.
10.2 Design Ground Motions

The designer must develop design ground motions at depths of interest in terms of 5-percent damped horizontal and vertical design response spectra associated with the FEE and SEE events for the permanent underground structures and retaining structures. The horizontal design response spectra at reference horizons must be determined by the seismic hazard assessments. See Chapter 10, section 10.1, Seismic Hazard. Then, the horizontal design response spectra at depths of interest must be computed by performing site response analyses with the input of the reference horizon ground motions and site-specific subsurface models. See subsections 10.2.1, Design Ground Motion Time Histories at Reference Horizon and 10.2.2, Site Response Analysis. The design response spectra for the vertical component of FEE and SEE ground motions must be based on the application of an appropriate vertical to horizontal (V/H) spectral ratio to the horizontal design response spectra at depths of interest from the site response analyses. V/H ratios must be estimated using empirical V/H models (Gülerce and Abrahamson 2011 and Bozorgnia and Campbell 2016) along with the controlling earthquakes (i.e., pairs of magnitude and distance) based on the hazard deaggregation from PSHA; see Section 10.1, Seismic Hazard.

The design ground motions along with time histories and site response analyses must be peer-reviewed in conformance with Section 10.10 and approved by the TJPA.

10.2.1 Design Ground Motion Time Histories at Reference Horizon

For each reference horizon design response spectrum, a minimum of eleven sets of outcrop ground motion time histories must be developed using recorded ground motions appropriate for the characteristics of the controlling earthquakes, including strong ground motion durations and local site conditions. Appropriate simulated ground motions may supplement the suite of recorded ground motions if necessary. Each set must consist of two horizontal components and one vertical component. In time history analyses, the average response from the full suite of time histories must be used in the design.

The time histories must be modified to be compatible with their associated target design response spectra by either amplitude scaling approach, spectral matching approach, or both approaches. For either approach, the horizontal-to-horizontal period-dependent variability must be maintained for each set. The average horizontal response spectrum of two horizontal components for a given set must be within +/-20 percent of the target design response spectrum over the periods of interest. For a full suite of time history sets, the average of all eleven horizontal spectra must be within +/-5 percent of the target design response spectrum over the periods of interest. Also, the suite of modified time histories must have the engineering characteristics such as peak ground motion parameters, Arias intensity, and strong motion durations suitable for the controlling earthquakes and target design response spectra. Empirical correlations may be used for appropriate means and ranges of the engineering characteristic parameters. In addition, the non-stationary characteristic must be maintained between the initial seed time history and the modified time history.

For near-fault sites, pulse-like motions from forward-directivity effects must be included in the suite of time histories, and the original pulse characteristics of the seed time histories must be maintained in the modified time histories. The selected number of pulse-like motions may be estimated from empirical models (e.g., Hayden et al. 2014; Shahi and Baker 2011) along with the PSHA hazard deaggregation information in Section 10.1, Seismic Hazard.
10.2.2 Site Response Analysis

Site response analysis of representative subsurface models must be performed to determine free-field ground motions at desired depths. The subsurface models must include the soil units/layers from the ground surface below the bottom of the underground structures of interest down to the reference horizon; see Section 10.1. The reference horizon time histories must be input as outcrop motions from the reference horizon as the elastic half-space. A subsurface model must consist of an idealized soil stratigraphy, small-strain shear wave velocities and damping, nonlinear shear modulus reduction and damping curves, and unit weights. The nonlinear curves must be selected from published models for similar soil or derived from laboratory tests. The selected nonlinear models must be adjusted so that their implied shear strengths are comparable to the estimated shear strengths of site soil based on site investigation data.

The site response analyses must be performed using both equivalent linear and nonlinear techniques. An adequate technique must be adopted considering the level of nonlinearity in soil response and their result comparison.

For liquefiable soil, a one-dimensional, two-dimensional or three-dimensional site-response analysis must capture the local extent of the potentially liquefiable soil layer if applicable.

10.3 Permanent Underground Structures

The cross sections of the mined tunnel and cut-and-cover structures must be sized to satisfy dynamic load considerations. Thereafter, the design must be checked for its ability to resist the anticipated earthquake ground motions and forces.

The general procedure for the seismic design of permanent underground structures must be based primarily on the ground deformation approach. During earthquakes, underground structures move with the surrounding ground. The structures, therefore, must be designed to accommodate the deformations imposed by the ground.

10.3.1 Analysis

Underground tunnel structures undergo three primary modes of deformation during seismic shaking: ovaling/racking, axial, and curvature deformations. The ovaling/racking deformation is caused primarily by seismic waves propagating perpendicular to the longitudinal axis of the tunnel. Vertically propagating shear waves are generally considered the most critical type of waves for this mode of deformation. The axial and curvature deformations are induced by components of seismic waves that propagate along the longitudinal axis. The effects of all three modes of deformation must be considered in the design of the permanent underground structures.

Axial compression and tension and longitudinal bending must be analyzed simultaneously to ensure that strains remain within acceptable limits using closed form solutions.

For tunnels and cut-and-cover structures, the techniques proposed by Ostadan and Penzien (2001) and Hashash et al. (2001, 2005, and 2010) must be followed. In general, the analyses must include the following analyses:

- Pseudostatic analysis under which the structure’s response to prescribed free-field earthquake deformations is evaluated
- Dynamic soil-structure interaction analyses
The need for dynamic soil-structure interaction analyses and the scope of the analyses must be determined by the designer and accepted by the TJPA. Numerical modeling simulations are generally required for full dynamic analyses. The results of the pseudo-static analyses must be used as a basis for determining the scope of the more detailed dynamic analyses, and whether two-dimensional or three-dimensional analyses may be required. In the soil-structure analysis, elastic models are acceptable if the structural response remains elastic. In elastic analysis, an appropriate fraction of the Ig (e.g., 0.5 Ig) must be used if cracked slabs/walls are considered while the Ig must be used if uncracked slabs/walls are considered. If the structural response is into inelastic range, non-linear analysis must be performed, and the resulting strains must be evaluated.

Given the anticipated length of the underground box structures, several representative two-dimensional analyses must be used to check different ground conditions. Where there are significant changes in tunnel geometry (including ventilation structure connections) and alignment, and/or soil stratigraphy (e.g., a tunnel from rock to soft soil site, or vice versa), a three-dimensional analysis of the tunnels must be completed. Numerical methods used to evaluate soil-structure interaction must be peer-reviewed and approved by the TJPA in conformance with section 10.10.

The results of the dynamic soil-structure interaction analyses must include structural deformations and forces.

In addition to maintaining structural capacity, the underground structure must also maintain its barrier to the ingress of flowing groundwater as a result of FEE and SEE events.

Load sharing between the temporary construction support and the final lining of the mined tunnel is not permitted.

If joints are proposed within the mined tunnel final lining, the designer must verify the magnitude of joint openings and ensure that adequate joint compression is maintained during seismic events. Ductile segmental joints must be designed as follows:

- No net tension across the joint is permitted.
- Joint shear capacity must be evaluated and compared to shear demands.
- Joint bearing and compressive capacity against its bearing surface must be evaluated and compared to applicable demands.

### 10.3.2 Seismic Load Combinations

The following seismic load combination, consistent with current standards of practice in the San Francisco Bay Area, must be used in the design of the permanent underground structures.

The transverse and longitudinal earthquake loads must be applied simultaneously in two directions in conformance with the Caltrans SDC and combined with the vertical earthquake loads.

The earthquake load must be included in Extreme Event T-I, as defined in Chapter 12, subsection 12.2.1, and AASHTO LRFD Road Tunnel.
10.3.3 Structural Component Design

For non-ductile structural components prohibited from inelastic deformation and structural components shown to behave elastically in a design earthquake, resistance factors are defined in AASHTO LRFD Road Tunnel.

For ductile structure components allowed to undergo inelastic deformation in a design earthquake, structure components must be designed according to the Caltrans SDC for global displacement, displacement ductility, overstrength demand, and capacity protection. Proper detailing at the ductile components must be provided to support overall seismic design through evaluating the displacement capacity of the structure, capturing its ductile non-linear response.

The design of permanent structural components, for which the design load, including seismic, is controlled by soil deformations and their structural capacities are controlled by ductile structural resistance modes such as bending, a displacement ductility ratio of 1.0 may be acceptable as the criteria for operability performance.

The shear capacities of concrete structures and structural components must be designed for, at a minimum, the strength demands, including strength demands based on seismic load combinations. Capacity protected members must be designed to resist the overstrength demands imparted by seismic critical members and sacrificial members in conformance to the Caltrans SDC. The shear capacity of seismic critical members must be designed to resist the overstrength shear associated with the overstrength moment in conformance to the Caltrans SDC. The strength demands, including strength demands based on seismic load combinations. Effective section properties of the walls must be used to evaluate demands associated with seismic racking. Structures designed for an inelastic behavior in a design earthquake SEE must be modeled by appropriate methods, accounting for material, component, and geometric nonlinearities. Special attention should be paid to the connections of all the structural members. Positive connections must be designed and detailed. The diaphragm walls and bracing struts should also be checked for soil pressure generated by the localized liquefied soil.

10.3.4 Material Properties and Allowable Strains

- All steel bars for concrete reinforcement must conform to ASTM A706.
- Grade 60 must be used for all seismic-critical members.
- Do not use Grade 80 in seismic-critical members. Grade 80 may be used in capacity-protected members.
- Caltrans SDC provides values and formulations for expected material properties.
- Based on the analyses described, strains should not exceed those indicated in Table 10-1.

Table 10-1: Allowable Strains

<table>
<thead>
<tr>
<th>Earthquake</th>
<th>Mined/Bored Tunnel Liner</th>
<th>Cut-and-Cover Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concrete in Compression</td>
<td>Steel in Tension*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEE</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>SEE</td>
<td>0.0033</td>
<td>0.02</td>
</tr>
</tbody>
</table>
10.3.5 Ventilation/Access Shafts

The seismic considerations for the design of vertical shaft structures are similar to those for the mined tunnel structure. Consideration must be given to the curvature strains and shear forces of the lining resulting from vertically propagating shear waves. Force and deformation demands may be critical in cases where shafts are embedded in deep, soft deposits.

In addition, potential stress concentrations at the following critical locations along the shaft must be properly considered: (1) abrupt change of the stiffness between two adjoining geologic layers, (2) shaft/tunnel or shaft/station interfaces, and (3) shaft/surface building interfaces.

10.3.6 Interface Joints

Flexible joints must be provided at locations identified in Chapter 12, subsection 12.2.2, Serviceability Requirements. In addition, flexible connections must be used between any two structures in poor ground conditions that have stiffness-to-mass ratios outside of the following range:


\[
0.75 \leq \frac{k_i}{m_i} \leq 1.33
\]

Where

- \( k_i \) = effective stiffness of structure i
- \( k_j \) = effective stiffness of structure j
- \( m_i \) = mass of structure i
- \( m_j \) = mass of structure j

The design movements (peak relative displacements) must be established from dynamic analysis and presented in design memoranda.

10.4 Retaining Structures

Retaining walls and u-wall structures must be designed for appropriate static and seismic soil and water pressures depending on the restraining conditions of the wall in accordance with AASHTO LRFD Road Tunnel.

For shallow embedded structures, the stability of the structures against flotation due to uplift forces induced from liquefied soils below the base of the structures must be evaluated and considered in the design.

10.4.1 Seismic Design of Retaining Structures

Several types of retaining structures may be built, including gravity retaining walls, mechanically stabilized earth walls, cantilevered retaining walls, and anchored walls. U-walls may also be built using gravity or other retaining systems. Seismic loading estimates for these walls must be based on whether the wall is yielding or non-yielding. Design considerations related to wall types are discussed in the following Sections. U-walls must
be classified as either yielding or non-yielding and analyzed in conformance with the appropriate procedures discussed in Chapter 10, subsection 10.4.2, Seismic Loading on Yielding Retaining Structures, or subsection 10.4.3, Seismic Loading on Rigid (Non-Yielding) Retaining Structures.

10.4.2 Seismic Loading on Yielding Retaining Structures

Yielding retaining structures are those that can tolerate active earth pressures behind the structure and may deflect to mobilize them.

Seismic loading must be estimated by adding a seismic pressure to the static pressure with consideration of the inertial force of the wall when earthquake accelerations are applied. Active seismic pressures on retaining structures must be estimated using Mononobe-Okabe (M-O) analyses or general limit equilibrium method as described in NCHRP Report 611. The M-O analysis must not be employed if any of the following conditions is not met:

- The soil wedge supported by the retaining wall consists of homogeneous, dry, and cohesionless soil.
- The soil failure plane is much steeper than the backfill slope.

If the M-O analysis is inadequate, general limit equilibrium method or alternate approaches must be used such as described in AASHTO LRFD Road Tunnel.

Additional considerations are required if liquefaction is anticipated in the ground behind the walls in either seismic event. The M-O method is not directly applicable in these cases. Liquefiable soils near the walls at the structures must be removed and replaced with engineered fill or remediated, or the design of retaining structures must accommodate anticipated loads from liquefied soils behind the wall subject to both FEE and SEE.

10.4.3 Seismic Loading on Rigid (Non-Yielding) Retaining Structures

Rigid retaining structures are defined as those that are restrained enough to preclude the amount of deflection required to mobilize active earth pressures along the wall. A deformation-based soil-structure interaction analysis or a racking analysis based on free-field seismic shear strains, similar to the racking analysis discussed in subsection 10.3.1, Analysis, must be conducted.

10.4.4 Factors of Safety for Earth Retaining Structures under Seismic Loading

Failure modes of retaining structures are grouped into three categories: sliding, overturning, and bearing capacity. The seismic criteria for each of these failure modes are discussed as follows:

**Sliding:** A factor of safety of 1.15 is required for sliding in the FEE event. The factor of safety for sliding during the SEE event must be estimated but must not control the design (permanent displacement of wall controls the design). Instead, calculated wall displacements must be evaluated if a factor of safety less than 1.0 is estimated for sliding during the SEE. The wall must be designed such that any permanent deformation of the wall resulting from the SEE event must not compromise running clearances, as described in CHAPTER 7, Guideway Geometrics.
Overturning. Overturning stability must be maintained through limiting the maximum eccentricity based on the following formula:

Equation 10.2. Overturning

\[ e_{\text{max}} \leq B/6 \quad \text{for FEE} \]
\[ e_{\text{max}} \leq B/3 \quad \text{for SEE} \]

Where

- \( e_{\text{max}} \) is the maximum eccentricity.
- \( B \) is the width of the base of the retaining wall footing.

Bearing Pressure. Soil bearing pressure below retaining structures must be estimated for both FEE and SEE.

Seismic-induced deformations, settlements, and displacements of retaining structures must be evaluated based on the local geometry and the requirements of the structure and track supported by the retaining structures. CHAPTER 10 STRUCTURES, referred to limits on maximum permissible deformations, settlements, and displacements.

In addition, the factor of safety for the overall retaining structure and slope should be evaluated, as discussed in Section 10.4.4, Factors of Safety for Earth Retaining Structures under Seismic Loading.

10.5 Temporary Underground Structures

The seismic design of temporary underground structures including support of excavation and initial support of the mined tunnel with an expected use duration of five years or less must be based on ground motions with a 10 percent probability of exceedance in ten years, corresponding to a return period of approximately 100 years. Temporary underground structures must be designed to resist increases to lateral soil pressure due to a seismic event.

For temporary structures with an expected use duration of over five years, the seismic loading for permanent underground structures must be used. Inquiries on the definition of temporary underground structures must be directed to the TJPA for further specifications, if necessary.

10.6 Bridges

The seismic design of roadway bridges and roadway bridge temporary structures must conform to the Caltrans SDC.

The seismic design of railway bridges and railway bridge temporary structures must conform to the AREMA Manual for Railway Engineering.

10.7 Buildings and Surface Facilities

The seismic design of buildings, surface facilities, and temporary structures must conform to the SFBC, CBC, and ASCE/SEI 7.
10.8 Non-structural Components

Consideration must be given to the seismic design of all appurtenances to the tunnel—equipment, equipment supports, and anchorages, which include the tunnel finishes, fasteners, and connections for fans, lighting, signage, and other facilities. The seismic design of equipment, equipment supports, and anchorages must conform to the CBC and ASCE/SEI 7.

The design of essential equipment, defined as equipment required for safety (including fire protection, ventilation fans, and emergency power) or the operation of trains (including uninterruptible power supply (UPS), batteries, inverters, and power control equipment), may use an importance factor of 1.5. The structural design of non-structural components, such as ceiling elements, overhead lighting, and ventilation ducts, in areas of emergency egress, access, and assembly must use an importance factor of 1.5. Non-essential equipment, equipment supports, and anchorage outside of areas of emergency egress, access, and assembly may be designed using an importance factor of 1.0 where permitted by the applicable codes.

Equipment that is deemed essential and fragile may require dynamic analysis, with the approval of the TJPA.

10.9 Other Considerations

10.9.1 Liquefaction Considerations

Liquefaction triggering evaluation must be carried out for the FEE and SEE events in conformance with AASHTO LRFD Road Tunnel. Where liquefaction is anticipated for the design earthquake, mitigation measures must be recommended by the California-registered geotechnical engineer.

10.9.2 Seismically Induced Settlement and Lateral Spreading

Seismically induced settlement and lateral spreading analyses must be performed for both FEE and SEE events. Where the results of these analyses indicate the effects of settlement or lateral spreading to be detrimental to the performance of the DTX structures in achieving the specified design life, mitigation measures must be recommended by the California-registered geotechnical engineer.

10.9.3 Seismic Design of Reinforced and Unreinforced Slopes

Slope design at the portals within the excavation support system walls must confirm to the criteria discussed in this subsection. A finite amount of space must be available for the slopes. If adequate space is not available for the installation of unreinforced slopes to the required factors of safety, then slope reinforcement may be considered. Slope reinforcement techniques should be recommended by the geotechnical engineer, consistent with any requirements of the Caltrain Standards for Excavation Support Systems.

Seismic Design of Permanent Unreinforced Slopes

Unreinforced earth slopes must have minimum factors of safety noted in this subsection and must be no steeper than 2:1 horizontal to vertical ratio (2H:1V), which corresponds to a slope angle of approximately 26 degrees. Slopes may need to be shallower than this angle if adequate factors of safety cannot be attained for 2H:1V slopes.
Slope stability must be analyzed using pseudo-static limit equilibrium type analyses with applied seismic coefficients. The seismic coefficient in these analyses must be provided by the California-registered geotechnical engineer. A reduction in soil strengths may be necessary for these analyses. Soil strength reduction factors, if applicable, must be provided by the geotechnical engineer.

Regardless of the specific analysis method selected, the slope stability factor of safety must be greater than 1.2 in the FEE event. For the SEE event, the factor of safety must not control design of the slope. If the SEE factor of safety is less than 1.0, earthquake-induced lateral displacements must be evaluated using Newmark type analyses (Newmark 1965) in conformance with AASHTO LRFD Road Tunnel and NCHRP Report 611. The slope must be designed such that sliding resulting from the SEE event must not compromise DTX running clearances as described in CHAPTER 7, Guideway Geometrics. The seismic design of temporary slopes does not need to be explicitly considered, although temporary slopes are expected to conform to the requirements contained in the PCJPB Engineering Standards. Instead of pseudo-static limit equilibrium analyses and Newmark type analyses, a fully representative two-dimensional or three-dimensional numerical model may be used, but this approach must include a peer review and approval by TJPA.

### 10.10 Peer Review

This chapter identifies the engineering tasks requiring peer review. Peer reviews must conform to the specifications in this subsection in addition to the requirements in the Caltrans SDC (Memo to Designers 20-16) and the SFBC Administrative Bulletin AB-082, Guidelines and Procedures for Structural Design Review.

A peer reviewer or peer reviewers must be selected prior to initiation of significant portions of the engineering work to be reviewed. Peer reviewers must be California licensed engineers and recognized technical experts in the subject matter, familiar with governing regulations. They must be independent of the project with no other involvement with the project before, during or after the review. Peer reviewers must be approved by the TJPA before the peer review begins.

The peer review must be performed at an early stage throughout the duration of the work. Contractors must provide peer reviewers with a full range of data, models, and methods considered in the work in an organized fashion. Peer reviewers and contractors must document all comments and responses. Upon completion of the peer review, peer reviewers must submit directly to the TJPA a written report and a closure letter stating that the review process was completed, and all review comments were satisfactorily resolved. The report must summarize the peer review and include the following information:

- Scope of the peer review
- Status of the documents reviewed at each stage
- Key review comments and resolutions
- Limitations of the peer review, if applicable
- Formal documentation of all peer review correspondence
CHAPTER 11 PROTECTION OF EXISTING INFRASTRUCTURE

SCOPE

This chapter establishes the requirements for the protection of existing infrastructure next to the Downtown Rail Extension (DTX) alignment from ground movements—settlements, rotations, or both—resulting from excavation associated with the construction of the DTX cut-and-cover structures and tunnel. Existing infrastructure may include buildings, bridges, station platforms, tracks, utilities, and other physical assets near the DTX construction. This information must be used in conjunction with the 2018 Final Supplemental Environmental Impact Statement/Environmental Impact Report (Final SEIS/EIR) prepared for the Transbay Program and the Draft SEIS/EIR issued to the public and public agencies for review and comment in December 2015.

CODES, STANDARDS, AND GUIDELINES

The design of protection schemes for existing buildings must conform to the latest edition of the San Francisco Building Code.

See CHAPTER 6, Utilities, for requirements for the relocation or protection-in-place of utilities.

REFERENCES


11.1 Ground Movements/Settlement Estimates

Initial support systems must be designed to withstand the design loads and control the ground movements that could otherwise affect overlying buildings, utilities, and streets. The design must make use of proven construction techniques to control ground movement. Support systems for excavations must be selected, where possible, to minimize unsupported ground in the tunnel as much as practical.

11.1.1 Preliminary Evaluation

The method used for the preliminary evaluation of tunnel settlements must follow industry-accepted practice pioneered by Peck (Peck 1969) and updated by Mair, Taylor, and Burland (Mair et al. 1996). Although the work of Peck and Mair was developed for tunnel boring machine tunneling methods, the approach can be applied to sequential excavation methods within the context of a preliminary evaluation. For sequential excavations, the settlement curves resulting from each excavation stage will be superimposed, i.e., multiple settlement curves will be developed, and an enveloping settlement curve will be developed. Volume loss for each individual drift will be evaluated.

The maximum settlement and width of the settlement trough is a function of the volume of lost ground, the depth of the tunnel, and the geotechnical characteristics of the soils. The volume of the settlement trough must be assumed to be equal to the total volume of lost ground during tunneling, which is usually given as a percentage of the excavated area. Lost ground is defined as the volume of all ground movements occurring around a tunnel or each individual drift or sequence.

The designer is responsible for developing estimates of face loss along the DTX tunnel alignment to be used in the calculation of surface settlements. Surface settlement calculations must be reviewed by a geotechnical engineer and approved by the Transbay Joint Powers Authority (TJPA).

Ground loss values used for analyses must reflect the excavation method and be based on historical data obtained from projects using similar methods in comparable soil and groundwater conditions.

Consolidation settlements, including horizontal and vertical, must be assessed and superimposed on the tunneling-induced settlements. Settlement contour plans along the full alignment must be prepared. Horizontal movements and strains resulting from tunneling must also be predicted.
11.1.2 Numerical Methods

Numerical methods, using finite element or finite difference techniques approved by the TJPA, must be used in detailed evaluations of ground movements and the potential impacts on existing buildings and adjacent facilities. The methods used for these evaluations must consider the excavation and support sequences being proposed and must include sensitivity analyses, as defined in section 11.2, to assist with the determination of construction approaches that can minimize potentially damaging ground movements.

Confirm the results of the numerical methods using comparisons with empirical methods. Differences between the two types of analyses must be explained to the satisfaction of the TJPA.

11.1.3 Impacts of Construction-Induced Deformations on Adjacent Structures

Studies must evaluate the potential impacts of construction-induced surface and subsurface deformations on adjacent structures. Use empirical methods to perform an initial screening, with the objective of identifying the most critical impacts. Additional detailed studies may be required, including soil-structure interaction analyses to properly evaluate the impacts on adjacent structures. The designer must evaluate the need for special studies and include a discussion of additional needs within the reports prepared during the initial study phase and submit to the TJPA for approval.

11.2 Assessment of Ground and Structure Movements

Temporary works, including support of excavation and tunnel initial support, must minimize ground movements associated with the excavation and construction of the tunnels and strictly limit the extent of underpinning and other protective works required beyond the limits of the excavations. The design of temporary works must make use of proven construction techniques and assume a high quality of workmanship during construction.

The influence of existing structures or facilities on excavation or tunneling and the corresponding influence of excavation or tunneling on existing infrastructure must be analyzed and evaluated from both a structural and geotechnical standpoint.

All existing structures that encroach on or are immediately next to the DTX alignment must be evaluated. All structures within the zone of influence, defined as the horizontal or vertical ground movement of 0.25 inch (1/4 inch) or greater, must be assessed for damage.

Determination of the 0.25-inch ground movement contour must consider overlapping zones, including, for example, where cut-and-cover excavations and tunnels are in close proximity or where dewatering and excavations may both be sources of ground movement. In addition to proximity to the alignment, the age, type, use, and construction of existing structures must be considered. Buildings that have been reconstructed, retrofitted, or renovated such that they have mixed foundations must be evaluated in detail, with consideration given to the nature of the building structure and the foundations.

The influence of excavation on existing structures must be evaluated, and design parameters for allowable settlement, differential settlement must be established for each affected structure. Damage risk assessments must be in accordance with the approach developed by E.J. Cording (Cording et al. 2010), or similar methods approved by the TJPA. See Chapter 9, section 9.6, Instrumentation and Monitoring, for instrumentation and monitoring requirements.
11.2.1 Cut-and-Cover Structures

The design parameters for allowable settlement, differential settlement, and rotation must be developed considering the existing infrastructure. The design parameters will be the subject of agreement between the TJPA and the owner of each infrastructure asset.

Impacts on existing infrastructure near cut-and-cover construction may be attributable to ground movements outside of the excavation as a result of:

- Installation of the excavation support walls
- Lateral movement of the excavation support walls during excavation
- Consolidation of compressible soil layers
- Grouting, piling, soil improvement, or similar measure required for the construction of works

Seepage analyses must be carried out for all excavations, and the potential for consolidation settlements, piping, blow-in, and heave must be assessed. Settlement contour plans associated with cut-and-cover excavations that include immediate and consolidation settlements must be prepared.

Soil-structure interaction analyses must be undertaken to demonstrate that the anticipated ground movements resulting from the proposed construction would result in allowable settlements, differential settlements, and rotations that are within the limits of the established design parameters for each structure considered.

Where ground movements will affect pile-supported structures, the effects of soil movements induced by excavation must be evaluated in a moment curvature space. Should the additional load imposed on the pile by the ground movements reduce the pile’s capacity to carry its original design load (lateral and axial), the design must be revised to reduce the ground movements. The design must be documented in a report to the Geotechnical Engineer and TJPA. A secondary report must be prepared for the evaluation of Caltrans pile-supported structures.

To the maximum extent possible, the design of excavation support systems must limit ground movements to an extent that damage is repairable by redecoration (Cording et al. 2010). Where preliminary design indicates that the design parameters—allowable settlements, differential settlements, and rotations for existing structures—are exceeded, the design must be revised as necessary.

The following mitigations must be considered:

- Redefine the sequence of excavation and construction
- Increase the stiffness of the excavation support system through incorporation of the following:
  - Reduced spacing of bracing elements
  - Increased size of bracing elements
  - Thicker support walls or incorporation of wall stiffening elements such as ‘T’ panels
- Conduct ground improvement (i.e., grouting)
- Alternate method(s) approved by the TJPA
Where these and other appropriate mitigation measures are unsuccessful in reducing structure movements to within the limits of the agreed design parameters, underpinning or other protective works must be considered in accordance with section 11.3

11.2.2 Tunnel

Impacts on infrastructure near tunnel construction may be attributable to ground movements that occur as a result of the sequence of excavation and ground support. Design of the tunnel should avoid reliance on the following construction methods, where possible, and in accordance with the project’s Final SEIS/EIR:

- Groundwater lowering by pumping
- Groundwater lowering by pervious temporary linings or support systems

Numerical methods, using finite element or finite difference techniques, must be used to evaluate ground movements and the potential impacts on existing buildings and adjacent facilities. These methods must consider the excavation and support sequences being proposed and include sensitivity analyses to determine construction approaches that can minimize potentially damaging ground movements.

For piles located within a 1:1 line extending upwards and outwards from the tunnel springline, soil-structure interaction must be used to evaluate ground movement and the potential for building damage.

11.3 Protective Works

Protective works are required for infrastructure within the zone of influence of the cut-and-cover structures and tunnel where predicted values for movement exceed the limits of parameters established in section 11.2. However, the implementation of protective works can cause deformations that may be as severe as the deformations that these measures are intended to mitigate, and this must be considered in the selection of protective works methods.

The designer must develop a toolbox of methods to be implemented for protective works. Protective works can comprise building strengthening, underpinning, and ground improvement or some combination of these methods, or any other appropriate methods. When determining the appropriate protection for an existing structure or utility, the designer must consider the sequence of construction and the effect of placement of protection on other phases of construction and vice-versa.

A summary assessment for every building, utility, or other structure or facility within the zone of influence must be prepared for TJPA acceptance. The summary assessment must include an estimate as well as a description, category of potential damage, and proposed mitigations, including a recommendation for the use of protective works and the nature of the proposed protective works.

For structures identified as historically significant in the Final SEIS/EIR for the Transbay Program or supplements to that document, damage must be limited to that which can be repaired by redecoration. No advance mitigation measures will be permitted without agreement from the relevant authority having jurisdiction and the TJPA.

The assessments must be documented in a Property Protection Study Report that includes a list of all structures within the zone of influence and their associated damage risk category, in accordance with Cording (Cording et al. 2010) or similar methodology. The Property Protection Study Report must include the results of the evaluation of damage to utilities (including joint rotation and pullout), and infrastructure within the influence zone.
CHAPTER 12 STRUCTURES

SCOPE

This chapter establishes the requirements for structures, including the following:

♦ Transbay Joint Powers Authority (TJPA)-owned facilities, including cut-and-cover structures, passenger stations, support of excavation, u-walls, earth-retaining structures, ventilation and egress structures, buildings, and miscellaneous structures

♦ Temporary structures and permanent facilities owned by others that are constructed or modified as part of the Downtown Rail Extension (DTX) project, including bridges, passenger stations, buildings, and miscellaneous structures

See the following chapters for criteria for other structure types:

♦ CHAPTER 11, Protection of Existing Infrastructure
♦ CHAPTER 13, Tunnels
♦ CHAPTER 18, Rail Systems

The design of structures built or modified as part of the DTX project, but owned by others, must meet the requirements of the agencies that have jurisdiction over said structures.

CODES, STANDARDS AND GUIDELINES

The design of TJPA-owned structures must conform to the latest edition of the following standards, codes, and guidelines unless otherwise specified in these criteria:

♦ American Association of State Highway and Transportation Officials Load and Resistance Factor Design Road Tunnel Design and Construction Guide Specifications (AASHTO LRFD Road Tunnel)

♦ American Concrete Institute (ACI) Manual of Concrete Practice, including:
  ● ACI 201.2R, Guide to Durable Concrete
  ● ACI 224R, Control of Cracking in Concrete Structures
  ● ACI 301, Specifications for Structural Concrete
  ● ACI 315R, Guide to Presenting Reinforcing Steel Design Details
  ● ACI 318, Building Code Requirements for Structural Concrete and Commentary
  ● ACI 365.1, Service-Life Prediction—State-of-the-Art Report
  ● ACI 506.2, Specification for Shotcrete
  ● ACI 506.5R, Guide for Specifying Underground Shotcrete


♦ American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering
American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) standards:
- ASCE/SEI 7, Minimum Design Loads and Associated Criteria for Buildings and Other Structures
- ASCE/SEI 37, Design Loads on Structures during Construction

ASTM International standards:
- ASTM A36, Standard Specification for Carbon Structural Steel
- ASTM A53, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
- ASTM A307, Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength
- ASTM A416, Standard Specification for Low-Relaxation, Seven-Wire, Steel Strand for Prestressed Concrete
- ASTM A615, Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
- ASTM A706, Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement
- ASTM A709, Standard Specification for Structural Steel for Bridges
- ASTM A722, Standard Specification for High-Strength Steel Bars for Prestressed Concrete
- ASTM A820, Standard Specification for Steel Fibers for Fiber-Reinforced Concrete
- ASTM A1064, Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
- ASTM A1085, Standard Specification for Cold-Formed Welded Carbon Steel Hollow Structural Sections (HSS)
- ASTM F1554, Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength
- ASTM F3125, Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength, Inch and Metric Dimensions

California Building Code (CBC)

California High-Speed Rail Authority (CHSRA), Design Criteria Manual (DCM)

Caltrans (California Department of Transportation) Bridge Design Specifications (CBDS), which include Caltrans Amendments to the AASTHO LRFD Bridge Design Specifications

Caltrans Seismic Design Criteria

Caltrans Trenching and Shoring Manual

City and County of San Francisco Municipal Transportation Agency (SFMTA) – Central Subway Design Criteria


National Fire Protection Association - NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems
12.1 Materials

Structural materials used in the temporary and permanent construction for the DTX must meet the requirements listed in the following subsections.

12.1.1 Concrete

The minimum 28-day compressive strengths \( f'_{c} \) for concrete must be as shown in Table 12-1:

<table>
<thead>
<tr>
<th>Type</th>
<th>Compressive Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast-in-place substructure concrete</td>
<td>4000 psi</td>
</tr>
<tr>
<td>Cast-in-place superstructure concrete</td>
<td>4500 psi</td>
</tr>
<tr>
<td>Shotcrete</td>
<td>4000 psi</td>
</tr>
<tr>
<td>Precast concrete</td>
<td>5000 psi</td>
</tr>
<tr>
<td>Prestressed concrete</td>
<td>5000 psi</td>
</tr>
</tbody>
</table>

The minimum compressive strength of concrete at the time of initial prestress must be 4000 psi. The designer may specify higher compressive strengths for concrete where needed, if justified.

12.1.2 Concrete Reinforcing Steel

Reinforcing steel must conform to ASTM A706, minimum Grade 60, with the following allowances:

- Reinforcing steel for drainage junction structures and sign and signal foundations independent of cut-and-cover, permanent earth-retaining, and bridge structures must conform to ASTM A615, Grade 60.
- Reinforcing steel for concrete barriers must conform to ASTM A615, Grade 40 or 60.

Design and construction of uncoated seven-wire, stress-relieved or low-relaxation strand reinforcing steel must conform to ASTM A416.

Design and construction of uncoated high-strength reinforcing steel bar must conform to ASTM A722.

Steel fibers for fiber-reinforced concrete must conform to ASTM A820.

12.1.3 Structural Steel

All structural steel must conform to the requirements in the CBDS, be weldable, and have the following properties:

- Permanent construction must conform to ASTM A709, Grade 50.
- Temporary works construction must conform to ASTM A709, Grade 36 or Grade 50.
Pipe temporary works must conform to ASTM A53, Grade B (Type E or S), with a minimum yield strength ($f_y$) of 35 ksi or with ASTM A709 Grade 36 or 50.

Hollow structural sections for permanent works must conform to ASTM A1085.

### 12.1.4 Structural Steel Connections

All structural steel must conform to the requirements in the CBDS and have the following properties:

- High-strength bolts must conform to ASTM F3125.
- Low-strength bolts must conform to ASTM A307.
- Anchor rods must conform to ASTM F1554.
- Welding must conform to applicable American Welding Society (AWS) standards.

### 12.1.5 Overhead Anchors

The use of adhesive anchors for overhead applications subject to sustained tension loads is prohibited.

### 12.1.6 Existing Materials

Determination of the mechanical properties and capacity of existing materials to be used for structure design must be consistent with applicable record documents related to the design and construction of the existing facility. Where records are not available or if the properties of the existing material require it, material sampling and laboratory testing must be employed.

### 12.1.7 Minimum Unit Weights

Use the minimum unit weights for materials shown in Table 12-2 to ensure the consistency of the DTX design. For materials not listed, see CBDS or CBC, as applicable.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Required Minimum Unit Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td></td>
</tr>
<tr>
<td>plain</td>
<td>145 pcf</td>
</tr>
<tr>
<td>reinforced</td>
<td>150 pcf</td>
</tr>
<tr>
<td>Steel</td>
<td>490 pcf</td>
</tr>
<tr>
<td>Water and Groundwater</td>
<td>62.4 pcf</td>
</tr>
<tr>
<td>Compacted sand, gravel, earth</td>
<td></td>
</tr>
<tr>
<td>saturated</td>
<td>130 pcf</td>
</tr>
<tr>
<td>buoyant</td>
<td>68 pcf</td>
</tr>
<tr>
<td>Compacted sand, gravel, earth (flotation case)</td>
<td></td>
</tr>
<tr>
<td>saturated</td>
<td>120 pcf</td>
</tr>
<tr>
<td>buoyant</td>
<td>58 pcf</td>
</tr>
<tr>
<td>Pavement</td>
<td>150 pcf</td>
</tr>
<tr>
<td>Rock</td>
<td>150 pcf</td>
</tr>
</tbody>
</table>
### 12.1.8 Waterproofing

Underground structures must be designed to be completely waterproofed and must be approved by the TJPA. A waterproofing system must be installed between the initial support and final of all underground structures and between the temporary precast tunnel linings and cast-in-place final linings of bored tunnels. Waterproofing design must accommodate anticipated hydrostatic pressures. Waterproofing systems must include:

- Geotextile fabric
- Compartmentalized sheet membrane waterproofing, with provision for remedial grouting
- Waterstops at all construction joint locations
- Re-injectable grout hose within waterstops

Where reinforced concrete is to be placed against the waterproofing membrane, no damage to the exposed membrane surface that would permit seepage through the membrane is allowed. The design must include provisions for the repair of the waterproofing system as well as the collection and removal of water from underground structures in the event of leakage.

Do not use a waterproofing membrane with bentonite clay components.

### 12.1.9 Fire Resistance

All DTX structures must conform to the fire resistance requirements in the National Fire Protection Association (NFPA) 130 and the CBC. Fire resistance design must be approved by the authority having jurisdiction. See CHAPTER 15, Fire Life Safety.

### 12.2 Cut-and-Cover Structures

The design of cut-and-cover structures must conform to the requirements in AASHTO Load and Resistance Factor Design (LRFD) Tunnel and this section. Underground stations and ventilation and egress structures constructed using cut-and-cover methods must also conform to the requirements of the SFBC.

### 12.2.1 Loads and Forces

All cut-and-cover structures and associated components to be constructed or modified as part of the DTX project must be proportioned to withstand all applicable loads, forces, and combination of loads defined in AASHTO LRFD Road Tunnel and additional minimum loads in this subsection.
Permanent Loads

A: Dead Loads (DC). The dead load consists of the actual weight of the structure and the weight of all installations considered fixed, such as concrete track slab and safety walks. In stations and structures, the dead load also includes the weight of masonry partition walls and stairs and landings.

B: Superimposed Dead Loads (DW). The weights of suspended and affixed rail systems equipment, finishes, utility services, running rail and ties, and other system elements are considered removable and must be classified as superimposed dead load. In addition to the unit weights in Table 12-2, assume the following allowances in the design for superimposed dead load:

- 20 psf minimum for finishes on floor slabs and platforms
- 40 psf minimum for the weight of ceiling finishes and services below roof slabs and suspended slabs

In addition to the stated allowances, localized impacts on the cut-and-cover structures from unique mechanical and electrical equipment, such as elevators, escalators, and jet fans, must be considered in the design. The structures must be able to support the maximum reactions from any manufactured units.

Electrical equipment rooms, pump rooms, service rooms, storage space, and machinery rooms must be designed for a minimum uniform load of 250 psf, which must be increased if storage or machinery loads dictate. The loads for which such rooms are designed must be indicated on the structural drawings.

C: Earth Vertical Load (EV). Cut-and-cover structures must be designed for the actual depth of cover over the roof slab according to the proposed ground surface elevation and as recommended in the geotechnical reports and design memoranda.

D: Earth Horizontal Load (EH). Lateral earth pressures imposed by vertical soil loads on the cut-and-cover structures must be derived using the effective soil unit weight together with the appropriate strength parameters. The geotechnical engineer will establish the lateral earth pressures. Pressure diagrams will be developed and presented within the Geotechnical Interpretive Report (GIR) or included in specific design memoranda. One set of lateral earth pressure diagrams will be developed for the excavation support with due consideration given to the type of retaining system to be used, and another set for the permanent structures.

At the request of the geotechnical engineer, and as approved by the TJPA, numerical analyses may be performed, and equivalent lateral earth pressure diagrams resulting from these analyses, developed. When numerical analyses are performed, the load factor used for active pressure or apparent earth pressure must be used in the design. Numerical analyses also provide information, such as bending moments, shear forces, and earth pressures, that can be used by structural engineers and shoring designers to design both the shoring system and permanent structures.

E: Earth Surcharge Loads (ES). Underground structures must support lateral earth surcharge loads from adjacent buildings or other structures, including both existing structures and future developments next to the DTX alignment, as allowed under existing zoning and land use regulations or as defined in this chapter. Unsymmetric loading must be considered to produce the greatest effects for the structural element under consideration.

Existing Building Earth Surcharge. Cut-and-cover structures (temporary and permanent) must accommodate surcharge loading imposed by existing adjacent buildings when the horizontal distance from the building line to the nearest face of the structure is within the influence zone as defined in CHAPTER 11 Protection of Existing Infrastructure.
Do not consider building surcharge loads where the adjacent structures are founded or permanently underpinned at a depth below the influence zone of the structure.

Existing structures must be considered individually, based on the outcomes of surveys of existing plans and field confirmation of the building configuration. Existing structure surcharge loads must be determined from as-built drawings. In the absence of as-built drawings, estimate the surcharge loads using structural observations and engineering judgement relative to building height, construction type, foundation type, and current SFBC requirements.

The designer must develop a report that details for each existing building the source of building information and the development of estimated building loads, including but not limited to dead and live loads and associated calculations. This existing building report must be submitted to TJPA for review.

**Adjacent and Future Development Earth Surcharge.** Where developments are planned or in progress, estimate the surcharge loads from the planning documents.

Where there is potential for future development directly over the DTX’s structure, including at all subsurface easements on privately owned portions of the right-of-way, use a surcharge estimated from the maximum height development allowed by zoning; the analysis must consider conditions of unloading during construction and reloading.

In the absence of defined loading, the following scenarios must be considered:

- **Unloading:**
  a. Excavation to a depth to the top of the cut-and-cover structure at center point. Excavation scenarios must consider full excavation above and adjacent to the structure and the following partial excavation scenarios:
     i. An excavation width equal to the zone of influence
     ii. Asymmetric excavation
     iii. Symmetric and asymmetric excavation adjacent to the structure to an excavation boundary equal to the zone of influence
  b. Excavation to a depth 40-feet below ground level adjacent to the structure, with the excavation boundary width equal to the zone of influence

- **Reloading and surcharging:**
  a. New construction represented by a vertical surcharge load of 1,000 psf plus the weight of the removed soil applied 45 feet above the structure centerline, applied for a width equal to the zone of influence
  b. New construction represented by a vertical surcharge load of 1,600 psf plus the weight of the removed soil applied at excavation invert level, applied outside of the zone of influence
  c. New construction represented by a vertical surcharge of 1,600 psf applied at ground surface level at all non-public right-of-way where future development may occur

**Transit-Oriented Development Earth Surcharge Load.** Cut-and-cover structures that will be supporting future transit-oriented development (TOD) must accommodate the dead load construction of buildings with a maximum of eleven above-grade stories over the entire cut-and-cover structure footprint. These cut-and-cover structures include the Southeast TOD cut-and-cover structure bounded by the limits of
Howard Street, Second Street, and Tehama Street, and the northeast TOD cut-and-cover structure bounded by Howard Street, Second Street, and the Transit Center.

**F: Shrinkage (SH).** Shrinkage and creep effects must be incorporated into the concrete design in accordance with AASHTO LRFD Road Tunnel and ACI 318, Building Code Requirements for Structural Concrete and Commentary.

### Transient Loads

**A: Live Loads (LL).** Live loads consist of rail live loads, Caltrain and high-speed tracks, San Francisco Municipal Railway tracks, impact loads, roadway live loads, transit-oriented development live loads, and pedestrian area live loads.

- **Rail live loads.** must be applied within cut-and-cover structures. Rail live loads must also be applied to the roof of cut-and-cover structures where the potential for future trackwork may exist.

- **Caltrain and High-speed Tracks.** Assume that rail live loads within the limits of the Caltrain right-of-way are consistent with Cooper E-80 loading. Axle load, spacing, load distribution, and simultaneous loading on adjacent tracks and impact load must conform to AREMA Manual for Railway Engineering.

  Arrange the Cooper E-80 loading in combinations to produce the most critical conditions for axial, bending, shearing, and torsional stresses, deflections, and stability.

  The effects of impact load associated with live load must be considered in accordance with AREMA.

- **San Francisco Municipal Railway (Muni).** The San Francisco Municipal Transportation Agency’s Central Subway project crosses the DTX at the intersection of Fourth and Townsend streets. The two Muni tracks, running north/south in the center of Fourth Street, pass at-grade over the DTX underground bridging structure.

  One Muni train consists of not more than two cars.

  The distance between the Muni track centers is 14 feet 6 inches. A train on each track concurrently must be considered.

Figure 12.1 shows the legacy Muni light rail vehicle (LRV) for the Central Subway manufactured by AnsaldoBreda (model LRV2). Muni is in the process of replacing its legacy fleet with the Siemens S200 LRV. The physical characteristics of the legacy Muni LRV (AnsaldoBreda) as well as the Siemens S200 models are provided in Table 12-3.

![Figure 12.1: AnsaldoBreda Muni Light Rail Vehicle](image-url)
Table 12-3: Muni LRV Models

<table>
<thead>
<tr>
<th>Load Distribution Parameters</th>
<th>AnsaldoBreda LRV2</th>
<th>Siemens S200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track Gauge</td>
<td>4 ft 8.5 in.</td>
<td>4 ft 8.5 in.</td>
</tr>
<tr>
<td>Length over coupler faces</td>
<td>75 ft</td>
<td>75 ft</td>
</tr>
<tr>
<td>Distance between trucks</td>
<td>24 ft</td>
<td>24 ft</td>
</tr>
<tr>
<td>Truck wheel base</td>
<td>6 ft 3 in. (approx.)</td>
<td>6 ft 3 in. (approx.)</td>
</tr>
</tbody>
</table>

Use an LRV crush load (AW3) weight of 110,000 pounds (AnsaldoBreda) in the DTX design; this includes the weight of the vehicle and passenger load. The weight is distributed as follows:

<table>
<thead>
<tr>
<th></th>
<th>AnsaldoBreda LRV2</th>
<th>Siemens S200</th>
</tr>
</thead>
<tbody>
<tr>
<td>End trucks (each)</td>
<td>35% of LRV weight</td>
<td>38,500 pounds</td>
</tr>
<tr>
<td>Center truck</td>
<td>30% of LRV weight</td>
<td>33,000 pounds</td>
</tr>
</tbody>
</table>

The weight criteria of the Muni LRV provided by SFMTA Central Subway Design Criteria are as follows:

- **AW0** – Empty car weight is 76,000 pounds
- **AW1** – Fully-seated weight (62 passengers plus operator) is 85,700 pounds
- **AW2** – Fully-seated load with moderate standee density (155 passengers plus operator) is 100,000 pounds
- **AW3** – “Crush load” weight, Fully-seated load with maximum standee density (220 passengers plus operator) is 110,000 pounds

Distribute Muni live loads as follows:

- For fill height less than 2 feet: apply roadway live loads directly to the roof slab as concentrated loads.
- For fill height greater than 2 feet: distribute live loads through the fill over a square area, the sides of which are equal to 1.75 times the depth of fill. Where distribution areas overlap, distribute the total load uniformly over an area defined by the outside limits of the individual areas.

**Impact Loads.** The design of cut-and-cover underground structures supporting rail loading must consider the live load impact. Calculate the impact loading as a percentage of the live load based on the depth of fill over the underground structure as shown in Table 12-4:

Table 12-4: Impact Loading

<table>
<thead>
<tr>
<th>Fill Depth</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ft to 1.0 ft</td>
<td>30% of live load</td>
</tr>
<tr>
<td>1.0 ft to 2.0 ft</td>
<td>20% of live load</td>
</tr>
<tr>
<td>2.0 ft to 3.0 ft</td>
<td>10% of live load</td>
</tr>
<tr>
<td>over 3.0 ft</td>
<td>0</td>
</tr>
</tbody>
</table>

The fill depth for all loading is measured from the proposed ground surface elevation to the top of the cut-and-cover structure.
Roadway Live Loads. The effect of live loading from roadway traffic must be considered in the design. For cut-and-cover structures underneath City streets, the roadway live loads must conform to the CBDS. The distribution of roadway live loads through backfill and the calculation of impact factors is as described for the distribution of rail live loads. See Chapter 12, subsection 12.2.1, Transient Loads.

Transit-Oriented Development Live Loads. For areas where the cut-and-cover structure will be supporting a future transit-oriented development, the minimum live loads are as defined in ASCE/SEI 7 and SFBC, as follows:

- For Strength Combinations: Full Building Live Load x 0.5
- For Safety Evaluation Earthquake Combinations: Full Building Live Load x 0.25
- For all other load combinations: Full Building Live Load

The aforementioned conditions apply where transit-oriented development is planned.

Pedestrian Area Live Loads. Station platforms, stairways, pedestrian ramps, mezzanines, and other pedestrian areas must be designed for a uniform load of 150 psf. Stair treads for a uniform load of 100 psf or a concentrated load of 300 pounds.

Emergency walkways must be designed for a uniform live load of 100 psf on the walkway area or a concentrated load of 1,000 pounds. The concentrated load must be applied at any point on the walkway and distributed over an area of 2 feet by 2 feet.

Sidewalks must be designed to support a minimum uniformly distributed load of 250 psf pedestrian load and the live load of AASHTO standard modified design truck S20-44, not applied concurrently. The loading must be patterned to produce the maximum load effects.

B: Live Load Surcharge (LS).

Minimum Live Load Surcharge. For future traffic loads, an area surcharge applied at the ground surface both over and next to underground structures must be used to simulate possible roadway and sidewalk live loads. This surcharge must also simulate conditions during future construction activities next to the underground structures. Such construction may result in permanent loads or temporary loads from construction equipment, the stockpiling of construction materials, or the deposition of excavated earth.

An area surcharge must be applied at the ground surface both over and next to underground structures. The vertical surcharge must be considered as a static uniform load applied at the ground surface as follows, where x is the vertical distance from the top of the tunnel roof to the ground surface, in feet:

- 600 psf for $x < 5$
- $600 - 40(x - 5)$ psf for $5 \leq x \leq 20$
- 0 for $x > 20$

The above surcharge must not be applied when:

- an alternative traffic loading is specified, or
- a specific, applicable building surcharge is applied

Live load lateral surcharge pressures imposed on the cut-and-cover structures must be considered from the following sources as appropriate. The surcharge loads and limits of their application in the design will be established by the geotechnical engineer and presented within the GIR or in specific design memoranda.
Transit-oriented Development and Existing Buildings. Where earth surcharge from existing buildings and
transit-oriented development (see section 12.2.1, subsection E) are considered, the live load surcharge
must also be considered. The minimum live load surcharge pressures are as defined in ASCE/SEI 7 and
SFBC, as follows:
- For Strength Combinations: Full Building Live Load x 0.5
- For SEE Combinations: Full Building Live Load x 0.25
- For all other load combinations: Full Building Live Load

The designer must document the development of the estimated live load in each existing building in a
report. All existing building reports must be submitted to TJPA for review. See Chapter 12, section
12.2.1, subsection E: Earth Surcharge Loads (ES), for further description of the existing building
reports.

Rail. Derive and apply surcharge loads for cut-and-cover structures within the limits of the Caltrain
right-of-way in accordance with the Caltrain Engineering Standards for Excavation Support Systems.

Roadway. Calculate and apply roadway surcharge loads in accordance with the CBDS.

Construction/Minimum. Construction/minimum surcharge loads that reflect potential conditions during
construction and anticipated future conditions will be established by the geotechnical engineer and
presented within the GIR or in specific design memoranda.

C: Centrifugal Force (CE). Centrifugal force must be considered in the design of DTX cut and-cover-
structures on curved sections of the alignment. Calculate and apply centrifugal force in accordance with
AREMA.

D: Longitudinal Force (BR). Apply longitudinal force for Caltrain and high-speed trains in accordance with
AREMA.

Longitudinal force resulting from Muni LRV acceleration and deceleration must be considered as follows:
- 16% of Muni train loading for accelerating trains
- 21% of Muni train loading for decelerating trains

Apply the longitudinal force to the rails and supporting structure as a uniformly distributed load over the
length of the train in a horizontal plane acting at the top of rail elevation.

E: Air Pressure Loads (AP): Air pressure loads and piston effects of trains entering and leaving tunnels must
be considered, in conformance with AASHTO LRFD Road Tunnel.

A minimum 0.3 psi must be applied inward or outward, whichever causes the more significant effects on
all walls, partition walls, and glazing panels.

F: Water Loads (WA, Waf, WAt). The effects of hydrostatic pressure must be considered whenever the
presence of groundwater is indicated. Hydrostatic pressure is computed at 62.4 psf per foot of depth below
the design groundwater level for the condition being assessed.

The California-licensed geotechnical engineer will establish and present the groundwater levels to be
used in the design within the GIR or in specific design memoranda. The TJPA will review and approve the
groundwater levels to be used in design. Design ground water levels must include tidal influences and the
effect of sea level rise over the service life of the structure. Water pressures will reflect the likely
fluctuations of groundwater levels anticipated during the life of the structure, based on historical data
available at the time of design, data from monitoring wells, and in accordance with recommendations of
the geotechnical engineer in consultation with hydrogeologists/geologists. Analyses will be undertaken
using the most critical water pressure that is expected for the analysis, which may correspond to either
the lowest or highest water pressure anticipated depending on the type of analysis being used.

Long-term variations in the groundwater level and the possibility of future significant changes in
groundwater elevation will be considered in establishing the design groundwater levels.

The completed permanent structure must be designed for hydrostatic pressures arising from the
following conditions:

- Normal high water
- Normal low water
- 100-year flood level

**G: Collision Loads (CT).** Collision loads arising from the derailment of a train must be considered, in
conformance with AREMA Manual for Railway Engineering.

Vehicle collisions loads must be considered in accordance with the CBDS for above grade section only.

**H: Derailment Loads (DR).** In the event of derailment, damage to structures must be minimal. Progressive
collapse and global instability of the structure are not permitted.

A single line of rail live wheel loads equal to the design load per rail including impact must be applied at
an eccentricity of 5 feet from the centerline of track, but no further than the offset to structural elements
that are designed to resist collision loads.

**I: Nosing and Hunting Effects (NE).** Nosing and hunting effects must be considered. This must be accounted
for as a lateral force of 22 kips applied at the top of rail, perpendicular to the track centerline at the most
unfavorable position.

NE must be considered simultaneously with CE for the most unfavorable loading condition.

**J: Seismic (EQ).** See CHAPTER 10, Seismic Design, for seismic design requirements.

**Load Factors and Combinations**

Collision loads, derailment loads, and nosing and hunting effects must be added to the AASHTO load
combinations and load factors shown in AASHTO LRFD Road Tunnel Table 3.4.1, Load Combinations
and Load Factors, as follows:

- Add “CT” collision loads and “DR” derailment loads to the second to the last column of Table 3.4.1
  under “SS.”
- Add “NE” nosing and hunting effects to second column of Table 3.4.1 under “PL.”
- For the Service T-IA load combination, change the load factor for “WA” and “Wt” to 1.25.
Buoyancy

Provisions must be made for cut-and-cover structures to resist hydrostatic uplift forces. Calculate the buoyancy force as the total hydrostatic uplift pressure applicable at the underside of the invert slab, multiplied by the projected horizontal area of the base slab. Use the unit weight of water in Table 12-2 in the calculation of the buoyancy force.

Design water levels must include effects of sea level rise over the design life of the structure.

The buoyancy force will be resisted by the dead weight of the structure and by backfill and groundwater within a vertical plane extending upwards from the external limits of the structure roof slab. The depth of backfill calculated to resist uplift must not include the top 2 feet of cover. Use the unit weight of compacted material backfill in Table 12-2 in the calculation of the resisting force.

Do not use the following in the calculation of the force resisting hydrostatic uplift:

- Effects of skin friction on the walls of the structure
- Any live load internal or external to the structure
- Superimposed dead loads—electrical and mechanical equipment/plant loads
- Building dead load above the structure

During construction, buoyancy must be mitigated by dewatering or depressurization within the support of excavation system to ensure that a minimum factor of safety of 1.10 is maintained at all stages of construction.

Where the structure itself is unable to economically meet the prescribed factors of safety, the designer may propose alternative means of meeting the factor of safety. These may include providing a positive connection between the support of excavation system and the cut-and-cover structure, in which case, the effects of skin friction on the support of excavation below the level of excavation may be considered. Allowable skin friction values less than those for compression will be determined by the geotechnical engineer. Deviations from these criteria must be approved by the TJPA through a design variance request. See Chapter 1, section 1.8, Variances and Changes to Design Criteria.

12.2.2 Serviceability Requirements

The following design and detailing requirements must be met to help ensure the durability of the DTX cut-and-cover structures in achieving their desired service life.

Exposure Conditions

The minimum distance from concrete surface to the outermost surface of steel reinforcement (or encased steel beams) must conform to the CBDS.

Crack Width/Control

For serviceability limit states, reinforcement must be designed to limit crack widths less than or equal to 0.008 inches at a 2-inch depth of cover.

Crack widths in temporary construction elements do not need to be checked.
The minimum area of longitudinal (temperature and shrinkage) reinforcement will be 0.002 times the gross concrete area for slabs and 0.0025 times the gross concrete area for walls. This temperature and shrinkage reinforcement area need not exceed 0.79 in²/ft placed at each face regardless of the thickness of the wall or slab.

**Deflection**

All structural elements must conform to deflection limits under service loading conditions in accordance with AREMA Manual for Railway Engineering and AASHTO LRFD Road Tunnel.

**Detailing**

Dimensioning of bar lengths, laps, bar bends, etc., must conform to the requirements of AASTHO LRFD Road Tunnel and the CBDS.

Detailing of reinforcement must conform to ACI 315R and satisfy durability requirements given in ACI 201.2R.

In addition to requirements stated in this subsection, the following specific requirements must be adopted:

- Spacing of reinforcement must not be greater than 6 inches in either direction.
- In concrete members designed to accommodate axial tension forces, avoid lap splices in tension members; however, when required, laps on adjacent bars must be staggered such that the minimum distance between the ends of adjacent lapped bars or connectors will be the largest of 30 bar diameters or 1.75 feet.
- Welded butt splices are not permitted.
- Avoid the use of shear reinforcement in two-way structures, such as slabs and walls, except when required for plastic hinges.
- Shear stirrup reinforcement in beams will form a closed loop to maintain confinement of the section.
- Shear reinforcement in walls and slabs will have alternating 135° and 90° hooks.
- Walls and slabs must have a minimum of two layers of reinforcement, one at each face of wall or slab.

**Joints**

**A: Interface Joints.** Interface joints must be provided at the interface between different structure types such as tunnel to cut-and-cover structure and locations of cross section changes.

Interface joints must be designed and constructed so that the joints are fully watertight over the range of predicted movements in all directions. Design details must accommodate differential settlements, thermal expansion and contraction, fire resistance, and seismic compatibility. See CHAPTER 10, Seismic Design, for additional requirements.

Interface joints must include a preformed filler, a joint sealant, and a centerbulb-type waterstop made of plastic or rubber.

Each interface joint must include a re-injectable grouting system.
Joints must be watertight with the full range of calculated in-service movements taken into account in the design.

**B: Construction Joints.** Construction joints must be able to transmit all the forces that may occur under any design condition.

♦ Transverse joints in interior walls, invert slabs, and emergency egress corridors of the tunnel structure must be detailed as construction joints.

♦ Reinforcement must be continuous through the construction joint.

♦ Each construction joint must contain an intentionally roughened surface to a 0.25-inch amplitude.

♦ Construction joints must be watertight. Waterstops must be used in all construction joints in exterior walls, floors, and roofs.

♦ The Engineer of Record must approve location of all construction joints.

### 12.3 Temporary Excavation Support

The criteria in this section govern the design of temporary excavation support systems constructed as part of the DTX project. See section 12.4 for the criteria for excavation support systems that will be part of a permanent structure.

The design of excavation support structures must conform to the criteria in subsections 12.3.1, Planning for Excavation Support and Underpinning, through 12.3.6, Bracing to Wall Connections. In addition, excavation support system design must conform to the specific requirements of the CBDS, AREMA, and the Caltrain Standards for Excavation Support Systems in the Caltrain right-of-way. The design of excavation support structures within City-owned and Caltrans rights-of-way must conform to the requirements of the Caltrans Trenching and Shoring Manual.

#### 12.3.1 Planning for Excavation Support and Underpinning

The Engineer-of-Record, in coordination with the TJPA, must investigate existing structures that are to remain over, or next to, the construction sites of DTX facilities. Existing structures must be protected and permanently supported and underpinned, as necessary.

The types of buildings and structures, that require support and underpinning include

♦ buildings and structures extending over the DTX structures to such an extent that they must be temporarily supported during construction and permanently underpinned.

♦ buildings and structures immediately next to the DTX structures that require temporary support during construction.

♦ buildings and structures that may be affected by groundwater lowering. In certain areas, the uncontrolled lowering of the groundwater for DTX construction may cause the settlement of buildings within the influence zone.
12.3.2 Design Requirements

Analyses of excavation support systems must consider all conditions and loadings that might occur during the various stages of construction, including sequential dewatering, excavation, installation of bracing elements, construction of the permanent structure, and removal of bracing. The excavation support system design must meet the requirements for strength, deformation, and stability at all stages of excavation and construction. Submit details of proposed software and models to the TJPA for approval prior to undertaking any design.

The analyses must use estimates of the actual earth, water, and surcharge pressures on the wall and consider the effect of construction-induced ground movements on adjacent structures. The design of earth support systems must also consider the effects of the relocation and temporary support of utilities.

Where lateral loading conditions on opposite sides of an excavation are not equal and struts are used, the wall and bracing system must be designed for the larger loading conditions, and the entire temporary support system must be analyzed for the resulting asymmetric loading.

A distinction must be made between drained and undrained strengths for short-term (construction) and long-term loading conditions. Support walls used in the permanent structural load resisting system must resist the loads from at-rest earth pressure in the final ground condition if there is not enough wall displacement to mobilize active and passive pressures; the permanent structural system design must consider any residual stresses resulting from the temporary condition.

The geotechnical engineer will derive the earth pressures for the excavation support system design using the effective unit weights of soil layers together with the appropriate strength parameters. The geotechnical engineer will develop limiting wall movements that are based on the adjacent structure or foundation type. Pressure diagrams and limiting wall movements will be developed and presented within the GIR or included in specific design memoranda.

Shoring support must extend at least 10 feet below the base of the excavation or into a competent soil or rock layer, whichever is deeper, unless the Engineer-of-Record shows that vertical and horizontal support requirements can be developed at less than 10 feet below the excavation depth. The minimum depth of shoring below the excavation depth must be 2 feet.

The weight of shoring walls may be used to resist the effects of buoyancy only if the shoring walls are structurally connected to the remainder of the permanent structure, subject to meeting the design requirements of permanent underground structures. Deviations from these criteria must be approved by the TJPA through a design variance request. See Chapter 1, section 1.8, Variances and Changes to Design Criteria.

Underpinning walls or piers that support structures and form a portion of the excavation support system must extend to a minimum depth identified in the GIR or included in specific design memoranda.

Underpinning

Methods used to protect or underpin existing structures must account for the site-specific soil and groundwater conditions and include bracing systems.

Bracing systems must be tight for the effectiveness of underpinning and for the protection of wall support. The Engineer of Record must indicate requirements for the installation and removal of the temporary bracing systems that relate to the design of underpinning and protection walls, such as the levels of bracing tiers, the maximum distances of excavation below an installed brace, and the amount of preloading.
Other geotechnical considerations outlined in CHAPTER 9, Geotechnical Requirements, must also be considered.

### 12.3.3 Wall Bracing and Tie-backs

Bracing must provide support to the wall system, resisting all excavation dead and live loadings and bearing either directly on the wall or on a horizontal wale. Bracing must be of adequate spacing and stiffness to minimize support wall deflections, deformations and inward movements.

The depth of placement and preload on the first level of struts must minimize deformations of the system, avoid deformations detrimental to adjacent utilities, and be consistent with optimizing the design of the shoring.

The uppermost level of bracing must be installed as close to the ground surface as practical. Vertical spacing may be increased when struts are removed, provided that the invert slab has achieved at least 60 percent of its 28-day design strength and the support system is designed for such increased spacing.

Temporary bracing must account for the effects of temperature, as temperature variations in cut-and-cover excavations can cause substantial load increases on the bracing systems. The design temperature variation must conform to AASHTO LRFD Road Tunnel.

The use of tiebacks will be limited by right-of-way constraints and will not be used in the Caltrain right-of-way at the Fourth and King Street Station. However, the designer must investigate the use of tiebacks in the approach to the Transit Center under Second Street.

### 12.3.4 Loads

Applicable minimum loads and forces must conform to section 12.3.5. Seismic forces for excavation support systems are defined in CHAPTER 10, except as modified in this section.

For structures to be shored for 5 years or less, wind loading and design must conform to ASCE/SEI 37.

For structures to be shored for over five years, wind loading and design must conform to applicable codes for permanent structures.

Excavation support must limit movements to a level coordinated with the necessary adjacent property and utility protection measures. The Engineer-of-Record must demonstrate that the anticipated wall movements are coordinated with the proposed property and utility protection measures.

Soil load redistribution caused by temporary excavation support or existing foundation systems must be analyzed.

### 12.3.5 Load Factors and Combinations

In selecting critical loading combinations, consideration will be given to appropriate combinations of maximum and minimum vertical loads with maximum and minimum horizontal loads and to unsymmetrical loads. See Chapter 12, subsection 12.2.1, Loads and Forces/Load Factors and Combinations.
The design of temporary structures constructed using concrete must conform to ACI 318 and AASTHO LRFD Road Tunnel. Loads caused by construction equipment and the design of other temporary structures must conform to ASCE/SEI 37.

### 12.3.6 Bracing to Wall Connections

Filler plates, shims, or grout must be used to obtain a tight fit between bracing elements and a wale or wall. Upon completion of the wall bracing and support system, no further driving of wall piles will be permitted.

Connections between struts, wales, and the wall system must accommodate a minimum tensile and shearing load equal to the greater of the actual tensile/shear forces as derived from analysis or 10 percent of the design compressive strut load.

### 12.4 Permanent Earth-retaining Structures

The criteria in this section govern the design of permanent earth-retaining structures constructed or modified as part of the DTX project. Permanent earth-retaining structures include u-walls, retaining walls, and abutments and wing walls for bridges.

The design of earth-retaining structures must conform to the criteria specified herein and the specific requirements of the CBDS, AREMA, and the Caltrain Standards for Design and Maintenance of Structures.

#### 12.4.1 Types

Earth-retaining structure type selection must meet the project’s functional and durability requirements and be consistent with the requirements of the Caltrain Standards for Design and Maintenance of Structures.

#### 12.4.2 Loads

Earth-retaining structures must be proportioned to resist the applicable loads as described in subsection 12.2.1, Loads and Forces. Seismic forces must conform to the requirements in CHAPTER 10 SEISMIC DESIGN.

#### 12.4.3 Load Factors and Combinations

The load factors and load combinations for earth-retaining structures must conform to the CBDS.

#### 12.4.4 Buoyancy

Adhere to the requirements for buoyancy in subsection Chapter 12, subsection Buoyancy.

#### 12.4.5 Serviceability Requirements

Adhere to the requirements for serviceability in subsection 12.2.2, Serviceability Requirements, unless indicated otherwise in section 12.4, Permanent Earth-retaining Structures.
12.4.6  Deflections

The maximum permissible top of wall deflections for cantilevered structures and mid-height deflections for structures laterally supported at the top will be established by the geotechnical engineer and submitted for TJPA approval. Tolerable wall movements will be developed and presented within the GIR or included in specific design memoranda.

12.4.7  Stability

**Base Pressure**

Earth-retaining structures must be proportioned such that the base pressure does not exceed the allowable soil bearing capacity. To minimize differential settlement and outward tilting of walls, proportion the walls so that the pressure under the footing is as uniform as practical under long-term loading.

Where the structure cannot be economically proportioned to meet the allowable soil bearing capacity or where the base pressure produces excessive differential settlement, the structures must be founded on piles.

**Stability – Overturning**

A minimum factor of safety of 2.0 against overturning under permanent loads must be maintained. For structures resting on rock, a minimum factor of safety of 1.5 against overturning under permanent loads must be maintained.

**Stability – Sliding**

A minimum factor of safety of 1.5 against sliding under permanent loads must be maintained.

Ignore the uppermost 3 feet of finished grade earth at front (toe) of the wall in the calculation of sliding resistance.

**Global Soil Mass Stability**

The overall stability of earth-retaining structures must be considered in the design. A minimum factor of safety of 1.5 under permanent loads must be maintained.

12.5  Bridges

The criteria in this section govern the design of bridges that are constructed or modified as part of the DTX project. These criteria also apply to structures whose failure will affect DTX facilities or operations.

Required modifications to the I-280 Sixth Street off-ramp and the I-80 structure on Second Street are the scope of this section.

Roadway and highway bridge design must also meet the requirements of the CBDS.
Railway bridge design must also meet the requirements of AREMA, as modified by the Caltrain Standards for Design and Maintenance of Structures.

12.5.1 Loads

Loads for bridge design must be calculated and applied as specified in this subsection and must also meet the requirements of the CBDS for roadway and highway bridges and AREMA standards, as modified by Caltrain Standards for Design and Maintenance of Structures for railway bridges.

Differential Settlement

Differential settlements of existing bridges affected by DTX construction must be limited to the values agreed with the respective bridge owners. The settlement limits will be established by the geotechnical engineer and presented within the GIR or included in specific design memoranda.

Collision Loads

Bridge piers or substructure elements located within 25 feet or less from the centerline of a railroad track must be of heavy construction as defined in AREMA or must be protected by a reinforced concrete crash wall, in accordance with AREMA. The impact must not cause the instability or failure of major structure elements.

The use of derailment containment devices must be considered as mitigation for derailment impact forces.

12.5.2 Load Factors and Combinations

Load factors and combinations of loads for roadway and highway bridges and railway bridges must conform to the CBDS and AREMA standards, respectively, as modified by Caltrain Standards for Design and Maintenance of Structures.

12.5.3 Buoyancy

The effects of buoyancy must be considered in the design of substructures.

Adhere to the safety factors against flotation in subsection, Chapter 12, subsection Loads and ForcesBuoyancy, for new construction. For modifications to existing structures, maintain the existing factors of safety against hydrostatic uplift.

12.6 Buildings

The criteria in this section govern the design of new buildings and modification of existing buildings. Buildings include above-ground station facilities, ventilation and egress structures, and maintenance and storage buildings.

The design of buildings must meet the requirements of the SFBC. Modifications to the Caltrain station at Fourth 4th and King streets and 4th and King Railyards must conform to the Caltrain Design Criteria and Caltrain Standards for Design and Maintenance of Structures.
12.6.1 Loads

Loads for building design must meet the requirements of the SFBC.

12.6.2 Load Factors and Combinations

Load factors and combinations of loads for buildings must conform to the SFBC.

12.6.3 Design Considerations

Building structures must accommodate the installation, maintenance, and replacement of heavy electrical and mechanical equipment.

12.6.4 Detailing

Dimensioning of bar lengths, laps, bar bends, etc., must conform to the requirements of SFBC and ACI 318.

Detailing of reinforcement must conform to ACI 315R and satisfy durability requirements given in ACI 201.2R.

12.7 Miscellaneous Structures

The criteria in this section govern the design of miscellaneous structures that are not specifically referenced in prior sections of this chapter. These may include visual walls, sound walls, barrier walls, signs, and other similar structures.

The design of miscellaneous structures must conform to the SFBC. Highway and roadway structures must conform to the requirements of the CBDS. Structures within the Caltrain right-of-way must conform to the requirements of AREMA, as modified by the Caltrain Standards for Design and Maintenance of Structures.

The calculation of loads, load factors, and combinations of loads must conform to the designated code.

12.8 Foundations

Foundations for structures within the Caltrain right-of-way must conform the requirements of AREMA, as modified by the Caltrain Standards for Design and Maintenance of Structures. Foundations for highway and roadway structures must conform the requirements of the CBDS. Building foundation design must conform to the requirements of the SFBC.

Permissible values for load resistance capacity, movement capacity, stability analyses, and settlement for foundations will be established by the geotechnical engineer and presented within the GIR or included in specific design memoranda.
12.9  Watertightness and Leakage Mitigation

Underground structure design must limit water ingress. Any visible water leakage must be prevented.

Materials used in preventing or stemming water ingress must not compromise the fire safety or the durability of the structures in which they are used. If passive fire protection or architectural finishes are required inside the tunnel, seepage drainage must be designed for and provided behind such systems.

Allowable daily infiltration rates and criteria must conform to Table 12.3. All infiltration values must be measured at the source of the leak.

Table 12-5: Allowable daily infiltration rates

<table>
<thead>
<tr>
<th>Water Tightness Class</th>
<th>Dampness Characteristics</th>
<th>Definition</th>
<th>Infiltration (gal/sf)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Absolutely dry</td>
<td>No damp areas visible on the surface</td>
<td>0.00025</td>
<td>All room surfaces containing equipment. Zones used to house electrical, systems and communications equipment.</td>
</tr>
<tr>
<td>2</td>
<td>Substantially dry</td>
<td>Occasional damp patches which do not discolor blotting paper, detectable on the surface</td>
<td>0.0012</td>
<td>All public area surfaces of underground stations. Underground structures used by public.</td>
</tr>
<tr>
<td>3</td>
<td>Capillary dampness</td>
<td>Occasional damp patches on the surface, but no movement or water apparent to the eye or drops of water</td>
<td>0.0025</td>
<td>All emergency egress and ventilation structure surfaces</td>
</tr>
<tr>
<td>4</td>
<td>Small amounts of dripping or moving water</td>
<td>Occasional drops of water or water moving along surface</td>
<td>0.005</td>
<td>Guideway structure surfaces not covered above</td>
</tr>
</tbody>
</table>

Limit water ingress at any individual locations to less than 0.025 gallons/ft²/day and no more than 1 drip per minute at any location.

Do not permit water drips over the trainway or emergency walkway surfaces or where they have the potential to cause damage to equipment; to cause the malfunctioning of any electrical power, signaling, lighting, control, or communication equipment; or to compromise electrical clearances.

Do not permit the ponding of water on emergency walkway surfaces.

Embedded electrical boards, electrical conduits, and other similar elements must be completely waterproofed and watertight.

All joints—construction joints, expansion joints, and interface joints between structure types—must be fully watertight over the range of anticipated movements.

12.10 Drainage
Regardless of the waterproofing system used and permissible leakage criteria, drainage systems must be provided in underground structures and must collect condensation, infiltration, spilled water, and other flows over the service life of the structures. Tunnel drainage must conform to the criteria in CHAPTER 16MECHANICAL SYSTEMS.

The linear underground structure profiles must be designed to maintain positive drainage.

Any seepage in guideway structures must be carried away by the track drainage.

All rooms and spaces in underground structures must have the means to collect and drain water from inside the structure to the track drainage, station, or ventilation and emergency egress structure drainage system, as appropriate.

Interface and expansion joints must have the means to collect and channel any infiltration to an appropriate drainage system.
CHAPTER 13 TUNNELS

SCOPE

This chapter establishes the requirements for the design of the Downtown Rail Extension (DTX) tunnel, including mined tunnels constructed using sequential excavation method (SEM), bored tunnels excavated by tunnel boring machine (TBM), and initial support and final lining systems for tunnels. This chapter also includes the codes, standards, guidelines, and criteria governing the design of initial support and final lining systems for tunnels.

“Initial support” refers to the support installed in conjunction with tunnel excavation operations to maintain stability and safety of the excavation and to minimize ground movements.

“Final lining” refers to the lining installed independent of and following tunneling operations to provide permanent support of the tunnel, satisfy watertightness requirements, and provide a surface finish that achieves acceptable performance in terms of the owner’s requirements.

See CHAPTER 7, Guideway Geometrics, for the required clearances for tunnel sections. Tunnels inclusive of required or specified tolerances must be designed to achieve these clearances and accommodate all rail and tunnel operating systems as well as specified tolerances.

See CHAPTER 9, Geotechnical Requirements, for geotechnical guidance for use in the design of mined tunnels.

See CHAPTER 12, Structures, for additional load and infiltration criteria for tunnels as defined herein.

CODES, STANDARDS AND GUIDELINES

Tunnel design for the DTX must conform to the latest edition of the following standards, codes and guidelines unless otherwise specified in these criteria:

♦ American Association of State Highway and Transportation Officials Load and Resistance Factor Design Road Tunnel Design and Construction Guide Specifications (AASHTO LRFD Road Tunnel)

♦ American Concrete Institute (ACI) Manual of Concrete Practice, including:
  ● ACI 224R, Control of Cracking in Concrete Structures
  ● ACI 301, Specifications for Concrete Construction
  ● ACI 318, Building Code Requirements for Structural Concrete and Commentary
  ● ACI 365.1, Service-Life Prediction—State-of-the-Art Report
  ● ACI 506.2, Specification for Guide to Shotcrete and associated committee reports
  ● ACI 506.5R, Guide for Specifying Underground Shotcrete
  ● ACI 533.5R, Guide for Precast Concrete Tunnel Segments
  ● ACI 544.7R, Report on Design and Construction of Fiber Reinforced Precast Concrete Tunnel Segments

♦ American Railway Engineering and Maintenance of Way Association (AREMA), Manual for Railway Engineering
American Society of Civil Engineers/Structural Engineering Institute – ASCE/SEI 7, Minimum Design Loads for Buildings and Other Structures

ASTM International standards:

- ASTM A36, Standard Specification for Carbon Structural Steel
- ASTM A53, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
- ASTM A572, Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
- ASTM A615, Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
- ASTM A706, Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement
- ASTM A709, Standard Specification for Structural Steel for Bridges
- ASTM A820, Standard Specification for Steel Fibers for Fiber-Reinforced Concrete
- ASTM A1064, Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
- ASTM A1085, Standard Specification for Cold-Formed Welded Carbon Steel Hollow Structural Sections (HSS)
- ASTM C1116, Standard Specification for Fiber-Reinforced Concrete
- ASTM C1550, Standard Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)
- ASTM C1609, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
- ASTM D412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
- ASTM D7205, Standard Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars

California Occupational Safety and Health Administration (Cal/OSHA) Tunnel Safety Orders, California Department of Industrial Relations Division of Occupational Safety and Health, Title 8, Tunnel Safety Orders

Caltrans (California Department of Transportation) Bridge Design Specifications (CBDS)

National Fire Protection Association - NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems

REFERENCES

Appropriate references, including the following, may also be used in support of the analysis and design of mined tunnels.


German Committee for Structural Concrete. 2015. DAFStb Guideline: Steel Fiber Reinforced Concrete.


Institution of Civil Engineers (ICE). 1996. Sprayed Concrete Linings (NATM) for Tunnels in Soft Ground.


PAS 8810 Tunnel Design-Design of Concrete Segmental Linings-Code of Practice, British Tunneling Society.
13.1 Materials

Structural materials used for initial support and final lining of tunnel excavations must conform to the requirements of CHAPTER 12, Structures, section 11.1.

13.1.1 Cast in Place Concrete

The structural behavior of tunnel components constructed from concrete must be investigated for each stage of construction, including handling, transportation, and erection, and during the service life of the structure that they are part of. Structures must be proportioned to satisfy the requirements at the strength, extreme event, service, and fatigue limit states.

Use the following minimum 28-day concrete compressive strength, $f'_c$, for structural elements:

- Cast-in-place concrete: 4,000 psi
- Precast concrete tunnel lining: 6,500 psi

Structural concrete must conform to ACI 301. Do not use lightweight concrete for load bearing structural concrete. Lightweight concrete may be used for non-structural applications (e.g., walkways, non-structural finishes). Recycled materials may be used for non-structural applications.

13.1.2 Shotcrete

Shotcrete compressive strength must conform to the requirements for cast-in-place concrete. See subsection 13.1.1, Cast in Place Concrete.

Shotcrete must conform to ACI 506.2 and ACI 506.5R.

Shotcrete materials must conform to the most recent applicable ASTM standards. Steel or synthetic fibers may be used in initial support shotcrete to improve flexural strength, ductility, and toughness. Energy absorption capacity and residual flexural strength for fiber-reinforced shotcrete must be specified to suit the intended application and demonstrated with preconstruction testing in conformance with ASTM C1550 or ASTM C1609.

13.1.3 Reinforcement

Reinforcing steel for concrete reinforcement must be deformed bars conforming to ASTM A706.

Welded wire fabric must conform to ASTM A1064.
Steel fiber reinforcing must conform to ASTM A820. Steel and synthetic fibers must conform to ASTM C1116.

Polypropylene microfibers must be provided in the final linings of tunnels to help mitigate the incidence of explosive concrete spalling during a design fire event.

Reinforcement used for presupport of SEM excavations or to stabilize and strengthen the rock mass and provide supplemental initial support must meet the requirements in Chapter 12, subsection 12.1.5, Overhead Anchors.

**Structural Steel Piping For Pipe Canopy**

Structural steel pipe must conform to ASTM A53.

**Steel Spiles**

Pipe spiles must conform to ASTM A53; presupport must have a minimum yield strength of 35 ksi.

Bar spiles must conform to ASTM A615, with a minimum yield strength of 60 ksi.

**Rock Bolts**

Rock bolts must conform to ASTM A615, with a minimum yield strength \( f_y \) of 60 ksi. However, the use of Grade 150 rock bolts is not permitted because of their brittle failure characteristics.

**Fiberglass Dowels**

Fiberglass dowels must have a minimum tensile strength of 70 ksi, conforming to the requirements of ASTM D7205, Standard Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars.

**13.1.4 Structural Steel for Initial Support**

Structural steel elements used in the design of the initial support for SEM tunnels must have the properties described as follows:

**Structural Steel Ribs.** Structural steel ribs must conform to ASTM A36 Grade 36, or ASTM A572 or equivalent, A709, Grade 36 or Grade 50.

**Lattice girders.** Primary bar reinforcements must have a minimum yield strength of 70 ksi, conforming to ASTM A615. Steel plate for connecting elements must conform to ASTM A36.

**13.1.5 Waterproofing**

Mined tunnels must be completely waterproofed. A waterproofing system must be installed between the initial support and final lining of all mined tunnels and between the temporary precast tunnel linings and cast-in-place final linings of bored tunnels. Waterproofing material requirements are defined in Chapter 12, subsection 12.1.8, Waterproofing.
13.1.6 Precast Tunnel Lining Gaskets and Other Materials

Precast tunnel lining segments must include perimeter gaskets conforming with ASTM C920 and ASTM D412 to prevent waterflow through joints.

Gasket materials must withstand sustained exposure to any aggressive environment present in the ground or groundwater. The gasket material must withstand chemical attack and biological degradation such that the gasket functions properly over its service life. Hydrophilic seals and other types of gaskets can be used as secondary seals or in conjunction with the primary gaskets. If hydrophilic gaskets are used as secondary seals, long-term performance must be confirmed.

Gaskets must resist the anticipated hydrostatic pressures including fluctuations in water level through compression of the gasket for its service life, under conditions of maximum joint gap and gasket offset with an appropriate factor of safety, as approved by the geotechnical engineer. At a minimum, gaskets must be designed for double the maximum hydrostatic pressure on the tunnel lining to account for long-term performance of the gasket. The long-term durability and deterioration of the performance of the gasket due to creep and stress-relief must also be considered in the design.

Precast tunnel lining segments must be connected across both their radial and circumferential joints. For temporary linings, bolted connections must be used in radial and circumferential joints. For final linings, bolted connections must be used in radial joints, and dowels must be used in circumferential joints.

13.2 Loads, Load Factors, and Load Combinations

The design of initial support and final linings must consider loading conditions described in this section; loads, load factors, and load combinations must conform to Chapter 12, Structures, and AASHTO LRFD Road Tunnel.

Loadings imposed on the mined tunnel by the ground surrounding the tunnel and applicable surface surcharge loadings (i.e., loads induced by adjacent building foundations, street-level motor vehicle and rail traffic, and stockpiles of materials and equipment for construction) must accord with the results of the geotechnical investigation program and be consistent with the tunnel geometry and assumed construction methods.

13.2.1 Dead Loads

Dead loads and applicable allowances for superimposed dead loads—weights of elements affixed to the final lining, such as the overhead contact system (OCS), communications and electrical equipment, standpipes, etc., as defined in Chapter 12, section 0, Permanent Loads, must be accommodated in the mined tunnel design.

13.2.2 Live Loads

Design live loads consist of any non-permanent loads placed on or in the tunnel, including live loads that are due to rail and roadway traffic within and above the tunnel and pedestrian loads. Live load intensity including impact factors must be calculated and applied to conform to the criteria in Chapter 12, subsection B: Live Load Surcharge (LS).
13.2.3  Ground Loads

Use the following to develop ground loads in the design:

- Preliminary ground loads may be determined using accepted empirical methods commonly used to classify ground conditions to estimate ground loads and support requirements.

- Where the cover above the tunnel is less than 1.5 times the excavated span of the tunnel, the initial support must be designed for a ground load equal to the full overburden pressure, unless detailed numerical analyses are conducted to determine the loading more accurately.

- Initial load on tunnels in rock with cover greater than 1.5 times the excavated span must be designed for a rock load that considers arching. Soft ground tunnels may also consider arching, if appropriate, for temporary loading and must be designed for the full overburden pressure.

- Long-term load on tunnels in rock with cover greater than 1.5 times the excavated span must be designed for a rock load that considers arching. The design must also consider the weight of unstable rock blocks and wedges daylighted by the tunnel excavation. These blocks/wedges must act as point loads on the final lining and be applied in eccentric locations to produce conditions of maximum stress on the lining. Soft ground tunnels may only consider arching if appropriate for granular soils. Long-term loading on tunnels in cohesive soils must be based on full overburden.

- For watertight initial support system, groundwater pressure must be considered; otherwise, the pressure relief of the initial liner is required.

- Ground loads for final linings must include full hydrostatic groundwater pressure. No reduction in hydrostatic pressures is permitted, whether or not a pressure relief system is installed. Design groundwater pressures must conform to the groundwater levels as indicated in CHAPTER 12, subsection 0F, Water Loads.

- For tunnels, ground-structure interaction modeling must be used. Models must consider long-term behaviors and potential creep of the soil formations. Models must include loads imposed as a result of localized ground improvement such as TBM break-in/break-out and intervention locations.

- Groundwater loads applied must be the actual hydrostatic pressure on the tunnel, as determined by the ground water elevation or water surface elevation.

- Tunnel lining design must consider temporary conditions during construction, including dewatering, in-service conditions, and the 100-year flood inclusive of sea level rise caused by global warming.

13.2.4  Surcharge

Surcharge loads from existing buildings above tunnels must be considered in the design in conformance to the requirements in CHAPTER 12: Structures, subsection 0.E, Earth Surcharge Loads. Appropriate surcharge loads will be determined by the geotechnical engineer.

13.2.5  Thermal

Linings must be designed for thermal loads resulting in thermal expansion ($T_e$) and contraction ($T_c$) with temperature variations as defined in CHAPTER 12: Structures, subsection 12.4.5 Serviceability Requirements.
Additionally, the final lining system must be designed for a thermal gradient of 20 degrees Fahrenheit between the inside and the outside surface of the lining.

### 13.2.6 Shrinkage

The effects of shrinkage, creep, and early thermal cracking must be considered in the design of the final lining system, as defined in CHAPTER 12, subsection 12.4.5, Serviceability Requirements.

### 13.2.7 Collision Loads

Collision loads arising from the derailment of a train must be considered in the design of the mined tunnel, as described in CHAPTER 12, subsection 0.G, Collision Loads.

### 13.2.8 Extreme Events

Extreme event loads must be considered separately and must not be combined with other extreme loads.

**Seismic Performance**

Seismic performance of tunnels must be evaluated in accordance with Chapter 10, Seismic Design. The final lining system of the tunnel must have sufficient ductility and strength to withstand the ground deformations imposed on the tunnel by ground shaking.

**Fire**

Tunnel final linings and other structural elements essential to the stability of the tunnel must meet the construction requirements of the National Fire Protection Association (NFPA) 130.

The structural capacity of the lining must be confirmed during a fire event. The heat transfer to the structural elements from the design fire event must be derived from numerical analysis, including computational fluid dynamic modeling of the fire growth and the temperature increase and rate of gain of temperature increase of the tunnel lining. The analysis must include the tunnel lining and any other structural elements essential for tunnel stability, without the consideration of any mechanical fire-suppressing systems. Proposed methods of analysis must be approved by the Transbay Joint Powers Authority (TJPA). See CHAPTER 15, Fire-Life Safety, for a definition of the “design fire.”

The design fire must not result in the collapse of structural members. The performance of the tunnel lining and internal structure after the design fire event must be verified, considering any loss of section comprising spalled materials or material whose properties are diminished by exposure to high temperature. The tunnel lining must be capable of supporting in-service loads until it is repaired.

Alternatively, the tunnel lining and other structural elements may be passively protected from exposure to heat by sacrificial layers, protective coatings, or a protective screening. Protective measures must provide protection against the heat released by the design fire for a minimum of two hours with a maximum temperature at the surface of the protected element of 482 degrees Fahrenheit. All proposed protective measures must be accepted by the TJPA.
Flood

The effects of tsunami, flood water, and sea level rise must be accounted for in the design over the service life of the project. Tsunami and flood water surface elevation levels must be determined from historical data or modeling.

Blast

Tunnel security requirements must conform to the project's Threat and Vulnerability Assessment.

13.2.9 Construction Loads

Construction loads are dependent on construction methodology, construction sequence, and procedures. These may result in conditions that are more severe than the permanent loading conditions. Mined and bored tunnels must be designed to resist the load effects generated during construction.

Examples of construction loads include those defined in AASHTO LRFD Road Tunnel and the following:
♦ Crane and other equipment loading.
♦ Loads imposed by construction vehicles operating inside the tunnel.
♦ Data Retrieval.
♦ Loads arising from imperfect erection of bored tunnel lining rings. Ovalization must be determined based upon proposed segment ring configuration but must not be less than 0.25 percent of the tunnel lining radius.
♦ Loads induced by the installation or removal of ground improvement, and the driving of adjacent adits or excavations.

Construction loads must be applied with appropriate dynamic load factors. All temporary conditions must be assessed before installation of internal structures, including walkways, etc., that may have a relieving effect.

13.2.10 Load Factors and Combinations

Loads must be applied with load factors and in such combinations as defined in AASHTO LRFD Road Tunnel as a minimum. The designer is responsible for ensuring that all potential conditions and variations of stress on the lining are adequately represented in the design and must evaluate if there are other load combinations that must be addressed.

13.3 Buoyancy

The effects of buoyancy must be considered in the design of mined tunnels. Adequate resistance to flotation and buoyancy must be provided at each excavation and construction stage based on the groundwater level recommendations in the Geotechnical Interpretive Report (GIR).

Resistance to uplift must consist of the dead weight of the structure, overburden, and backfill within a vertical plane extending upward from the external limits of the excavation. Do not consider shear strength and friction of overburden. Do not use the elements listed in CHAPTER 12, subsection 0, Buoyancy, in the calculation of the resisting force.
Minimum factors of safety for construction and in the permanent condition must conform to Chapter 12, subsection 0, Buoyancy.

### 13.4 Analysis of Tunnel Structures

Tunnel lining design must incorporate Load and Resistance Factor Design in accordance with AASHTO LFRD Road Tunnel. The design of tunnel linings must account for performance requirements. These include service life; proposed use; ground and groundwater conditions, including flood water levels and buoyancy; ground and groundwater chemistry; and extreme events, including seismic and fire. Tunnel design must account for the impact of the tunnel on existing infrastructure and the impact of such infrastructure on the tunnel lining for both the short-term (during construction) and permanent conditions. Tunnel design must account for the sequence of construction and for future developments.

#### 13.4.1 Methods of Analysis

State-of-the-art numerical modeling techniques comprising finite element or finite difference models and simulation procedures must be applied. Proposed software must be fully validated for its intended use. All analyses must be carried out in an auditable manner, in accordance with the Construction Industry Research and Information Association’s guidance (CIRIA 2020) or similar approach acceptable to the TJPA.

The numerical simulations must be applicable to and reflect the work and construction sequence proposed. Analysis must take into account the in-situ stress conditions within the ground and short- and long-term soil-structure interaction characteristics of the ground and the tunnel lining.

A range of ground strength parameters must be considered; these include average and conservative parameters, overburden conditions, and excavation states. Soil strength and stiffness parameters used in models must reflect local ground conditions. The design must address changes in the groundwater table and maximum flood water elevation to account for maximum and minimum foreseeable groundwater pressures. Sensitivity analyses must be undertaken to account for variations in ground properties, tolerances, and loading conditions.

Numerical modeling results must be verified for reasonableness using alternative analysis methods—hand calculation, use of different software. The alternative analysis methods may be supported by comparison of the design output with data from comparable projects—in terms of geology and groundwater conditions, tunnel cross section, excavation sequence, etc.

#### 13.4.2 Critical Sections Analysis

All critical sections for the analysis and design of tunnel linings must be selected on the basis of parameters that include tunnel geometry, alignment and profile, geological conditions, groundwater table, and proximity to existing infrastructure. Critical sections for bored and mined tunnels must be considered separately. Critical sections selected for analysis must include at a minimum:

- Locations of minimum and maximum ground cover
- Locations of maximum and minimum groundwater elevation
- Locations where mixed face soil conditions (both from natural ground and improved ground) are anticipated
♦ Locations where existing adjacent or overlying infrastructure is within the zone of influence

♦ Locations where adjacent structures are planned next to the tunnel alignment resulting in unloading conditions or out-of-balance load conditions

♦ Locations of eccentric loadings arising from future junctions or mined excavations

♦ Locations where the tunnel is within one tunnel diameter of deep foundations

♦ Locations where ground improvement measures are employed; such analysis must consider conditions where ground improvements are fully intact and where ground improvements have subsequently been removed or have fully degraded to native soil conditions

♦ Locations of interventions ahead of the TBM cutterhead for bored tunnels

Use appropriate modeling to determine the appropriate degree of ground relaxation. The modeling of bored tunnels must also consider that different face pressures may be employed for different amounts of cover and water levels, as well as during interventions.

Critical sections at tunnel interfaces with other structures or other types of tunnels must be considered separately. Use 3D ground-structure interaction modeling to assess intersections and analyze them based on the intersection geometry and the specific loading and geotechnical conditions at such locations. Determine the magnitudes of differential displacements between the different structure types and design appropriate interface joints as needed.

Tunnel lining modeling and design must consider the presence of internal structures under static and seismic loading conditions. The lining design must accommodate the transfer of all loads to and from internal structures.

13.5 Mined Tunnel Lining

Mined tunnels comprise temporary support elements—presupport and initial support, a waterproofing membrane, and a final lining. The analysis and design of initial support and final linings must conform to the requirements of Section 13.4, Analysis of Tunnel Structures.

13.5.1 Initial Support

The initial support system must support the actual ground loads shortly after excavation to provide a stable opening. The design of the initial support system including presupport must account for anticipated ground deformations and ensure that adequate clearance is maintained for installation of the final lining.

Presupport may comprise pipe canopy, pipe or bar spiles, rock bolts and anchors, face dowels, and other ground reinforcement elements. Initial support must include fiber-reinforced shotcrete supplemented with welded wire mesh, bar reinforcement, lattice girders or steel ribs, as necessary.

Initial support must be designed for application as close to the face as practical to limit loosening and enhance the arching characteristics of the ground, both to protect construction personnel and control ground movements.
The spacing of lattice girders or steel ribs must not exceed the designed length of advance, to assist with maintaining the cross-sectional tunnel geometry within specified tolerances.

Rock mass classification systems must be used to characterize ground conditions and assess general initial support system requirements. The rock mass must be classified on the basis of available geotechnical data in conformance with Terzaghi’s rock condition categories, the Rock Mass Rating system, and Q-system (USACE 1997; Proctor et al. 1988; Hoek and Brown 1980; and Barton et al. 1974). Ground conditions for tunnels in soil (or soft ground) must be classified in conformance with procedures in the technical reports, “Important Ground Parameters in Soft Ground Tunneling” (Heuer 1974) and “Design of Tunnel Liners and Support Systems” (Deere et al. 1969).

The initial support system must be designed to support the ground above the opening and limit ground movements to acceptable levels (in terms of minimizing potential impacts on facilities above and next to the tunnel), taking into account the ground-lining interaction that occurs in the ground surrounding the tunnel excavation. The extent of the interaction must be directly dependent upon the excavation and support installation sequence and timing.

The design of the initial support must consider the following:

- Ground conditions, including stratigraphy, soil and rock types, groundwater conditions, strength, in situ stress-strain characteristics, and Poisson’s ratio
- Material properties of the support elements, including the strength and stiffness (modulus) of each element
- Ground-lining interaction, including the deformation properties of the ground and lining system and the impacts of any adjacent construction or ground treatment

Define a robust construction sequence detailing excavation and support measures required at each intermediate excavation stage to achieve the final tunnel geometry in the anticipated ground conditions. At a minimum, the excavation and support sequence analysis and design must address the following:

- Standup time of excavated face, length of advance and speed of ring closure
- Need for face support, presupport, or ground improvement measures
- Ensure stability and control of ground movements at all stages of tunnel excavation
- Geotechnical hazards, including impacts of variation of ground conditions and groundwater
- Impacts on adjacent infrastructure and construction
- Drainage
- Deformations/alert levels/trigger levels and corresponding required safety action

The initial support must be designed for sufficient longevity to provide stability of the excavations until the final lining has been installed. The design must define a systematic process for installing support measures, including time of installation and time when support becomes effective. The design must coordinate the initial support shotcrete rate of strength gain with the excavation sequence and durations. The effect of all support measures, with the exception of presupport elements, must be included in all stages of the analysis.

Initial support elements must conform to the same code and regulatory requirements that apply to the final lining and must be designed to accommodate all applicable loads and load combinations. Do not apply
13.5.2  Analysis

Methods for analyzing initial support must be capable of representing loads and deformations in accordance with the geologic and construction conditions and accurately accounting for the ground-lining interaction.

The excavation and support sequence will affect the behavior of the surrounding ground and possibly the ground surface. When designing the excavation and support sequences and initial support, consider the anticipated deformations and ground movements associated with such construction must be considered.

The design and construction methodology for mined tunnel initial support must address the following:

- Ground conditions:
  - Strength and physical ground characteristics
  - In situ stress conditions
  - Standup time of excavated face
  - Deformation properties
  - Groundwater conditions and permeability
  - Criteria for ground treatment

- Construction parameters:
  - Size, layout, and sequence of excavation stages
  - Need for presupport, face support, or ground treatment measures
  - Length of advance
  - Tunnel crown and side wall support
  - Speed of ring closure
  - Requirements for building protection and ground treatment. See CHAPTER 11, Protection of Existing Infrastructure
  - Drainage
  - Waterproofing between initial support and final lining
  - Deformations/alert levels/trigger levels and corresponding required safety action

Initial support design analyses must conform to the general design procedures developed by Rabcewicz and Golser (1973).

The ground mass behavior must be analyzed by varying the different rock mass parameters in a range of possible or expected values (parametric study). Each step of the sequence must be analyzed, with consideration given to the expected time between each step and consequent changes, for example, the change in shotcrete properties during curing.

The result of the computations must address:

- the stresses, strains, and deformations in the ground mass
stresses or sectional forces and deformations of the initial support

the ground loads on the support/outer lining calculated for the state of equilibrium

The analyses must be used for initial sizing of the initial support, subject to modification based on observations during construction. Selected safety factors must be commensurate with the nature of the work.

The results must be analyzed and must undergo a critical assessment to indicate the stability of the rock mass-support/initial support system. Sensitivity analyses, as required by CHAPTER 11, Protection of Existing Infrastructure, section 11.2 must be used to define supplemental support measures or toolbox items to be used in conjunction with the initial support.

13.5.3 Final Lining

The final lining must provide a smooth surface that conforms to the operational, structural, and fire-life safety criteria in CHAPTER 2, Owner’s Requirements; CHAPTER 12, Structures; and CHAPTER 15, Fire-Life Safety, respectively.

The final lining must be constructed from cast-in-place concrete or shotcrete. Final lining shotcrete will be subject to the same durability, design, and construction requirements as cast-in-place concrete. Final linings must be bar steel-reinforced or a combination of bar steel-reinforced and fiber-reinforced. Final linings using solely fiber-reinforced concrete are not permitted. Do not use fiber-reinforcement as primary reinforcement for tension-controlled structural members.

Final lining design must consider space and mounting requirements for equipment, utilities, alcoves, and emergency access and egress provisions.

Final linings must withstand the loads and combinations of loads in Chapter 12, section 0, subsection Load Factors and Combinations, using design codes and minimum materials requirements provided in Chapter 12, section 12.1, Materials. In addition to the requirements of Chapter 12, section 12.3, Temporary Excavation Support, final linings must consider a condition whereby the ground load is taken by the initial support, but the groundwater load is acting upon the final lining.

The final lining must not be installed until movement of the initial support has ceased, as defined by the designer.

13.5.4 Load Sharing

Load sharing between the initial support and the final lining is not permitted.

13.6 Bored Tunnel Lining Design

Bored tunnel linings may be used as initial support or as the final lining for bored tunnels. Bored tunnel linings comprise a segmental, gasketed, precast concrete tunnel lining connected across segment joints using a combination of bolts and dowels.
Bored tunnel linings must provide a durable structural support for water, soil, and other loads either until the tunnel final lining is constructed or to allow safe operation of the transit system for the service life indicated for final linings.

Precast concrete tunnel lining analysis and design must conform to the requirements of subsections 12.1 through 12.10. Load conditions for temporary precast concrete tunnel linings must conform to the requirements for initial support for mined tunnels; see subsection 13.5.1.

13.6.1 General Requirements

Precast concrete tunnel linings must be constructed of bar steel-reinforced concrete or a combination of bar steel and steel fiber-reinforced concrete. Precast concrete tunnel linings using only steel fiber-reinforced concrete must conform to ACI 544.7R and will only be accepted by the TJPA with demonstration of satisfactory seismic performance. Precast concrete tunnel linings used as initial support may be constructed using bar steel-reinforced concrete, steel fiber-reinforced concrete, structural synthetic fiber, or a combination of these.

Precast concrete tunnel linings must be designed to resist the effects resulting from the loads and load combinations specified in subsection 0.

Determine the configuration of the lining rings, individual segments and details of joints and connections to suit ground and groundwater conditions, handling loads, erection and TBM thrust loadings, methods and sequences of construction, tail void grouting pressures, and all functions in the completed tunnel. The design must address the following:

♦ Ring configuration, including tapered rings to fit the alignment vertical and horizontal curvature, to correct line and grade during construction and attain the required degree of water tightness of the tunnel. Cruciform joints are not permitted.

♦ Do not use spacers between segments or rings for negotiating curves. Joint packing may be used for stress redistribution or plane correction.

♦ Annular space between the ground and the lining must be filled with cementitious grout through the tail shield of the TBM.

♦ Connection details and other components, including circle (circumferential) joint connectors, cross (radial) joint connectors, demolding, handling, stacking, transportation and installation, holes, niches, recesses and fixtures for other system components, allowances for tolerances in segment production and in building the rings, and water tightness of gaskets.

♦ Drilling locators (such as small indentations) or other means for the attachment of the temporary and permanent tunnel services must be provided.

♦ Segmental concrete linings do not require contraction joints.

Special rings may be used at bored tunnel opening locations and may incorporate removable panels or other connection details within the ring to facilitate the controlled removal of segments to form openings. Special lining segments must accommodate the resulting load transfer and stresses from the removal of multiple segments while maintaining stability and watertightness.
13.6.2 Lining Stiffness

The effective moment of inertia of the tunnel lining must be used in the analysis of lining stiffness. This may be calculated using Equation 13.1 (Muir-Wood 1975), which must be modified to account for tunnel diameter and increased number of lining segments:

Equation 13.1. Effective Moment of Inertia

\[ I_e = I_i + I_g (4/n)^2 \]

Where:

- \( I_e \) is effective moment of inertia, in inches\(^4\)
- \( I_i \) = movement of inertia of the joint (in\(^4\))
- \( I_g \) = gross moment of inertia of the lining section (in\(^4\))
- \( n \) = number of joints in the lining ring

13.6.3 Segment Joint Design

Joints must resist resultant effects from the loads and load combinations specified. The design of segment joints for bearing and bursting effects must be based on the actual contact surface area available, considering the contact area lost to chamfers, packing, and gaskets used to seal the joints.

Joint design must conform to ACI 533.5R and PAS 8810.

Connecting devices across circumferential and radial joints between segmental lining rings and between segments within a ring must not provide structural moment capacity or flexural continuity. They must accommodate rotational flexibility of the segment joints while maintaining gasket closure. The pull-out capacity of connecting devices must be checked for erection and permanent loading conditions.

13.6.4 Construction Deviations

Precast concrete tunnel linings must be designed for the load effects and stresses resulting from deviations, load eccentricity, and offsets during construction. Load effects and overstresses must be calculated based on proposed construction tolerances.

13.6.5 Analysis

Finite element or finite difference analyses must be used to design the final lining. These analyses must be checked against an alternative simplified analysis method to verify that the results of the finite element analyses are within the expected range. Any significant differences between the finite element analyses and corresponding simplified analyses must be submitted to the TJPA for acceptance.

Specific analysis must be performed where there are large variations in the ground modulus over short distances.

13.7 Shaft Design

Shafts for ventilation or emergency egress constructed using SEM must be designed using the applicable criteria specified in this chapter. Lateral earth pressures, groundwater pressures, and surcharges used
to estimate ground loads must be based on recommendations provided by the Geotechnical Engineer of
Record.

Shaft excavation support systems must be compatible with shaft excavation methods, and their design
must consider the effects of breaking out into an adit or crossover cavern from the shaft excavation.

13.8 Serviceability Requirements

The design must conform to durability requirements provided in subsection 13.8.1, Durability, to help ensure
that the mined tunnel structures achieve the desired service life. The requirements in this section and
sections 13.9 and 13.10 must also be met.

13.8.1 Durability

Assess the durability of reinforced concrete structures and their associated metal components, if used, with
regard to the following: materials, additives, concrete strength, fabrication and curing techniques, cover to
reinforcement, climate parameters, concrete diffusion coefficient, concrete permeability, surface chloride
concentration (loading rates) level, and threshold value to initiate steel corrosion, which must demonstrate
how the proposed design intends to fulfill the durability and service life requirements. The analysis must
include structural components including gaskets, bolts, dowels, and other associated inserts used in
precast concrete tunnel lining design.

Final lining design must account for the potential effects of material deterioration, corrosion, corrosive
characteristics of the soils and groundwater, leakage, stray currents, natural and man-made extreme events,
and other potentially deleterious environmental factors on each of the material components composing the
structure, and for load effects resulting from the construction process. The service life must be presented in
a Durability Report, which must consider all final lining elements. The Durability Report must contain a service
life prediction, in accordance with ACI 365.1, and probabilistic durability analysis, in accordance with fib

13.8.2 Crack Control

Analyses must demonstrate that final lining reinforcement is sufficient to ensure against excessive cracking
by limiting crack widths to less than the following:

♦ Mined tunnels
  Conform to the recommendations in section 13.5

♦ Bored tunnel segmental lining
  Design for crack control by distribution of reinforcement must conform to AASHTO LRFD Road
  Tunnel, with an exposure factor corresponding to a maximum crack width of 0.004 inches.

13.8.3 Minimum Reinforcement

The minimum area of temperature and shrinkage reinforcement for tunnels and underground structures
must be calculated in accordance with AASHTO LFRD Road Tunnel.
Reinforcing bar spacing must not exceed the lesser of 12 inches or a distance equal to 1.5 times the lining thickness. Reinforcement must be continuous and evenly distributed and must be placed in two curtains, one at each surface.

13.8.4 Structure Joints

Interface Joints

Interface joints must be provided at the interface between different structure types, such as tunnel to cut-and-cover structure, tunnel to adit, or adit to shaft.

Joints must be designed and constructed so that the joints are fully watertight over the range of predicted movements in all directions. Design details must accommodate differential settlements, thermal expansion and contraction, fire resistance, and seismic compatibility. See CHAPTER 10, Seismic Design, for additional requirements.

Interface joints must be designed to accommodate all relative movements in the longitudinal, transverse, and vertical directions. Relative joint movements must be determined by numerical modeling or other suitable analytical methods with appropriate consideration of the effects of soil-structure interaction. The Engineer of Record must consider other loads, such as settlement, spatial variation of the ground motion, and fault displacement that may influence joint movements. A minimum factor of safety of 2.0 must be applied to the maximum calculated displacement demand to determine the necessary joint movement capacity.

Each interface joint must include a re-injectable grouting system.

Construction Joints

Construction joints must be designed to transmit all the forces that may occur under any design condition.

Transverse joints in interior walls, invert slabs, and emergency egress corridors of the tunnel structure must be detailed as construction joints.

Reinforcement must be continuous through the construction joint.

Each construction joint must contain an intentionally roughened surface to a 0.25-inch amplitude. Construction joints in the final lining must be watertight.

Waterstops must be provided in all external construction joints.

13.9 Watertightness and Leakage Mitigation

Groundwater inflows into mined tunnels during the construction phase must be minimized through the use of relatively impervious shotcrete linings.

Estimate the leakage using analytical methods that take into consideration the effects of the lining, geologic conditions, groundwater levels, and hydraulic conductivity of the deposits, as determined by the geotechnical investigations.
The effects of tunnel construction on the groundwater regime must be analyzed for impacts to adjacent buildings and facilities. Similar methods must be used to estimate groundwater flows into permanent drainage systems installed in tunnels.

Completed tunnels must be designed to limit water ingress. Groundwater infiltration into completed mined tunnels must be controlled to within limits defined herein by a waterproofing system applied between the initial support and the final lining. The final lining must be designed to withstand the pressures associated with design groundwater levels, with no contribution from the initial support.

Groundwater infiltration into completed bored tunnels must be controlled to within limits defined herein by the use of gaskets mounted to the perimeter of tunnel lining segments in conformance with the requirement in section 13.6.

Visible leakage is not permitted above the axis or springline of the completed tunnel. Any water ingress must not cause the piping of soil or rock particles to enter the tunnel.

The design must include provisions to facilitate repair or restoration to achieve a dry tunnel in the event that leakage in excess of the allowable values occurs after construction.

No materials used in preventing or stemming water ingress must compromise the fire-life safety or the durability of the structures in which they are used. If passive fire protection or architectural finishes are required inside the tunnel, seepage drainage must be designed for and provided behind such systems.

13.9.1 Mined Tunnels

Allowable infiltration rates for mined tunnels must conform to those defined for cut-and-cover structures. See CHAPTER 12, section 12.2, for allowable infiltration rates for mined tunnels.

13.9.2 Bored Tunnels

Precast concrete tunnel linings must be designed to limit infiltration by the density of the concrete and the use of gaskets. Allowable daily infiltration rates must conform to the values in Table 13.1. All infiltration values must be measured at the source of the leak.

Table 13-1: Allowable Daily Infiltration Rates for Precast Concrete Tunnel Linings

<table>
<thead>
<tr>
<th>Tightness Class</th>
<th>Dampness Characteristics</th>
<th>Dampness Definition</th>
<th>Allowable Daily Infiltration [gal/sf]</th>
<th>As applied to Bored Tunnels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Absolutely dry</td>
<td>No damp areas visible on the tunnel lining</td>
<td>0.00025</td>
<td>Zones in bored tunnel used to house electrical, systems and communications equipment.</td>
</tr>
<tr>
<td>2</td>
<td>Substantially dry</td>
<td>Occasional damp patches which do not discolor blotting paper, detectable on the tunnel lining</td>
<td>0.0012</td>
<td>Bored tunnel within limits of a station or track crossover.</td>
</tr>
<tr>
<td>3</td>
<td>Capillary dampness</td>
<td>Occasional damp patches on the tunnel lining, but no movement or water apparent to the eye or drops of water.</td>
<td>0.0025</td>
<td>All guideways or storage tracks within bored tunnel.</td>
</tr>
</tbody>
</table>
13.9.3  Drainage

A drainage system that will collect and remove water infiltration resulting from a waterproofing failure, as well as water discharged for cleaning or firefighting purposes, must be provided in all tunnels.

Drainage requirements for tunnels must conform to the criteria in CHAPTER 16, Mechanical Systems.

13.10 California Occupational Safety and Health Administration (Cal/OSHA) and Safety Requirements

Tunnels must be constructed to conform to the requirements of Cal/OSHA, as identified in the Tunnel Safety Orders, and on the Cal/OSHA Underground Classification that must be issued prior to construction, as well as any amendments that may be made by Cal/OSHA during the design and construction process.

The excavation sequence and initial support designs must avoid the need for workers to be under unsupported ground or freshly sprayed shotcrete.
CHAPTER 14 ARCHITECTURE AND VERTICAL CONVEYANCE

SCOPE

This chapter establishes the requirements for architectural and spatial design and vertical conveyances for the Downtown Rail Extension (DTX) project. These architectural and spatial design criteria and guidelines supplement the Caltrain Design Criteria, Chapter 3 and the California High-Speed Rail Authority (CHSRA) Design Criteria Manual, for design of the following facilities:
- Fourth and Townsend Street Station
- Transit Center train box fit-out of the lower concourse and platform levels
- Ventilation and egress structures
- Ancillary structures. The criteria and requirements for ancillary structures, including worker facilities and substation enclosures, must be agreed with Caltrain and CHSRA.

The criteria for vertical circulation, including stairs, ramps, escalators, and elevators, apply to the Fourth and Townsend Street Station, Transit Center train box fit-out, ventilation and egress structures, and ancillary structures.

Station infrastructure requirements must be coordinated with the design of the existing Caltrain surface station at 4th and King streets to avoid unnecessary duplication and redundancy.

These criteria do not apply to the existing Caltrain station at 4th and King streets or the 4th and King Railyards, which are the responsibility of Caltrain.

CODES, STANDARDS AND GUIDELINES

Architectural design and the design of vertical circulation must conform to all applicable portions of the general laws and regulations of the State of California and the City and County of San Francisco (City) and the latest edition of the following governing standards, codes, and guidelines:
- American Public Transportation Association (APTA) guidelines:
- American Society of Mechanical Engineers (ASME) A17: Safety Code for Elevators and Escalators
- Americans with Disabilities Act (ADA) Standards for Accessible Design
- California Building Code (CBC)
- Caltrain Engineering Standards
- CHSRA Design Criteria Manual
- CHSRA environmental and engineering technical memoranda
14.1 Station Planning Considerations and Features

The Fourth and Townsend Street Station and Transit Center train box fit-out will be designed and configured for the use of Caltrain and CHSRA. Some characteristics and planning, as described in this section, will be common to both stations.

The ability of passengers to safely and efficiently navigate between station entrances and platforms requires a simple and coherent design. To that effect, the station design must:

♦ Minimize the number of decisions passengers need to make
♦ Promote clear and logical circulation
♦ Provide consistent and clear directional signage
♦ Minimize turns to avoid passengers' becoming disoriented and conflicting movements. Where turns are unavoidable, adopt right-hand circulation to minimize conflicting passenger movements

14.1.1 Station Capacity

The critical elements of passenger circulation systems in stations are entrances and exits, passageways, vertical circulation, and platforms. These elements must be sized to accommodate the projected volume of passengers under peak period operating conditions and emergency conditions at a required level-of-service. Level of service is generally defined by the Transportation Research Board's Transit Capacity and Quality of Service Manual, 2nd Edition. Requirements for high-speed rail waiting areas are as defined by the International Air Transport Association (IATA) Airport Development Reference Manual, 9th Edition.
Table 14.1 shows the desired level of service for various station components.

Table 14-1: Desired Level of Service (LOS)

<table>
<thead>
<tr>
<th>Station Component</th>
<th>Operating Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td>Circulation Areas</td>
<td></td>
</tr>
<tr>
<td>Open concourses</td>
<td>Circulation LOS B</td>
</tr>
<tr>
<td>Corridors</td>
<td>Circulation LOS C</td>
</tr>
<tr>
<td>Waiting/queuing Areas</td>
<td></td>
</tr>
<tr>
<td>Commuter waiting areas on mezzanine level</td>
<td>Queuing LOS C</td>
</tr>
<tr>
<td>Rail platforms</td>
<td>Queuing LOS C</td>
</tr>
<tr>
<td>High-speed rail waiting area</td>
<td>IATA Holdroom LOS C</td>
</tr>
<tr>
<td>Queuing at fare gates and escalators</td>
<td>Maximum queues must not extend to upstream escalators</td>
</tr>
<tr>
<td>Platform vertical circulation (non-evacuation conditions)</td>
<td>Clear platform or waiting area queue in 4 minutes</td>
</tr>
<tr>
<td>Platform evacuation</td>
<td>N/A</td>
</tr>
</tbody>
</table>

The following level-of-service performance standards will be maintained for public stairways for normal use:

**Stairs.** LOS C: 10 to 15 square feet per person, corresponding to an average flow volume of 7 to 10 persons per foot of width per minute.

**Queuing areas.** LOS C: 7 to 10 square feet per person corresponding to an average spacing between persons of 3 feet to 3 feet 6 inches.

Station emergency egress requirements must conform to the requirements of the CBC and NFPA 130.

Special event occupancy loads will be accommodated through operational procedures—for example, more frequent train headways or station access controls at street level—and will not be a governing factor in the station design.

### 14.1.2 Accessibility

Stations must be fully accessible in conformance with CBC, ADAAG, and Occupational Safety and Health Administration (OSHA) requirements regarding access and emergency egress. A barrier-free path of travel must be provided for all passengers, including persons with disabilities, including mobility, hearing, and visual impairments. Stations must conform to the following accessibility standards:

- Each station platform must have at least one accessible entrance from an accessible route that connects directly to other transportation modes.
- At least two elevators must connect the street level entrance to the mezzanine level and the mezzanine level to the platform level.
14.1.3 Station Components

Subsections 0, Station Components/Station Entrances, through 0, Station Components/Platforms, present the requirements for station components in the sequence of the customer's path through the station, from entering the station to boarding the train. See also subsection 14.6, Vertical Circulation.

Station Entrances

The number of station entrances must be based on an analysis of customer access and egress requirements and comply with CBC and NFPA 130.

Station entrances must meet the following requirements:

♦ Convenient access. The location of station entrances must provide convenient access in public plazas and positioned beyond the public way to preserve sidewalk space for pedestrians. Entrances must provide access to crosswalks and adjacent transportation facilities. Where entrances extend into the public way, a minimum sidewalk width of 10 feet must be maintained.

♦ Clear identification. Station entrances must be clearly visible, well lit, and recognizable as a part of the blended Caltrain and CHSRA system.

♦ Safe environment. Station entrances must be well lit and include lockable gates. See CHAPTER 3, System Safety and Security, for more information on safety and security.

♦ Compatibility with surroundings. Station entrances must be integrated with the existing neighborhood aesthetic as well as provide a connecting point for other nearby transit connections. See subsection 14.4.5, Wayfinding, for more information about signage and wayfinding.

♦ Protection from the weather. Station entrances must have canopies to protect stair and escalator surfaces and provide shelter to passengers.

In addition, station entrances must be designed to accommodate a 100-year storm event and sea level rise for the duration of the project's life cycle. See CHAPTER 4, Environmental Requirements, for more information.

Concourse Level and Lower Concourse

The station entrances will lead to the concourse level at the Fourth and Townsend Street Station and the lower concourse at the Transit Center station. These areas will accommodate passenger amenities such as ticketing machines, maps, and schedule information and house the following infrastructure:

♦ Station agent booth

♦ The station agent booth
  The point of control for day-to-day station operations, including customer service, regulation of ticket vending, elevators, escalators, and passenger information.

♦ Ticket vending cluster near the agent booth
Ticket vending infrastructure
Include ticket and information windows and ticket vending machines for both Caltrain and CHSRA, queueing space, change machines, Clipper (or other regional system) card-charging stations, and automated teller machines. The number and location of machines depends on the operator requirements, expected ridership, and vertical circulation configuration.

Information kiosks
Public restrooms
Passenger benches
A wellness room
Drinking fountains/water bottle filling stations
Fare barriers and queuing space for CHSRA
The number of barriers will be based on maximum platform capacity, with passengers boarding and alighting simultaneously on both faces of each platform.
Caltrain card readers and card interface devices (CIDs)
City and system maps and departure and service information conforming to MTC Regional Transit Wayfinding Guidelines and Standards
Communications systems, including public address, public and passenger assistance telephones, and audiovisual systems that conform to ADAAG, as defined in Chapter 19, Communications.

The design of the concourse and lower concourse areas must
be sized to allow passengers direct and unencumbered access to the station platforms based upon projected passenger flows.
minimize cross flows and conflicting movements between arriving and departing passengers.
must have 10 feet of minimum clearance between the floor and the lowest point in the concourse ceiling. The preferred clearance is 12 feet wherever possible without major modification to existing building structure or equipment.
must maintain a minimum clearance of 8 feet 6 inches under signs, lighting fixtures, closed-circuit television (CCTV) cameras, and other elements wherever possible without major modification to existing building structure or equipment.

The design of the station agent booth must
be located to facilitate supervision of the station entrances, ticket vending cluster, public restrooms, and stairs, escalators, and elevators to the platforms. The booth must be approximately 100 square feet in plan area.
have a fully accessible interior.
have a reservoir space at least 100 square feet for customer queuing to avoid affecting normal passenger circulation. The customer service window must be fully accessible.
have monitors and alarms for station communications systems.

Public restrooms will be gender neutral and fully accessible. Public restrooms must not have entrance doors; a vestibule or other means must be used to block direct view into the restrooms. The following fixtures must be provided, and the number of each fixture type must be based on the anticipated ridership at each station.
- Accessible toilets with stall, door, and privacy latches
- Standard toilets with stall, door, and privacy latches
- Urinals with stall
- Sinks (lavatories) with mirrors
- Infant changing table

**Platforms**

Platform design must facilitate passenger circulation along platforms, queuing at platform edges and bench areas, train boarding and alighting, and queuing at or exiting vertical circulation.

All station platforms must be configured to allow level boarding, as defined in the CFR 49, Part 37, Appendix A, section 10.3.1(9) as involving a horizontal gap between the edge of the vehicle floor and the edge of the platform of no more than 3 inches and a vertical gap of no more than 0.625 inches.

In accordance with 49 CFR Part 37, where meeting gap requirements is infeasible, the designer must recommend the use of mini-high platforms, car-borne or platform-mounted lifts, ramps or bridge plates, or similar manually deployed devices that meet the applicable requirements of 36 CFR, Part 1192, or 49 CFR Part 38. Recommended devices must be accepted by the TJPA and the operators, Caltrain and CHSRA.

Platform-level features for publicly accessible areas must include:
- Passenger benches
- City and system maps and schedule/service information
- Communications systems including public address system, public and passenger assistance telephones, blue light phones for emergency communications, and audiovisual systems, in conformance with ADAAG, as defined in Chapter 19, Communications
- Advertising displays
- Platform end gates
- Fire department facilities, including standpipes, hose cabinets, and extinguishers
- Under-platform access, where feasible, understanding Caltrain platforms are 8” above top of rail
- Emergency egress

Platform design must meet the following requirements:
- All elements of the platform area will support safe circulation and access to and from trains.
- Design must facilitate the rapid clearing of platforms of all passengers.
- Vertical circulation elements must be sited to promote balanced boarding and alighting from trains.
- Visual obstructions must be minimized. Alcoves, or hidden areas, must be avoided to promote station safety and security.
- The platform area must not contain any support or non-transit functions that may obstruct or impede the circulation of patrons.
♦ The path of emergency egress along the platform must be clearly identified.
♦ No pedestrian track crossings at the platform level will be permitted.
♦ Vertical clearances between the floor and ceiling are not less than 12 feet in the general platform areas, unless precluded by existing building structure. If 12 feet vertical clearance cannot be achieved, any variance must be approved by the Transbay Joint Powers Authority (TJPA).
♦ In limited areas, such as under partial mezzanines and at the platform ends next to the emergency stair and service area, vertical clearances may be reduced to 10 feet.
♦ A clearance of no less than 8 feet 6 inches must be maintained below elements such as signs, lighting fixtures, and CCTV cameras.

14.2 Fourth and Townsend Street Station

Fourth and Townsend Street Station infrastructure and requirements must be coordinated with Caltrain and CHSRA. The design and operation must be integrated with Caltrain requirements for the existing surface station at 4th and King streets to the maximum extent possible to avoid unnecessary redundancy and operating and maintenance expenditures.

14.2.1 Public Areas

Public areas of the station comprise the street-level station entrances, concourse, and platform areas. subsections 14.2.1 Public Areas/Street Level, through subsection 14.2.1 Public Areas/Platforms, discuss the programmatic, infrastructure, and spatial requirements for each of these areas.

Street Level

Station design at street level must incorporate features that promote ease of intermodal transfer between Caltrain and CHSRA and the following:
♦ San Francisco Municipal Transportation Agency (SFMTA) bus lines
♦ San Francisco Municipal Railway (Muni) Central Subway
♦ Caltrain surface station at 4th and King streets

Dedicated spaces for taxis, shuttle vans, paratransit service, and curbside vehicle drop-off must be coordinated with SFMTA and the existing Caltrain surface station at 4th and King streets.

Concourse Level

In addition to the requirements in subsection Station ComponentsConcourse Level and Lower Concourse, the concourse will house a lost-and-found and a first-aid station.

Platforms

Caltrain. Minimum platform dimensions must conform to CHAPTER 3 SYSTEM SAFETY AND SECURITY and the Caltrain Design Criteria. However, because passengers move in multiple directions on platforms, due
consideration must be given to platform width. Base the final platform sizing on level-of-service and emergency exiting requirements and the following geometric requirements:

- Platform width must accommodate the design parameters (headways, ridership, and level-of-service) defined in this chapter and in CHAPTER 2 OWNER’S REQUIREMENTS. The minimum outboard or side platform width is 18 feet. Center platform width is a minimum of 28 feet with a preferred width of 32 feet. A design variance request must be submitted to Caltrain for approval for any nonstandard design.

- Total platform length must be a minimum of 875 feet.

- All platform boarding edges must have detectable tactile warning strips measuring 24 inches in width and running the full length of the platform. A darker “pre-warning strip” must be provided in conformance with the ADAAG.

- Horizontal clearance must be a minimum clearance from nearest track center is 25 feet for permanent structures and 16 feet for minor structures at stations (e.g., poles, posts, canopies, benches, wheelchair lifts, elevators, and escalators).

- Platform placement must be 21.7 inches from the top of rail to the top of the finished platform. The station platform edge is 5 feet 8 inches from the centerline of the nearest track.

See subsection 14.1.3, Concourse Level and Lower Concourse, for vertical clearance requirements.

**CHSRA.** Platform dimensions must conform to CHSRA Design Criteria. However, because passengers move in multiple directions on platforms, due consideration must be given to the platform width. Base the final platform sizing on level-of-service and emergency exiting requirements and the following geometric requirements:

- Platform width must accommodate the design parameters (headways, ridership, and level-of-service) defined in Chapter 2, Owner’s Requirements. The minimum outboard or side platform width is 17 feet.

- Total platform length must be a minimum of 800 feet.

- All platform boarding edges must have detectable tactile warning strips measuring 24 inches in width and running the full length of the platform. A darker “pre-warning strip” must be provided in conformance with the ADAAG.

- Base the minimum clearance between fixed platform elements, such as escalators, stairs, guardrails, and partitions around openings, and the platform edge on pedestrian circulation requirements.

- Platform placement must be 51 inches from the top of rail to the top of the finished platform surface measured at the outer edge of the platform.

- Clear refuge areas must be provided under the platform edge at the track level. Refuge areas must be a minimum of 30 inches high and 30 inches deep along the entire length of the platform and have exits at the platform ends. If platform edge doors are provided, refuge areas are not required.

See subsection 14.1.3, Concourse Level and Lower Concourse, for vertical clearance requirements.

### 14.2.2 Owner and Operator Areas

The concourse and platform levels must have areas with secure and restricted access for the sole and specific use of TJPA, Caltrain, and CHSRA personnel. Exact programmatic space requirements to
accommodate the "blended" system for TJPA and the operators will be determined as the design progresses. The station operator is Caltrain.

**Concourse Level**

Owner and operator areas on the concourse level must include receptacles for recycling, refuse, organic waste, and hazardous waste and refuse storage rooms. Bus operator facilities may also need to be provided, but this decision is pending with SFMTA.

**Caltrain Staff Rooms.** Rooms for the use of Caltrain staff must include a station administration office, facility maintenance office, a janitor’s closet, and storage areas for station supplies and operations and maintenance equipment.

**Fire Command Post.** The design must include provisions for a fire command post. See CHAPTER 15, Fire-Life Safety.

**Mechanical Spaces.** Provisions must be made in or next to the station to accommodate the following:

- Tunnel fan rooms and ventilation shafts
- Station electrical power supply
- Station communications and signaling equipment
- Station environmental control
- Pumps for stormwater and sanitary sewer
- Elevator/escalator machinery
- Valve rooms for station deluge and sprinkler system
- Alternative automatic fire extinguishing system equipment

The requirements, sizing, and location of various mechanical spaces and equipment must be coordinated with the appropriate design disciplines and conform to the requirements in CHAPTER 15, FIRE-LIFE SAFETY; CHAPTER 16, MECHANICAL SYSTEMS; and CHAPTER 17, Electrical Systems, as appropriate.

The design of mechanical spaces and other operator areas must consider requirements for the maintenance and replacement of equipment such that (a) routine maintenance can be performed without disrupting normal station operations and (b) equipment that is large and difficult to move can be easily replaced.

**Platform Level**

The platform level must accommodate a security booth.

The platform level must also house the following Caltrain spaces:

- Facilities maintenance cleaning closet (one per platform) with water and power sources for floor scrubber machines
- Signals maintenance facility
- Communication battery room
- Third-party communications room
14.3 Transit Center

The Transit Center train box fit-out must be configured for the use of Caltrain and CHSRA. This section discusses the spaces that must be fit-out for the DTX.

14.3.1 Public Areas

The main public areas of the station are the station entrance in the grand hall, the lower concourse, and the platform level. Programmatic, infrastructure, and spatial requirements for each of these areas is provided.

Lower Concourse Level

See subsection 14.3.2, Lower Concourse Level.

Platform Level

**Caltrain.** Minimum platform dimensions will be the more stringent of and in accordance with the requirements in Caltrain Design Criteria, Chapter 3. However, because passengers move in multiple directions on platforms, due consideration must be given to platform width. Base the final platform sizing level-of-service and emergency exiting requirements and the following geometric requirements:

- Platform width must accommodate the design parameters (headways, ridership, and level-of-service) defined in this chapter and in CHAPTER 2, OWNER’S REQUIREMENTS. The minimum center platform width is 28 feet.
- Total platform length must be a minimum of 875 feet.
- All platform boarding edges must have detectable tactile warning strips measuring 24 inches in width and running the full length of the platform. A darker “pre-warning strip” must be provided in conformance with the ADAAG.
- Horizontal clearance from nearest track center must be a minimum of 25 feet for permanent structures and 17 feet for minor structures at stations (e.g., poles, posts, canopies, benches, wheelchair lifts, elevators, and escalators).
- Platforms must be 21.7 inches from the top of rail to the top of the finished platform. The station platform edge is 5 feet 8 inches from the centerline of the nearest track.

See subsection 14.2.1, Platforms, for vertical clearance requirements.

**CHSRA.** Because passengers move in multiple directions on platforms, due consideration must be given to the platforms’ width. Minimum platform dimensions will be the more stringent of, and in accordance with the CHSRA Design Criteria. Base the final platform sizing on level-of-service and emergency exiting requirements and the following geometric requirements:
Platform width must accommodate the design parameters (headways, ridership, and level-of-service) defined in this chapter and in CHAPTER 2 OWNER’S REQUIREMENTS. Total platform length is a minimum of 800 feet.

All platform boarding edges must have detectable tactile warning strips measuring 24 inches in width and running the full length of the platform. A darker “pre-warning strip” will be provided in accordance with the ADAAG.

Minimum horizontal clearances between fixed platform elements such as escalators, stairs, guardrails, or partitions around openings and the platform edge are based on pedestrian circulation requirements.

Platforms must be 51 inches from the top of rail to the top of the finished platform surface measured at the outer edge of the platform.

A clear refuge space must be provided under the platform edge at the track level. Refuge areas must be a minimum of 30 inches high and 30 inches deep along the entire length of the platform and have exits at the platform ends. If platform gates or doors are provided, refuge areas are not required.

See subsection 14.1.3 for vertical clearance requirements.

14.3.2 Owner and Operator Areas

The lower concourse and platform levels must have areas with secure and restricted access for the sole and specific use of TJPA, Caltrain, and CHSRA personnel. Exact programmatic space requirements to accommodate the “blended” system for TJPA and the operators will be determined as the design progresses. The assumed station operator is TJPA.

Lower Concourse Level

TJPA-operated Facilities. The following facilities will be operated by the TJPA:

- Security office – required for TJPA
- Police office (for transit police) – required for SFPD
- Alternate security operations center, if feasible, which would include a break room and conference room for security and SFPD use
- Security-SFPD break room
- Security-SFPD conference room
- Men security lockers/restroom
- Women security lockers/restroom
- Security storage room
- SFPD men’s lockers/shower/restroom
- SFPD women’s lockers/shower/restroom
- TJPA security lockers and restrooms with storage room
- Visitor/conference rooms
Janitor’s closet
Refuse storage rooms
Staff wellness room

CHSRA-specific Facilities. The following are CHSRA-specific facilities:

- Fare barriers
- Ticket information windows
- Ticket vending machines
- Business lounge, including food storage/prep and unisex restrooms
- Janitor’s closets
- Facilities to support train operations, including:
  - Administrative support office
  - Crew lounge/ready room
  - Shift supervisor office
  - Car inspector office
  - Gang foreman office
  - Cleaning machine storage
  - Maintenance equipment storage lockers
  - Train grooming team ready room
  - Commissary food storage
  - Commissary office
  - Staff lockers/showers/restrooms

Caltrain-specific facilities. The following are Caltrain-specific facilities:

- Ticket vending machines
- Departure board displays and infrastructure
- Information kiosks
- CID
- MTC Regional Transit Wayfinding Guidelines and Standards
- Caltrain conference room
- Signals maintenance facility with parking for three ladder rack trucks at street level
- Ready room
- General storage, mainly used for customer service materials
- Car inspector office
- Rail operations supervisor office
- Staff locker rooms, showers, and restrooms
Supply storage

**Shared space.** Vendor space available to business owners.

**Mechanical Spaces.** Provisions must be made in or next to the station for the following:
- Tunnel fan rooms and ventilation shafts
- Station electrical power supply
- Station communications and signaling equipment
- Station environmental control
- Pumps for stormwater and sanitary sewer
- Elevator/escalator machinery
- Valve rooms for station deluge and sprinkler system
- Alternative automatic fire extinguishing system equipment

The requirements, sizing, and location of the various mechanical spaces and equipment must be coordinated with the appropriate design disciplines and conform to the requirements in **CHAPTER 15 FIRE-LIFE SAFETY**, **CHAPTER 16 MECHANICAL SYSTEMS**, and **CHAPTER 17 ELECTRICAL SYSTEMS**, as appropriate.

The design of mechanical spaces and other operator areas must consider requirements for the maintenance and replacement of equipment such that (a) routine maintenance can be performed without disrupting normal station operations, and (b) equipment that is large and difficult to move can be easily replaced.

**Platform Level**

The platform level must house the following:

**TJPA-operated Facilities.** The following are TJPA-operated facilities:
- Facilities maintenance cleaning closet (one per platform), which include water and power sources for the floor scrubbers
- Facilities equipment storage room, including a charging port for service equipment such as small lifts
- Communication battery room
- Third-party communications room
- Electric switch room
- Battery room

**Restrooms and janitor closet CHSRA-specific Facilities.** The following:
- Platform agent booth (one per platform)
- Refuse rooms (three per platform)
- Maintenance equipment storage lockers (three per platform)
- General storage locker (one per platform)
- Cleaners’ room (one per platform)
♦ Cleaning supplies storage room (one per platform)
♦ Station storage room (one per platform)

**Caltrain-specific facilities.** The following:
♦ Refuse rooms (three per platform)
♦ Vehicle maintenance equipment storage room
♦ Platform operations room
♦ Caltrain train control and communications room

The requirements, sizing, and location of the various mechanical spaces and equipment must be coordinated with appropriate design disciplines.

The design of mechanical spaces and other operator areas must consider requirements for the maintenance and replacement of equipment such that (a) routine maintenance can be performed without disrupting normal station operations, and (b) equipment that is large and difficult to move can be easily replaced.

### 14.4 Environment and Shared Design Characteristics

#### 14.4.1 Climate

See CHAPTER 16, Mechanical Systems, for the design parameters for temperature and humidity control within the station public and ancillary spaces.

#### 14.4.2 Lighting

See CHAPTER 17, Electrical Systems, for the design parameters for illumination within the station public and ancillary spaces.

Station design must incorporate and maximize the use of natural lighting to reduce energy consumption.

Where natural lighting is not a feasible option, all station lighting, including those used for public areas, back-of-house areas, or accent lighting, must minimally meet Title 24 and best practice lighting footcandle requirements.

#### 14.4.3 Acoustics

Acoustical calculations to determine the amount, type, and placement of acoustical treatments must conform to FTA Report No. 0123, Transit Noise and Vibration Impact Assessment Manual.

See subsection 14.4.6, Materials and Finishes, for the criteria for materials and finishes for the acoustic treatment of various areas of the station.
14.4.4 Sustainability

No specific sustainability performance goals have been established for the DTX project, but the principles of sustainability, where applicable, will be applied. Sustainable design opportunities in the areas of water savings, materials selection, and the use of recycled materials must be considered. Also, for areas affected by the presence of groundwater, methods to reduce power consumption related to dewatering pumping over the project’s life cycle will be evaluated. The designer must give due consideration to each of the categories of the United States Green Building Council and seek to maximize opportunities for sustainability in the execution of the DTX project.

14.4.5 Wayfinding

Fixed message signage will conform to MTC Regional Transit Wayfinding Guidelines and Standards.

The following wayfinding and information signage designed for customer orientation must conform to regulatory requirements and accessibility guidelines:

♦ Station and operator identification
♦ System identification and customer orientation signage
♦ Ticket vending and use information
♦ Route and destination information for boarding passengers
♦ Station area orientation for arriving passengers including transit connection orientation
♦ Accessible routes to platform or street level, including visual, tactile, or Braille signage in accordance with ADAAG and CBC Title 24
♦ Regulatory signage
♦ Emergency egress routes
♦ Room identification and function signs

14.4.6 Materials and Finishes

Materials and finishes for floors, walls, and ceilings must be safe, resistant to fire and vandalism, durable, maintainable, cost effective, and aesthetically appealing. Materials must meet applicable ASTM International’s testing standards and the following general requirements.

Materials will be hard, dense, non-porous, non-staining, and resistant to acids, alkalis, ultraviolet rays, chemicals, salts, and dirt for color retention and finish, longevity, and low maintenance.

Smooth surfaces are preferred over textured surfaces for ease of cleaning, with the exception of the following:

♦ Metal panels must be designed to reduce the visual impact of scratches.
♦ Flooring must provide adequate slip resistance. However, highly textured concrete must not be used as it is slippery when wet.

The design must specify materials that do not interfere with wireless communications.
Materials and finishes for non-public areas of the station must meet the same performance requirements as those for public areas. As the non-public areas are subject to reduced traffic and wear and tear, the following materials may be used, provided the requirements specified herein for safety, durability, and maintenance are met:
  ♦ Acoustic ceiling tile
  ♦ Exposed fire-rated structure
  ♦ Concrete masonry unit (painted)
  ♦ Vinyl composition tile
  ♦ Cement/vermiculite mix (smooth troweled or spray-applied in non-exposed areas only)

**Fire Resistance and Smoke Generation**

Materials will be certified Class A materials, offering maximum resistance to fire and having minimum burning rate, smoke generation, and toxicity characteristics.

Building construction type and fire separation must conform to the CBC. Public and ancillary occupancies must be separated from non-transit occupancies by two-hour fire-rated construction, as defined in NFPA 220. The fire ratings of doors must conform to NFPA 80.

**Resistance to Vandalism**

Materials used in the design must be difficult to deface, damage, or remove. All surfaces in public areas must be scratch-resistant or patterned to hide scratches and finished in a manner that allows for the easy removal of graffiti through normal maintenance techniques. The design must include provisions and procedures for repairing damage for each finish used in public areas within 9 feet of the floor surface.

Fasteners must be tamper-resistant and concealed wherever possible.

Platform areas must have intrusion protection and closed-circuit video surveillance 24 hours a day, seven days a week to protect electric multiple units and trainsets against vandalism.

**Slip Resistance**

Flooring materials must have slip resistant surfaces. Stairways, landings, platform edges, and areas around equipment must use materials with high non-slip properties.

Flooring materials must be ADA-compliant.

Table 14.2 specifies the coefficient of friction for floor materials.
Freeze Thaw Resistance

Materials must have low water absorption and the ability to resist freezing. Impervious flooring with a water absorption rate of less than 0.5 percent must be provided at station entrances and in areas subject to exterior weather directly or indirectly. Internal flooring not affected by the weather must have an absorption rate of less than 3.0 percent.

Attachment

The design of attachments must prevent the dislodgement of finishes resulting from temperature variation, vibration, wind, seismic activity, or other causes.

Do not use adhesive anchors in sustained tensile-load overhead applications.

Reflectance

Materials must be bright and light-colored to enhance reflectivity and maximize the effectiveness of lighting using a minimum number of fixtures.

Conversely, reflective materials must not interfere with the functioning of CCTV or the readability of wayfinding signage. Material reflectivity must not conflict with other safety-related functions including slip resistance. Do not use mirrored surfaces except for accent items.

Coordinate materials selection with the lighting design to provide the recommended reflectance values for station surfaces shown in Table 14.3

Table 14-3: Reflectance Value for Station Surfaces

<table>
<thead>
<tr>
<th>Surface</th>
<th>Reflectance Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Painted surfaces (ceilings and walls)</td>
<td>55% to 70%</td>
</tr>
<tr>
<td>Unpainted surfaces (ceilings and walls)</td>
<td>40% to 60%</td>
</tr>
<tr>
<td>Floors (dark)</td>
<td>15% to 20%</td>
</tr>
<tr>
<td>Floors (light)</td>
<td>20% to 30%</td>
</tr>
</tbody>
</table>

Reflectance values do not consider the accumulation of dirt.
Abrasion Resistance

Materials used for flooring and wall surfaces that can be touched or rubbed against by passengers and luggage must resist wear and easily conceal dirt and scratches. Finishes must resist the effects of cleaning materials and procedures over their lifetime.

Floor surfaces must resist abrasion and other damage resulting from passenger traffic, cleaning equipment, or other maintenance equipment.

Sound Absorption

Material that absorb sound must be used to promote an environment where patrons can communicate clearly and easily and buildup of excessive noise is suppressed. Placement of sound absorptive materials must be coordinated with the station’s public address system to ensure that audibility requirements are met.

Sound absorptive materials must comply with the following characteristics:

- Lightweight
- Low flammability and smoke emission
- Cleanable and vandal-resistant
- Long-term reliable bond for fixing to flat horizontal and vertical surfaces and curved surfaces
- Stable when exposed to high positive and negative pressures
- Resistant to vibration
- Suitable for a wet environment
- Rot-proof and odorless
- Resistant to mold and rodents

Ease of Maintenance and Replacement

Materials must be easily maintained, repaired, or replaced. Material, fastening, and joint selection must support the removal and replacement of a section of finish without damaging or affecting the finish of adjacent sections.

Avoid using surfaces or details that complicate cleaning or collect dirt.

14.5 Ventilation and Emergency Egress Structures

Spatial planning, materials, and finishes for ventilation and emergency egress structures must conform to the requirements for non-public areas of the Fourth and Townsend Street Station. See subsection 14.2, Fourth and Townsend Street Station.

The building environment must conform to the requirements in CHAPER 15FIRE-LIFE SAFETY, CHAPTER 16, MECHANICAL SYSTEMS, and CHAPTER 17, Electrical Systems.
Above-grade building exteriors may require specific contextual materials that are compatible with adjacent buildings. The street level appearance of ventilation structures must be coordinated with the San Francisco Planning Department.

14.6 Vertical Circulation

14.6.1 Stairs

Public stairs must conform to the requirements of this section. Stairs provided for emergency egress only must comply with the requirements of NFPA 130 and CBC Section 443, Fixed Guideway Transit and Passenger Rail Systems.

Stairs will be the primary mode of vertical circulation where the vertical rise between levels is less than 12 feet. Stairs are recommended as the primary mode of vertical circulation in the downward direction where the vertical rise between levels is less than 20 feet.

Stairs must be well lit, visible, and easily identifiable as a means of access to the levels they connect.

Stairs must include runnels to facilitate drainage, maintenance, and cleaning.

When paired with escalators, stairs must rise at the same angle as the escalator. Stair nosings must be at or below the line of the escalator treads such that the top of stair handrail is below the height of the escalator balustrade.

Width

Stair widths must be based on anticipated levels of service. The minimum stair width is 5 feet, unless precluded by existing building structure. If a stair width of 5 feet cannot be achieved, the designer must submit a variance request for review and acceptance by the TJPA. See Chapter 1, section 1.8, Variances and Changes to Design Criteria.

Queuing and Run-off Space

Sufficient queuing and run-off space must be provided at the top and bottom of all stairs. The minimum queuing and run-off space must be the greater of the stair width or 8 feet. When a stair is paired with an escalator, the queuing and run-off areas must be coincident.

Level of Service

The following level of service (LOS) performance standards will be maintained for public stairways for normal use:

Stairs. LOS C — 10 to 15 square feet per person, corresponding to an average flow volume of 7 to 10 persons per foot of width per minute.

Queuing areas. LOS C — 7 to 10 square feet per person corresponding to an average spacing between persons of 3 feet to 3 feet 6 inches.
Headroom

A minimum clear headroom of 9 feet, measured perpendicular from the line of the tread nosing to the underside of the ceiling, must be maintained, unless precluded by existing building structure. If 9 feet of clear headroom cannot be achieved, the designer must submit a variance request for acceptance by the TJPA. See Chapter 1, section 1.8, Variances and Changes to Design Criteria.

Guardrails and Handrails

Barriers, guardrails, and handrails must conform to the requirements of the CBC and San Francisco Building Code. All finishes must be Grade 316 stainless steel. If glass is used, it must be laminated and tempered.

14.6.2 Ramps

Ramps must conform to the accessibility provisions of the CBC, ADAAG, and the following:

♦ The maximum slope of a ramp must not exceed 1:12 along its entire length.

♦ All ramps with a rise exceeding 6 inches must have handrails conforming to the handrail requirements specified for stairs. See subsection 14.6.1, Guardrails and Handrails.

♦ The level change of ramps within passenger circulation paths must be limited to less than 30 inches.

♦ The minimum width for ramps must be 5 feet to allow free passage of wheelchairs. Ramps located within corridors must extend the full width of the corridor.

♦ Clear landings must be provided at the top and bottom of each ramp and must extend the full width of the ramp by a minimum length of 60 inches.

♦ Floors with a slope of less than 1:20 do not need to conform to the requirements for ramps.

14.6.3 Escalators

Escalators will be the primary mode of vertical circulation where the vertical rise between levels exceeds 12 feet, except where stairs are required, in lieu of escalators, to meet projected passenger loads.

Escalator loading, controls, and other key aspects for operation must conform to the requirements and standards in ASME A17.1.

Space Requirements

Queuing and Run-off Space. A minimum unobstructed queuing and run-off space of 25 feet must be maintained at the top and bottom of each escalator, as measured from the escalator working points. Where escalators are provided in sequence, and there are no pedestrian cross-flows or other obstructions to passenger movement, the minimum requirement may be reduced by 25 percent. The width of the queuing and run-off space must correspond to the modular width of the escalator.

Headroom: A minimum clear headroom of 9 feet, measured perpendicular from the line of the tread nosing to the underside of the ceiling, must be maintained.
Design Features

Escalators must be heavy-duty, commercial grade with the following design features:

**Width.** The nominal width of all escalators must be 48 inches, or 40 inches measured at a point between the skirt panels. The designer is responsible for determining the actual dimensional requirements for escalators from information available from current suppliers.

**Vertical Rise.** Escalators will operate on a 30-degree incline from the horizontal. Vertical rise will be determined from design drawings for the Fourth and Townsend Street Station.

**Seismic Support System.** Escalators must have a combination slip/sliding seismic support system for end and intermediate supports. See CHAPTER 10, Seismic Design.

**Treads.** Design Class A and B escalators must have three contiguous treads level beyond the comb plate at the top and bottom landings. Design Class C escalators must have four contiguous level treads beyond the comb plate at the top and bottom landings.

**Landing Plates.** Landing plates must be level. Adjacent floors will have a texture that contrasts with the landing plate for detection by persons with visual impairments.

**Handrails.** V-groove, synthetic rubber or neoprene covered synthetic fabric, outdoor Type 2.

**Balustrades.** If glass balustrades are used, a protective film must cover the glass surfaces in areas within the reach of passengers.

**Load rating.** 300 pounds per step.

**Power supply.** 480 V, 3 phase, 60 Hz.

**Motor and Controls.** Motors and controls must have the following features:

- Remote escalator control panels that include start and stop, direction selection, and emergency brake reset functions.
- Pressure-activated emergency stop buttons and key actuated directional switches that are mounted at the upper and lower landing newels
- A hinged cover for the emergency stop button that will sound an alarm when opened.
- A control panel installed in the machine room for truss heating and pit lights and receptacles. The control panel must house an appropriately sized circuit breaker, heating contactor, and a key switch on the enclosure door.
- Capability of being stopped locally by a manual stopping device at the escalator.
- Motors that comply with National Electrical Manufacturers Association MG 1, Insulation Class B, and have wye-delta or solid-state starting.
- Motors and controls that can run on partial windings (at reduced power) when not under full load.
- Stopping mechanism that allows the escalator to coast to a stop before applying the brakes will be provided, unless stopping is initiated by a safety device.
- Step drive mechanism equipped with automatic step-chain lubricators.
Metal oil drip pan covering the full width and length of the escalator to collect and hold oil and grease drippings from lubricated components. The pan must be designed to sustain a load of 250 lbf on a 1.0 square-foot area at any location without permanent deflection.

Escalators must be interlocked with the fire alarm system to enable the fire alarm system to remotely stop an escalator from moving in the opposite direction of the evacuation route during an emergency as part of a pre-planned evacuation response.

**Speed.** Speed must not exceed 90 feet per minute (fpm). Units must be provided with an overspeed governor that is activated if the speed of steps exceeds rated speeds by more than 20 percent.

**Safety Features.** Escalators must conform to the following safety requirements:
- Be constructed of noncombustible materials.
- Be equipped with red and green indicator lights at least 2 inches in diameter in both balustrade newels at both the upper and lower landings. A green light indicates entrance end, and a red light indicates exit end. When the escalator is stopped, red lights are illuminated at both ends.
- Have recessed light fixtures with flush mounted lenses in skirt panels to each side of the combplates.
- Have step upthrust devices at upper landings that are activated if a step is displaced against the upthrust track at the upper curve in passenger-carrying line of track system.
- Have comb-step impact devices that are activated if a force is applied in the direction of travel that exceeds the following:
  - A horizontal force of 112 lbf at either side or 225 lbf at the center of the front edge of the combplate
  - A resultant force in upward direction of 150 lbf at the center of the front edge of the combplate

**Maintenance and Replacement.** Escalator design must allow for routine operations and maintenance without disruption to normal station operations. Provisions must be made for replacing escalator components, as required, beyond the design life of the escalator.

**Operational Performance**

**Level of Service.** The following LOS performance standards must be maintained:

Escalators: 70 persons per minute

Queuing areas: LOS C — 7 to 10 square feet per person, corresponding to an average spacing between persons of 3 feet to 3 feet 6 inches

**Hours of Operation.** Hours of operation are 24 hours per day, 7 days per week.

**Operating Environment.** Escalators must be able to operate in temperatures ranging from +25 degrees Fahrenheit (°F) to +120°F (dry bulb) and all conditions of relative humidity while exposed to airborne dust and debris.

Escalators must be in a secured area when the station is closed and be located under cover to protect from the effects of direct sunlight, rain, and snow. Weatherproofing requirements for escalators must be consistent
with exposure conditions. Corrosion resulting from exposure and galvanic action from the use of dissimilar metals must be avoided.

Escalator design must consider the thermal expansion and contraction of complete escalator assemblies and for any movement of the facility caused by trains braking when fully loaded.

**Direction of Travel**

Direction of travel must be either direction, and the unit must be up and down reversible.

**Monitoring of Escalator Operation.** Escalators must be provided with a microprocessor unit that monitors safety devices, motor temperature, and escalator speed and records in a nonvolatile memory the date, time, and device identification if a safety device is activated or escalator malfunctions.

Escalator operation must be capable of being monitored and controlled through the supervisory control and data acquisition system (SCADA).

**Reliability, Availability, Safety**

Escalator reliability requirements are based on the following parameters.

- System operating time: 20 hours per day (7,300 hours per year)
- Preventive maintenance: 4 hours per day
- Maximum requirements:
  - 90 percent of full load capacity for peak periods of 2-hour duration twice each day
  - 50 percent of full load capacity during off-peak periods

Escalator design must conform to APTA Escalator Design Guidelines for 95 percent availability and include safety devices, barriers, and signage in conformance with the ASME Safety Code for Elevators and Escalators.

**14.6.4 Elevators**

Hydraulic elevators must be provided at the Fourth and Townsend Street Station as follows:

- A minimum of two elevators must connect the street level with the concourse level
- A minimum of two elevators must connect the concourse level with the platform level

Elevator loading, controls, and other key aspects for operation must conform to the standards in ASME A17.1.

Higher capacity freight elevators must be provided in ventilation buildings.

Each platform at the Fourth and Townsend Street Station must be serviced by two elevators, or by a single elevator and an alternate means of ADA-compliant access, such that platforms remain fully accessible when one elevator is out of service.
Queuing and Run-off Space

The clear elevator landing depth to any obstruction must be a minimum of the greater of either (a) 1.5 times the depth of the cab by the full width of the elevator or (b) 10 feet by the full width of the elevator.

Elevator landing areas must not impede general passenger circulation or be hidden from view.

Queuing space must be distinct and separate from the space provided for other vertical circulation elements and equipment.

Location

Elevator locations will depend on specific site constraints and safety and security requirements.

Depending on the availability of surface right-of-way, escalators from street level to the concourse level and from the concourse level to the platform level may be in different locations. Each platform at the Transit Center and Fourth and Townsend Street Station must have one dedicated service elevator.

Elevator locations must maximize safety, accessibility, and visibility and maintain pedestrian flow.

Safety. Where feasible

♦ elevators must be located at manned or partially manned entrances.
♦ elevators must be visible to security personnel, station staff, and the public. Shafts and cabs must be transparent for maximum visibility of the cab interior. CCTV surveillance must be provided within the cabs and at all elevator waiting areas.
♦ elevators at street level must not impair the visibility of the drivers of surface vehicles on roads next to the station entrances.

Accessibility. Elevators must be located to

♦ conveniently serve all customers and facilitate access for persons with limited mobility or other disabilities.
♦ serve the broadest possible portion of the station’s service area.
♦ provide direct access to the local pedestrian circulation network, including sidewalks, plazas, building entrances, and crosswalks.
♦ provide convenient access to other modes of public transportation.
♦ be in close proximity to other vertical circulation elements.

Pedestrian Flow. Elevators must not obstruct pedestrian circulation on sidewalks and in the public right of way.

Elevators will be located as close as possible to the direct path of travel between station entry and the platform. However, the elevator location will not obstruct general passenger circulation or visually obscure other vertical circulation elements.
Design Features

Elevators must be heavy-duty commercial-grade as follows:

**Passenger Elevators.** As follows:
- Capacity: 3,500-5,000 lbs, net passenger capacity
- Rated Speed: 125-450 fpm, full load up direction
- Vertical Rise: as required
- Power Supply: 480 V, 3 phase, 60 Hz

**Service Elevators.** As follows:
- Class C2 loading
- Capacity: 10,000 lbs net capacity for interior service elevators
- Capacity: 10,000 lbs net capacity for loading dock service elevator
- Rated Speed: 2000 fpm, full load up direction
- Vertical Rise: As required
- Power Supply: 480 V, 3 phase, 60 Hz

**Size.** As follows:
- Elevator size must comply with ADA and emergency service requirements
- Elevators must be able to accommodate wheelchairs
- Elevators must be able to accommodate least one horizontally positioned stretcher or gurney
- Elevator size must consider local characteristics, including bicycle commuters, customers with baggage, and requirements for station cleaning and maintenance equipment

**Frames.** Cars frames must be of stainless-steel material or galvanized.

**Hoistway Entrances.** Hoistway entrances must include doors, doorjambs, sills, hardware, transom panels, and accessories. Sight guards (of the same finish as the doors) must conceal unfinished material or construction.

**Controls.** Elevator controls must conform to ASME A17.1. Elevator controls must include the following:
- Cabinet-type programmable logic controller-based car controller designed with built-in internal diagnostics, which are readily accessed and interpreted without priority codes. No decaying memory will be permitted.
- Solid-state elevator starter containing current limiting soft start and fault detection, phase reversal, and phase loss detection.
- Phase I emergency recall key switch station at elevator landings for the use of the San Francisco Fire Department (SFFD). In addition, a Phase II key switch will be provided on each elevator cab control panel, providing exclusive control of elevator movements to emergency personnel.
Where elevators are paired, interlocked controls must be provided such that only one elevator responds to a call.

Avoid the use of propriety programs, hardware, or software.

Additional requirements for elevators for firefighter use must conform to the requirements of the CBC and SFFD administrative bulletins.

**Machine Rooms.** Machine rooms must be provisioned with equipment that is appropriate to the elevator type.

**Safety Features.** Elevators must conform to the following safety requirements:

- Elevators must have power-operated doors that operate automatically in response to calls and are governed by safety controls.

- Emergency power during a power failure. The car lighting, car alarm, and the exhaust blower must be supplied with emergency power over the same feeders that supply normal power to the elevator controllers. In addition, the design will include a car-mounted battery unit to operate the alarm bell and lighting.

- Elevator fire recall landing design must include provisions whereby all affected elevators return to the fire recall landing immediately after power is transferred to the building emergency power system.

- **Aesthetics for Exterior Elevators.** The scale, materials, and form of elevators at street level must complement the surrounding urban context and minimize visual impacts on adjacent structures.

**Operational Performance**

**Hours of Operation.** Hours of operation are 24 hours per day, 7 days per week.

**Operating Environment.** Elevators must be able to operate in temperatures ranging from +25°F to +120°F (dry bulb) and all conditions of relative humidity while exposed to sunlight, rain, snow, and airborne dust.

Elevators exposed to rain must continue to operate safely and function without interruption.

Machinery in elevator equipment rooms must be able to operate in underground temperatures ranging from 25°F to 85°F (dry bulb) and all conditions of relative humidity while exposed to airborne dust.

**Noise.** Steady-state noise produced by elevators or associated equipment (excluding entrance door operations) must not exceed 65 dBA in public spaces. Noise produced by the operation of the elevator door must not exceed 65 dBA 3 feet or more from the elevator door, inside or outside of the elevator cab.

**Monitoring and Control of Elevator Operation.** Elevator operation must be capable of being monitored through the SCADA system.

Elevators must have remote control capabilities for both emergency and routine operations. Remote control will originate from the Security Operations Center, using the link between the elevators and the SCADA system.
Reliability, Availability, Safety

Elevator reliability requirements are based on the following parameters.

♦ System operating time: 20 hours per day (7,300 hours per year)
♦ Preventive Maintenance: 4 hours per day
♦ Maximum requirements:
  • 90 percent of full load capacity for peak periods of 2-hour duration twice each day
  • 50 percent of full load capacity during off peak periods

Elevators must meet APTA Elevator Design Guidelines for 97 percent availability.

Elevator safety devices must conform to ASME A17.1, Safety Code for Elevators and Escalators.
CHAPTER 15  FIRE-LIFE SAFETY

SCOPE
This section establishes the requirements for fire-life safety, including the fire alarm system, fire suppression system, firefighters’ air system, blue light stations, and emergency egress. These criteria apply to the Downtown Rail Extension (DTX) mined tunnel, cut-and-cover structures, the Fourth and Townsend Street Station, Transit Center train box fit-out, egress shafts, ventilation buildings, and ancillary structures.

This chapter addresses specific fire-life safety elements only. The communications aspects of the fire-life safety systems—emergency telephone, radio, variable message signs, and public address—are addressed in CHAPTER 19, Communications. CHAPTER 12, STRUCTURES, and CHAPTER 14, ARCHITECTURE AND VERTICAL CONVEYANCE, contain requirements for fire-resistant construction. CHAPTER 17, Electrical Systems, contains electrical requirements, including requirements for emergency power and lighting.

CODES, STANDARDS AND GUIDELINES
The design of fire-life safety elements and systems for the DTX must conform to the latest edition of the following standards, codes, and guidelines unless otherwise specified in these criteria:

♦ American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering
♦ Americans With Disabilities Act (ADA) Standards for Accessible Design
♦ California Building Code (CBC)
♦ Federal Railroad Administration (FRA) Accessibility Standards Applying to Passenger Rail Cars
♦ National Fire Protection Association (NFPA) Standards
  ● NFPA 10, Standard for Portable Fire Extinguishers
  ● NFPA 14, Standard for the Installation of Standpipe and Hose Systems
  ● NFPA 70, National Electrical Code (NEC)
  ● NFPA 72, National Fire Alarm and Signaling Code
  ● NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems
  ● NFPA 750, Standard on Water Mist Fire Protection Systems
♦ Threat and Vulnerability Assessment for the Transbay Program. 2022.
  Prepared by AECOM for the Transbay Joint Powers Authority.
♦ San Francisco Building Code (SFBC), which includes San Francisco Code Amendments (SF Amendments)
♦ San Francisco Fire Department (SFFD) Administrative Bulletins
15.1 Design Fire Size

Design fire sizes are shown in Table 15.1.

Table 15-1: Design Fire Sizes

<table>
<thead>
<tr>
<th>Location</th>
<th>Maximum Fire Size (Mw)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station Concession</td>
<td>5</td>
<td>Fourth and Townsend Street Station only</td>
</tr>
<tr>
<td>Trash/Baggage</td>
<td>1.5</td>
<td>Fourth and Townsend Street Station and tunnels</td>
</tr>
<tr>
<td>Train</td>
<td>20</td>
<td>Fourth and Townsend Street Station and tunnels; fast fire growth rate</td>
</tr>
</tbody>
</table>

In addition to the design fire sizes shown in Table 15-1, tunnel and station design must accommodate the fire sizes indicated in the Program’s Threat and Vulnerability Assessment.

15.2 Emergency Management

Caltrain’s Central Control Facility (CCF) will have the ability to manage all emergency situations in the tunnel, the Fourth and Townsend Street Station, and portions of the Transit Center station (pending execution of the Master Cooperative Agreement with Caltrain and future CONOPS agreements). Additionally, incident command (fire department) must have the ability to override remote control and control locally the following systems for emergency response:

- Emergency ventilation system
- Fire detection and alarm system
- Public address system
- Standpipe system

The CCF will have system monitoring, control and communication capability of the following:

- Two-way FM radio communications with:
  - Operating personnel
  - Personnel at the CCF and the local train control room at the Transit Center
  - San Francisco Fire Department (SFFD), Emergency Medical Services, and San Francisco Police Department personnel including those inside the station and tunnels
- Close-circuit television system
- Public address system
- Telephone systems
- Supervisory control and data acquisition system
- Station and tunnel heating, ventilation, and air conditioning normal and emergency systems
- Fire alarm and suppression systems
- Electrical distribution system
15.2.1 Ventilation System Monitoring and Control

In fire or emergency mode, the station and tunnel ventilation system must be controllable by the fire alarm system. Input through the fire alarm system must override all other ventilation system controls.

The ventilation console video display unit at the CCF will:
- depict the tunnel with multiple emergency ventilation zones.
- Indicate which control panel is in control of the tunnel ventilation system.
- monitor the status of the tunnel ventilation system and show the current operating mode and emergency evacuation direction, if associated with the operating mode.
- allow the Operations and Control Center (OCC) operator to define (or redefine) the emergency circumstances in terms of disabled train location and emergency evacuation direction.
- allow the CCF operator to initiate the most appropriate emergency ventilation mode to automatically energize fans in their required mode and bring motor-operated dampers to their required emergency positions.

15.2.2 Fire Command Posts

A primary fire command post must be located in the Transit Center station for the use of emergency responders for the management of fire and security emergencies. A secondary fire command post with duplicate equipment must be provided at the Fourth and Townsend Street Station.

Fire command posts will provide firefighters and emergency responders with access to the following:
- Fire alarm control panel
- Visual mapping of the areas being monitored by the fire alarm system that shows all emergency exits and routes by which firefighters may reach the area where an emergency condition is indicated.
- Public address system with the ability to override all other public address announcements.
- Preprogrammed emergency messages for display on variable message signs.
- Status, location, and direction of trains in the tunnels and where the traction power is energized.
- Status and controls of emergency ventilation fans, dampers, and other emergency ventilation equipment.
- Status and controls of escalators and elevators.
- Status of emergency exit stair doors.
- Status and controls of the uninterruptible power supply (UPS) system.
- Digitized floor plans of the DTX facilities showing the locations of fire suppression systems, means of egress, and emergency equipment closets.
- Sufficient floor space for a desk, computer equipment, and drawings.
15.3 Fire Alarm System

The fire alarm system consists of fire alarm control panels and field-mounted devices, such as manual fire alarm pull stations, automatic fire detection devices, audible and visual alarm indicators, and auxiliary control devices.

15.3.1 Fire Alarm System Requirements

A fire alarm system must be installed in stations, police zone facilities, ventilation structures, train control rooms, traction power facilities, and other wayside system structures. The fire alarm system must be fully addressable at all levels and conform to the National Fire Protection Association (NFPA) 72 requirements for a remote station system.

The fire alarm system must be a distributed intelligence addressable-type system, comprising a primarily microprocessor-based, intelligent-type local fire alarm control panel and associated peripherals.

The system must be designed to have 25 percent spare capacity. Each fire alarm control panel must have 25 percent spare fire alarm-initiating circuits, indicating appliance circuits and auxiliary control circuits, and 25 percent spare device or auxiliary control relay capacity.

The fire alarm system must annunciate all alarms, diagnostics, and system conditions and status by type and specific location through text and graphics at the fire alarm control panel and associated annunciator, station agent’s booth, the CCF, and the local emergency responder station.

Fire alarm devices, initiating devices, notification appliances, and signaling line circuits must be designated as Class A, as defined in NFPA 72, section 3-4. All initiating circuits, control circuits, and indicating circuits must be independently supervised for opens, shorts, and grounds that impair the functioning of the system. The system must operate fully through a short-circuit condition. No alarm or trouble signals can be lost when the system is operating in the shorted mode or any system loop. The abnormal status must be separately and distinctly annunciated at the fire alarm control panel and the CCF.

Where circuits leave the ancillary rooms, additional transient protection must be provided for each circuit. Devices must be UL-listed.

The fire alarm system must be electrically supervised and connected to the emergency power source so that loss of the station’s primary power will not cause a loss of alarm capability.

15.3.2 Fire Alarm Device Requirements

Locations and installation requirements for all fire alarm devices must conform to NFPA 130, the CBC, and the local jurisdiction’s fire ordinances and regulations.

Fire Alarm Control Panel

Fire alarm control panels must be located as follows:

- Near the point of surface entry by emergency responders, with specific locations agreed to with the fire department
- In the following secure areas: the OCC, each fire command post, each ventilation structure, each emergency egress structure, and each traction power substation
Fire alarm control panels must indicate, by audible and visual alarm, the activation and location of any fire signal generated within the DTX facilities. Fire alarm control panels must also indicate fire system supervisory signals and a fire alarm control panel trouble signal.

Fire alarm control panels must be lockable, red in color, and meet the following requirements:

- The fire alarm control panel at each location must interface with manual alarm pull stations, smoke and heat detectors, sprinkler water flow switches, standpipe flow switches, bells, horns, strobe lights, and all other detection systems provided at each location.
- All fire alarm control panels must be interconnected.
- A signal from the fire alarm control panel must trigger a tone generator to initiate public address system announcements directing passengers to evacuate.
- Fire alarm control panels must provide operating power for the initiating, indicating, and annunciation devices that are connected to the fire alarm control panel.
- Each fire alarm control panel must control systems including:
  - Air handling and emergency ventilation systems
  - Elevator recall
  - Emergency shut-off for power supplies
  - Automatic fire detection devices
  - Automatic sprinkler systems
  - Station deluge system

A permanent map of the facility served by the protective signaling system must be mounted next to the fire alarm control panel. The map must show the locations of shutoff controls for fire suppression and domestic water systems, gas, and electricity. The map must also show the locations of fire alarm zones, emergency exits, and hose cabinets. The map must be made of durable materials to withstand the environment and handling to which it will be exposed.

**Automatic Fire Detection Devices**

Automatic fire detection devices must be installed in the public areas of the Fourth and Townsend Street Station, the station at the Transit Center (where not already installed during Phase 1), all train control and communication equipment rooms, electrical equipment rooms, and traction power facilities. Where environmental conditions are such that smoke detectors are not suitable, heat detectors must be used. Where smoke detectors or heat detectors are used, design coverage must conform to NFPA 72.

Automatic fire detection devices (products of combustion detectors) must be installed in the following locations:
- Train control and communication equipment rooms (if located next to the station)
- Traction power facilities (if located next to the station)
- Electrical equipment rooms
- Storage rooms
- Building maintenance rooms
- Ventilation ducts
♦ Elevator hoistway entrances  
♦ Concessionary kiosks that are not equipped with sprinklers  
♦ Escalator and elevator machine rooms  

**Smoke Detectors.** Smoke detectors must continually monitor changes in sensitivity resulting from the environmental effects of dirt, dust, smoke, temperature, and humidity and be activated by the presence of combustion products.

Smoke detectors must be addressable ionization detectors of the double-chamber type with adjustable sensitivity. The first or reference chamber must compensate against sensitivity changes caused by variations in temperature, barometric pressure, and humidity. The second or sensing chamber must be open to the outside elements through a protective screen that permits products of combustion to enter, while preventing insects and foreign matter from entering and causing false alarms. The ionizing material for detection and the reference chamber must be Americium 241.

The detector mounting base must be the twist/lock type with screw terminals.

**Heat Detectors.** Heat detectors must be the addressable, rate compensation type and factory-calibrated for a set point of 190°F.

**Air Duct Detectors.** Air duct detectors must operate on a cross-sectional air sampling principle. Remote test stations must be provided for duct smoke detectors. Remote test stations must be in a locked cabinet or controlled by key-activated switches as close as possible to the duct detector location.

**Manual Fire Alarm Pull Stations**

Manual pull stations must be provided throughout passenger platforms and stations in conformance with the requirements of NFPA 72 and NFPA 130.

Manual pull stations must be located in the free and paid areas of each train station within sight lines of the primary station agent’s booth. The TJPA and the SFFD must approve the location of all other manual pull stations.

Manual pull stations must  
♦ be red in color.  
♦ be manually operated by pulling down on a lever that is exposed and readily accessed.  
♦ have tamperproof covers.  
♦ be housed in waterproof boxes if located outside or exposed to weather conditions.  
♦ have closed-circuit television coverage for pull stations in public areas or boxes with integrated cameras.  
♦ upon activation, signal an alarm in the station agent’s booth and the CCF.  
♦ upon activation, sound audible and visual alarms throughout the station.

Activation of a manual pull station must automatically trigger the repeated broadcast of a prerecorded announcement over the PAS of the affected train station warning passengers that all escalators will stop.
within 90 seconds and instructing passengers on escalators to take hold of the escalator handrail. The announcement must be preceded by chimes and broadcast in, at a minimum, English, Spanish, and Chinese.

All escalators in the station must automatically come to a full stop 90 seconds after activation of the manual pull station.

All elevators in the station must automatically go to a pre-determined floor within 90 seconds after activation of the manual pull station. The elevators must be coordinated with the fire department to allow override control. Station platforms must have emergency waiting area or areas for mobility-impaired passengers to wait for fire department to assist with evacuation. The designer must demonstrate the tenability of emergency waiting area for a period of no less than the required duration of tenability as determined by the fire department.

**Audible and Visual Indicators**

Audible indicators must provide 90 dB at 10 feet from the device and conform to NFPA 72.

Visual signal indicators must be the strobe-type with a minimum intensity of 750 foot-candles. When installed in corridors, visual signal indicators must be equipped with a side viewing lens.

**15.4 Fire Suppression Systems**

**15.4.1 Standpipe**

The tunnel including, the Fourth and Townsend Street Station, must be equipped with Class I standpipes meeting the following criteria. A standpipe is required to

♦ be installed at each end of each platform.

♦ be manual wet type, connected to the City of San Francisco water supply.

♦ have a minimum inside diameter must be 4 inches.

♦ be hydraulically sized to provide 500 gpm for the most hydraulically remote standpipe, and 250 gpm for each additional standpipe.

♦ supply a minimum pressure of 75 pounds psi at the hose valve outlets with the maximum pressure of 150 psi supplied at the inlets by the SFFD. Where SFFD pumpers cannot supply the required system demand through an SFFD connection, an auxiliary water supply consisting of high-level water storage with additional pumping equipment or other means acceptable to the authority having jurisdiction must be provided.

♦ have SFFD connections be located not less than 18 inches or more than 48 inches above the level of the adjoining ground.

♦ have outlets will be located at 200-foot centers along the DTX alignment, corresponding with blue light station locations. The centerline of the outlet valve will be located at a height of 42 inches above the finished floor wherever practicable. However, where this criterion cannot be met, outlet valves must be located not less than 3 feet or more than 5 feet above the floor.

♦ have outlet valves will be placed to provide a minimum clearance of 6 inches on all sides of the handle and 18 inches on all sides of the threaded outlet.
place connections and outlets so that doors or walls do not interfere with the use of the outlet valve.

♦ have outlet valves discharge horizontally.

♦ have SFFD connections and outlet valves 3-inch National Standard hose threads.

♦ not embed fire suppression system piping.

Fire hose cabinets will be provided on platforms, as required by the SFFD.

15.4.2 Automatic Sprinkler System

Sprinkler systems must be provided in all rooms and areas of the Fourth and Townsend Street Station, egress shafts, and ventilation buildings except for rooms containing sensitive electronic equipment. The requirements for sprinklers in ancillary structures must be approved by the TJPA and SFFD. Do not embed fire suppression system piping.

Sprinkler system design must conform to the requirements of NFPA 13 for spaces classified as ordinary hazard, Group 1.

15.4.3 Station Deluge System

An under-vehicle deluge system must be provided for each platform track in the Fourth and Townsend Street Station and the Transit Center. Design and installation of the deluge system must conform to the requirements of the CBC.

The deluge system must be interconnected with the overhead contact system (OCS) such that the OCS will be de-energized prior to activation.

15.4.4 Alternative Automatic Fire-Extinguishing System

A water mist fire extinguishing system conforming to NFPA 750 must be provided for rooms containing sensitive electronic equipment, such as train control equipment, communications equipment, and UPS equipment.

15.4.5 Fire Extinguishers

Ancillary rooms must be provided with fire extinguishers in conformance with NFPA 10.

15.5 Firefighters Air System

An air replenishment system must be provided to enable firefighters to refill air bottles for self-contained breathing apparatuses. The replenishment system must include a piping distribution system that conforms to the requirements of SFFD Administrative Bulletin 5.07, Air Replenishment Systems.
15.6 Blue Light Station

Blue light stations must be provided at maximum 200-foot centers throughout the tunnel. Station locations must be marked by a blue light fixture and include information signage that identifies the location of the station and the distance to an exit in each direction.

Each blue light station must have a unique identification number, marked in a prominent manner on a readily accessible, protective enclosure and annunciated at the CCF. Each enclosure must contain the following equipment:
- Tunnel emergency intercom
- Fire telephone jack box
- Fire extinguisher Type 20A:120B:C, with marine-type clamps
- Standpipe outlet valves (blue light stations in underground sections only)
- 120-V duplex convenience electrical outlet. See CHAPTER 17, Electrical Systems for electrical requirements

Blue light stations will be monitored by closed-circuit television. See CHAPTER 18, Rail Systems, for electrical requirements at blue light stations. See CHAPTER 19, Communications, for closed-circuit television system requirements.

15.7 Tunnel Egress

The design of tunnel egress facilities must conform to the requirements of NFPA 130, unless otherwise stated herein.

15.7.1 Walkways

Walkways must be provided next to each track in the tunnel as a means for passengers to evacuate the guideway to reach a point of safety. Walkways must
- have a minimum width of 2 feet 6 inches.
- maintain an unobstructed clear height of 6 feet 8 inches over the width of the walkway.
- be elevated 8 inches above top of rail unless the walkway is in between tracks.
- have walking surfaces with a uniform slip-resistant design.
- have handrails that do not obstruct egress from trains and are located opposite of the track adjacent to the tunnel wall.
- include signage at regular intervals that indicates the emergency egress direction and distances to the nearest exits in both directions and clearly identified cross-passageway doors in portions of tunnel with a partition wall.

The Transit Center station must include crosswalks between the center track walkways and the side walkways at a maximum of 400-foot centers and at the following locations:
Where wayside equipment, signal boxes, and other obstructions interrupt the continuity of the crosswalk

Each side of track crossovers

At the ends of the side walkways to connect with the station platforms

No crosswalks will be provided in the Fourth and Townsend Street Station.

15.7.2 Points of Egress

Egress from the tunnel must be by means of fire-resistive enclosed passageways and stairways leading to exits at the surface. Points of egress must be located such that the maximum distance between exits does not exceed 2,500 feet. All egress points must be identified with illuminated signage.

Doors and hatches must conform to NFPA 130, the CBC, and the San Francisco Building Code.

The fire rating for exit stairs and doors must conform to Chapter 7 of NFPA 101, except where modified by NFPA 130 section 6.3.3.10.

15.8 Underground Stations

15.8.1 Occupant Load

The occupant load for the Fourth and Townsend Street and Transit Center stations must conform to NFPA 130 and the CBC. The occupant load must be based on an emergency condition requiring the evacuation of train and station occupants to a point of safety. Occupant load will be based on the methodology in NFPA 130, section 5, using crush-load vehicle weight.

15.8.2 Number and Capacity of Exits

The number and capacity of egress routes must be sufficient to allow evacuation of the station platforms in 4 minutes or less and evacuation from the most remote point on the platform to a point of safety in 6 minutes or less. The maximum travel distance to a point of egress from any point on the platform must not exceed 300 feet. A common path of travel from the platform ends must not exceed 75 feet or one car length, whichever is greater.

Exiting calculations must conform to NFPA 130, using egress capacity in person-per-inch-per-minute and passenger travel speed in feet-per-minute, determined to conform to the most stringent of the requirements of NFPA 130 and the CBC.
CHAPTER 16 MECHANICAL SYSTEMS

This chapter establishes the requirements for mechanical systems for tunnel ventilation, heating and air conditioning, and plumbing and drainage for the Downtown Rail Extension (DTX) tunnel, Transit Center train box fit-out, Fourth and Townsend Street Station, ventilation and egress structures, and ancillary structures.

CODES, STANDARDS AND GUIDELINES

The design of mechanical systems for the DTX must conform to the latest edition of the following standards, codes, and guidelines govern unless otherwise specified in these criteria:

❖ American National Standards Institute/ American Iron and Steel Institute (ANSI/AISI)
❖ ASTM International standards:
  ● ASTM A653, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
  ● ASTM G90, Standard Practice for Performing Accelerated Outdoor Weathering of Materials Using Concentrated Natural Sunlight
❖ American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) standards:
  ● ASHRAE Handbook – Fundamentals
  ● ASHRAE Standard 52.2, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size
  ● ASHRAE Standard 169, Climatic Data for Building Design Standards, Addendum A
❖ Air Movement and Control Association (AMCA) standards
❖ American National Standards Institute (ANSI)
❖ California Building Code (CBC)
❖ California Energy Code
❖ California High-Speed Rail Authority (CHSRA) Design Criteria Manual
❖ Caltrain Engineering Standards
❖ City and County of San Francisco (City) Municipal Code; San Francisco Plumbing Code
❖ National Fire Protection Association (NFPA)
  ● NFPA 70, National Electrical Code (NEC)
  ● NFPA 90A, Standard for Installation of Air-Conditioning and Ventilation Systems
  ● NFPA 92, Standard for Smoke Controls Systems
  ● NFPA 92A, Standard for Smoke Control Systems Utilizing Barriers and Pressure Differences
  ● NFPA 101A, Guide on Alternate Approaches to Life Safety
16.1 Tunnel Ventilation

The DTX tunnel ventilation system comprises reversible ventilation fans, dampers, sound attenuators, flexible connectors, and ducted connections between the tunnel and openings at or above grade.

Tunnel ventilation system design must consider three operating conditions: normal, congested, and emergency, as defined in the following sections.

16.1.1 Normal Operations

During normal operations, trains move in the tunnel according to schedule, and the flow of passengers is unobstructed. The ventilation system controls tunnel air temperature, tunnel air velocity, and tunnel air pressure change rates.

The ventilation system under normal conditions must dissipate heat generated by trains during peak-hour activity by exchanging system air with outside air. Air exchange must be accomplished through the piston effect of trains moving through the tunnel, supplemented by mechanical ventilation, as necessary. Ambient air temperatures in the tunnel must be managed.

16.1.2 Congested Operations

During congested operations, the movement of trains is impeded, trains are stationary in the tunnel, or the flow of passengers to and from the station platforms is obstructed. During congested conditions, the ventilation system must control air temperature, air velocity, and air pressure change rates in the tunnel.

The ventilation system under congested conditions must dissipate heat generated by stopped trains, including heat given off by vehicle air-conditioning systems and the residual heat emanating from the train propulsion system. Air exchange must be accomplished by a mechanical ventilation system. Ambient air temperatures must not exceed the conditions for summer peak design.

The ventilation design for congested operations must consider non-incident trains within adjacent affected tunnel ventilation zones. The heat emitted from multiple stopped trains will result in higher air temperatures in the tunnel than the heat emitted by a single stopped train, which necessitates greater overall airflow requirements.
If congested conditions necessitate train evacuation, the fan speed must be set to maintain a tenable environment in conformance with NFPA 130 conditions, consistent with emergency operations. See subsection 16.1.3.

16.1.3 Fire Emergency Operations

Fire emergency operations are triggered by a fire incident within the tunnel. During fire emergency operations, passengers will be evacuated from the incident train, and the ventilation system will control tunnel air temperature, tunnel air velocity, and the direction of smoke movement. Other trains may be stationary in the tunnel. The design and operation of the tunnel ventilation system must be coordinated with the signaling system and traction power blocks to conform to NFPA 130.

The ventilation system must maintain a single egress path that leads from the incident train and is clear of smoke and hot gases to promote safe egress and facilitate firefighting operations.

The ventilation system must be capable of moving air in either direction across the train at the required air velocity to maintain a smoke-free path. The design must consider the effect of non-incident trains within adjacent tunnel ventilation zones on the required air velocity.

The emergency ventilation system must be reviewed by the Transbay Joint Powers Authority’s subject matter expert.

Detailed computer simulation studies must be undertaken to evaluate the performance of the tunnel ventilation system, including tunnel air temperature and tunnel air velocity, for each of the operating conditions.

A control mode table for damper and fan operations covering each tunnel ventilation zone in the system under each operating condition must be developed.

NFPA 130 provides guidance on tenability criteria. The required time of tenability must be developed for each station and follow guidance from the SFFD and first responders as well as an emergency response plan.

If single extract mode is anticipated in a particular location, additional discussion and description of this mode will be added.

16.1.4 Maintenance and Train Recovery Operations

Maintenance and train recovery operations are expected to be performed using diesel-powered equipment. An operations procedure will be written and approved by the operators. The ventilation system must be used during any operations involving the use of diesel equipment in the DTX tunnel. The designer must develop a ventilation system sequence of operation and mode tables and must verify the adequacy of the tunnel ventilation for this purpose.
16.1.5 Environment Design Conditions

Outside Conditions

Use the following outside ambient conditions in the computer analysis for determining the required capacity of the ventilation system for normal and congested operations:

- Extreme summer dry bulb temperature: 109°F
- Summer dry bulb temperature: 83°F
- Summer mean coincident wet bulb: 63°F
- Winter dry bulb temperature: 37°F
- Extreme winter dry bulb temperature: 28°F

Indoor Design Conditions for Normal Operations

Air Temperature. The maximum air temperature in the tunnel must not exceed 105°F.

Heating. Heating will not be provided in the tunnel. Sub-freezing temperatures may occur in the tunnel during extreme winter design conditions.

Humidity. Do not provide dehumidification.

Air Velocity. Air velocity control will not be provided during off-service hours.

Air Pressure Transients. The criterion for rapid pressure changes, applicable when the total change in pressure is greater than 0.10 psi (2.8 inches water gauge per second), is that no person (neither patron nor employee) will be subjected to a rate of pressure change greater than 0.06 psi per second (1.7 inches water gauge per second).

Emergency Operations

Emergency ventilation system design must meet the following requirements:

Train Fire Heat Release Rate. The design train fire size and growth rate must conform to the fire sizes indicated in the Transbay Program’s Threat and Vulnerability Assessment.

Evacuation Route Air Temperature. The maximum temperature will not exceed 140°F (ignoring radiant heating) for momentary exposures. The average air temperature in the evacuation route will not exceed 120°F for the first six minutes of the exposure.

Evacuation Route Air Velocity. The minimum air velocity will not be less than that required to control the spread of smoke and hot gases from the fire into the evacuation path. The maximum air velocity in the evacuation path must not exceed 2,200 fpm. The designer must calculate the critical air velocity required to prevent backlayering using approved methods.

Single Point Extraction. Single point extraction must conform to NFPA 130, section 7.2.2 – Single Point Extraction.
Design Air Velocities

Design air velocities must meet the system performance requirements and minimize pressure loss and energy consumption, airborne noise generation, draft, and the intake of dust particles. The design velocities in air distribution systems are as follows:

**Shafts and Ducts.** The average air velocity in the tunnel ventilation shafts and ducts must not exceed a maximum of 2,000 fpm.

**Fan Dampers.** The air velocity across the tunnel ventilation dampers must not exceed a maximum of 2,000 fpm over the gross face area.

**Plenum Areas.** The average air velocity in tunnel ventilation plenum areas must not exceed a maximum of 2,000 fpm.

**Fan Sound Attenuators.** The air velocity through the fan sound attenuators must not exceed a maximum of 2,000 fpm over the gross face area.

**Outside Air Intakes 10 feet or More Above Grade or Away from Public Areas.** The face area of grating must be sized for a maximum air velocity of 1,500 fpm.

**Exhaust Air 10 feet or More Above Sidewalk Level, or Away from Public Areas.** The face area of grating must be sized for a maximum air velocity of 1,500 fpm.

16.1.6 System Equipment and Arrangement

All system components located in the air stream (including fans, fan motors, dampers and damper actuators) must be capable of operating in an air stream temperature of 482°F, for a minimum of one hour.

**Fans**

Fans must be housed in fan rooms, in shafts, or, in the case of jet fans, within the tunnel cross section and must be arranged either horizontally or vertically. Fan dampers and bypass dampers must be provided in the structure separating the fan room from the tunnel.

Fan motor starters and related operating control devices must be isolated from the ventilation airflow by a physical separation having a fire resistance rating of two hours or more.

**Axial Flow Fans.** Axial flow fans must

- have an internally mounted, direct drive motor.
- achieve their full operating speed from a stopped position in no more than 30 seconds and will be reversible, from full supply to full exhaust or vice versa, within 60 seconds.
- have manually adjustable pitch blades.
- have equipment that includes inlet and outlet transition pieces and flexible connectors. The minimum acceptable reverse (supply) airflow capacity must be 100 percent of the forward (exhaust) airflow capacity.
- have a total fan efficiency of not less than 65 percent in the forward (exhaust) mode.
• have motor units with a capacity range of 150,000 cubic feet per minute (cfm) to 250,000 cfm and operate in the stable range of the fan performance curve through the entire operating pressure range.
• have motors with sealed motor bearings.
• have modular, rectangular sound attenuators on both inlet and discharge sides. The length of the sound attenuators will be based on the dynamic insertion loss levels required to meet the applicable noise criteria.

Fans may be controlled by single, double, or variable speed drives.

**Jet Fans.** Jet fans must
• be of the axial flow type with an internally mounted direct drive motor.
• achieve their full operating speed from a stopped position in no more than 30 seconds; they must be reversible to go from fully forward to fully reversed or vice versa within 60 seconds.
• be capable of providing specified exit velocity and static thrust in either direction of operation.
• have power requirements for the reverse direction that do not exceed power requirements of the forward direction.
• have manually adjustable fixed pitch blades.
• Have an efficiency of not less than 60 percent when operating in the forward direction of airflow at the specified nominal static thrust and exit velocity.
• have cylindrical (tubular) sound attenuators directly mounted in the end of the fan. Attenuator length will be selected to ensure the tunnel noise criteria are not exceeded. The minimum attenuator length will be the equivalent of one fan diameter.
• be supplied with a support and suspension system to provide support as required against fluctuating loads imposed by fan operation and moving traffic.
• have an assembly that operates under and resists the effects of water spray washing.
• be designed to run to destruction when during emergency operations.

**Dampers**

Isolation dampers must prevent airflow through the tunnel ventilation fans when the fans are not running.

In their closed position, fan and bypass dampers must provide the equivalent of a two-hour fire resistance rating. Where necessary during normal operations, bypass shafts must allow air exchange between the outside ambient and the tunnel. Bypass dampers must be provided to prevent the short-circuiting of airflow around the bypass shaft during fan operations. Bypass dampers must be located nearest to the ventilation shafts extending to grade.

Isolation dampers, bypass dampers, and fan dampers must
• be the heavy duty, industrial, parallel-blade type.
• be capable, along with their associated structural supporting members, of withstanding a maximum differential static pressure across the dampers of 14 inches water gauge, and minimum differential static pressure of 4 inches water gauge for 2,000,000 reversals.
♦ not leak more than 5 percent of the design airflow.
♦ not take longer than 30 seconds to operate from fully open to fully closed (or vice versa).
♦ have a predetermined position upon which to return following power loss or actuator failure.

Sheet Metal Ducts

Sheet metal ducts must
♦ be constructed of galvanized steel with airtight joints. The measured leakage must not exceed 5 percent of the design airflow.
♦ be sufficiently stiffened and supported to avoid sagging and vibration. Ductwork fabrication must conform to the Sheet-Metal And Air Conditioning Contractors National Association (SMACNA) pressure classifications to be specified for each system.
♦ have sufficient thermal insulation to limit the exposed surface temperature to 120°F, if the ducts are intended to operate at air temperatures exceeding 120°F.

Shafts

Shaft design must
♦ avoid abrupt transitions in the shaft cross-section.
♦ minimize the number of bends and elbows. Turning vanes may be used to reduce pressure losses.
♦ have air passages constructed of smooth concrete or sheet metal ductwork.
♦ locate outside air exhaust/intake openings 10 feet (minimum) from lot lines or buildings on the same lot. Where outside air openings front on a street or public way, the distance from the opening will be measured to the centerline of the street or public way.
♦ protect with corrosion-resistant screens all exhaust/intake openings that terminate outdoors.

Equipment Access and Handling

The design must provide for the installation, maintenance, and subsequent removal/replacement of ventilation equipment as follows:
♦ All openings, shafts, doors, hatches must be sized with adequate clearances such that equipment can be installed or removed without disassembly or special construction or demolition.
♦ Monorails, lifting hooks, and removable panels must be incorporated into the design, as necessary, to facilitate the installation and removal of equipment.

Emergency Exit Pressurization System

Emergency exits from the tunnel must house a dedicated mechanical ventilation system capable of maintaining a smoke-free environment during a fire incident. Emergency exit ventilation systems must meet the following requirements:
♦ Emergency exit spaces must be maintained at a minimum pressure of 0.14-inch water gauge above the pressure within the tunnel. The maximum pressure within the emergency exit must be the lesser
of 0.3-inch water gauge or the pressure required to permit the trackside door to be opened with a maximum force of 50 pounds.

- Emergency exit space pressure must be maintained with all doors closed.
- Air supply used for pressurization must be drawn directly from an outside air shaft or louvers. The transfer of air from other spaces is not permitted.
- Supply ductwork must be contained within fire-rated enclosures or be fabricated from fire-rated ductwork prior to passing into the emergency exit.
- Fan operation indication must be provided to the Transit Center Security Operations Center and Caltrain’s Central Control Facility (CCF).

16.1.7 Control and Monitoring

The operation of the tunnel ventilation system must be controlled remotely from the CCF by means of the supervisory control and data acquisition (SCADA) system. The SCADA system will continuously monitor the status of the fans, motors, dampers, motor controllers, and other related systems, including alarms.

Tunnel ventilation system reliability requirements must conform to NFPA 130 sections 7.2.3 (6) and 7.2.4; they must also include provisions for local operation.

Fan Motor Controllers

The tunnel ventilation fan system will be fed from a redundant power supply. Fan motor controllers must be provided with dedicated feeders from two separate and distinct power sources. Starters for tunnel ventilation fans must

- be 480-volt, variable frequency drive type, multispeed, reversible, with motor circuit protectors.
- be located in electrical equipment rooms that are environmentally controlled and protected from unauthorized entry and suitable for the environment in which they are installed.
- have heavy-duty disconnect switches must be provided as a means to disconnect equipment from its feeder when the equipment is not within sight of the feeder breaker or the motor controller.
- have damper motor controllers located within damper control panels that are adjacent to the fan motor starters. The DCP will provide the means for both remote and local operation and testing of the dampers.
- have overcurrent elements used to protect conductors serving emergency equipment motors (e.g., fans, dampers) that are to be located in spaces other than main electrical distribution rooms.
- have overcurrent elements that are the magnetic type and do not depend on thermal properties for operation.

Control Panels

A ventilation control panel (VCP) must be provided in a dedicated local control room. The VCP must duplicate the essential remote control and monitoring capability of the supervisory control and data acquisition (SCADA) system for the tunnel ventilation system only and serve as a standby if controlling the ventilation
system from outside of the SCADA system becomes necessary. The VCP must also provide the capability for local, maintenance-related equipment testing operations.

A local control panel (LCP) must be provided in each ventilation plant to allow control of the ventilation equipment at that location only. The LCP must be controllable by emergency response personnel during a tunnel fire incident. The VCPs must not be exposed to the tunnel environment during emergency vent operations.

### Control and Communication

Dual redundant programmable logic controllers (PLCs) and dual communications to the SCADA system, the ventilation control panel, and local control panel must provide a high-availability system. The PLCs will receive mode commands from the SCADA system, VCP, or LCP and will sequence the ventilation plant by means of the damper control panels and fan motor controllers to control the dampers and fans. The PLCs will continually relay the status of the tunnel ventilation system to the supervisory control levels. The status must include the number and identification of operating fans and the position (open or closed) of each damper.

The source of control must be in the following order: (1) SCADA system, (2) ventilation control panel, and (3) local control panel. A hand down of control between the SCADA system, the VCP, and the LCP must be implemented to ensure that control conflicts do not occur. Control must be accomplished through the selection of an appropriate mode, with the mode representing a predefined ventilation response for normal, congested, and emergency conditions. During testing and maintenance, the fans and dampers must also be controllable individually from their respective motor controllers and DCP controls, located in close proximity to the fan rooms.

#### 16.1.8 Emergency System Operation

During emergency operations, fan start logic must conform to NFPA 130.

During emergency operations, the tunnel ventilation fans must achieve full operational mode within three minutes of activation. The local control system for the tunnel ventilation system will receive control commands from the SCADA system (or VCP) to control the ventilation system components and report equipment status, including operation alarms, to the SCADA system. The local control system must include an operational link with the local fire alarm control panel.

### Control and Monitoring

The SCADA system will provide the CCF workstation with

- local fan control indication.
- alarm screens and alarm log, e.g., high temperature, equipment fault/failure.
- recording of total energy consumption and operating hours for all ventilation equipment.
- program maintenance guides.
- confirmation of control level responsibility (remote or local).
- ventilation operator interface using a color graphic schematic of the ventilation system. During emergency conditions, the SCADA software must provide decision support to the operator to assist in the selection of the appropriate mode. The schematic will be dynamically updated with damper
and fan status. A real-time database will provide centralized logging of selected ventilation equipment and automatically generate standard periodic reports, including daily, weekly and monthly reports.

**SCADA Functions**

The SCADA system must be able to initiate operation of the tunnel ventilation system:

- by means of the DTX Control System in response to congested train operations resulting from a delay or operational problems.
- by means of the DTX Control System during or in preparation for normal train operations, if necessary.
- in response to an emergency condition. The SCADA system will enable the DTX Control System to quickly activate the appropriate operation mode to direct smoke away from the designated evacuation path. Indicate the local fan control.

**Programmable Logic Controller Functions**

The PLCs must be able to:

**Receive**

- and send data to the SCADA system.
- commands from the SCADA system and start the equipment sequentially, with adjustable preset time delays, to avoid excessive surge on the power supply system.
- digital status such as the on/off or alarm status of equipment to directly control the starting and stopping of fans and the opening and closing of associated dampers.
- analog signals in the form of voltage or current from field sensors; convert these signals into engineering units and report them to the SCADA system.
- set-point information from the SCADA system or p/m terminals and retain these values in memory for control reference and function.
- mode commands from the SCADA system and operate fans and dampers in a preset configuration, with insertion of time delays and interlocking logic.

**Monitor**

- the status and alarm indications of all ventilation equipment and provide automatic changeover to available standby or idling equipment.
- the status and alarm indications of ventilation equipment and report any change of status to the SCADA system and the programming and maintenance terminals.
- the activation of the push buttons or switches on the LCP and execute priority control.
Output

♦ analog signals in the form of voltage or current to the transducers in the control device panel of the equipment where they are converted into suitable signals to drive actuators or other control devices.

Log and report

♦ alarms of analog signals that have exceeded preset high, low, or rate-of-change limits.

16.2 Heating, Ventilation and Air Conditioning System

Heating, ventilation, and air conditioning (HVAC) design, where applicable, for the Transit Center train box fit-out and Fourth and Townsend Street Station, ventilation buildings, and ancillary structures must conform to the requirements in this section.

16.2.1 Environment Design Conditions

Outdoor Conditions

Underground station platform, ancillary areas, and other systems using 100 percent outside air (based on ASHRAE Standard 169, 0.4 percent summer and 99.6 percent winter annual conditions in San Francisco).

- Summer dry bulb temperature 83°F
- Summer mean coincident wet bulb 63°F
- Winter dry bulb temperature 40°F

Indoor Conditions for Normal Operations

Space design conditions and requirements – Hold for future input.

16.2.2 Minimum Ventilation Requirements

Ventilation of the DTX facilities must conform to the following minimum requirements:

- Platform 15 cfm/person
- Mezzanine circulation areas 15 cfm/person
- Service and ancillary areas As required by local code

The concourse and platform at the Fourth and Townsend Street Station must be naturally ventilated using the following requirements from San Francisco Municipal Transportation Agency’s criteria for the Central Subway project:

♦ Maximum temperature is 10 degrees above ambient temperature
♦ No heating is required
Air Supply

Spot cooling on platforms must have a maximum air terminal velocity (measured at 5 ft 6 inches above floor) of 30 to 50 fpm.

Design Velocities for Air-Distribution Systems

Design velocities must meet the required system performance and minimize airborne noise generation, draft, and the intake of dust particles. Use the following design guidelines for maximum velocities in air-distribution systems under normal operation:

Table 16-1: Sheet-metal Ducts

<table>
<thead>
<tr>
<th>Distribution Ducts</th>
<th>Preferred Maximum</th>
<th>Absolute Maximum (Where site limits do not allow preferred maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main supply ducts</td>
<td>1,800 fpm</td>
<td>2500 fpm</td>
</tr>
<tr>
<td>Branch supply ducts</td>
<td>1,500 fpm</td>
<td>2500 fpm</td>
</tr>
<tr>
<td>Outside air intake ducts</td>
<td>1,500 fpm</td>
<td>2500 fpm</td>
</tr>
<tr>
<td>Main exhaust and return ducts</td>
<td>1,800 fpm</td>
<td>2500 fpm</td>
</tr>
<tr>
<td>Branch exhaust and return ducts</td>
<td>1,200 fpm</td>
<td>2500 fpm</td>
</tr>
<tr>
<td>Transfer ducts</td>
<td>350 fpm</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Concrete Ducts and Plenums. Base velocities on the circular equivalent of the rectangular duct.

Air Outlets and Intakes

- Street intake louvers: 500 fpm over gross area
- Street intake grilles: 1,200 fpm over gross area
- Street exhaust louvers: 700 fpm over gross area
- Street exhaust grilles: 1,500 fpm over gross area
- Room exhaust and return grilles: 500 fpm over gross area
- Room supply registers and grilles: To be selected based upon the required throw and noise requirements for each space

Design Velocities for Ventilation Shafts

The maximum air velocity through a grating, louver, or grille will be computed using the gross face area of the grille or louver, exclusive of any support. Use the following air velocity design guidelines under normal and emergency operations:

Velocities through Horizontal Openings (Normal Operation)

- Outside air intakes 10 feet or more above grade level or away from a public area: 1,200 fpm
- Exhaust air 10 feet or more above sidewalk level or away from a public area: 1,000 fpm
Velocities through Vertical Louvers and Grilles **(Normal Operation)**
- Outside air intakes 10 feet above sidewalk level (ASHRAE Handbook - Fundamentals): Recommended 500 fpm, maximum 1,200 fpm
- Exhaust air 10 feet above sidewalk level: Recommended 500 fpm, maximum 1,000 fpm

Velocities through Vertical Louvers and Grilles **(Emergency Operation)**
- Exhaust air 10 feet above sidewalk level: 1,500 fpm
- Velocities for main ventilation shafts: (Emergency Operation); listed velocity may be increased up to 25 percent:
  - 2,000 fpm (preferred)
  - 2,500 fpm (maximum)

16.2.3 **Shaft Design**

HVAC shaft design must conform to the requirements of subsection 16.1.5, Environmental Design Conditions/Design Air Velocities.

16.2.4 **Public Area HVAC Systems**

Subsections Ventilation System Operation, and Ventilation System Operation, describe the HVAC requirements in public areas of the Transit Center train box fit-out and Fourth and Townsend Street Station.

Ventilation System Operation

**Platforms.** The supply air system must supply and distribute ventilation air at platform ceiling level.

An exhaust system must capture heat emitted by passenger and maintenance vehicles during normal and congested operations and purge smoke during emergency operations. The captured heat and smoke must be vented to the atmosphere.

**Concourse.** The concourse supply air system must supply and distribute ventilation air at concourse ceiling level.

An exhaust system must capture heat and smoke during emergency operations. The captured heat and smoke must be vented to atmosphere.

**HVAC Control and Monitoring System**

LCPs will be provided at the platform and concourse levels. The panels will override remote control from the CCF and be used by personnel for testing and maintaining equipment and in the case of failure of the CCF.

**Emergency Exit Air-Pressurization System**

Station emergency exit stairwells and corridors must be pressurized as described in section 16.1.6.6.
16.2.5  Nonpublic Area HVAC Systems

This subsection addresses the design of HVAC systems serving non-public areas of the Fourth and Townsend Street Station, ventilation buildings, and ancillary spaces. Table 16-2 summarizes the requirements for individual rooms. The temperature of rooms containing sensitive equipment will be dictated by the equipment operating temperature limits. If rooms are cooled by ventilation, the design must account for extreme daily temperatures rather than outdoor design conditions.

Table 16-2: HVAC Requirements

<table>
<thead>
<tr>
<th>Criteria Reference</th>
<th>Room Description</th>
<th>HVAC System Type</th>
<th>Air Change Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.2.4.1</td>
<td>Battery</td>
<td>Hydrogen and temperature control</td>
<td>-</td>
</tr>
<tr>
<td>15.2.4.2</td>
<td>Fan</td>
<td>Air change and temperature control</td>
<td>2/hour</td>
</tr>
<tr>
<td></td>
<td>Mechanical equipment</td>
<td>Air change and temperature control</td>
<td>2/hour</td>
</tr>
<tr>
<td></td>
<td>Pump</td>
<td>Air change and temperature control</td>
<td>2/hour</td>
</tr>
<tr>
<td>16.2.4.3</td>
<td>Control</td>
<td>Ventilating and cooling</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>General electrical services</td>
<td>Ventilation and cooling</td>
<td>-</td>
</tr>
<tr>
<td>16.2.4.4</td>
<td>Ventilation substation</td>
<td>Ventilation and temperature control (transformer rooms)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Traction power substation</td>
<td>Ventilation and temperature control (transformer rooms)</td>
<td>-</td>
</tr>
<tr>
<td>16.2.4.5</td>
<td>Sewage ejector</td>
<td>Air change</td>
<td>10/hour</td>
</tr>
<tr>
<td></td>
<td>Storage</td>
<td>Air change</td>
<td>2/hour</td>
</tr>
<tr>
<td></td>
<td>Sump</td>
<td>Air change</td>
<td>10/hour</td>
</tr>
<tr>
<td></td>
<td>Toilet</td>
<td>Air change</td>
<td>10/hour</td>
</tr>
<tr>
<td></td>
<td>Trash</td>
<td>Air change</td>
<td>15/hour</td>
</tr>
<tr>
<td></td>
<td>Valve</td>
<td>Air change</td>
<td>2/hour</td>
</tr>
<tr>
<td>16.2.4.6</td>
<td>Train control/communication</td>
<td>Pressurization and cooling</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Signal</td>
<td>Pressurization and cooling</td>
<td>-</td>
</tr>
<tr>
<td>16.2.4.7</td>
<td>Elevator machine</td>
<td>Temperature control</td>
<td>-</td>
</tr>
<tr>
<td>16.2.4.8</td>
<td>Staff (locker, lunch, meeting, offices)</td>
<td>Ventilation and cooling</td>
<td>4/hour (locker rooms only)</td>
</tr>
</tbody>
</table>

Hydrogen Concentration and Temperature Control Systems

Hydrogen concentration and temperature control systems must be provided in the following locations:
- Battery rooms
- Uninterruptible power supply rooms (as required by UPS equipment)
The system must limit the concentration of hydrogen gas within the space to 1 percent by volume and limit the temperature within the space to a maximum of 12°F above outdoor temperature.

A mechanical supply system must supply filtered 100 percent outside air or conditioned air from a public space, as applicable, to rooms located underground. If valve-regulated (sealed) batteries are used, calculate the hydrogen production using the same generation rates as standard lead acid batteries.

Exhaust air must be removed from a high level within the space and vented to the atmosphere.

**Equipment.** Hydrogen concentration and temperature control equipment consists of supply air and exhaust fans, filters, air-distribution ductwork and devices, air outlet dampers, room heaters, gas detection devices, warning lights, and automatic controls and must conforming to the following requirements:

- Supply system must be provided only in cases where air from adjacent spaces cannot be used.
- Battery rooms must have two supply and two exhaust fans. If one fan fails, the standby fan will operate. If multiple battery rooms exist at any location, a common system may serve all battery rooms.
- Exhaust fans must be spark-resistant with explosion-proof fan motors.
- Exhaust ducts and supply and exhaust grilles and registers within the battery rooms must be stainless steel or galvanized steel duct with inner epoxy layer.
- If required, additional wall- or ceiling-mounted unit heaters or electric duct-type heaters must be provided to maintain the room temperature to a minimum of 50°F. (The heat output of the equipment, except for the transformer, in the room will cannot be used to offset the space heat losses.)
- Room heaters must be spark-resistant with explosion-proof fan motors.
- Miscellaneous electrical devices located inside battery rooms must be explosion-proof.

**Operation and Control.** Hydrogen concentration and temperature control systems must be able to run continuously. An airflow switch located in the discharge duct of each fan system will monitor operation. A remote indication of fan operation must be provided to the CCF. An indication of no airflow must start the standby supply or exhaust fan and be transmitted to the CCF. Air outlet dampers on each fan must be sequenced to open when the fan is running and close when the fan is not running.

Battery rooms must have a hydrogen gas detection system that will send a warning to the CCF of the presence of hydrogen gas above 1 percent by volume within the room. The detection system must activate warning lights located both inside and immediately outside the affected room.

A dirty filter indicator must transmit a system fault indication to the CCF.

**Air Change and Temperature Control Systems**

The following rooms must have air change and temperature control systems:

- Fan rooms
- Mechanical equipment rooms
- Train control/communications rooms
- Pump rooms
Ventilation must be supplied entirely by filtered outside air. The required airflow must be the greater of the following:

- Airflow required to provide the air change rate listed in Table 16-2
- Airflow required to limit the room temperature to a maximum of 12°F above outdoor temperature

**Equipment.** Air change and temperature control equipment consists of supply air and exhaust fans, filters, air-distribution ductwork/devices, air outlet and inlet dampers, room heaters, and automatic controls.

Similar rooms may be served from a single-fan system, with individual ductwork connections to each room.

The heat output of the equipment cannot be used to offset the space heat losses. If required, additional wall- or ceiling-mounted unit heaters must maintain the room temperature to a minimum of 50°F.

**Operation and Control.** Air change and temperature control systems will be controlled by thermostats located within the rooms. A start/stop switch must be provided to allow manual control during maintenance. Where a system serves more than one space, operation of the entire system must be based on the dictates of the thermostat or manual start/stop switch in any single space.

An indication of fan operation must be transmitted to the CCF. A dirty filter indicator must transmit a system fault indication to the CCF.

**Ventilation and Cooling System**

Ventilation and cooling must be provided for the following rooms:

- Control rooms
- General electrical services rooms

Ventilation of the general electrical service rooms must be supplied entirely by filtered outside air.

The ventilation system design must specifically preclude recirculation. The airflow must be the greater of the airflow required to (a) limit the temperature within the room to a maximum of 12°F above outside air temperature or (b) pressurize the room to between 0.1-inch and 0.25-inch water gauge for space leading to the trackway.

Base the ventilation capacity required to control space temperature on a summation of the following internal heat gains:

- Lighting load
- Solar and transmission gains, where applicable
- Heat gain produced by equipment, calculated based on actual loads
- Occupants, where applicable (minimum 15 cfm per person)

**Equipment.** Ventilation and cooling system equipment consist of supply and exhaust air fans, filters, motorized dampers, ductwork and devices, air inlets and outlets, heaters, and automatic temperature controls and must meet the following requirements:

- Supply and exhaust fans must be electronically interlocked.
Exhaust air must be vented to atmosphere.

Single-supply air system must be provided for room pressurization for spaces leading to the trackway.

If required, additional wall- or ceiling-mounted unit heaters must maintain the room temperature at a minimum of 50°F. The heat output of the equipment cannot be used to offset the space heat losses.

Similar rooms may be served from a single-fan system, with individual ductwork connections to each room.

**Operation and Control.** Ventilation and cooling systems must be controlled by thermostats located within the room. A start/stop switch must allow manual control during maintenance. Where a system serves more than one space, operation of the entire system must be based on the dictates of the thermostat or manual start/stop switch in any single space.

An indication of fan operation must be transmitted to the CCF. A dirty filter indicator must transmit a system fault indication to the CCF.

**Pressurization and Temperature Control System**

Pressurization and temperature control must be provided for the following spaces:

- Traction power substations
- Tunnel ventilation fan transformer substations

Ventilation of substation rooms must be supplied entirely by filtered outside air.

The pressurization and temperature control system must ensure that the operating temperature within the space does not exceed 105°F, and that sufficient pressure is maintained to prevent rail dust, etc., from entering the substations and affecting electrical equipment operation.

Base the required ventilation capacity on a summation of the following internal heat gains:

- Lighting load
- Solar and transmission gains, where applicable
- Heat gain produced by equipment, calculated based on actual loads
- Occupants, where applicable (minimum 15 cfm per person)

**Equipment.** Pressurization and temperature control system equipment consists of supply and exhaust air fans, filters, motorized dampers ductwork and devices, air inlets and outlets, heaters, and automatic temperature controls and must meet the following requirements:

- Rooms must have a minimum of three identical exhaust fans. Two of the three exhaust fans together must be capable of meeting the ventilation requirement. The third exhaust fan will serve as a standby unit.
- Supply and exhaust fans must be electrically interlocked and must have a low-leakage damper to isolate the fan when not running.
- Exhaust air must be vented to atmosphere.
Single-supply air system must provide for room pressurization for the spaces leading to trackway and above grade.

If required, additional wall- or ceiling-mounted unit heaters must maintain the room temperature at a minimum of 50°F. With the exception of the transformer, the heat output of the equipment cannot be used to offset the space heat losses.

**Operation and Control.** Pressurization and temperature control systems must be controlled by a thermostat located within the space as follows:

- When the temperature of the space rises to 84°F, a single exhaust fan will start
- When the temperature continues to rise and reaches 104°F, a second fan will start
- When the temperature falls to 89°F, the second fan will stop
- When the temperature continues to fall and reaches 79°F, the first fan will stop

A local manual control must allow control of the ventilation system when the room is occupied by personnel.

An indication of fan operation must be transmitted to the CCF. A high-temperature thermostat (set at 110°F) and a dirty filter indicator each must transmit a system fault indication to the CCF.

**Air Change Systems**

Air changes systems must be provided for the following rooms:

- Sewage ejector rooms
- Storage rooms
- Sump rooms
- Restrooms
- Trash rooms
- Valve rooms

Exhaust air ventilation must provide the number of air changes specified in Table 16.1. Supply air must be drawn from an adjacent space through a transfer grille unless the adjacent space is either an emergency exit corridor or a pressurized space, in which case, a supply air system must be provided and sized to match the capacity of the exhaust air system.

**Equipment.** Air change systems consist of, as necessary, supply and exhaust air fans, filters, ductwork and devices, air inlets and outlets, heaters, and automatic temperature controls. Wall- or ceiling-mounted unit heaters must be provided in storage rooms and toilets to maintain the room temperature to a minimum of 50°F. Similar rooms may be served from a single-fan system, with individual ductwork connections to each room.

**Operation and Control.** Ventilation must operate continuously except when serving toilets. Ventilation controls in toilets must be interlocked with the room light switch.

An indication of fan operation must be transmitted to the CCF. A dirty filter indicator must transmit a system fault indication to the CCF.
Pressurization and Cooling Systems

Pressurization and cooling systems must be provided for the following rooms:
- Signal rooms
- Train control and communication rooms

Rooms must be provided with mechanical cooling, as required, to maintain a suitable environment for the operation of temperature- and humidity-sensitive equipment. Filtered ventilation air must be provided to maintain air quality for occupancy, where required.

Base the cooling load on a summation of the following heat gains:
- Heat gain produced by equipment
- Lighting load
- Pressurization ventilation requirement
- Solar and transmission gains, where applicable
- Occupancy, where applicable

Equipment. The pressurization and cooling system consists of an air conditioning system, supply air system, heaters, and an automatic temperature control that must meet the following requirements:
- Air conditioning equipment must be of the direct-expansion, fan-coil unit type.
- The air conditioning units must be located either in the room or in an adjacent mechanical equipment room. The air-cooled condenser may be a part of the air-conditioning unit or may be remote from it.
- Units must be provided with refrigerant R22 or its replacement and must fully recirculate room air and contain an integral return air filter.
- The supply air system must comprise a supply air fan, filter, coil, air-distribution ductwork and devices, and air inlet and outlets.
- Heating must be provided through wall- or ceiling-mounted unit heaters or incorporated into the packaged cooling units.

Operation and Control. A room thermostat (set point 78°F cooling/68°F heating) must maintain the room temperature at the thermostatic setting. Another room thermostat (set point 90°F) must transmit a high-temperature indication to the CCF. An indication of fan operation must be transmitted to the CCF.

The fan-coil unit air-conditioning system will automatically shut down in case fire or smoke is detected in the room.

Temperature Control Systems

Temperature control systems must be provided for elevator machine rooms.

Ventilation must be supplied entirely by filtered outside air. The airflow must limit the maximum temperature within the room to a maximum of 105°F.
The ventilation capacity required to control the space temperature will be based upon a summation of the following internal heat gains:

- Lighting load
- Solar and transmission gains, where applicable
- Heat gain produced by equipment in the equipment room calculated based on actual loads
- Occupants, where applicable

**Equipment.** Temperature and control systems consist of exhaust air fan, ductwork/devices, air outlet dampers, heaters, and automatic temperature controls.

Similar rooms may be served from a single-fan system, with individual ductwork connections to each room.

If required, additional wall- or ceiling-mounted unit heaters will be provided to maintain the room temperature to a minimum of 50°F. The heat output of the equipment in the space will not be used to offset the space heat losses.

**Operation and Control.** Ventilation systems will be controlled by a thermostat located in the space. Remote indication of fan operation will be provided to the CCF. A dirty filter indicator will transmit a system fault indication to the CCF.

**Ventilation and Cooling Systems with Air Cooled Air-Conditioning**

Ventilation and cooling systems with air-cooled air conditioning must be provided in areas with permanent or semi-permanent occupancy, including locker rooms, lunchrooms, meeting rooms, offices, and staff rooms.

Rooms must be provided with the filtered ventilation air and the mechanical cooling necessary to maintain a suitable environment for occupancy.

Minimum outside air ventilation requirements must conform to the CBC. Base the cooling load on a summation of the following heat gains:

- Heat gain produced by equipment
- Lighting load
- Ventilation requirement
- Solar and transmission gains, where applicable
- Occupancy

**Equipment.** Ventilation and cooling systems consist of an air conditioning system, supply air system, heaters, and automatic temperature control and must meet the following requirements:

- Equipment must be of the direct expansion, split system type.
- Air-conditioning units
  - must be located in either the room or an adjacent mechanical equipment room. The air-cooled condenser may be a part of the air-conditioning unit or remote from it.
  - must be fully recirculating and contain an integral return air filter.
  - must be provided with refrigerant R22 or its replacement.
Supply air system must consist of a supply air fan, filter, air distribution ductwork and devices, air outlet damper, and automatic controls to provide the outside air sufficient for human occupancy.

Economizer control must be considered for above-ground rooms if sufficient air intake louvers are available.

Conditional requirements include:

- Supply airflow rate. Should the supply airflow rate be sufficient to raise the room pressure above 0.25-inch water gauge, air must be relieved from the room to match ambient conditions through a relief opening connected to a relief shaft. A motor operated damper and a fire damper must be installed in the relief opening.
- Site conditions. If site conditions permit, locate the relief opening, shaft, and gratings as close to the room as possible; they must be sized to prevent an excessive positive pressure build-up in the room.
- Shaft terminus. Depending upon the proximity of the shaft terminus at grade level, mechanical exhaust may be required.

Heating will be provided by means of wall- or ceiling-mounted unit heaters or incorporated into the packaged cooling units.

Similar rooms may be served from a single supply air fan, with individual ductwork connections to each room.

**Operation and Control.** A room thermostat (set point 78°F cooling/70°F heating) must maintain the room temperature at the thermostatic setting. The outside air supply fan must operate continuously.

An indication of fan operation must be transmitted to the CCF. A dirty filter indicator must transmit a system fault indication to the CCF.

### 16.2.6 HVAC Equipment

All air-distribution duct systems design must conform to the guidelines in the latest edition of the ASHRAE Handbook – Fundamentals.

Supply and exhaust fans and associated equipment serving multiple rooms must be housed in a dedicated mechanical equipment room. Supply and exhaust fans and associated equipment serving single rooms may be installed within the room that they serve. Exhaust fans must be located as close to the outside air louvers or gratings as practical.

**Fans**

Supply and exhaust air fans for HVAC duty must be the centrifugal type and may be either direct-drive or belt-drive to suit the required duty. Vane axial fans, either direct-drive or belt-drive to suit the required duty, may be used for fan systems with airflow capacities of 2,000 cfm and above.

Fans must have a minimum total pressure efficiency of 65 percent. The pressure, at duty point, of fans used with substation and traction substation ventilation systems must be no more than 60 percent of the cut-off pressure for stable fan operation.
Fans associated with smoke purge systems must be direct-drive, vane axial type, able to operate while handling hot gasses at a temperature of 482°F (250°C) for a minimum of one hour.

**Ductwork and Fittings**

Galvanized sheet-metal ductwork must conform to ASTM A653, with zinc-coating thickness rating G90, and be mill-phosphatized and mill-stamped. Stainless-steel sheet-metal ductwork must be corrosion resistant ANSI/AISI Type 316.

The ductwork fabrication must conform to SMACNA construction standards for the pressure classification specified for each system.

Discharge-side ductwork for air-handling units must be constructed for pressure class (inches) equal to the external static pressure of the unit. Suction-side ductwork for air-handling units must be constructed for pressure class (inches) equal to the design suction static pressure of the unit.

Ductwork for supply and exhaust and return fan systems must be constructed for pressure class (inches) equal to the design external static pressure of the supply fan and equal to the design suction static pressure of the exhaust and return fan. Ductwork associated with reversible fans must be braced and reinforced to withstand positive and negative pressure.

Ductwork used for smoke removal must be two-hour fire-rated, galvanized steel and constructed in conformance with SMACNA standards for the system static pressures (as scheduled) and for seal class A/leakage class 6 (downstream of the fan).

All ductwork must have a minimum pressure class of 2 inches.

Elbows must have a minimum full centerline radius at least 1.5 times the width of the duct.

Where full radius curves are not feasible, elbows must be provided with turning vanes. Turning vanes must be the double-radius type.

**Access Doors**

Ducts and plenums must have access doors to service fans, dampers, turning vanes, etc. Access doors to plenums must be hinged and furnished with latches operable from both inside and outside; door edges must rest against silicone gaskets to form an airtight enclosure. Duct access doors must rest against silicone gaskets and be hinged or fastened by toggle tabs or wing nuts. Access doors in insulated ducts and plenums must be insulated using sheet-metal insulation construction.

**Flexible Duct Connectors**

Flexible duct connectors must be used on all fan connections to ductwork. The length of each joint must adequately accommodate both horizontal and vertical deflections of the fan units. The length of flexible material must not be less than 4 inches.

Flexible duct connectors for tunnel ventilation and station emergency exhaust fans must be capable of withstanding an air temperature of 482°F (250°C) for one hour.
Dampers

**Volume Dampers.** All branch ducts must have adjustable, opposed-blade volume dampers. Volume dampers must be equipped with locking quadrants with blades sufficiently stiffened at the edges to effectively close off the duct. Under all conditions of operation, volume dampers must be free from vibration.

**Splitter Dampers.** Splitter dampers must be used in multiple duct fittings for initial balancing in place of individual opposed-blade volume dampers in each branch of the multiple duct fitting. Splitters must be adjustable through locking quadrants and be single bladed; the blades must have edges sufficiently stiffened to avoid vibration under all conditions of operation.

**Backdraft and Relief Dampers.** Exhaust fans must have backdraft or motorized shutoff dampers where more than a single-fan discharges into a common exhaust. Weighted relief dampers must be used in exhaust ducts and openings where a positive pressure is required to be maintained by a forced air supply and relief exhaust. All backdraft and relief dampers must be the multi-bladed gravity-type with neoprene cushioning on blade edges.

**Air Extractors.** Air extractors must be used in branch duct connections and for registers and diffusers where the space to install multi-bladed volume dampers is inadequate. All air extractors must be the movable-blade, pivoted-type.

**Fire Dampers, Smoke Dampers, and Combination Fire/Smoke Dampers.** Fire/smoke dampers must conform to NFPA 90A. Fire/smoke dampers must be UL 555- or UL 555S-listed, or both, and installed for fire- and smoke-rated separation. Dampers must be made of galvanized steel and capable of returning to a predetermined position (open or closed) upon power or actuator failure. The damper must be fire-rated at two hours, and all related components exposed to the ventilation airflow must operate in an ambient atmosphere of 482°F (250°C) for a period of one hour.

Insulation

Insulation must be provided for:

- All supply ductwork for systems providing tempered or conditioned air—from outdoor air intake to room air supply inlets, including all casings, apparatus, sheet-metal plenum chambers, bypasses, and mixing boxes, including necks of supply air outlets

- All return ductwork for systems providing tempered or conditioned air

In each case, fiberglass insulation must be used. The insulation on indoor ductwork must be composite insulation with a metal jacket or a Kraft facing. The adhesive used to adhere a jacket or facing to the insulation must meet fire and smoke hazard ratings when tested in conformance with ASTM E84, NFPA 255, and UL 723. In addition to meeting these ratings, the adhesive must not exceed a flame spread of 25, a fuel contribution of 50, and a smoke development of 50. Accessories such as adhesives, mastics, cements, tapes, and cloths for fittings must meet similar component ratings.

Supply and return air ductwork within air-conditioned spaces and acoustically lined ductwork do not need to be insulated.

Acoustical liners may be used instead of attenuators for supply and return and exhaust ductwork for the first and last 25 feet of the duct.
Filters

Prefilters will be the synthetic media, disposable flat panel type and will be MERV 1, with a minimum efficiency value of 20 percent (E3) when tested in conformance with ASHRAE Standard 52.2.

Final filters must be the synthetic media, disposable deep-pleated type and must be MERV 9, with a minimum efficiency value of 85 percent (E3) and 50 percent (E2) when tested in conformance with ASHRAE Standard 52.2. Filters must have a maximum face velocity of 500 fpm or less, and a maximum combined (dirty) pressure drop of a 1.5-inch water gauge. Sensors will be provided to measure the pressure across the filter and determine whether dirt has affected the performance of the filter. Unless stated otherwise, the term filter in this section will include the requirement for prefilter and final filter combinations, complete with differential pressure switch for local and remote indication of high (dirty filter) pressure drop. All filter media will be UL Class 1.

Registers and Grilles

Supply air terminals for use in non-public areas must be double-deflection registers. Base their selection on the required throw and noise requirements for each space.

All registers must be provided with adjustable and double-deflection louvers and spin taps or opposed-blade adjustment volume dampers. All ceiling diffusers will be the square, rectangular, circular, or linear type. They must have adjustable throw, opposed-blade adjustable-volume dampers and adjustable air extractors. Close coordination with the architectural and lighting designs will be required.

Exhaust or return air terminals in non-public areas must be fixed-blade registers. Base their selection on the required pressure drop and noise requirements for each space.

All exhaust and return air grilles must be equipped with fixed, non-see-through blades or louvers, or the duct behind them must be painted matte black. All grilles must be equipped with opposed-blade, adjustable-volume dampers key-operated through the face.

Refrigeration Equipment

Base the selection of system refrigerant and chiller type on lifecycle cost analyses.

Packaged refrigeration equipment must employ refrigerant R22; however, for systems that employ long pipe runs to remote condensers, careful consideration must be given to the maximum concentration of refrigerant that can build up in a space because of refrigerant leakage. If the buildup is found to be in excess of OSHA guidelines, alternative (commercially available) refrigerants must be used. R134a may be used as a replacement for systems designed to operate with R22.

Equipment Foundations

All floor-mounted equipment must be placed on reinforced-concrete housekeeping pads that are at least 4 inches in height. Pits must meet the equipment requirements. All fluid tanks must be double-wall, above-ground insulated, as required for the stored fluids.
Vibration Isolation

All vibration-producing equipment must be isolated from the structure by spring or rubber-in-shear vibration isolators. All piping and ducts attached to rotating and oscillating equipment must be isolated from such equipment by flexible connections.

Seismic Restraint

The following systems must be designed in conformance with the seismic provisions of the CBC:

♦ Systems used for smoke purge and smoke control
♦ Systems used for ventilation of tunnel ventilation fan substations
♦ Systems required for the operation of fire protection/fire detection systems
♦ Systems related to fire-life safety, including pumps, equipment, controls, major conduit, and piping
♦ Systems designed using an importance factor of 1.5

Non-essential mechanical systems in conformance with the seismic provisions of the CBC may be designed using an importance factor of 1.0.

Equipment Access and Handling

Requirements for equipment handling and installation must conform to subsection Equipment Access and Handling.

16.2.7 HVAC Design Requirements

Velocities for Air-distribution Systems

Design velocities must provide the required system performance and minimize pressure loss and energy consumption, airborne noise generation, drafts, and the intake of dust particles. Design velocities must not exceed the maximum values specified in section 16.2.2.

Pressure Losses

The static pressure differential across supply or return air terminals must not exceed a 0.25-inch water gauge when the system is operating at full capacity. The static pressure drop across the grille or register must not exceed a 0.6-inch water gauge when the system is operating at full capacity.

Pressure loss must be calculated in conformance with the ASHRAE Handbook - Fundamentals. Duct sizes must have an equal pressure drop.

Energy Conservation

The HVAC system design must conform the requirements established by the California Energy Code and ASHRAE Standard 90.1 for energy conservation.
Air-side economizer cycles must be incorporated into the air-handling system where required by the California Energy Code.

16.3 Plumbing

16.3.1 Functional Requirements

Plumbing systems must convey potable water from municipal water main consumption and service points to DTX facilities including the Fourth and Townsend Street Station and ventilation and egress structures. The plumbing system must collect and convey sewage from service areas to the public sewer system.

Plumbing systems must conform to the CBC and the San Francisco Plumbing Code.

Potable Cold Water Systems

The domestic water services must be sized to accommodate peak demand (plumbing fixtures, service, and makeup) and an additional 10 percent for future requirements. Each domestic water service must have a main shutoff valve, a meter, and a backflow preventer. Remote meter reading facilities must be provided. Base the minimum service requirements for plumbing fixtures on fixture unit values. The service requirements of outlets such as makeup water and hose bibbs must be estimated separately and added to plumbing fixture requirements as a fixed value in gallons per minute to determine the required total service connection capacity.

Water service, meters, and backflow prevention devices must conform to San Francisco Public Utilities Commission regulations. Fire services and domestic water services must connect separately to the municipal mains.

Pressure-reducing valves must be provided at low sections of the system to limit the water supply pressure to fixtures to 60 psi.

Base the sizing of the domestic water distribution lines on maintaining uniform pressure at all plumbing fixtures located on the same level, minimizing shock and water hammer, and maintaining a minimum pressure of 30 psi at each flush valve. All pipelines must be run in a systematic manner; pipelines may run either parallel or at right angles with walls and must be properly pitched for drainage. Long pipe runs, flush valve branches, and quick-closing valves must have water hammer arresters.

Isolation valves must be provided in branch lines and for each floor level to facilitate maintenance. Pressure-reducing valves and backflow preventers must be provided where automatic makeup for HVAC equipment is connected to the potable water system. Cold water piping must be insulated to prevent condensation.

Potable Hot Water Systems

Potable hot water systems consist of water heaters, hot water distribution piping, and pipe accessories. Hot water circulating piping and circulating pumps must be provided where the developed length of hot water piping from the water heaters exceeds 50 feet. Electric temperature maintenance may be used instead of return circulation. All hot water pipes must be sized for the simultaneous fixture demand; pipes serving more than a single fixture must have a minimum pipe diameter of 0.75 inch. All pipes must be arranged in a
systematic manner, and provisions made for thermal expansion and drainage. All hot water piping must
be insulated. Isolation valves must be provided for all branches to facilitate maintenance.

In general, use of local point-of-use electric water heaters is encouraged for remotely located fixtures having
small demand. Electric point-of-use domestic water heaters must be of the storage or tankless type. They
must be glass-lined with fast-acting immersion heating elements. Heaters must be equipped complete with
temperature and safety controls and thermal insulation. Water heaters must be properly sized for the demand
on the plumbing fixtures they serve; water heaters must be UL-listed and bear the ASME stamp.

Soil and Waste Systems

Soil and waste systems consist of soil and waste piping from all plumbing fixtures and floor drains (except for
drains carrying clear water waste), sewage ejector stations, and ejector discharge piping. Sewage ejectors,
where required, must be the submersible non-clog type. Submersible grinder pumps must be used in caverns
where high discharge heads are required. Where practical, soil and waste lines must function by gravity flow.
Sewage ejector stations must be installed where gravity outfalls cannot be provided. Base the size of all soil
and waste pipes on fixture unit values. For continuous or intermittent flow into drains, such as flows from
a pump, a fixture unit value of 2 must be assigned for each gallon per minute of flow at rated capacity.
Connection to the City sewers must conform to the City plumbing code.
Piping installed underground or embedded in structure must not be less than 2 inches in diameter.

Sewage ejector systems must consist of a wet well with non-clog, submersible, wet-well centrifugal pumps.
Water level controls, electric pump on-off automatic switches, pump trouble, and high-water alarms must
annunciate to the CCF. Pumps must be sized for 100 percent of the sanitary flow rate. The pump head must
suit static and friction head of installation, and the pump motors must be non-overloading throughout the
entire pump curve without employing the service factor.

Vent Systems

All soil and waste systems must have complete vent systems, sized in conformance with the CBC. All
horizontal vent pipes must be kept as short as possible and pitched at 0.25 inch per foot toward the
soil and waste pipes served. Vertical risers to the outside must be accomplished in the most direct way.

Compressed Air System

A compressed air system for the emergency ventilation system must be provided, including a 150-psi
duplex air-compressor plant piped to all pneumatic dampers. Duplex rotary screw air-compressors, receiver,
prefilters and final filters, and desiccant dryers must be installed in the mechanical room. Piping must be run
to all air actuators and be properly sized to handle air loads expected at each damper. Piping must conform
to applicable plumbing codes and ordinances. Drains must be provided at all low points in the piping system.

16.3.2 Piping Systems

All piping systems fittings, flanges, valves, and accessories must conform to all applicable sections
of the CBC.
Piping

The appearance of all piping systems must be neat. All pipes must be properly sloped for drainage and venting, supported, guided, and anchored to provide complete flexibility. Piping systems must maintain the integrity of all systems without any damage or leaks during extremes of operating conditions. Piping must be accessible. Piping must not be embedded in concrete structures unless embedment is unavoidable because of architectural or structural requirements. Embedded piping must be provided with adequate clean-outs or access points. All valves and accessories must be accessible for operation without the use of chains or additional operating platforms. Sleeves must be provided wherever pipes pass through structures, and escutcheons must be provided in finished areas.

Pipe and Fittings

Exposed (non-embedded) sanitary, vent, and storm piping measuring 6 inches in diameter and smaller must be no-hub or hub-and-spigot cast iron. Exposed sanitary, vent, and storm piping larger than 6 inches must be service weight cast iron with bell-and-spigot joints and caulked or compression type gaskets. As an alternate, exposed storm piping 6 inches and larger may be Schedule 40 galvanized steel pipe with threaded or grooved couplings. Sanitary, vent, and storm piping installed in ground or embedded in structure must be of extra heavy cast iron with bell-and-spigot joints with compression gaskets.

Use ductile iron piping for pipes larger than 15 inches.

Cold water piping installed in ground or embedded in structure must be annealed copper tubing Type K. All other hot- and cold-water piping must be hard drawn copper tubing Type L with wrought brass or copper fittings. Copper tubing must conform to ASTM B 88.

Water service piping must be cement-lined ductile iron with mechanical joint fittings with retainer glands.

Force mains installed in ground or embedded in structure must be cement-lined ductile iron pipe with mechanical joint fittings with retainer glands.

Dielectric couplings must be provided to connect pipes of dissimilar metals.

Piping Accessories

Piping accessories must include strainers, vent cocks, dirt and drip legs with drain and flush connections, liquid flow indicators, vacuum breakers, backflow preventers, pressure-reducing valves, shock absorbers, water-hammer arresters, balancing cocks, relief valves, isolation valves, and pressure and temperature gauges. All piping accessories must be sufficiently sized to ensure trouble-free balancing, control, access, and the operation of all piping systems.

Piping accessories requiring maintenance or replacement must be placed in accessible locations. The dials of gauges and indicators must show English units of measure or measurements in both English units and International System of Units. Gauges and indicators must be sufficiently sized and arranged to be easily seen and read.

Piping expansion joints must provide for not less than 150 percent of the calculated transverse movements. All valves must be tagged and charted.
Unions or flanges must be provided on both the inlet and outlet sides of all apparatus, isolation valves, control valves, and accessories to facilitate easy removal for servicing.

Wherever two pipes made of dissimilar metals are connected, a dielectric union must isolate one pipe from the other.

**Valves**

Isolation valves must be provided on both sides of chillers, pumps, heating coils, cooling coils, control valves, multiple installations, and piping branches. Valve installations must be neat and provide easy groupings, with all parts accessible for operation and maintenance. Valve stems must be horizontal wherever possible.

**Pipe Supports, Hangers, Guides and Anchors**

The design of pipe supports, hangers, guides, and anchors must ensure proper alignment of all pipes for operating conditions. Consider the forces caused by the weight and motion of the fluid, water hammer forces, the weights of piping, valves and insulation, and thermal expansion and contraction in the design, as appropriate.

All hangers and supports must be arranged to prevent the transmission of vibrations from the piping to the structure. Anchors and guides must allow pipes to expand and contract without a build-up of excessive stress. Spring hangers must be used when piping is connected to vibrating equipment and where supporting vertical pipes.

**Pumps**

Pump type must be centrifugal, single, or double suction base-mounted, or inline. Pumps must be arranged so that they can be serviced without removing the piping system, including disconnecting piping from the pumps. Pumps must conform to the following:

- Maximum pump speed: 1,800 revolutions per minute
- Operating efficiency at design flow rate: Within 5% of maximum efficiency
- Motor sizing criteria: Non-overloading throughout full range of pump curve, without using the 15% motor service factor

Constant flow water pumps must be used when the pump motor is less than 18.6 kilowatts.

**Insulation and Freeze Protection**

All water piping, including cold water piping, hot water piping, water piping subject to freezing temperatures, and horizontal storm lines and portions of drainage lines subject to sweating must be insulated. Water piping subject to freezing temperatures must be electrically heat traced.

Exposed water pipe in tunnel and emergency exit areas must be protected with a metal jacket.

Cellular glass with jacket insulation must be used. Insulation and accessories must conform to the fire and smoke hazard ratings of the following testing procedures: ASTM E 84, NFPA 255 and UL 723. In addition,
insulation and accessories must not exceed a flame spread of 25, a fuel contribution of 50, and a smoke development of 50.

**Water Treatment**

Chemicals, service, and equipment must be provided for chilled water, condensing water, and hot water systems.

**Corrosion Control**

See CHAPTER 20, Stray Current and Corrosion Control, for requirements for the protection of buried pipe and fittings from corrosion.

**16.3.3 Plumbing Fixtures**

The location and type of plumbing fixtures must be fully coordinated with the architectural requirements. Fixtures intended for use by the disabled must conform to the CBC, City plumbing code, and Americans with Disabilities Act accessibility guidelines. Plumbing fixtures must be of the water saver type. Fixtures in toilet rooms must have electronic flushing and water supply devices.

Battery rooms and any other areas where corrosive materials are handled or stored must have emergency eye wash and body spray facilities. Hose bibbs must be provided at platform levels to facilitate cleaning operations.

**Fixtures**

Fixtures must conform to the following requirements:

- Water closets will be wall-hung, of the siphon-jet, elongated-bowl type, and provided with an automatic flush valve.

- Urinals will be wall hung, of the siphon-jet type, and provided with a flush valve.

- Lavatories will be wall hung.

- All wall-hung fixtures will be supported by standard chair supports.

- Service sinks will be of stainless-steel or monolithic precast terrazzo equipped with a stainless-steel rim guard. Service sinks in battery rooms will be acid-resistant and supplied with a wall hanger, rim guard, and trap standard.

- All supplies to fixtures will have key-operated service valves.
Service piping connections for plumbing fixtures must conform to the specifications in Table 16-3.

Table 16-3: Plumbing Fixture Schedule

<table>
<thead>
<tr>
<th>Fixture</th>
<th>Symbol</th>
<th>Soil or Waste</th>
<th>Trap</th>
<th>Vent</th>
<th>Hot Water</th>
<th>Cold Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Closet</td>
<td>WC</td>
<td>4 in.</td>
<td>Integral</td>
<td>2 in.</td>
<td>No</td>
<td>1.25 in.</td>
</tr>
<tr>
<td>Urinal</td>
<td>UR</td>
<td>2 in.</td>
<td>Integral</td>
<td>1.5 in.</td>
<td>No</td>
<td>1 in.</td>
</tr>
<tr>
<td>Lavatory</td>
<td>LAV</td>
<td>1.5 in.</td>
<td>1.25 in. x 1.25 in.</td>
<td>1.5 in.</td>
<td>0.5 in.</td>
<td>0.5 in.</td>
</tr>
<tr>
<td>Service Sink</td>
<td>SS</td>
<td>3 in.</td>
<td>3 in.</td>
<td>1.5 in.</td>
<td>0.75 in.</td>
<td>0.75 in.</td>
</tr>
<tr>
<td>Mop Sink</td>
<td>MS</td>
<td>3 in.</td>
<td>3 in.</td>
<td>1.5 in.</td>
<td>0.75 in.</td>
<td>0.75 in.</td>
</tr>
<tr>
<td>Eye Wash Station</td>
<td>EW</td>
<td>1.5 in.</td>
<td>1.25 in. x 1.25 in.</td>
<td>1.5 in.</td>
<td>0.5 in. tepid</td>
<td></td>
</tr>
</tbody>
</table>

16.4 Drainage Systems

The DTX tunnel, Fourth and Townsend Street Station, and ventilation and egress structures must have a drainage system to collect, convey, and remove groundwater seepage, stormwater runoff, and discharge from fire protection systems. Miscellaneous mechanical and staff rooms in the Fourth and Townsend Street Station and ventilation structures must have floor and area drains. The drainage system must convey drainage to the City sewer system.

16.4.1 Tunnel Drainage Systems

A below-track drainage system must be provided in the tunnel and U-Wall to convey water to City sewers and prevent flooding of the tunnel. Interceptor drains must be installed between the southern limit of the U-wall and tunnel portal to collect and convey rainwater to a sump at Fourth and Townsend Street Station. The system’s design must also prevent water from topping the track plinth when the under-platform deluge or other fire suppression system has been activated. The drainage system design must conform to the City plumbing code.

The track drainage system must consist of inlet drains, interconnecting piping, sump pits, sump pumps, and discharge piping to the street sewer connections.

In the Fourth and Townsend Street Station, the drainage system must accommodate inflow from two fire hose streams from the platform standpipe system, drainage (seepage through structure walls, etc.), and one under-car water spray protection system zone.

The drainage system must be capable of preventing tunnel fire standpipe system discharge (during tunnel fire events or standpipe testing). The drainage system must be designed to collect, convey, and remove infiltrated water resulting from the seepage of water into the tunnel (see Table 12-5 and Table 13-1).

Track drainage must follow the requirements of NFPA 502 section 12.10 and the following additional requirements:

- Tunnel track drainage system must effectively collect and remove water from the tunnel resulting from condensation, groundwater leakage, rain entering the tunnel, spilled water, fire-fighting activities, cleaning, and other sources.
Runoff from outside the tunnels must be prevented from entering the tunnel.

Drainage for tunnel track section must be accommodated in a trough with cover or pipe in the center of the trackway tunnel slab based on a gravity drainage system.

Critical facilities, such as traction electrification system, automatic train control, communications, portal sites and facilities, vent structures, traction power supply sites, operations control centers, etc., must be designed so that the finish floor elevation or top of slab foundation of these facilities are a minimum of 2 feet above the 100-year floodplain.

Inlets and Piping

Drain inlets must connect to main drain lines below the track slab. According to the California High-Speed Rail Authority Design Criteria Manual, the minimum diameter of the track drainage system must be 12 inches. The slope of the main drain lines must match the slope of the track profile and be sized to produce a minimum velocity of 2.5 fps with the pipe flowing half full. Minimum slopes must comply with the specifications showing in Table 16-4.

Table 16-4. Minimum Slope Specifications

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Minimum Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 inches</td>
<td>2.0% or 0.25 in. per foot</td>
</tr>
<tr>
<td>6 inches</td>
<td>1.0% or 0.125 in. per foot</td>
</tr>
<tr>
<td>8 inches</td>
<td>0.65%</td>
</tr>
</tbody>
</table>

If used for main track drains, fiberglass piping must not be exposed in its installed position. Suitable adapter fittings must be provided for connections between different pipe materials.

Sump Pits

Sump pits must be located at appropriate points along the trackway.

Sump pits must be provided with oil and grease separators and sand traps for extraction of oil, grease, sand, and other substances that are harmful or hazardous to the structure or public drainage systems. All separators and traps must have sufficient capacity to retain all sludge between cleanings.

Pump Stations

Drainage pump stations must be provided at the Fourth and Townsend Street Station, tunnel low points, and elsewhere, as deemed necessary by design. The pump stations consist of a wet well with three submersible pumps, water-level controls, electric pump on-off automatic switches, alternator, pump trouble, and high-water alarm annunciation to the CCF, and connections to City sewers. Each pump must have a pumping capacity of one-half of the station drainage volume. The third pump must be considered a standby. Pump head will suit static and friction head of installation. Pumps must be connected to the emergency power source.

Each pump must have a guide rail system, complete with discharge base elbows, sealing flange, guide rails, brackets, and lifting chain/cable.
16.4.2 Floor and Area Drains

All floor and area drains must be the bottom-outlet type, where possible. Where space is not adequate to use bottom-outlet drains, drains with side outlets may be substituted. Floor drains in public areas must be finished in nickel-bronze or stainless-steel; the finish will be determined by floor material and coordinated with architectural requirements. Floor drain gratings in public spaces must be fastened with vandal-proof screws.

Provide floor drains in mechanical rooms, toilet rooms containing two or more water closets (or a combination of one water closet and one urinal), under-platform areas, and battery rooms at the emergency eye-wash/shower unit.

Provide area or scupper drains at station entrance areas and in vent shafts.

Depressions in slabs, as required for escalator and elevator pits, must also contain drains. Where possible, drains must be connected by gravity to the track drainage system. Where gravity drainage is not possible, provide sump pits with sump pumps or dry sumps (depressed slab for portable sump pump).

Traps

Traps must be of plain pattern and have a seal of not less than 2.5 inches and not greater than 4 inches. Traps must be of the same material as the piping to which they are connected. All exposed traps in toilet rooms must have a chromium finish. Provide deep-seal traps where floor drains are not used frequently.

Cleanouts

Provide cleanouts on all soil, waste, and drain lines as follows: at 50-foot intervals, at changes of direction greater than 45 degrees, and at the base of each stack and leader.

All cleanouts brought to finished floors must terminate with removable covers flush with the floor. Cover material and finish must complement the floor finish.

Cleanouts for pipes 4 inches and smaller must be the same size as the pipe served. Cleanouts for pipes larger than 4 inches must be not less than 4 inches or one-half of the size of the pipe served.

Avoid, where possible, floor cleanouts in public areas.
CHAPTER 17 ELECTRICAL SYSTEMS

SCOPE

This chapter establishes the requirements for electrical systems for the Downtown Rail Extension (DTX) facilities, including the tunnel, Fourth and Townsend Street Station, Transit Center train box fit-out, ventilation and emergency egress structures, and related ancillary facilities.

Electrical systems comprise power distribution, unit substations, and secondary (low voltage) distribution equipment for tunnel and facility lighting and power; power for tunnel ventilation, HVAC, drainage, communications systems, safety and security systems, and associated raceways, conduits and wiring; and interfaces of the DTX electrical system with other rail systems.

The electrical design requirements must be coordinated with other chapters of this manual as follows:

♦ Chapter 3: System Safety and Security
♦ Chapter 15: Fire-Life Safety
♦ Chapter 16: Mechanical Systems
♦ Chapter 18: Rail Systems
♦ Chapter 19: Communications

CODES, STANDARDS AND GUIDELINES

Electrical systems design for the DTX must conform to the latest versions of the following codes, standards and guidelines unless otherwise specified in these criteria:

♦ American National Standards Institute (ANSI)
♦ American Society of Industrial Security
♦ ASTM International standard – ASTM B3, Standard Specification for Soft or Annealed Copper Wire
♦ California Building Code (CBC)
♦ California Code of Regulations (CCR)
♦ California Electrical Code (CEC)
♦ Code of Federal Regulations (CFR), Title 47, Telecommunication
♦ Electronic Industries Association (EIA)
♦ Federal Communications Commission (FCC)
♦ Illuminating Engineering Society (IES)
♦ Institute of Electrical and Electronic Engineers (IEEE)
  ● IEEE 446, Standard for Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications
  ● IEEE 1202, Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies
17.1 General Requirements

The more restrictive requirements of these codes governs the design. Where no provisions are included in these governing codes for specific design features or requirements, follow best industry practice.

The design may require integration of the DTX electrical systems into existing Caltrain systems in cases where common operation is required, such as the interface of the Fourth and Townsend Street Station and the existing Caltrain station at 4th and King streets and within the Transit Center.

All work must generally, as applicable, and where not in conflict with the requirements in this design criteria, conform to the Caltrain Engineering Standards where DTX systems are derived from or interface with Caltrain systems.

17.1.1 Power Supply

For reliability, the power supply to DTX facilities must be from two independent feeders from the electric utility. In addition to the dual power feeds, a standby emergency generator must be provided.

17.1.2 Utilization Voltage

The voltage rating of power equipment and motors must be as follows:

- Closed-circuit television (CCTV) cameras: 120 V, single phase
- Communications equipment: 120 V, single phase
- Convenience outlets: 120 V, single phase
- Exit signs: 277 V, single phase
- Vending machines: 120 V, single phase
- Heaters to 2900 watts: 120 V, single phase
- Heaters 2901 to 5500 watts: 208 V, single phase
Heaters 5.5 kilowatts and up: 480 V, three phase
Lighting fixture, LED and fluorescent types: 277 V, single phase
Lighting fixture, incandescent fixtures or compact fixtures: 120 V or lower, single phase
Motor controls: 120 V, single phase
Motors smaller than 373 watts: 120 V, single phase
Motors 373 watts and up to 74.6 kilowatts: 480 V, three phase
Motors, larger than 74.6 kilowatts: 4160 V, three phase
Station signage: 277 V, single phase
Special power outlets: as required

Alternate voltage levels may be used where practical and safe for the equipment.

17.1.3 Medium Voltage Feeders

For loads 50 kVA and higher with feeder lengths of 1,500 feet or longer, an evaluation must be performed to determine the more cost-effective system voltage between 4,160 V and 480 V.

17.1.4 Motor Control

Combination starters or manual starters must be provided for motors larger than 373 watts. Full voltage across-the-line starters must be used.

Manual motor starters must be NEMA size M-1 and may be used where local control is manual.

Grouped motor control centers must be used where two or more motors are in proximity, and starters are not furnished with the equipment.

Reduced voltage starters or “soft starters” must be used for motors 37,300 watts or greater on 480 V three-phase systems

17.1.5 Enclosures

Equipment enclosures must be of a NEMA classification suitable for the environment to which the equipment is exposed. NEMA 1 galvanized enclosures are for interior use only in dry, ventilated room temperature locations only. Where NEMA 4 watertight enclosures are required, bolt-down covers must not prevent access to the equipment. NEMA 4X (stainless steel grade 316) enclosures must be used in tunnel locations and areas exposed to rain or water and wind-borne particulate dust/carbon debris.

17.1.6 Wiring Methods

Wiring must be in conduits or ducts. Cable trays may be used only in areas approved by the TJPA.
17.1.7  **Wire and Cable Pulling**

Pulling calculations must take into account wire and conduit type, the number of 90-degree bends, and the change in elevation between pull points. The maximum number of bends allowed in any one conduit run must be as specified in the NEC.

17.1.8  **Cables**

Insulated cables must be appropriate for the voltage level, and readily available sizes must be used throughout the DTX. The number and size of cables in a particular circuit must be determined to provide adequate capacity, acceptable voltage drop, and system fault level.

17.1.9  **Seismic Design**

The design of equipment, equipment anchors, components, piping, raceways, and devices must conform to the criteria in Chapter 10, subsection 10.8, Non-structural Components.

17.1.10  **Safety and Security Considerations**

Building and equipment grounding must conform to the NEC. Solidly grounded systems, or low-resistance grounded medium voltage systems, must be used at distribution and utilization voltage levels. Additionally, where applicable, grounding provisions must follow the recommendations of NACE Standard RP0177-95, Standard Recommended Practice, Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems.

Heavy-duty disconnect switches (with appropriate NEMA enclosure type) must be provided where required by the NEC as a means to disconnect equipment from its feeder when equipment is not within the sight of either the feeder breaker or motor controller, as safety a switch for transformer primary side de-energization or where advantageous to separate feeder from electric loads to be supplied by others.

Overcurrent protection elements that are (a) designed to protect conductors serving emergency equipment motors (e.g., fans, dampers, pumps), emergency lighting, and communications equipment and (b) located in spaces other than the main distribution system equipment rooms must not depend on thermal properties for operation.

Electrical equipment and wiring materials and installations within stations and ventilation structures must conform to the requirements of NFPA 130, sections 5.4 and 7.7, respectively.

Equipment, raceways, and conductors in smoke exhaust plenums must be either rated or de-rated for operation at the expected elevated temperatures.

Conductors and cables interconnecting equipment, cabinets, or both, must be enclosed in conduits or raceways.

Battery rooms and rooms where batteries are charged must be ventilated. Lead-acid battery chargers must be interlocked with the mechanical ventilation to prevent charging without ventilation. The electrical system for the battery room and mechanical ventilation systems must conform to NFPA 70. Battery rooms must have hydrogen detection systems for worker safety and gas leak event notification.
The lighting systems design must provide the intended quality, visual comfort, and quantity of light for the individual areas. Lighting must be arranged so that any single unit failure does not leave an area in total darkness. Battery fixtures (where used) must have a minimum 90 run time capacity in conformance to NFPA 101 section (101) 7.9.2.1. Lighting fixtures must be accessible for inspection and maintenance.

17.2 DTX Power Supply and Distribution System

Each DTX facility must be served by two sources of power designated as primary priority and secondary priority feeds. One utility service must serve as the primary priority feed. The secondary priority feed must be a second independent utility service. A standby generator must also be provided for emergency use if both utility feeds are out of service. The design and function of the DTX traction power supply and distribution system must conform to Chapter 18, Rail Systems.

Alternative arrangements satisfying these criteria may be submitted for the TJPA’s review and acceptance.

17.2.1 Electrical Service

Normal Power

Incoming electrical metering, service disconnects, and transformation and distribution equipment switches must be of sufficient capacity to accommodate normal power loads and power provisions for tenancy spaces. The normal power (non-essential) loads include the following:

- Lighting on platforms, cross passages, stairs, support spaces, and mechanical and electrical rooms
- Escalators and elevators
- HVAC systems: ventilation systems (fans) that are not used for life-safety purposes and air conditioning equipment (chillers and related pumps)
- Miscellaneous loads: convenience receptacles, hot water heaters, ticket vending machines, visual information systems
- Tenant space provisions

17.2.2 Emergency Power

Equipment and systems serving life-safety and other critical operations must be considered essential loads. Emergency power sources must be provided to power all essential loads, which include the following:

- All egress and exit lighting, including exit stairwells, escalator comb and newel lighting, and emergency lighting for support spaces and mechanical and electrical rooms
- Vertical circulation systems: elevator machine rooms and elevators, including elevator cab lighting where used for firefighting, and selected escalators
- HVAC systems: ventilation systems (fans) which are used for life safety purposes (e.g., smoke exhaust and stair pressurization fans)
- Other loads: sprinkler system compressors, fire alarm system, public address system, security systems, CCTV system, blue light stations, heat tracing, elevator pit sump pumps, effluent pumps, and elevator cab lighting
Fire pumps
Tunnel ventilation fans and dampers, stair pressurization fans, track isolation dampers, and mechanical controls
Alternating current and direct current switchgear controls

Emergency power system design must also conform to the following requirements:

- Lighting must be fully functional within less than 10 seconds of a normal power outage event.
- Unit substations, transformers, and switchgear rooms must have a minimum of 50 percent of the lighting available from the emergency system.
- During power failures, emergency power must be available for a minimum of 90 minutes at each station for safety-critical functions, in conformance to NFPA 101.
- Emergency power system design must conform to IEEE 446, Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications, and NFPA 130.
- Wires and cables for emergency power and circuits must be run in separate raceways, independent of other electrical loads.
- An emergency bus must be provided to supply power to emergency loads in the event of power failure from the utility. The design of the emergency power supply system must consider the proximity of facilities within a common site, such that only one diesel-generator set is used to supply the emergency loads in all the facilities within a site.
- Emergency life-safety electrical loads must be located in designated life-safety power panels. Only life-safety loads (egress lighting, exit signs) may be located in life-safety or emergency-use power panels.
- Space must be provided for wayside cabinets to onboard communication systems and repeaters (if required).

Emergency Generators

Emergency generators must conform to the following requirements:

- Emergency generators to provide power to emergency systems must be installed, tested, and maintained in conformance to NFPA 110.
- Generator fuel supply must allow 8-hour operation and monthly exercising for 30 minutes. Anticipated maintenance and fuel refill at 6-month intervals must be assumed.
- Provisions must be made to permit draining the fuel tank at the bottom of the tank. The generator fuel tank must be an integral part of the generator assembly and must be located to provide access for refueling trucks. Generator fuel tank must be of double-wall construction and include leak detection notification on an annunciator-type panel.
- Generators must be located at street level where possible. Generator room access doors must face the street, be large enough to allow the removal of the generator from the room and be lockable. The generator control panel must be accessible from the floor level, and control devices must be within reach without the need to use steps or ladders. Generator sets (genset), radiators, and motors must be manufactured in the United States and be from the same manufacturer. The minimum warranty must be one year after construction is completed.
Walk-in (enclosure) type generators must be rated to a wind load of 120 mph. The roof load must be equal to 40 psf. Distributed floor load must be 200 psf. An enclosure rain test must be equal to 4 in/h. Seismic design must assume walk-in generators are essential facilities.

The roof must incorporate a positive camber and comprise mill-finish, extruded 6036-T6 aluminum perimeter channel or roof rail with 16 gage roll-formed galvanized cross members mechanically fastened to the roof rails. The roof must have total of 4 lift rings per side. The roof skin must be a nominal .04-inch-thick 3003-H16 or 3105-H14 mill-finish aluminum sheet and fastened to the roof rails and bows. The top skin must be rolled over the perimeter of the roof to provide additional weather protection. A weatherproof mastic sealant must be used at the perimeter as well as at any joints required.

Enclosure walls must be manufactured using mill prepainted .04-inch-thick 3004-H36 aluminum panels hard riveted to fabricated alumized steel Z-section wall posts located on 24-inch centers. The enclosure walls must incorporate an extruded structural “panel cap” of mill-finish, extruded 6063-T6 aluminum. The panel cap must interlock into the adjoining roof rail for a weatherproof structural connection between the roof and the sidewalls.

The floor structure for the enclosure must be rated for a minimum distributed load 200 psf and be reinforced, as required, to support prevailing point loading. The floor and underframe assembly must consist of rectangular steel tubing or structural I-beams welded to form the outer perimeter.

The perimeter must be combined with formed or structural steel crossmembers to create a welded steel support for the installed power generation equipment. A steel channel must be incorporated into the floor structure for adequate structural support and attachment of the generator set and vibration isolators. The cross members must be overlaid with a composite 0.72-inch-thick oriented strand board covered by 14-gage minimum diamond steel plate for load distribution.

A fuel tank must be installed beneath the floor and be listed as the primary containment above-ground tank for flammable and combustible liquids, in conformance to UL Standards and mounted within a combined rupture basin/floor/underframe. The interstitial space between the tank and the basin must be monitored (through electronic means) to indicate a rupture condition. Fuel tanks must be available as standard manual fill tanks (day tanks). All fuel tanks must include drainage and supply and return lines and fuel valve control. Fuel tanks must be outfitted with an electronic fuel monitoring system. The system must be programmable and digital. Output from the sender must be 4-20 mA and wired directly to the process meter. A local LED display must indicate the fuel level in gallons and indicate when the tank is full (FUEL FILL) and when the fuel level is low (LOW LEVEL). An independent float-operated contact must be supplied to indicate a rupture (leak) condition. Optional monitoring accessories (4-20 mA) must also be made available.

Commercial doors must be of 18-gage galvanized steel construction painted to match the enclosure exterior and incorporated into 16-gage painted galvanized steel frames that are structurally integrated into the enclosure wall. Door opener handles must be stainless steel.

Lift rings must be provided at the base of the tank perimeter for the purpose of lifting the complete enclosure with installed genset and empty fuel tank into place. The lift rings must be of 1.25-inch nominal steel plate and welded into the base perimeter at four locations.

Inlet and exhaust air handling equipment must be designed to maintain a combined total maximum static pressure drop 0.5 inch of water gage through the enclosure, including all air handling devices. Inlet air must be through a fixed or operable louver, weather hood, acoustic grid, or combination thereof, as specified, and provide the necessary level of attenuation. Inlet openings must be screened and sized to minimize entrance of debris and precipitation. Air discharged from the enclosure must be through gravity or motor-operated discharge dampers, weather hoods, acoustic...
grids, plenums, or a combination thereof, and provide the necessary level of attenuation. Discharge openings in fixed devices must be protected within the screen.

- Non-walk-in exterior generator enclosures must be equivalent (to the walk-in type described in this subsection) in enclosure-construction materials (roof and walls), fuel tanks, lift points, and air handling equipment.

### 17.2.3 Power Distribution

Normal and emergency power must be distributed to DTX facilities by means of dedicated independent distribution systems.

Normal and emergency power circuits must be physically separated (in separate power panels) to the maximum extent possible except in equipment rooms or where necessary to connect to common equipment.

Auto transfer switches must conform to NFPA 70, NFPA 110, and appropriate UL standards. The automatic transfer switches and bypass isolation automatic transfer switches must be designed, manufactured, and tested in conformance to the following:

- **Transfer switches (must)**
  - be designed to switch the load connection between two power sources.
  - include electrical and mechanical interlocks to prevent unintentional paralleling of the power sources.
  - be of double-throw construction and include power switches, circuit breakers, or both, in a fixed-mount configuration, with high-endurance characteristics capable of no-load and full-load interruptions equal to or exceeding UL standards endurance ratings.
  - include a mechanical coupling to facilitate completion of an open in-phase transition, such that any inrush current is equal to or less than normal starting current for inductive loads.
  - must include removable arc chutes, housed within an arc chamber constructed of high-dielectric high-strength material, that are mounted over each set of main contacts. Arc chutes must be constructed of metal plates and a baffle cover designed to extinguish an electrical arc and protect the main contacts. An insulating channel shield must be mounted above each power switch or circuit breaker to redirect flash from the arc chutes away from the enclosure front. A steel, dead-front panel must be mounted at the front of each power switch or circuit breaker to provide a physical barrier when the front door is open.
  - include pushbutton controls, mounted directly on the power switch or circuit breaker, to perform manual operation with an electrical load connected.
  - provide colored mechanical indication of main contact position (open or closed), mounted directly on the power switch or circuit breaker, for source 1 and source 2.
  - provide a colored mechanical indication of the charge state (charged, discharged), mounted directly on the power switch or circuit breaker, for source 1 and source 2.
  - be open transition and provide an in-phase monitor permitting an in-phase transition between two live sources that have a phase angle difference of +/- 8 degrees or less (no generator sources) and +/- 5 degrees or less (1-2 generator sources).
  - be of copper bus construction. A copper ground bus must be furnished firmly secured to the enclosure structure.
Generator docking stations/controls (must)
- conform to NFPA 70 and NFPA 110. The docking stations must be fully designed to accommodate input feeders of permanent and temporary generators. Life-safety circuit breakers must be in different compartment inside enclosure from standby service circuit breakers.
- be automatic and switch between generator (1) and generator (2) during a power failure.

Transfer switch main contacts must be of silver composition, electrically operated, and mechanically held in position. Inspection of the main contacts must be possible from the front of the transfer switch without major disassembly.

Power switches and circuit breakers must include an electrical operator with a reliable two-step stored energy mechanism to charge the closing springs. The closing springs must be capable of being charged electrically or manually. The closing of the main contacts must automatically charge the opening springs to ensure quick-break operation. After closing the main contacts, the closing springs must be capable of being recharged.

Control wires must be type SIS, and wire bundles must be secured to the assembly with nylon ties, pre-punched lances, or anchors. All current transformer secondary leads must first be connected to shorting terminal blocks with shorting screws. Control wires must be marked with an origin and destination over the entire length of the wire using a cured ink process to the maximum extent possible. Where ink marking is not possible, printed sleeve wire markers at each end of control wire must be provided.

Mechanical type lugs must be provided for all source 1, source 2, and load terminations suitable for copper or aluminum cable.

Front access to all power switch and circuit breaker secondary connection points must be provided for ease of troubleshooting and connection to external field connections.

Bus primary means of insulation and isolation must be by air gap. Minimal use of insulating material in addition to the air gap must be provided.

Feeders

Feeders must also conform to the following requirements:

- Normal and emergency feeders must be provided from service switchgear to distribution equipment located in electrical rooms. The number and location of these electrical rooms must be determined so that the loads served are located within reasonable distances. Feeder conductors must be copper only.

- Feeder lines must be equipped with load-interrupting switches with current limiting fuses, transformers, secondary circuit breakers, and 480 V switchgear with the required quantity of 480 V distribution panels for their associated connected loads.

- In ventilation structures with ventilation fans rated at 4,160 V, double-ended transformers, 4,160 V switchgear with tie-breaker, and associated 4,160 V controllers must be provided.

- Feeder lines from the electric utility must incorporate utility metering designed in conformance to the electric utility’s standards. Secondary side metering at 4,160 V and 480 V, as applicable, must also be provided.

- Specific details of the power distribution system must be shown on a single-line diagram complete with all necessary metering, monitoring, and control requirements. Switchgear, controller, and
switchboard equipment must meet all fault duty and ampacity requirements; circuit breakers must provide selective coordination.

Distribution Panels and Switchboards

Normal and emergency distribution panels and switchboards must be housed in DTX electrical rooms. These panels and switchboards must supply loads at utilization levels directly, or by means of lighting and receptacle panels, also located in DTX electrical rooms. Switchboards, power panels, and lighting panels must have fully rated circuit breakers.

Lighting Panels

Normal and emergency lighting loads must be supplied from separate panels. Circuit breakers for lighting branch circuits must be rated for switching duty service.

Receptacle Panels

Receptacle panels must supply power for receptacles and other 120/208 V miscellaneous loads by means of step-down (dry type) transformers, located with the panels in DTX electrical rooms.

17.3 Voltage Drop Limit

Voltage drops must be generally limited to a maximum of 5 percent total on both feeders and branch circuits. Maximum allowable voltage drop from 480 V or 208 V switchboards must not exceed 3 percent for all branch circuits. See subsection 17.1.2, Utilization Voltage.

17.4 Electrical Equipment Requirements

The design must incorporate space for electrical equipment, including conduit and cabling, with required protection (duct banks, raceways, cable trays) and maintenance access (manholes and pull boxes).

Design and installation of electrical equipment must conform to the NEC and all other applicable codes, rules and regulations and must meet the following requirements.

17.4.1 Equipment Location

Electrical power distribution equipment must be located in dedicated electrical rooms. The electrical rooms must be sized to allow for the equipment and any foreseeable system expansion. Lighting and Power electrical panels must include 20 percent spare circuit breaker capacity.

Receptacles, switches, and lighting must be provided in all rooms.
17.4.2 **Equipment Designation**

Equipment must be numbered on plans and single-line diagrams. Each piece of electrical equipment must be numbered according to the number of the feeding circuit breaker, except termination cabinets, which must be numbered sequentially.

Equipment numbers must be preceded by letter designations as follows:

- **Switchboard**
- **Power panelboard**
- **Lighting panelboard, 480/277 V**
- **Auxiliary power panel, 208/120 V**
- **Transformer**
- **Control panel**
- **Disconnect switch**
- **Motor**
- **Motor starter**
- **Terminal cabinet**
- **Automatic transfer switch**
- **Fare collection power panel**
- **Supervisory termination cabinet**
- **Motor control center**

17.4.3 **Motors, Starters, and Controls**

In general, motor control centers with combination starters of the motor circuit protector types must be used for 480 V motors. Control centers must be equipped with either a main circuit breaker or a fused circuit breaker with main busses that are adequately braced to withstand the available short-circuit current. Individually mounted combination starters of the motor-circuit protector types may be used where electrically advantageous and where the starter can be located in a physically secure area.

17.4.4 **Switchboards/Panelboards**

The distribution, lighting, and receptacle panelboards must be the molded-case, circuit-breaker type with copper bus. Circuit breakers must be the bolt-on type. The switchboards and panelboards must be constructed of code gauge galvanized steel. Panelboards must be of door-in-door construction. The lighting and receptacle panelboard cabinets must be provided with hinged doors and locks. Minimum, 20 percent, spare circuit breakers must be provided. Switchboards and panelboards must have fully rated circuit breakers.

17.4.5 **Disconnect Switches**

Heavy duty disconnect switches must be provided as required by the NEC as a means to electrically disconnect equipment from its feeder when equipment is not within the sight of either the feeder breaker or motor controller, or where there are advantages to separating the feeder from electric loads supplied by
others. In general, disconnect switches must be of the non-fusible type and must plainly indicate whether they are in the open (off) or closed (on) position. They must have the means of being locked in the open position. Where fuses are used, they must be of the current limiting type (UL Class J).

### 17.4.6 Transformers

Transformer size must be based on connected load plus 20 percent allowance for load growth. Transformers must conform to UL energy efficiency, testing, and certification standards. All operator-owned or TJPA-owned transformers located within buildings, tunnels, or stations must be air-cooled, vacuum-pressure-impregnated, dry-type. Transformers located outside of buildings may be oil cooled if provided by the utility company.

### 17.4.7 Conduit and Raceway

Common conduit/raceway systems must be provided to organize wiring, where practical and feasible. Conduit must be concealed as far as practicably possible. Exposed wiring or conduit serving lighting, public address speakers, electronic message boards, ticketing machines, and CCTV systems is not permitted.

Conduit and raceways may be of the following types.
- Galvanized rigid steel conduit
- Intermediate metallic conduit
- Cable tray (galvanized rigid steel or aluminum)
- Fiberglass
- PVC ([polyvinyl chloride]

Encased conduit elbows and stub-ups must be type rigid galvanized steel (RGS) or intermediate metallic conduit. All exposed conduit work, indoors or outdoors, must be rigid galvanized steel. Final connections to devices and motors, which may vibrate or require provisions for movement, must be made with liquid-tight flexible conduit.

Fiberglass and PVC conduit must only be used when encased in concrete, with a minimum of 2 inches of concrete cover.

Materials manufactured for use as raceways, conduits, ducts, and their surface finish materials must be capable of withstanding temperatures up to 932°F for a minimum of one hour (except where encased in concrete) and must conform to the NEC. The materials must also conform to NEMA, ANSI, and UL standards.

Raceways for normal and emergency power circuits must be physically separated to the maximum extent possible except in equipment rooms or where necessary to connect at common equipment.

One empty spare conduit with a pull cord must be provided for each conduit crossing beneath the tracks. Spare conduits must be the same size as that installed.

### 17.4.8 Duct Banks

Duct banks must be configured as required at the specific location. Manholes, pullboxes, junction boxes, and cable vaults must be spaced for ease of cable pulling and must meet applicable codes and operational
requirements, without exceeding cable-pulling tensions. Power and communications ducts and ducts with power cables rated over 1000 V must have separate manholes.

Concrete encased wayside duct banks must have a 3-inch minimum protective cover on all sides.

The radius of bends in conduits within a duct bank must be a minimum of 3 feet, regardless of size, and in conformance with manufacturer’s recommendation.

Underground duct banks must be sloped toward a manhole or box from which water may be drained or pumped. A sump pit in the manhole must be designed for collection of water and pump ejection.

Manholes must include sufficient space to maneuver, pull, and rack cables. Manholes must contain pulling eyes, ground rod, cable racks, a ladder, a cast steel frame, a cast steel lid, and a lid locking mechanism.

The design must be carefully coordinated with underground utilities to assure safe access within the right-of-way. Manholes spacing must not exceed 500 feet.

17.4.9 Receptacles

Receptacle faceplates and switches must be of consistent appearance throughout the DTX facilities.

Public Areas

Receptacles in public areas must be of specification grade, weatherproof, GFCI (ground-fault circuit interrupter) construction and NEMA 20 R configuration, unless noted otherwise. The spacing of duplex receptacles must allow a 100-foot extension to reach all public areas. Adjacent receptacles must not be placed on the same circuit. Receptacles in the free public area must be on dedicated circuit breakers.

Service Areas

Receptacles in service areas (e.g., equipment rooms, storage rooms, janitor rooms) must be of specification grade, weatherproof or non-weatherproof construction, and rated to meet service requirements. Configuration must be NEMA 20 R, unless otherwise noted. A minimum of one duplex receptacle for each 30 feet of wall space must be provided. Adjacent receptacles must not be placed on the same circuit.

Communications Room

Receptacles and lighting in communications rooms must be on separate circuits. A minimum of two 20-A, 120-V circuits must be provided for receptacles. A minimum of two 20-A, 277-V circuits must be provided for lighting.

Elevators and Escalators

Elevator machine room area lighting and receptacle circuits must be a separate 20-A, 120-V circuit. A cathodic protection circuit for the elevator must be on a separate 20-A, 120-V circuit. The 120-V circuits must be terminated in a weatherproof outlet box.

Weatherproof GFCI duplex, 20-A, 120-V receptacles must be provided in elevator pits and in escalator upper and lower pits.
17.4.10 Station Kiosks

Separate utility metering must be provided for each kiosk. Metering must be connected on the utility side of the station power. Each kiosk must be provided with minimum of three 2-inch-diameter conduits.

17.4.11 Cables

Low voltage power cables rated 600 V or below and medium-voltage power cables for cables rated above 600 V and up to 15 kV must meet the requirements in subsections 600 V Single-Conductor Cable through 600 V Multiple-Conductor Cable, below. All conductors must be insulated except ground wire, which may be bare.

600 V Single-Conductor Cable

Conductor material must be stranded or solid copper meeting the requirements of ASTM B3.

Conductor type

Conductor types must be as follows:
- Size 12 AWG and smaller: Solid conductor
- Size 10 AWG and larger: Class B stranded
- Size 14 AWG to Size 1/0 AWG: CEC, Type THHN or THWN, PVC thermoplastic insulated in conformance to NEMA WC5. Cable must be jacketed with clear polyamide nylon over the insulation.
- Size 2/0 AWG and larger: CEC, Type RHH, ethylene-propylene rubber (EPR)-insulated in conformance to NEMA WC8

Temperature rating. The temperature ratings of all 600 V single-conductor cables must be not less than 167°F.

Fire-retardant properties. Power cable for emergency fans and related equipment and emergency lighting cables must pass the flame propagating criteria of IEEE 1202 and have a minimum circuit time of 5 minutes in the flame test of IEEE 1202; a type test certificate is required with every shipment of cables. Power cables in tunnel areas must be of low-smoke-zero-halogen type.

Insulation rating. The insulation rating must be 600 V.

600 V Multiple-Conductor Cable

Multiple-conductor cable conforming to NEMA WC 5, approved for use in cable tray, must be provided.

Multiple-conductor cable for all power applications, except receptacles when installed in cable tray for sizes up to 4/0 AWG, must be provided.

Insulation must be as specified in subsection 600 V Single-Conductor Cable, for a single-conductor cable. The cable must be jacketed over the insulation.

A multiple-conductor for the control wire must be, at a minimum, 14 AWG stranded copper.
The insulation rating must be 600 V.

Multi-conductor cable must be made by assembling individual or twisted pairs of insulated conductors into a tight cylindrical form using fillers that are compatible with other materials in the cable.

Power cables in tunnel areas must be of low-smoke-zero-halogen type.

Medium-Voltage Cable

Medium-voltage power cables must consist of stranded copper conductors with a semi-conductive screen, EPR insulation, an insulation screen, metallic tape shield, a polyester film, and an outer jacket. The cable insulation and semi-conductive screens must be manufactured by a single-pass, triple-tandem extrusion.

Voltage rating. The voltage rating of the AC power cables must be 5 kV, 15 kV, and 34.5 kV at 133 percent insulation level.

Insulation. The insulation must be EPR and must meet all the requirements of NEMA WC 8. The insulation for the cable must have a minimum average thickness as determined by the conductor size.

The cable must be certified as passing the flame test specified in IEEE 383 Article 2.5.

Splicing. Where required, splicing must use materials of equivalent insulation type.

17.5 Lighting

The lighting criteria herein outline the design requirements for quantity of illumination, quality of illumination, and system components. Lighting systems design must conform to CCR Title 24, Part 1, Article 1, “Energy Building Regulations”; CBC Title 24; and IESNA lighting standards, including mandatory conservation requirements. All wiring materials and installations within the DTX tunnel must conform to the requirements of NFPA 130.

Lighting and associated control systems must include

- External roof lighting
- Interior open floor lighting
- Egress and access entrance lighting
- Safety exit sign lighting
- Perimeter street lighting
- Perimeter sign lighting
- Tunnel lighting

Lighting control must be designed to use energy efficiently. Automatic and manual control arrangements must ensure efficient utilization of energy and maintenance procedures.
17.5.1 Fourth and Townsend Street Station and Ancillary Structure Lighting Requirements

The subsection, Quantity of Illumination, through subsection Emergency Lighting and Exit Signs, following, contain the lighting requirements for the Fourth and Townsend Street Station, ventilation and egress structures, and ancillary buildings.

Quantity of Illumination

Illumination levels must define and differentiate between task areas, decision and transition points, and areas of potential hazard. Proper illumination must promote the perception of greater security among passengers. Platform lighting is essential to the safety and security of station facilities and must increase the safety of the passengers as they board and de-board trains.

The illumination levels must conform to Table 17-1.

Table 17-1: Illumination Levels for Fourth and Townsend Street Station and Ancillary Structures

<table>
<thead>
<tr>
<th>Location</th>
<th>Average Normal Illumination Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station entrances/exits</td>
<td>10 foot-candles</td>
</tr>
<tr>
<td>Mezzanine, waiting area and boarding platforms</td>
<td>15 -20 foot-candles</td>
</tr>
<tr>
<td>Stairs, escalators and elevators</td>
<td>10 -20 foot-candles</td>
</tr>
<tr>
<td>Public toilets</td>
<td>25-30 foot-candles</td>
</tr>
<tr>
<td>Ticket vending machines</td>
<td>50 foot-candles</td>
</tr>
<tr>
<td>Station agents booth</td>
<td>50 foot-candles</td>
</tr>
<tr>
<td>Offices</td>
<td>30 foot-candles</td>
</tr>
<tr>
<td>Equipment and control rooms</td>
<td>20 -30 foot-candles</td>
</tr>
<tr>
<td>Janitorial rooms/lockers</td>
<td>15 foot-candles</td>
</tr>
<tr>
<td>Storage rooms</td>
<td>20 foot-candles</td>
</tr>
</tbody>
</table>

Levels indicated must be at a plane 18 inches above floor level.

Lighting of station platform and concourse levels must be direct. Uplighting is acceptable for lighting the ceiling only and must not be used to light the floor level. Minimum average maintained foot-candle levels within stations and in similar rooms must conform to IESNA standards.

Illumination of emergency lighting must conform to section 0.

Brightness and Glare

Luminaries must be selected, located, and aimed to accomplish their primary purpose while producing a minimum of objectionable glare. Care must be exercised to prevent specular reflection on signage, direct glare from exposed lamps, high brightness areas of individual fixtures, and reflections in glazing or other specular surfaces.

Uniformity

The uniformity ratio of average to minimum levels must not exceed 3:1.
Color Temperature

Lamps of the same type within each area of illumination (e.g., room, yard, tunnel) must have the same color temperature. In areas where different types of lamps are required (e.g., metal halide, high-pressure sodium, fluorescent), the color temperature of each type must be matched closely to provide uniform color.

Site Glare Control

Special care must be taken to avoid objectionable glare to streets and adjacent property. Luminaires must be positioned to minimize spill light. Luminaires must be provided with internal shielding and located to prevent spill light and glare in the direction of neighboring residential or commercial properties. Luminaires placed within 50 feet of elevated freeways and overpasses must be designed to provide absolute cutoff in the direction of moving traffic.

The design must meet or provide lower light levels and uniformity ratios than those recommended by IES Recommended Practice Manual, Lighting for Exterior Environments (RP-33). The exception must be that in no case must light levels be less than 5 foot-candles at the walkway.

Exterior lighting must be designed such that all exterior luminaires with more than 1,000 initial lamp lumens are shielded, and all luminaires with more than 3,500 initial lamp lumens must meet the full cutoff IESNA classification.

The maximum foot-candle value of all interior lighting must fall within the building (not outward through windows), and the maximum foot-candle value of all exterior lighting must fall within the property.

Any luminaire within a distance of 2.5 times its mounting height from the property boundary must have shielding such that no light from that luminaire crosses the property boundary.

Emergency Lighting and Exit Signs

Emergency lighting systems must be designed, installed, and maintained in conformance to OSHA standards and provide a minimum of 2 foot-candles of floor-level illumination.

Exits must be marked with readily visible signs complying with the requirements of the CBC.

Illuminated exit signs must be supplied from the emergency lighting system. Emergency fixtures, exit lights, and signs must be separately wired from the emergency distribution panels. Wiring for exit sign control must terminate in a weatherproof junction box at sign locations.

Emergency lighting design for stairs and escalators must emphasize illumination on the top and bottom steps or landings. All escalator steps, newel, and comb lighting must be on emergency power circuits, in conformance to NFPA 130. A minimum of 1 foot-candle of emergency lighting must be provided at floor level throughout the entire run of each stair and escalator. Wall pack units, where used, must be equipped with self-testing features.
17.5.2 Tunnel Lighting Requirements

Quantity of Illumination

Lighting must be provided in all tunnels. Lighting must conform to the requirements of NFPA 101 and NFPA 130. The lighting at walkway surfaces must not be less than 1 foot-candle of illumination in at least the following locations.

- Within emergency exits
- Within subways at exit doors, threshold, walkway stairs, walkway ramps, and crosswalks
- All other means of egress walking surfaces

Circuiting of Walkway Lighting Fixtures

Tunnel walkway lighting fixtures must be powered from two alternating electrical power sources (i.e., every other fixture powered from the same electrical power source).

Emergency Exits

Yellow lights must be installed above tunnel exit doorways. Yellow lights must have two lamps, each supplied from separate feeder circuits.

Blue Light Stations

Requirements for blue light station locations are defined in CHAPTER 15, FIRE-LIFE SAFETY, and CHAPTER 18, Rail Systems.

Blue light stations must be supplied from alternate power sources, so that loss of power to a blue light station must not result in power loss to adjacent blue light stations.

A 120-VAC duplex outlet must be provided at each blue light station. Each outlet must be provided with 15-A service.

Emergency Lighting and Signage

Tunnels must be provided with an emergency lighting system in conformance to NFPA 101. Emergency lighting must not be less than 0.25 foot-candles measured at walkway floor level.

Illuminated exit signs must be supplied from the emergency lighting system. Emergency fixtures, exit lights, and signs must be separately wired from the emergency distribution panels. Wiring for exit sign control must terminate in a weatherproof junction box at sign locations.

17.5.3 Equipment

All luminaries and lamp types must be standardized systemwide to provide design and perceptual unity and simplify maintenance requirements. All site lighting fixtures should be waterproof and vandal-resistant and have tight gaskets to prevent the infiltration of dust. Luminaries must function effectively for a minimum of 20 years, allowing for routine maintenance.
Selection of ceiling fixtures must consider the use of open lenses for the maximum use of direct lighting.

Lighting fixtures in tunnels must be UL-listed for operation in a wet environment.

**Lamp Application**

Lamp applications must meet the following requirements:
- Interior and exterior platform and concourse: LED, fluorescent (if existing)
- Concession areas: High CRI (color-rendering index) fluorescent
- Displays: High CRI fluorescent
- Accent: Incandescent or compact fluorescent
- Ancillary rooms and vent structures: Interior fluorescent or metal halide
- Exterior: LED
- Walkways, sidewalks, and street crossings: Metal halide
- Vault and pit areas: LED with wire guard, suitable for wet locations

**Lamp Types**

All new lamps must be LED type. Fluorescent and compact fluorescent, metal halide, and high-pressure sodium may be used to replace existing lamps in-kind.

Lamps for Type T8 fluorescent lighting must have reduced mercury contents that meet the USEPA toxic characteristic leaching procedure test for non-hazardous fluorescent light waste pursuant to 22 CCR Section 66260.200(e). The soluble concentrations of the inorganic constituents, as measured by the toxic characteristic leaching procedure pursuant to Title 22, CCR, Section 66261.24(a), must be below the established regulatory thresholds.

**Incandescent**. High-efficiency and long-life type for limited use only.

**Fluorescent ballast (existing condition only)**. Fluorescent ballast must be electronic integrated circuit, solid-state, full-light-output, energy-efficient type, compatible with lamps and lamp combinations to which it is connected. Type must be Class P, high power factor, (minimum 90 percent). Total harmonic distortion of ballast current must be less than 10 percent and conform to CFR 47 for electromagnetic interference.

**LED drivers**. LED drivers must accept 277 VAC or 120 VAC and be rated for either interior or exterior applications.

**17.6 Electrical Systems Instrumentation and Controls**

Medium-voltage electrical equipment must be controlled by a direct current source backed-up by battery. Where practical, gauges and instruments on electrical equipment must be microprocessor-based multi-functional.

Sump pump control must be standard for operation with high-water alarm controls.
17.7 Grounding

The grounding of systems and equipment must conform to listed codes. Grounding resistance to earth must not exceed 5 ohms, as measured by the fall-of-potential method. Grounding connections must not be made on mechanical and utility pipes (including water) on the service side of dielectric couplings.

Grounding for passenger stations (and facilities) must consist of a ground system under each facility comprising a buried, exothermically welded grid and rod system or concrete-encased electrode. All metal components/materials of transit facilities and within 15 feet of centerline of track including shelters, fences, poles, guardrails, handrails, doors, metallic benches, and bollards that are susceptible to contact by patrons or maintenance personnel and likely to become energized by falling overhead contact wire, must be electrically bonded to the ground electrode. Ground electrical raceways, fittings, and equipment as required by NFPA 70 (NEC). The grounding grid scheme for electrically conductive or metallic materials running along the alignment must be developed to minimize the flow of stray currents and limit touch potentials to safe levels.

All electrically conductive materials used near the platform edge (e.g., platform edge nosing and end-of-platform gates) must be isolated from electrical ground. Any exposed, electrically grounded, metallic elements on the platform must not be closer than 6 feet to the platform edge.

17.8 Load Flow Analysis

Power system analyses must verify that all equipment is rated for the voltage, ampacity, and fault duty to which it is exposed and that the system will operate satisfactorily for both initial and projected electrical power capacity requirements with regard to the quantity, quality, and reliability required for the electrical distribution system equipment. Load calculations must include normal loads, emergency loads, and essential loads.

Power system analyses must include short-circuit calculation, overcurrent protective device coordination, arc flash analysis, and load flow evaluation. Calculations must use the most recent version of SKM PowerTools for Windows software, or ETAP software.

The short-circuit analysis must begin at the utility company’s primary fault current side, with current and impedance values obtained from the utility company. Device interrupting ratings must be based on the short-circuit calculation. Overcurrent protection devices must be selectively coordinated in the report. Arc flash analysis must be based on the most recent version of IEEE 1584 and NFPA 70.

Load-flow analysis (study) must prove all cables have adequate capacity and all voltage drop tabulations are within tolerances. The overall power system report must include the following:

- Study overview and utility company data
- Executive summary
- Recommendations
- Short circuit summary table
- Computer output data (short circuit calculations, cable impedances)
- Single line diagram with utility information, interrupting ratings, device information cable sizes and lengths
- Protective device setting table
• Time current curve (log-log) plots
• Arc flash analysis table with incident energy tabulations, device opening times, panel and switchgear information
• Voltage drop tables listing percent voltage drop at the bus area and the cable reference

The study must also provide arc flash labels. Arc flash labels must be OSHA-, NFPA 70-, and IEEE 1584-compliant. Computer-generated labels must include the following information:
• Arc flash boundary
• Incident energy level in calories/in²
• Personal protective equipment required
• Shock risk voltage
• Glove class
• Limited approach
• Restricted approach
• Study company and date
• Equipment name and upstream protective device

The study must be approved by the TJPA prior to label printing. Labels must be installed.

Lighting analyses must verify that the number, type, and placement of lighting fixtures must meet the criteria for the quantity. Calculations must be based 6 inches above the finished grade, with an assumed light loss factor of 0.75. Lighting manufacturers’ computer software must be used in the calculations. Analysis must include point-to-point print-outs adequately sized (either 11 x 17-inches or 24 x 36-inches) for readability. The analysis must include a table with average maintained foot-candle values of each light fixture type.

Other calculations, such as those for conduit jam analysis and cable-pulling tension, must verify that the geometry of raceways will allow for the proper installation of wire and cables within the parameters specified by equipment and material manufacturers. The analysis must also verify that conduit fill calculations conform to NEC guidelines and do not exceed over 40 percent conduit fill, or as specified by the authority having jurisdiction.
CHAPTER 18  RAIL SYSTEMS

SCOPE

This chapter establishes the requirements for the traction power supply and distribution system, voice and train control communications system, and signals and train control system for the Downtown Rail Extension (DTX).

The DTX will be an extension of the existing Caltrain system under the Peninsula Corridor Joint Powers Board (Caltrain) Peninsula Corridor Electrification Project (PCEP). Correspondingly, the design of the DTX rail systems must be compatible and consistent with the PCEP design and must conform to the PCEP Design Criteria. Rail systems design must reference the following chapters of the PCEP Design Criteria:

- Chapter 15: Rolling Stock
- Chapter 20: Traction Power System (TPS)
- Chapter 21: Overhead Contact System (OCS) and Traction Power Return System
- Chapter 22: Grounding and Bonding Requirements
- Chapter 23: Corrosion Control
- Chapter 24: Signaling and Train Control
- Chapter 25: Grade Crossings
- Chapter 26: Electromagnetic Compatibility and Interference
- Chapter 27: Supervisory Control and Data Acquisition (SCADA)
- Chapter 28: Communications

The design of DTX rail systems must be coordinated with Caltrain and California High-Speed Rail Authority (CHSRA) infrastructure. Signaling, traction power, and train control must be interoperable and fully integrated with the Caltrain electrified corridor.

The criteria and guidelines provided in this chapter supplement the Caltrain Engineering Standards and PCEP Design Criteria.

CODES, STANDARDS AND GUIDELINES

The design of the communications systems for the DTX must conform to the latest edition of the following codes, standards, and guidelines, if not established in the Caltrain Design Criteria:

- American Institute for Steel Construction Manual of Steel Construction
- American National Standards Institute (ANSI)
- American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering
- American Welding Society (AWS), Standard D.1.1, Structural Welding Code
- ASTM International
California Building Code
California Electrical Code
California High-Speed Rail Authority (CHSRA) Design Criteria Manual
California Public Utilities Commission (CPUC) General Orders (GO):
  - GO 26-D, Regulations Governing Clearances on Railroads and Street Railroads with Reference to Side and Overhead Structure Parallel Tracks, Crossings of Public Roads, Highways and Streets
  - GO 95, Rules for Overhead Electric Line Construction
  - GO 118-A, Regulations Governing the Construction, Reconstruction, and Maintenance of Walkways Adjacent to Railroad Trackage and the Control of Vegetation Adjacent Thereto
  - GO 128, Rules for Construction of Underground Electric Supply and Communication Systems
  - GO 176, Rules for Overhead 25 kV AC Railroad Electrification Systems for a High-Speed Rail System
Institute of Electrical and Electronics Engineers
Insulated Cable Engineers Association
National Electrical Safety Code (NESC)
National Fire Protection Association (NFPA)
  - NFPA 70, National Electrical Code (NEC)
  - NFPA 110, Standard for Emergency and Standby Power Supply Systems
  - NFPA 130, Standard for Fixed Guideway Transit and Passenger Railway Systems
  - NFPA 780, Standard for Lightning Protection Systems

In addition to the specific codes, standards, and guidelines listed, other local, state, and national codes, regulations, or rules may be applicable to any aspect of the design, as set forth in this chapter.

### 18.1 Power Distribution System

#### 18.1.1 Traction Power Cable Support and Conduit Systems

Traction power cables from the 25 kV AC feeder breaker connections or disconnect switch terminals and rail return cables from the return bus connections must be installed in appropriate raceways including conduits or concrete-encased duct banks. Cable trays may be used only in areas where approved by the Transbay Joint Powers Authority (TJPA). Conduit and cable trays, where approved for use, must conform to the requirements provided in CHAPTER 17 Electrical Systems.

Exposed conduit must be galvanized rigid steel, which will be grounded to the station ground bus. All conduits will be sized to provide adequate spare capacity, and the radius of bends must be sufficient to maintain cable sidewall pressures within manufacturers’ recommendations during pulling, especially for high-voltage cables with shields. All conduits will terminate in end-bells where the duct lines enter vaults.

Where approved for use, cable trays will provide adequate cross-sectional area to permit a neat alignment of the cables and avoid crossing or twisting. The comingling of high-voltage cables with low-voltage cables in
trays is prohibited. High- and low-voltage cables may be laid in the same tray if separated by a non-conductive barrier.

Cables in manholes must be supported on non-metallic racks or fiberglass cable support insulators. Such supporting arms or racks must be spaced to avoid excessive weight or pressures on the cable insulation. The cables must be arranged in not more than one layer.

18.1.2 Traction Power Load Flow Calculations

It is anticipated that the most northerly traction power facility in the PCEP will be a paralleling station (PS-1), which will be constructed next to the proposed Common Street grade crossing at Caltrain milepost 1.27.

The DTX design, through a series of traction power load-flow and power supply calculations, must determine whether PS-1 can provide sufficient traction power to the DTX. Load flow analyses must consider Caltrain and CHSRA operations under both normal and degraded conditions.

The calculations must be based on the parameters for rolling stock provided in CHAPTER 2, OWNER’S REQUIREMENTS.

18.1.3 Traction Power Facility Data

The proposed traction power facilities for the PCEP and their locations are shown in Table 18.1.

Table 18-1: PCJPB Traction Power (TP) Facilities

<table>
<thead>
<tr>
<th>TP Facility</th>
<th>Location (by milepost)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Label</td>
<td>Type</td>
<td>Civil</td>
</tr>
<tr>
<td>PS-1</td>
<td>Paralleling Station</td>
<td>1.27</td>
</tr>
<tr>
<td>PS-2</td>
<td>Paralleling Station</td>
<td>4.95</td>
</tr>
<tr>
<td>TPS-1</td>
<td>TP Substation</td>
<td>9.65</td>
</tr>
<tr>
<td>PS-3</td>
<td>Paralleling Station</td>
<td>15.02</td>
</tr>
<tr>
<td>PS-4</td>
<td>Paralleling Station</td>
<td>20.05</td>
</tr>
<tr>
<td>SWS-1</td>
<td>Switching Station</td>
<td>26.62</td>
</tr>
<tr>
<td>PS-5</td>
<td>Paralleling Station</td>
<td>33.55</td>
</tr>
<tr>
<td>PS-6</td>
<td>Paralleling Station</td>
<td>38.85</td>
</tr>
<tr>
<td>TPS-2</td>
<td>TP Substation</td>
<td>45.75</td>
</tr>
<tr>
<td>PS-7</td>
<td>Paralleling Station</td>
<td>51.0</td>
</tr>
</tbody>
</table>
Each traction power substation is assumed to have two 115/50 kV (2 x 26.25 kV) transformers, each feeding a separate electrical section. A 26.25 kV no-load secondary voltage (52.5 kV feeder to OCS) is also assumed.

The high-voltage transformers will have a rating of 60 MVA, with 10 percent impedance.

At paralleling stations, a single 50/25 kV autotransformer will be assumed, rated at 10 MVA, with 1.2 percent impedance. The same parameters will be assumed on each side of the switch break at the switching station.

### 18.2 Overhead Contact System

The DTX OCS design must conform to the Caltrain PCEP Design Criteria and CPUC GO 176.

#### 18.2.1 Design Requirements

The design of the DTX electrification system must conform to the following requirements in subsections Environmental Conditions and Maximum Authorized Speed, below.

**Environmental Conditions**

See CHAPTER 4, Environmental Requirements, for specific environmental conditions applicable to the DTX project.

The OCS design for below-grade sections of the DTX must accommodate the environmental conditions provided in Table 18.2.

**Table 18-2: Environmental Conditions for Below-Grade OCS Design**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Operating</th>
<th>Non-operating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum air temperature</td>
<td>40°F*</td>
<td>n/a</td>
</tr>
<tr>
<td>Normal air temperature</td>
<td>68°F*</td>
<td>n/a</td>
</tr>
<tr>
<td>Maximum air temperature</td>
<td>95°F*</td>
<td>109°F*</td>
</tr>
<tr>
<td>Ice on conductors</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Wind</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Maximum wire temperature</td>
<td>145°F***</td>
<td>n/a</td>
</tr>
</tbody>
</table>

* Temperature considered without solar heating or wind effects.

** Maximum wire temperature is the continuous operational wire temperature without solar heating or wind effects.

** Maximum Authorized Speed**

The OCS must accommodate at least the maximum authorized speed within the project limits, as defined in Chapter 7, GUIDEWAY GEOMETRICS.
18.2.2 OCS Wire Particulars

All wires and cables associated with the DTX OCS must match those used for the Caltrain PCEP. See the PCEP Design Criteria and drawing W6001 “Electrification Project Overhead Contact System – Catenary Wires.

18.2.3 Overhead Line Loading

Do not consider wind loading in the design of the below-grade sections of the DTX.

18.2.4 Foundations

Foundation design must conform to the recommendations of the DTX geotechnical reports referenced in Chapter 9, GEOTECHNICAL REQUIREMENTS.

18.2.5 Clearances

Horizontal and vertical clearances must conform to the requirements of section 7.3 and must also satisfy CPUC GO 26-D.

18.2.6 Electrical Clearances

The design for fixed termination components of the OCS must provide for live-to-ground electrical clearances, as provided in Table 18.3. The electrical clearances may only be adopted with the approval of the TJPA and must be maintained under all defined climatic conditions. The design must accommodate a pantograph head width ranging between 4 feet 9 inches and 6 feet 6 inches (horn tip to horn tip).

Table 18-3: Live-to-Ground Electrical Clearances

<table>
<thead>
<tr>
<th>Clearance Category</th>
<th>Static</th>
<th>Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>10.5 in.</td>
<td>8 in.</td>
</tr>
<tr>
<td>Minimum</td>
<td>8 in.</td>
<td>6 in.</td>
</tr>
</tbody>
</table>

18.2.7 Electrical Requirements

Within the DTX tunnel, sectionalizing of the OCS must conform to requirements of NFPA130, such that the traction power blocks are coordinated to be coincident with the signaling system and ventilation zones.

Disconnect Switches, must conform to PCEP Design Criteria. The OCS will be equipped with disconnect switches at all primary feeding and bypass feeding locations and monitored by supervisory control and data acquisition system. See CHAPTER 19, Communications. All disconnect switches must be motor operated, capable of remote operation and of local motorized or manual operation.

18.2.8 Mechanical Requirements

OCS Type. The OCS for the at-grade portion of the DTX must be simple catenary (messenger and contact wire), automatic tension (A.T.) system and conform to the PCEP Design Criteria. The below-grade portion of the DTX must be low-profile, simple catenary, fixed termination (F.T.) system.
Stagger, Tension, Sags and Spans. OCS conductor tensions, wire sag, and span length design must conform to the requirements established by the AREMA Manual for Railway Engineering, Chapter 33, NESC, and CPUC GO 176.

Along-track movement of the OCS and the resulting stagger change due to pivoting of registration assemblies is not anticipated to be significant, as the total temperature range is limited. Therefore, upper- and lower-temperature stops to limit along-track movement of the conductors are not required. However, a safety stop must be fitted in any at-grade A.T. OCS design to limit the travel of the balance weights in the event of a broken-wire condition.

The OCS conductors and wires must be designed using tensioning parameters that obtain the lowest structural loading consistent with acceptable current collection and performance. The OCS design tensions, sags, and spans must be compatible with the selected catenary configuration for either the F.T. or A.T. types.

OCS Tension Lengths. Splicing of OCS conductors will not be permitted during initial construction, and therefore the limits for the wire length for the F.T. equipment in the below-ground section of the DTX must be based on the manufacturing process or the reel length. The reel length will be determined by suppliers, and the design must be developed accordingly.

Overlaps, Turnouts and Crossovers. Insulated overlaps will be used to the greatest extent practical for sectionalizing purposes. In the event that an insulated overlap is not physically feasible or practical, a section insulator may be used instead.

The interface between at-grade A.T. OCS and below-grade low-profile, simple catenary, F.T. system must be designed such that temperature variations will not create hard points in the transition overlap.

Wire Heights and Gradients. Contact wire height (CWH) is the distance between the underside of the contact wire and the top of rail (TOR); CWH is measured along the projected centerline of track in conditions where the track is superelevated. The absolute minimum CWH for below-grade portions of the DTX will be 17 feet 5 inches.

Contact wire gradients must not exceed 1.3% for below-grade portions of the DTX.

18.3 Voice Radio

Due to the fact that the tunnel alignment includes multiple horizontal curves, radiating coaxial cable must be used in the DTX tunnel instead of tunnel radios. The design and implementation of radiating coaxial cable must conform to the PCEP Design Criteria.

18.4 Signals and Train Control

The design of the DTX voice and train control system must be compatible and consistent with Caltrain’s design standards and include bi-directional communications to the CHSRA’s operations control center to relay all fault codes and health and diagnostic voice, video, and text messages. Operational data will be shared to ensure performance metrics such as punctuality and timetable adherence are met across the blended network to facilitate delay attributions amongst owners and operators in the event of service perturbation.
Caltrain has implemented a positive train control (PTC) system upgrade of its signal and train control system. The PTC system will consist of wayside, vehicle, office, and communication systems that work in concert to provide for the safe operation of the Caltrain system.

All tracks within the DTX project limits must be signaled for reverse running.

Transit Center platforms signals must allow for adding and cutting cars.

Signal block design must be coordinated with the tunnel ventilation design to meet the criteria of the maximum number of trains in each ventilation section. See CHAPTER 16, Mechanical Systems.

18.4.1 Traction Current Return

Trains operating on the DTX alignment must be provided with 25 kV of electrical energy via the OCS. Return energy is deposited on the track through the trains’ wheels. Connection to the rails is necessary to provide a path to return energy back to the power source and distribute the energy along adjacent rails, thus increasing the ampacity of the system. The train detection system residing on the rails needs to be isolated from these rail connections and avoid potential sneak paths that could cause a false clear.

The primary method for isolation is in the use of impedance bonds. These devices provide very low impedance to the propulsion current and relatively higher impedance to the train control system. Impedance bonds are used at cut sections where insulated joints separate track circuits at track circuit boundaries and interlockings. They are also located where the traction current return is taken back to the power source. These are typically placed at cut sections, but not in all cases. In addition to provisions for impedance bonds, train detection equipment must protect against incompatible traction return current such alternating current immune relays and filters.

In propulsion terms, all the rails are connected where current is returned to the supply, the signal system being isolated from the current by the impedance bonds. In addition, the rails are connected at intervals to provide balance of the propulsion system as well as increase ampacity. These are known as cross-bonds. There must be a minimum of two track circuits with cut sections between cross-bonds. There must be a minimum of three track circuits with cut sections between cross-bonds if one includes a return to the propulsion system.

Impedance bonds must be provided at the ends of track circuits leading from electrified tracks to non-electrified tracks to bleed-off the return current. The center tap of the impedance bond at the non-electrified end will be connected to the static wire or to the center of an impedance bond on the adjacent electrified track. Impedance bonds are not required at insulated joints within crossovers or on track circuits that are wholly within non-electrified tracks.

Impedance bonds must provide adequate impedance for the steady energy track circuits, electrified Electro Code, and any audio frequency track circuits that are located within the boundaries of the track circuit. The neutral leads between adjacent impedance bonds must be designed in a manner that will minimize the likelihood of theft.

The actual ratings of the impedance bonds must accommodate the absolute value of the return current as required by the traction power designer.
The signal designer must work with the traction power designer in developing the cross-bonding scheme for traction power return conductors attached to impedance bonds. The cross-bonding plans must be provided by the signal designer.

**18.4.2 Tunnel Operations**

The DTX tunnel is made up of several ventilation zones. Only one train will be allowed in a ventilation zone at any one time. The locations of the signals must be coordinated to be in concert with this requirement. The signal designer must coordinate this work with operational planning and tunnel ventilation groups. The DTX PTC must be fully integrated with Caltrain’s existing PTC system.
CHAPTER 19  COMMUNICATIONS

SCOPE

This chapter establishes the requirements for communications systems and the supervisory control and data acquisition system for the Downtown Rail Extension (DTX). These criteria apply to the following facilities:

♦ DTX tunnel
♦ Transit Center train box fit-out
♦ Fourth and Townsend Street Station
♦ Ventilation and egress structures
♦ Ancillary structures
♦ Existing Caltrain facilities serving as primary head end for communication systems and supervisory control and data acquisition (Menlo Park Control Center and San Jose Control Center)

The criteria and guidelines in this chapter supplement the latest version of the following Caltrain standards:

♦ Caltrain Engineering Standards
♦ Peninsula Corridor Electrification Project (PCEP) Design Criteria

Any discrepancies or inconsistencies between the respective criteria must be brought to the attention of the Transbay Joint Powers Authority (TJPA) for resolution. The requirements of the communications systems must be coordinated with the requirements contained in the following chapters:

♦ Chapter 15: Fire-Life Safety
♦ Chapter 17: Electrical Systems
♦ Chapter 18: Rail Systems

CODES, STANDARDS AND GUIDELINES

The design of the communications systems for the DTX must conform to the latest edition of the following codes, standards, and guidelines if not established in Caltrain’s design criteria:

♦ American National Standards Institute (ANSI) publications, all applicable sections
♦ Americans with Disabilities Act (ADA)
♦ California Building Code (CBC)
♦ California High-Speed Rail Authority Design (CHSRA) Design Criteria Manual
♦ Electronic Industries Association/Telecommunications Industry Association (TIA) standards
♦ Institute of Electrical and Electronics Engineers publications, all applicable sections, including the National Electrical Safety Code (NESC)
National Fire Protection Association (NFPA) publications:
- NFPA 70 – National Electrical Code
- NFPA 130 – Standard for Fixed Guideway Transit Systems
- San Francisco Electrical Code
- Code of Federal Regulations (CFR), Title 47, Telecommunication Regulations, all applicable sections
- Underwriters Laboratories Inc.

19.1 Operations Technology Network

The DTX operations technology network must comprise a fully redundant, no single-point-of-failure, communications fiber-optic backbone that interfaces with Caltrain’s interoperable electronic train management system/positive train control system and conforms to the PCEP Design Criteria. The DTX operations technology network design must eliminate network delays and outages because of network spanning tree convergence.

The DTX design must provide a backbone loop throughout the DTX alignment, including the Transit Center train box fit-out, tunnel, and Fourth and Townsend Street Station.

The DTX backbone loop must be connected to the Caltrain wide area network at the current Caltrain station at 4th and King streets.

19.2 Conduits, Ducts, and Raceways

Conduits, ducts, and raceways must conform to the PCEP Design Criteria.

19.3 Public Address System and Talking Sign

A public address system conforming to the Caltrain Design Criteria must be provided in the Transit Center train box fit-out and Fourth and Townsend Street Station and provide clear, audible, announcements to passengers. The PAS must have speakers located along boarding platforms. The PAS speakers in the Fourth and Townsend Street Station must be wall mounted.

Talking signs for persons with visual impairments conforming to the Caltrain Design Criteria must be provided at the Transit Center and the Fourth and Townsend Street Station. The talking-sign system must comprise an American with Disabilities Act-compliant multipoint, closed-radio system that provides a trail of audible information to an individual user on the direction to go and turn to arrive at a particular train departure location.

19.4 Closed Circuit Television

A closed-circuit television system conforming to the PCEP Design Criteria must be installed throughout the DTX facilities. Coverage must include the following locations:
Points of access to the DTX system including the tunnel portal and entrances to the Fourth and Townsend Street Station and Transit Center

Station waiting areas including concourse and platforms

Points of access to restricted areas, including entrances to ventilation and emergency egress structures and the specific owner and operator areas identified in Chapter 14, subsection 14.5 Ventilation and Emergency Egress Structures

Escalator and elevator boarding areas

Elevator cabs

Ticket vending machines and other fare collection systems

Blue light stations

Cross-passage doorways (only applicable in portion of tunnel with a partition wall)

Cameras located at tunnel entry and exit locations must have dedicated coverage. Station platforms must have overlapping coverage of all passenger-accessible locations.

### 19.5 Variable Message Signs

Variable message signs (VMS) conforming to the Caltrain Design Criteria must be provided.

A minimum of two VMS boards are required on each boarding platform for passenger convenience and for redundancy. The VMS boards will be located approximately one-third of the platform distance from each platform end.

The minimum vertical clearance from the platform floor to the bottom of the VMS board must be 8 feet. The tip of the VMS board must not be closer than 9 feet from the track centerline, and for maximum visibility, not more than 11 feet from the track centerline.

### 19.6 Telephone

The telephone system design must conform to the Caltrain Design Criteria and PCEP Design Criteria.

### 19.7 Voice Radio

The voice radio communications design must comply with the Caltrain Design Criteria and PCEP Design Criteria.

### 19.8 Intrusion Detection/Access Control

An intrusion detection/access control system is required and must monitor access to all entryways and exitways to non-public spaces. The doors to these spaces must have tamperproof magnetic locks with either mag-card activated-, insertion-, or swipe-type readers. The system must conform to Caltrain Design Criteria and PCEP Design Criteria.
19.9 Supervisory Control and Data Acquisition System

The supervisory control and data acquisition (SCADA) system for the DTX must meet the requirements of PCEP Design Criteria. Once Caltrain completes electrification, SCADA system communications will be relayed via a fiber-optic backbone. The SCADA for the DTX will be a stand-alone local area network that will be connected into the Caltrain wide area network as an extension.

Given that the DTX is principally underground, equipment unique to the DTX limits must also be communicated on the fiber-optic system including:

♦ Tunnel ventilation
♦ Traction power
♦ Sump pumps
♦ Intrusion alarms
♦ Fire alarms
♦ Blue light stations (including all appurtenances found at these locations)
♦ Cross-passage doorways (only applicable in portion of tunnel with a partition wall)

19.10 Automated Fare Collection System

Ticket vending machines for the Fourth and Townsend Street Station and Transit Center must be furnished, tested, and commissioned by Caltrain, be compatible with the Clipper system, and conform to the PCEP Design Criteria. Conduit, power, and foundation requirements must be installed as part of the DTX project. The locations of ticket vending machines and conduit must be coordinated with Caltrain.
CHAPTER 20 STRAY CURRENT AND CORROSION CONTROL

SCOPE

This chapter establishes the requirements for stray current and corrosion control measures and are applicable to all Downtown Rail Extension (DTX) engineering disciplines.

CODES, STANDARDS AND REFERENCES

The design of stray current and corrosion control measures for the DTX must conform to the latest edition of the following standards, codes, guidelines, and design criteria:

- National Association of Corrosion Engineers (NACE) standards
- Peninsula Corridor Electrification Project (PCEP) Design Criteria

20.1 General Design Requirements

The design of the stray current and corrosion control measures must ensure that the required service life of the DTX infrastructure is not compromised by corrosion-related problems or failures. These criteria are separated into three areas: stray current corrosion, soil corrosion, and atmospheric corrosion. Corrosion control measures must satisfy the following objectives:

- Prevent premature failure caused by corrosion
- Protect against detrimental effects to DTX facilities caused by stray direct current earth currents from other transit operations
- Be economical to install, operate, and maintain

Stray current and corrosion control designs must be coordinated to avoid conflicts and the risk of one measure rendering another ineffective.

20.1.1 Environmental Conditions

Specific environmental conditions applicable to the DTX project are presented in CHAPTER 4, ENVIRONMENTAL REQUIREMENTS. Additional testing requirements for soil corrosivity will be identified as necessary for corrosion control designs.

20.1.2 Survey

The DTX alignment must be surveyed to identify existing corrosion control measures in utilities, buildings, equipment, direct current transit system facilities, and large objects along the corridor. If considered necessary by the Transbay Joint Powers Authority (TJPA), field testing may be performed in areas of high concern.
Survey information must include the type of facility, relative location from the alignment, name and owner, existing corrosion measures, type of circuit used. These data must be stored in a database or spreadsheet and used as the baseline for existing conditions prior to the implementation of any stray current or corrosion control measures undertaken as part of the DTX project.

20.2 Related Documentation

Stray current and corrosion control measures must consider the design requirements of other engineering disciplines specified within this manual.

The documentation listed under References in CHAPTER 9 must be considered during the course of the design of the stray current and corrosion control measures.

20.3 Grounding, Bonding and Lightning Protection System

All grounding designs must be coordinated with the measures specified herein to ensure that the respective designs do not conflict and render either system ineffective. Grounding and bonding must conform to the PCEP Design Criteria.

20.4 Stray Current Corrosion Control Mitigation

The designs must mitigate detrimental effects to DTX facilities caused by stray direct current and earth currents from other transit operations or adjacent structures or facilities owned by others.

20.4.1 Basic Requirements

Stray current control designs must provide a means to mitigate and monitor stray current activity produced by other sources on buried and embedded metallic structures of the DTX system. The basic requirements for stray current mitigation and monitoring control are to

♦ operate and maintain the mainline system with no direct or indirect electrical connections to direct current traction power distribution circuits of adjacent transit systems

♦ design underground pressurized metallic utilities owned by TJPA to include electrical continuity, protective coating, cathodic protection and appropriate monitoring facilities. Evaluate non-pressurized underground metallic utilities owned by TJPA on an individual basis to determine the need for stray current mitigation.

♦ establish electrical continuity of steel reinforcement in cast-in-place concrete structures by selective welding or mechanical coupling of the reinforcing bars (where determined necessary for stray current mitigation).

♦ provide accessible test facilities capable of monitoring stray current activity on the bonded reinforcement during revenue operations.

While utility owners and authorities having jurisdiction of adjacent light rail and mass transit systems are responsible for minimizing the impact of stray currents originating from their infrastructure on the DTX, the
designer must ensure that the DTX design and operation will mitigate the impact of adjacent direct current transit infrastructure by protecting DTX structures and equipment from direct contact with direct current system grounded elements such as anchors and foundations.

### 20.4.2 Underground Structures

Reinforcing steel in permanent cast-in-place underground structure inverts must be electrically continuous only where determined to be necessary for stray current mitigation from other sources or for grounding purposes. Where required, the minimum requirements for the reinforcing steel from the top of rail down must include:

- welding or mechanical coupling of all longitudinal lap splices.
- welding or mechanical coupling of all longitudinal members to a transverse (collector) member at regular intervals, not to exceed 200 feet and at both sides of electrical (physical) breaks in the longitudinal reinforcing steel, such as at expansion/contraction joints.
- continuity across expansion/contraction joints be accomplished through the use of bond cables exothermically welded to collector bars on each side of a joint. The minimum bond cable size will be AWG #1/0 stranded copper cable.
- test facilities installed at each end of the structure and at select collector bar or expansion/contraction joint. Test facilities must consist of insulated copper wires, conduits, and enclosures, terminating at accessible locations or block-outs exposing bond cables. Test facilities must include embedded reference electrodes and must be configured for convenient monitoring of the magnitude of stray current on the bonded reinforcement.

The requirements for permanent structural steel members must be reviewed on an individual basis to determine the need for special measures, such as increased thickness, external coating system, electrical bonding, and cathodic protection.

### 20.5 Soil and Water Corrosion Control

The designs must consider the effect of corrosion on the specified design life objectives for buried structures. Corrosion control provisions are required for all facilities when failure of such facilities resulting from corrosion may affect safety or interrupt continuity of operations. The corrosivity of the underground environment must be evaluated based on information obtained from the geotechnical reports. Additional borings or testing must be identified if the available information is insufficient for an adequate assessment of the soil and groundwater corrosivity.

Protection of metal structures must include corrosion control techniques, such as coating, electrical isolation, electrical continuity, and cathodic protection. The designer must identify reinforced concrete structures that may be subject to attack by chlorides or sulfates and specify cement types in conformance with ASTM C150. For severe environments, supplemental cementitious materials, inhibitors or coatings may be required.

Structures that may be affected by soil and water corrosion must be identified. Typically, these include:

- Buried and at-grade reinforced concrete structures
- Metallic piping systems (water, fire water, sewage ejectors, etc.)
- Underground storage tanks
Consider the corrosion control measures for facilities owned by others in the design and coordinate with the owners of the facilities to avoid conflicts, such as interference with cathodic protection systems.

20.5.1 Materials and Structures

Reinforced Concrete Walls and Slabs

The design for concrete in contact with soils (excluding the tunnel liner) must specify

- the Type I cement, generally. Type II cement must be used if the soil pH is less than 5.5 or the sulfate concentration is between 1000 ppm and 2000 ppm. Type V cement must be used if the soil sulfate concentration exceeds 2000 ppm. In very severe exposure where the sulfate concentration exceeds 20,000 ppm, pozzolans will be added to the cement for additional protection.
- a maximum of 200 ppm chloride concentration in mixing water and admixtures combined.
- a minimum of 2 inches concrete cover on the soil side of all steel reinforcement where the concrete is poured within a form or a minimum of 3 inches cover where the concrete is poured directly against soils.

Non-metallic Materials

Plastics, fiberglass, and other non-metallic materials for pressurized piping can be used to aid in corrosion control. The corrosion control design must coordinate with the piping design to consider the following factors in the selection of proposed materials:

- Manufacturers’ recommendations
- Mechanical strength and internal pressure limitations
- Elasticity/expansion characteristics
- Comparative costs
- Expected life
- Failure modes
- Local codes
- Experience with the proposed non-metallic material in similar applications

20.5.2 Coatings

Buried metallic structures requiring coatings must be provided with a bonded dielectric protective coating. Mill-applied coatings must be specified wherever possible with the use of compatible coating systems for field touchup and repairs. The corrosion control design must specify the surface preparation, application procedure, primer, number of coats, and minimum dry film thickness for each coating system. The use of polyethylene encasement will not be permitted where cathodic protection will be applied.

20.5.3 Electrical Isolation

The corrosion control design must establish the need for and the location of insulated flanges, spacers, couplings, and unions. Insulated fittings must have a minimum resistance of 10 megohms before installation;
they must be designed for compatibility with material carried, including pressure and temperature restrictions. No more than 2 percent of a test current applied across the insulating device can flow through the insulator. Wherever possible, a minimum clearance of 12 inches must be provided between new and existing metallic structures. Where field conditions prohibit a 12-inch clearance, the design must include special provisions, such as insulating spacers, to prevent electrical contact with the existing structures.

20.5.4 Electrical Continuity

Continuity bonds must be made with insulated copper cables attached by exothermic welds. Cable design must have a minimum of two wires per joint for redundancy. Bond cables must be sized so that the total resistance of the pipeline circuit does not exceed 120 percent of the theoretical resistance of the pipeline. The minimum continuity bond cable size must be AWG #6 stranded copper cable. All exothermic welds must be coated.

20.5.5 Cathodic Protection

Cathodic protection installations must conform to structure life objectives and NACE International standards. Sacrificial anodes must be used wherever possible to avoid corrosive interference effects with underground utilities. Impressed current rectifier systems must be used only when the use of sacrificial anodes is not technically or economically feasible. Impressed current systems must be designed using variable voltage and current output rectifiers. Rectifier ratings must be a minimum of 50 percent above calculated operating levels to allow for unanticipated changes in structure or ground bed resistances, or the presence of or changes to interference bonds.

All new, replaced, or relocated pressurized utility piping associated with DTX construction must be protected from corrosion in conformance with the requirements of each utility. At a minimum, test wires must be installed for future testing.

Cathodic protection of all new buried metallic pressure piping and storage tanks is required, including the

♦ application of a protective coating to the external surfaces of the piping, tank, or both.
♦ electrical insulation from interconnecting piping and other structures, and segregation into discrete electrically insulated sections depending upon the total length of the piping.
♦ electrical continuity through installation of insulated copper wires across all mechanical joints other than intended insulators.
♦ permanent test/access facilities for verifying continuity and effectiveness of isolation and coating, and evaluating protection levels, installed at all insulated connections and at intervals not greater than 100 meters.
♦ installation of sacrificial anodes or impressed current anodes and rectifier units.

Cathodic protection designs must consider the following:

♦ Soil environment
♦ Mutual protection or interference configurations
♦ Limitations of protection potentials
♦ Test monitoring
Cathodic protection designs must be based on theoretical calculations using site environmental soil data. Designs must include the following minimal factors:

- Minimum assumed bare surface area of 1 percent
- Calculated anode bed resistance
- Anode size, spacing, and quantity
- Calculated anode life
- Rectifier direct current output ratings, where required

The calculated anode life must not be less than structure design life objectives where periodic anode replacement is not feasible.

20.5.6 Test Facilities

The requirements for test facilities for soil and water corrosion control must be included as part of the design.

20.5.7 Casings

Casings, if required, must be installed bare, unless coating and a sacrificial anode system is required by the owner or manufacturer. Casing insulators must be installed on the carrier pipe to avoid electrical contact between the casing and carrier pipe. End seals will be used to prevent infiltration of soil and groundwater in the annular space between the pipe and casing. Test leads are required on the casing and the carrier pipe.

20.6 Atmospheric Corrosion Control

The corrosivity of the atmosphere will be assessed based on the location of the structure and the conditions of atmospheric exposure. The requirements for materials and protective coatings will be coordinated with the structural and architectural design disciplines. These criteria are provided to ensure the function, preservation, and appearance of structures exposed to the atmosphere. Criteria include the following:

**Materials Selection.** Acceptable materials must have proven performance records for the service application.

**Protective Coatings.** Barrier or sacrificial coatings must be used on steel in unconditioned spaces with the exception of weathering steel. Barrier coatings or anodization and sealing may be used on aluminum materials where necessary for corrosion prevention or to enhance appearance. Coatings may be applied to concrete surfaces where necessary for corrosion prevention or to enhance appearance.

**Design.** Recess moisture traps and dissimilar metals must be avoided.

**Sealants.** Accumulation of moisture in crevices must be prevented by sealants.

**Electrical Equipment.** All wayside electrical equipment, except train control equipment, must be enclosed in temperature-controlled environments, or must otherwise incorporate design techniques to prevent moisture condensation and corrosion of integral parts.

**Structures.** Structures that may be affected by atmospheric corrosion must be identified, including the following:
Exposed metal surfaces in tunnel structures
Exposed metal at passenger stations
Catenary installations and related metallic hardware
Right-of-way and enclosure fences
Electrical, mechanical, signal, and communications devices and equipment, and signal and traction power facility housings

The following subsections contain design criteria for various metals and coatings.

20.6.1 Steel and Ferrous Alloys
Carbon steel, ductile iron, and cast iron exposed to the atmosphere must be coated with a sacrificial and barrier-type coating applied to all external surfaces. Rail and rail fasteners do not require coatings. High-strength low-alloy steels must be protected in a manner similar to carbon steels, except where weathering steel is used and is exposed to the outside environment. Coating of metallic contacting surfaces, crevice sealing, and surface drainage must be addressed in the designs. The staining of adjacent structures may result from insufficient material used for the coatings and must be considered.

Series 200 and 300 stainless steels are suitable for use in most exposed situations without further protection. Series 400 stainless steels are acceptable but must be evaluated for possible staining resulting from insufficient material used for the coatings. Welded stainless steel surfaces must be cleaned and passivated after fabrication.

20.6.2 Copper Alloys
Copper and its alloys can be used where exposed to the weather without additional protection. Avoid using bimetallic couplings unless intended as part of the design.

20.6.3 Zinc Alloys
Zinc alloys can be used without additional protection. Avoid using bimetallic couplings.

20.6.4 Aluminum Alloys
An anodized and sealed finish or barrier coating application must be used to provide the best weather-resistant surface. Avoid using bimetallic couplings.

20.6.5 Magnesium Alloys
Magnesium alloys must have a barrier coating applied where long-term appearance is critical. Avoid using bimetallic coupling unless intended as part of the design.

20.6.6 Coatings
Coatings must be compatible with the metallic surface to be coated. Resistance to chalking and color and gloss retention must be satisfactorily established through a proven past performance record for the design life of the coating.
20.6.7 Organic Coatings

Organic coating systems must consist of a wash primer (if substrate requires), a primer, intermediate coats, and a finish coat. Acceptable organic coatings are:
- Acrylic, where there is no exposure to direct sunlight
- Alkyd enamel
- Aliphatic polyurethanes where there is no exposure to submersion
- Epoxy, as a primer in an atmospheric environment, or a complete coating system where protected from direct sunlight
- Vinyl copolymers

20.6.8 Metallic Coatings

Acceptable metallic coatings (for carbon and alloy steels) are:
- Aluminum
- Aluminum-zinc
- Zinc (hot dip galvanizing)
## APPENDIX A: ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>Ampere</td>
</tr>
<tr>
<td>A.T.</td>
<td>automatic tension</td>
</tr>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway And Transportation Officials</td>
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<tr>
<td>ACI</td>
<td>American Concrete Institute</td>
</tr>
<tr>
<td>ADA</td>
<td>Americans with Disabilities Act</td>
</tr>
<tr>
<td>AISC</td>
<td>American Institute of Steel Construction</td>
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<tr>
<td>AMCA</td>
<td>Air Movement and Control Association</td>
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<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>APTA</td>
<td>American Public Transportation Association</td>
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<tr>
<td>APWA</td>
<td>American Public Works Association</td>
</tr>
<tr>
<td>AREMA</td>
<td>American Railway Engineering and Maintenance-of-Way Association</td>
</tr>
<tr>
<td>ASCE</td>
<td>American Society of Civil Engineers</td>
</tr>
<tr>
<td>ASHRAE</td>
<td>American Society of Heating Refrigeration And Air-Conditioning Engineers</td>
</tr>
<tr>
<td>ASME</td>
<td>American Society of Mechanical Engineers</td>
</tr>
<tr>
<td>ASSE</td>
<td>American Society of Sanitary Engineers</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing And Materials</td>
</tr>
<tr>
<td>AT&amp;T</td>
<td>American Telephone and Telegraph Company</td>
</tr>
<tr>
<td>AWG</td>
<td>American wire gauge</td>
</tr>
<tr>
<td>AWS</td>
<td>American Welding Society</td>
</tr>
<tr>
<td>AWSS</td>
<td>Auxiliary Water Supply System</td>
</tr>
<tr>
<td>BART</td>
<td>Bay Area Rapid Transit</td>
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<tr>
<td>Cal/OSHA</td>
<td>California Department of Industrial Relations Division of Occupational Safety and Health</td>
</tr>
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<td>Caltrans</td>
<td>California Department Of Transportation</td>
</tr>
<tr>
<td>CATTCH</td>
<td>California Temporary Traffic Control Handbook</td>
</tr>
<tr>
<td>CBC</td>
<td>California Building Code</td>
</tr>
<tr>
<td>CBDS</td>
<td>California Department of Transportation (Caltrans), Bridge Design Specifications</td>
</tr>
<tr>
<td>CCF</td>
<td>(Caltrain’s) Central Control Facility</td>
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<td>California Code of Regulations</td>
</tr>
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<td>CCS</td>
<td>California Coordinate System</td>
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<tr>
<td>CCTV</td>
<td>closed-circuit television</td>
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<td>CEC</td>
<td>California Electric Code</td>
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<tr>
<td>CEQA</td>
<td>California Environmental Quality Act</td>
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<tr>
<td>cfm</td>
<td>cubic feet per minute</td>
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<td>CFR</td>
<td>Code of Federal Regulations</td>
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<td>California High-Speed Rail Authority</td>
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<td>CID</td>
<td>card interface devices</td>
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<td>City</td>
<td>City and County of San Francisco</td>
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<td>CP</td>
<td>control point</td>
</tr>
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<td>CRI</td>
<td>color-rendering index</td>
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<td>CWH</td>
<td>contact wire height</td>
</tr>
<tr>
<td>dBA</td>
<td>A-weighted decibel</td>
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<td>dc</td>
<td>direct current</td>
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<tr>
<td>DPT</td>
<td>San Francisco Department of Parking and Traffic</td>
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<td>DSHA</td>
<td>deterministic seismic hazard assessment or assessments</td>
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<td>DTX</td>
<td>Downtown Rail Extension</td>
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<tr>
<td>EMU</td>
<td>electric multiple unit</td>
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<tr>
<td>EPR</td>
<td>ethylene-propylene rubber</td>
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<tr>
<td>°F</td>
<td>degrees Fahrenheit</td>
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<tr>
<td>f'c</td>
<td>compressive strength</td>
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<td>FCC</td>
<td>Federal Communications Commission</td>
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<tr>
<td>FCP</td>
<td>fire command post</td>
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<td>FEE</td>
<td>Functionality Evaluation Earthquake</td>
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<td>Federal Emergency Management Agency</td>
</tr>
<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
</tr>
<tr>
<td>fpm</td>
<td>feet per minute</td>
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<tr>
<td>fps</td>
<td>feet per second</td>
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<td>FRA</td>
<td>Federal Railroad Administration</td>
</tr>
<tr>
<td>ft</td>
<td>foot or feet</td>
</tr>
<tr>
<td>ft/sec²</td>
<td>feet/sec/sec</td>
</tr>
<tr>
<td>ft²</td>
<td>square foot or square feet</td>
</tr>
<tr>
<td>FTA</td>
<td>Federal Transit Administration</td>
</tr>
<tr>
<td>fy</td>
<td>minimum yield strength</td>
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<td>GBR</td>
<td>Geotechnical Baseline Report</td>
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<td>GDR</td>
<td>Geotechnical Data Report</td>
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<tr>
<td>GFCI</td>
<td>ground-fault circuit interrupter</td>
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<tr>
<td>GIR</td>
<td>Geotechnical Interpretive Report</td>
</tr>
<tr>
<td>GO</td>
<td>(CPUC) General Order</td>
</tr>
<tr>
<td>gpm</td>
<td>gallons per minute</td>
</tr>
<tr>
<td>HASP</td>
<td>health and safety plan</td>
</tr>
<tr>
<td>HV</td>
<td>high-voltage</td>
</tr>
<tr>
<td>HVAC</td>
<td>heating, ventilation and air-conditioning</td>
</tr>
<tr>
<td>Hz</td>
<td>hertz</td>
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<tr>
<td>IATA</td>
<td>International Air Transport Association</td>
</tr>
<tr>
<td>ICEA</td>
<td>Insulated Cable Engineers Association</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers</td>
</tr>
<tr>
<td>IESNA</td>
<td>Illuminating Engineering Society of North America</td>
</tr>
<tr>
<td>IMC</td>
<td>intermediate metallic conduit</td>
</tr>
<tr>
<td>in.</td>
<td>inch or inches</td>
</tr>
<tr>
<td>in²/ft</td>
<td>square inches per foot</td>
</tr>
<tr>
<td>in/h</td>
<td>inches per hour</td>
</tr>
<tr>
<td>ISRM</td>
<td>International Society of Rock Mechanics</td>
</tr>
<tr>
<td>kips</td>
<td>kilopounds</td>
</tr>
<tr>
<td>ksi</td>
<td>kips per square inch</td>
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<tr>
<td>kV</td>
<td>kilovolt</td>
</tr>
<tr>
<td>LAN</td>
<td>local area network</td>
</tr>
<tr>
<td>lbf</td>
<td>pound-force</td>
</tr>
<tr>
<td>LCP</td>
<td>local control panel</td>
</tr>
<tr>
<td>LED</td>
<td>light emitting diode</td>
</tr>
<tr>
<td>lg</td>
<td>gross moment of inertia</td>
</tr>
<tr>
<td>LOS</td>
<td>level of service</td>
</tr>
<tr>
<td>LRFD</td>
<td>Load and Resistance Factor Design</td>
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<td>LRV</td>
<td>light rail vehicle</td>
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<tr>
<td>mA</td>
<td>milliampere</td>
</tr>
<tr>
<td>MAS</td>
<td>maximum authorized speed</td>
</tr>
<tr>
<td>mph</td>
<td>miles per hour</td>
</tr>
<tr>
<td>mph/s</td>
<td>miles per hour per second</td>
</tr>
<tr>
<td>Muni</td>
<td>San Francisco Municipal Railway</td>
</tr>
<tr>
<td>Mw</td>
<td>maximum moment magnitude</td>
</tr>
<tr>
<td>NACE</td>
<td>National Association of Corrosion Engineers</td>
</tr>
<tr>
<td>NAD 83</td>
<td>North American Datum of 1983</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Definition</td>
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<tr>
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<td>------------</td>
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<tr>
<td>NAVD 88</td>
<td>North American Vertical Datum of 1988</td>
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<tr>
<td>NEC</td>
<td>National Electrical Code</td>
</tr>
<tr>
<td>NEMA</td>
<td>National Electrical Manufactures Association</td>
</tr>
<tr>
<td>NESC</td>
<td>National Electrical Safety Code</td>
</tr>
<tr>
<td>NFPA</td>
<td>National Fire Protection Association</td>
</tr>
<tr>
<td>NGS</td>
<td>National Geodetic Survey</td>
</tr>
<tr>
<td>NGVD 29</td>
<td>National Geodetic Vertical Datum of 1929</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>operations and maintenance</td>
</tr>
<tr>
<td>OCC</td>
<td>Operations and Control Center</td>
</tr>
<tr>
<td>OCS</td>
<td>overhead contact system</td>
</tr>
<tr>
<td>OSHA</td>
<td>Occupational Safety and Health Administration</td>
</tr>
<tr>
<td>PCEP</td>
<td>Peninsula Corridor Electrification Program</td>
</tr>
<tr>
<td>pcf</td>
<td>pounds per cubic foot</td>
</tr>
<tr>
<td>PCJPB</td>
<td>Peninsula Corridor Joint Powers Board</td>
</tr>
<tr>
<td>PG&amp;E</td>
<td>Pacific Gas and Electric Company</td>
</tr>
<tr>
<td>PLC</td>
<td>programmable logic controllers</td>
</tr>
<tr>
<td>ppm</td>
<td>parts per million</td>
</tr>
<tr>
<td>PS</td>
<td>paralleling station</td>
</tr>
<tr>
<td>psf</td>
<td>pounds per square foot</td>
</tr>
<tr>
<td>PSHA</td>
<td>probabilistic seismic hazard assessment or assessments</td>
</tr>
<tr>
<td>psi</td>
<td>pounds per square inch</td>
</tr>
<tr>
<td>PTC</td>
<td>positive train control</td>
</tr>
<tr>
<td>PVC</td>
<td>polyvinyl chloride</td>
</tr>
<tr>
<td>RAMS</td>
<td>reliable, available, maintainable and safe</td>
</tr>
<tr>
<td>RGS</td>
<td>rigid galvanized steel</td>
</tr>
<tr>
<td>RWQCB</td>
<td>Regional Water Quality Control Board</td>
</tr>
<tr>
<td>SCADA</td>
<td>supervisory control and data acquisition</td>
</tr>
<tr>
<td>SEE</td>
<td>Safety Evaluation Earthquake</td>
</tr>
<tr>
<td>SEIS/EIR</td>
<td>Supplemental Environmental Impact Statement/Environmental Impact Report</td>
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<tr>
<td>SEM</td>
<td>sequential excavation method</td>
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<tr>
<td>SFCTA</td>
<td>San Francisco County Transportation Authority</td>
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<tr>
<td>SFFD</td>
<td>San Francisco Fire Department</td>
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<tr>
<td>SFMTA</td>
<td>San Francisco Municipal Transportation Agency</td>
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<tr>
<td>SFPUC</td>
<td>San Francisco Public Utilities Commission</td>
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<tr>
<td>SMACNA</td>
<td>Sheet-Metal and Air Conditioning Contractors National Association</td>
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<tr>
<td>SSMP</td>
<td>safety and security management plan</td>
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<tr>
<td>TJPA</td>
<td>Transbay Joint Powers Authority</td>
</tr>
<tr>
<td>TMP</td>
<td>traffic management plan</td>
</tr>
<tr>
<td>TOD</td>
<td>transit-oriented development</td>
</tr>
<tr>
<td>TRB</td>
<td>Transportation Research Board</td>
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<tr>
<td>TVM</td>
<td>ticket vending machine</td>
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<tr>
<td>UL</td>
<td>Underwriters Laboratories, Inc.</td>
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<tr>
<td>UPS</td>
<td>uninterruptible power supply</td>
</tr>
<tr>
<td>USACE</td>
<td>United States Army Corps of Engineers</td>
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<tr>
<td>USBR</td>
<td>United States Bureau of Reclamation</td>
</tr>
<tr>
<td>USDOT</td>
<td>United States Department of Transportation</td>
</tr>
<tr>
<td>USEPA</td>
<td>United States Environmental Protection Agency</td>
</tr>
<tr>
<td>V</td>
<td>volt</td>
</tr>
<tr>
<td>V/H</td>
<td>vertical to horizontal</td>
</tr>
<tr>
<td>VAC</td>
<td>volts alternating current</td>
</tr>
<tr>
<td>VCP</td>
<td>ventilation control panel</td>
</tr>
<tr>
<td>VMS</td>
<td>variable message sign or signs</td>
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# APPENDIX B: CODES, STANDARDS, GUIDELINES & REFERENCES

<table>
<thead>
<tr>
<th>Association</th>
<th>Code, Standard, Guideline</th>
<th>Abbr.</th>
<th>In-Text Ref.</th>
<th>Type</th>
<th>Ch. #</th>
<th>Section #</th>
<th>SOURCE LINK</th>
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<td>American Association of State Highway and Transportation officials</td>
<td>A Policy on Geometric Design of Highways and Streets (Green Book)</td>
<td>AASHTO</td>
<td>AASHTO Green Book</td>
<td>IN</td>
<td>05</td>
<td>5.1, 5.2.1</td>
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<tr>
<td>American Association of State Highway and Transportation officials</td>
<td>Load and Resistance Factor Design Road Tunnel Design and Construction Guide Specifications</td>
<td>AASHTO</td>
<td>AASHTO LRFD Road Tunnel</td>
<td>IN</td>
<td>10, 12, 13</td>
<td>10.3, 10.4, 10.9, 12.2, 12.3, 13.2, 13.8.2</td>
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<td>ACI 201.2R, Guide to Durable Concrete</td>
<td>ACI</td>
<td>ACI 201.2R</td>
<td>IN</td>
<td>12</td>
<td>12.2.2, 12.6.4</td>
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<td>13.1.1</td>
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<td>ACI 315R, Guide to Presenting Reinforcing Steel Design Details</td>
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<td>Code, Standard, Guideline</td>
<td>Abbr.</td>
<td>In-Text Ref.</td>
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<td>Section #</td>
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<td>American Concrete Institute</td>
<td>ACI 533.5R, Guide for Precast Concrete Tunnel Segments</td>
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<td>Okabe, S. 1926. “General theory of earth pressure.” Journal of the Japanese Society of Civil Engineers, Tokyo, Japan: 12.</td>
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<td>Parsons Transportation Group &amp; Wood Environmental &amp; Infrastructure Solutions, Inc. April 22, 2022. Geotechnical Data Report, Downtown Rail Extension Project, Transbay Program (four volumes). Prepared for the Transbay Joint Powers Authority, San Francisco.</td>
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<td>Parsons Transportation Group. April 30, 2010. Final Geotechnical Interpretive Report, Part I, Soil and Rock Characterization for Mined Tunnel Design for the Caltrain Downtown Extension.</td>
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<td>Parsons Transportation Group. May 18, 2010. Final Geotechnical Interpretive Report, Part II, Design Recommendations for the 30% Preliminary Engineering Design Phase of the Cut-and-Cover Segment of the DTX Alignment for the Caltrain Downtown Extension.</td>
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CROSSINGS AT GRADE OF RAILROADS WITH PUBLIC STREETS, ROADS, STRUCTURES, PARALLEL TRACKS, CROSSINGS OF PUBLIC ROADS, AND HIGHWAYS IN THE STATE OF CALIFORNIA

RULES GOVERNING THE CONSTRUCTION AND MAINTENANCE OF PUBLIC AND PRIVATE UTILITIES INCLUDING SFPUC COMBINED SEWER SYSTEM PERFORMANCE CRITERIA. CONFIRM THAT SEISMIC DESIGN WILL ALSO BE FOLDED INTO OTHER IMPROVEMENTS.

Chapter 13 is no longer a standalone chapter for seismic design. It is indicated that improvements.

• New at-grade maintenance-of-way track and turnback track running adjacent to trackwork includes the mainline tracks through the tunnel and stations as well as a 1/2-mile of at-grade tracks within the existing Caltrain right-of-way that include the tie-in with Fourth & King station leads, a part of the TJPA's program, but no larger part of the DTX program.

• Notice to Designers” – Design Criteria.

To replace with updated DTX project description.

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Note: The PMPC maintains the turnback tracks, not the whole alignment.
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</table>
practicable remote condition monitoring equipment shall be used

add a sentence, “CHSRA is not expected to begin operations until construction of...”

are currently based upon candidate wide-body HSR trainsets.

an adhesion rate of 33% shall be assumed for load flow purposes."

Add a sentence, “...shall accommodate both Caltrain commuter and high-speed...”
<table>
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<tr>
<th>No.</th>
<th>Reference</th>
<th>By whom</th>
<th>Date (mm/dd/yy)</th>
<th>Reviewer Comment</th>
<th>Date (mm/dd/yy)</th>
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<th>PNEG Response</th>
<th>Date (mm/dd/yy)</th>
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</table>
| TA.003 | Section 2.3.1, Commuter Trains (Para 1) | 9/1/22 | | The responder (PMPC Team) answered the inquiry, no change required - comment this comment is considered closed. | | | | | | |}
| TA.005 | Section 2.3.1, Commuter Trains (Para 2) | 9/1/22 | | The Caltrain EMU will have regenerative braking capabilities but for the purpose of this section it is more convenient to assume no regenerative braking | | | | | | |}
| TA.006 | Section 2.3.1, Commuter Trains (Para 3) | 9/1/22 | | The responder (PMPC Team) answered the inquiry, no change required - comment this comment is considered closed. | | | | | | |}
| TA.008 | Section 2.3.1, Commuter Trains (Para 4) | 9/1/22 | | The responder (PMPC Team) answered the inquiry, no change required - comment this comment is considered closed. | | | | | | |}
| TA.009 | Section 2.3.1, Commuter Trains (Para 5) | 9/1/22 | | The responder (PMPC Team) answered the inquiry, no change required - comment this comment is considered closed. | | | | | | |}
| TA.010 | Section 2.3.1, Commuter Trains (Para 6) | 9/1/22 | | The responder (PMPC Team) answered the inquiry, no change required - comment this comment is considered closed. | | | | | | |
### Downtown Rail Extension (DTX)

**Reviewer Organization:**
Preliminary Engineering

**Responder Organization:**
DTX Design Criteria DRAFT Book Revision 02 - Chapter 03, Safety and Security

### Review Team

- Chukwuma Umolu (Design Team/Parsons)
- Meghan Murphy (PMPC/AEC)

### Review Team PMPC Team

<table>
<thead>
<tr>
<th>No.</th>
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<td>1.01</td>
<td>GEC.001 Chapter 3, Codes, Standards &amp; Guidelines</td>
<td>CU 11/29/21</td>
<td>Add NFPA 130 and any other relevant NFPA guidelines.</td>
<td>05/09/22 KS A NFPA 130 and CBC added 08/05/22 ROK 08/05/22 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 08/05/22 CC</td>
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<tr>
<td>1.02</td>
<td>GEC.002 3.2 - Safety and Security Certification, ¶3-1</td>
<td>CU 11/29/21</td>
<td>Suggest identifying roles of FLS Committee relevant to all design phases.</td>
<td>05/16/22 MM DE Revised to read as follows: “The documentation will comprise a series of certificates attesting to conformance with safety and security requirements of the individual system elements, procedures, and training programs.” 08/05/22 ROK 08/05/22 MM The responder (PMPC Team) has made changes to the document that negate original comment; therefore this comment is considered closed. 08/05/22 CC</td>
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<td>1.03</td>
<td>HSR.001 3 - General</td>
<td>JRD 04/15/22</td>
<td>CH 3 should address Crime Prevention thru Environmental Design except as reference - what do you want them to do?</td>
<td>05/13/22 MM C TJPA’s Threat and Vulnerability Assessment and associated project-specific criteria will address this item. 05/13/22 ROK 05/13/22 MM The responder (PMPC Team) acknowledged original comment; therefore this comment is considered closed. 05/13/22 CC</td>
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<td>1.04</td>
<td>HSR.002 3 - General</td>
<td>JRD 04/15/22</td>
<td>CH 3 should address ATPA safety and security guidelines and standards</td>
<td>05/13/22 MM C TJPA’s Threat and Vulnerability Assessment and associated project-specific criteria will address this item. 05/13/22 ROK 05/13/22 MM The responder (PMPC Team) acknowledged original comment; therefore this comment is considered closed. 05/13/22 CC</td>
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<td>1.05</td>
<td>HSR.003 3 - General</td>
<td>JRD 04/15/22</td>
<td>CH 3 does not address anti-terror provisions</td>
<td>05/13/22 MM C TJPA’s Threat and Vulnerability Assessment and associated project-specific criteria will address this item. 05/13/22 ROK 05/13/22 MM The responder (PMPC Team) acknowledged original comment; therefore this comment is considered closed. 05/13/22 CC</td>
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<td>HSR.004 3 - General</td>
<td>JRD 04/15/22</td>
<td>CH 3 consider accident prevention thru design processes</td>
<td>05/13/22 MM C TJPA’s Threat and Vulnerability Assessment and associated project-specific criteria will address this item. 05/13/22 ROK 05/13/22 MM The responder (PMPC Team) acknowledged original comment; therefore this comment is considered closed. 05/13/22 CC</td>
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</table>

### TA.001

**Chapter 3, System Safety and Security (Codes, Standards, and Guidelines, first sentence)**

LZ 07/04/22 Add “will” before “guide” 9/1/2022 MJS A Revised as noted (will was added but there is no “Guided” in the sentence) 09/27/22 MJS The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 09/27/22 CC
<table>
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<th>No.</th>
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<td>Reference to Chapter 4 Civil Design, added</td>
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<td>GEC.006 General SL 09/12/16 LEGACY Comment GEC16.001 - Did not review drainage/hydrology design</td>
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<td>GEC.005 DC 4.8.4 PC 10/18/18 LEGACY Comment GEC18.033 - Simply reference to geotechnical documents?</td>
<td>MM</td>
<td>10/28/22</td>
<td>MJS</td>
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<td>4</td>
<td>GEC.002 4.8.1 - Geotechnical Data, ¶1-1</td>
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<td>These documents are in the process of being updated. Referenced dates will need</td>
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<td>GEC.004 DC 4.8.1 PC 10/18/18 LEGACY Comment GEC18.032 - We will have to update all references to Cal.001 Chapter 4 Section 4.2; TA.001 Section 4.9, Atmospheric Pollution No. Reference By</td>
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Total Comments: 9

% Complete: 100%

The responder (PMPC Team) has agreed to provide ambient/design temperature and humidity ranges within the tunnel and underground structures during the next phase of design. The comment will be considered closed for this revision of the DTX Design Criteria and will become an action item to carry forward.

For clarity add "of the SEIS/EIR" after "D.2" 09/01/22 MJS C

Noted. The PMPC team has researched sea level rise and 100-year storm event - a criterion to be revised.

The responder (PMPC Team) has agreed to provide ambient/design temperature and humidity ranges within the tunnel and underground structures during the next phase of design. The comment will be considered closed for this revision of the DTX Design Criteria and will become an action item to carry forward.

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Yes, this will be the Traffic Management Plan (TMP). References to a “MPT Plan.

Phase:

GEC.001 Chapter 5, Codes and Standards,

GEC.021 5.6.4 CF 10/01/18 LEGACY Comment GEC18A.008 - This section references DPT, but the

GEC.009 Section 5.1.2,

GEC.005 5.4.4 - Drainage Infrastructure, ¶1-

GEC.002 Chapter 5, Codes and Standards,

GEC.018 5.6.1 CF 10/01/18

GEC.007 Section 5.1.1,

GEC.013 Section 5.2.1.2,

GEC.020 5.6.3 CF 10/01/18 LEGACY Comment GEC18A.007 - This section is appropriate for a Traffic

No. Reference By

Page 5-2,  (Table 5.1) QM 09/12/16 LEGACY Comment GEC16.024 - Benchmark AB 7677: revise Northing to 37 44

2 CU 11/29/21

Page 5-2,  (Table 5.1) QM 09/12/16 LEGACY Comment GEC16.023 - Benchmark AB 7679: revise Northing to 37 42

Downtown Rail Extension (DTX)

Line 5

Page 5-3,

Transbay Program

Charles Felder (Design Team/CHS)

Q. Mehirdel (Design Team)

Downtown Rail Extension (DTX) Design Criteria DRAFT Book Revision 02 - Chapter 05, Civil Design

QM 09/12/16 LEGACY Comment GEC16.028 - Add the following after “Traffic Control

MBr

AG

KS

LZ

Review Team PMPC Team Review Team PMPC Team

between Bryant Street and Townsend Street).

33 (per NGS online database) 10/28/21 AG B Agree, confirmed online. 11/18/21 ROK

utility companies might have different clearance standards, should also include

appropriate agency would be SFMTA.

Potential for what will be Traffic Management Plan (within the context of the design

LEGACY Comment GEC18A.005 - No reference is made to potential transit delay

occur on weekday nights and weekends only.

LEGACY Comment GEC18A.004 - Paragraph 3 states that “Road closures may be

LEGACY Comment GEC18A.003 - The AASHTO Policy on Geometric Design of

criteria).

term for what will be Traffic Management Plan (within the context of the design

05/13/22 KS A Done 8/5/2022 ROK 8/5/2022 MJS

05/09/22 KS A Done 8/5/2022 MJS

05/13/22 KS A Done 8/5/2022 MJS

05/04/22 CC

8/5/2022 CC

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**Summary:**

The document includes a table with various comments and responses, indicating progress and action items. The comments cover a range of topics within the project, and responses are marked as ROK (response okay) or CC (comment closed). The table provides a structured overview of the review process, including due dates and responsible parties. The document appears to be a comprehensive report or summary of a project review, detailing the status and next steps for each comment.
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### Review Comment Sheet

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<td>RB</td>
<td>10/18/18</td>
<td>LEGACY Comment Cal18.007 - Underground utilities should be identified to determine impact to project and a decision made to relocate or replace prior to project award.</td>
<td>PMPC Team</td>
<td>A</td>
<td>02/28/22</td>
<td>A: On-going surveys are being undertaken to identify all existing underground utilities. Actions prior to project award.</td>
<td>Rick Bartholomew (Caltrain)</td>
<td>02/28/22</td>
<td>Call train did not object or reopen this comment during official review of the DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this comment review log.</td>
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<td>A: Section 6.6.7 Telecommunications PCJPB Fiber Optic Cable (backbone)</td>
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**Notes:**
- **PANC Response:** The action taken by the reviewer.
- **Back-check Comment:** Notes from back-check review.
- **Final Review:** The final status of the review.

---

**Project:** Multiple

**Phase:** PMPC Team

**Document name:** Document date:

**AC – Action Code**
- A: Responder agrees and will comply
- R: Responder disagrees for reasons noted
- C: Source provided no action needed
- B: Designee to evaluate

**RS – Response Status**
- O: Project open
- ROK: Response okay
- C: Comment closed

**BRS - Back-check Response Status**
- CC: Comment closed
- OC: Comment open
- RD: Comment revised/developed
- RC: Comment retracted

**DE – Designer to evaluate**

**MM**

**MJS**

**WS**

**JU**

---

**Initials Name Initials**

**Project organization:** Preliminary Engineering

**Responder organization:** Downtown Rail Extension (DTX) Design Criteria DRAFT Book Revision 02 - Chapter 06, Utilities

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**Reviewer Organization:** Preliminary Engineering

**Responder Organization:** DTX Design Criteria DRAFT Book Revision 02 - Chapter 06, Utilities

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**Reviewer Team:** PMPC Team

**Responder Team:** PMPC Team

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**Date:**
- 2/28/22
- 8/5/2022
- 8/4/2022
- 8/3/2022
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GEC.020 7.3.1 - Definition of Clearance

GEC.002 7.1.2, Eqn 7.1 Variable "Eu" FB 03/18/22 Revise to read as "Eu is the maximum unbalanced superelevation, in ... Revised as noted 8/5/2022 ROK 8/5/2022 MM The responder (PMPC Team) agreed to update per original comment; therefore this

GEC.019 7.3 - Clearances SM 03/18/22 Need to list special clearance situations such as platform edges, and walkways

GEC.023 GEC.022 GEC.010 7.2.2.2 - Minimum Radius of Curvature, Eqn #? SM/FB 03/18/22 R = (4V^2)/e (square velocity), most agencies use (4.011V^2)/e

GEC.007 GEC.006 7.2.1.2 - Tangent Track Spacing CU 03/18/22 Consolidate track spacing requirements scattered here, 7.2.5 and 7.2.7.4 into one

GEC.003 7.1.3 - Maximum Speeds through Curvature, ¶5-1 Circular Curves, ¶2-1 Spacing

7.3.4 - Adjustments to Clearances

GEC.019 7.3.6 - Minimum Horizontal and Vertical Clearances

Downtown Rail Extension (DTX)

Transbay Program

PMPC Team

Reviewers

FP - Frank Blachly (Design Team)
DD - Designers/Consultants
PGi - Preliminary Engineering
SW - Stephen Metz (Design Team)
FB - Frank Blachly
MC - Multiple Comments
JH - John Hristov (Design Team/Robin Chiang & Co.)
GP - George Pace (Design Team/Robin Chiang & Co.)
ZB - Zhen Song
JP - John Pan (Design Team)
CJ - CJ Choe (Design Team)
PF - Paul Fung (Design Team/Robin Chiang & Co.)
DMcL - David McLoud (CHSRA)
DC - David Chen
CC - Christine Cheng
GP - George Pace (Design Team/Robin Chiang & Co.)
DC - David Chen
ZB - Zhen Song
DMcL - David McLoud (CHSRA)
JH - John Hristov (Design Team/Robin Chiang & Co.)
SW - Stephen Metz (Design Team)
PGi - Preliminary Engineering
FP - Frank Blachly
CJ - CJ Choe (Design Team)
CF - Cliff Fung
SM - Stephen Metz (Design Team)
PF - Paul Fung (Design Team/Robin Chiang & Co.)
JP - John Pan (Design Team)
ZB - Zhen Song
CJ - CJ Choe (Design Team)
SW - Stephen Metz (Design Team)
PGi - Preliminary Engineering
FP - Frank Blachly
CJ - CJ Choe (Design Team)
CF - Cliff Fung
SM - Stephen Metz (Design Team)
ZB - Zhen Song
CJ - CJ Choe (Design Team)
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Caltrain Design Criteria (third edition, dated August
1989). The maximum speed for trains between the Fourth and King Street Stations is limited according to the design criteria. The authorized speed for trains approaching the Fourth and King Street Station between 40 mph and 50 mph. The maximum authorized speed for trains approaching the Fourth and King Street Stations between 30 mph and 40 mph. The maximum authorized speed for trains approaching the Fourth and King Street Station between 40 mph and 50 mph. The maximum authorized speed for trains approaching the Fourth and King Street Station between 30 mph and 40 mph.

### Track Spacing - Tangent Track (currently 7.2.1.2)

- Spiral, easement, or transition curves will be used between horizontal tangents and authorized speed for trains approaching the Fourth and King Street Station between 40 mph and 50 mph. The maximum authorized speed for trains approaching the Fourth and King Street Station between 30 mph and 40 mph.

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| Cal.019 | Section 7.2.3 | HL | 03/10/22 | "Cal.019 Section 7.2.3 - "Spiral curves are not required under the terms of operating speed at the minimum drivable roundabout, if the minimum drivable radii is not met."" | 03/10/22 | A | Interim Response with color (Draft Design Criteria) | 05/10/22 | N/A | Corroborated by color (Draft Design Criteria) | 05/10/22 | N/A | The responder agreed to update the original comment to be consistent with Cal.019 Design Criteria. The responder agreed to complete any additional work required to complete the comment is completed and closed. | 05/10/22 | CC
| Cal.019 | Section 7.2.4 | HL | 03/10/22 | "Cal.019 Section 7.2.4 - "The responder (PMPC Team) has confirmed that the criteria is compliant with the criteria shown in the existing comments, therefore this comment is closed. | 03/10/22 | A | Interim Design Criteria | 05/10/22 | N/A | Corroborated by color (Draft Design Criteria) | 05/10/22 | N/A | The responder (PMPC Team) has confirmed that the criteria is compliant with the criteria shown in the existing comments, therefore this comment is closed. | 05/10/22 | CC
| Cal.019 | Section 7.2.5 | HL | 03/10/22 | "Cal.019 Section 7.2.5 - "Spiral curves are not required under the terms of operating speed at the minimum drivable roundabout, if the minimum drivable radii is not met."" | 03/10/22 | A | Interim Design Criteria with color (Draft Design Criteria) | 05/10/22 | N/A | Corroborated by color (Draft Design Criteria) | 05/10/22 | N/A | The responder (PMPC Team) has confirmed that the criteria is compliant with the criteria shown in the existing comments, therefore this comment is closed. | 05/10/22 | CC
| Cal.019 | Table 7.6 | HL | 03/10/22 | "Cal.019 Table 7.6 - "Vehicles Dynamic Online" | 03/10/22 | A | Interim Design Criteria | 05/10/22 | N/A | Corroborated by color (Draft Design Criteria) | 05/10/22 | N/A | The responder (PMPC Team) has confirmed that the criteria is compliant with the criteria shown in the existing comments, therefore this comment is closed. | 05/10/22 | CC
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| Cal.019 | Section 7.1.6 | HL | 03/10/22 | "Cal.019 Section 7.1.6 - "Spiral curves are not required under the terms of operating speed at the minimum drivable roundabout, if the minimum drivable radii is not met."" | 03/10/22 | A | Interim Design Criteria | 05/10/22 | N/A | Corroborated by color (Draft Design Criteria) | 05/10/22 | N/A | The responder (PMPC Team) has confirmed that the criteria is compliant with the criteria shown in the existing comments, therefore this comment is closed. | 05/10/22 | CC
| Cal.019 | Section 7.1.7 | HL | 03/10/22 | "Cal.019 Section 7.1.7 - "Spiral curves are not required under the terms of operating speed at the minimum drivable roundabout, if the minimum drivable radii is not met."" | 03/10/22 | A | Interim Design Criteria | 05/10/22 | N/A | Corroborated by color (Draft Design Criteria) | 05/10/22 | N/A | The responder (PMPC Team) has confirmed that the criteria is compliant with the criteria shown in the existing comments, therefore this comment is closed. | 05/10/22 | CC
| Cal.022 | Section 7.1.1 | JB | 03/28/22 | "Cal.022 Section 7.1.1 - "Spiral curves are not required under the terms of operating speed at the minimum drivable roundabout, if the minimum drivable radii is not met."" | 03/28/22 | A | Interim Design Criteria | 05/10/22 | N/A | Corroborated by color (Draft Design Criteria) | 05/10/22 | N/A | The responder (PMPC Team) has confirmed that the criteria is compliant with the criteria shown in the existing comments, therefore this comment is closed. | 05/10/22 | CC

Table 1: Document Control File Code (DCFC) Details
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- **Document Control File Code (DCFC):** EMT-026
- **Revision:** EMT-026-026
- **Creation Date:** 02/28/22
- **Issue Date:** 05/10/22

**PEP (Project Engineer's Perspective):**
- **Owner:** A
- **Contractor:** A
- **Designer:** A

**KBS (Kick-Off Meeting Summary):**
- **Owner:** A
- **Contractor:** A
- **Designer:** A

**Comment:**
- **Type:** A
- **Date:** 02/28/22
- **KB:** N/A

**Black Check Comment:**
- **Type:** A
- **Date:** 05/10/22
- **KB:** N/A

**Addendum/Response/Next Steps:**
- **Type:** A
- **Date:** 05/10/22
- **KB:** N/A

**Read:**
- **Type:** A
- **Date:** 05/10/22
- **KB:** N/A
### Traction Program

#### Sectional Finalization (SF) - Final Section 72 - Chapter 73: Indemnity

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*Note: The table above contains information related to the project and its sections, including comments, responses, and dates of revisions.*
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**Trends Program Requirements and Objectives:**

- **Total Comments:** 125
- **Status:** Completed
- **Comments Closed:** 125
- **% Completed:** 100%

**Review Summary:**

- **Reviewers:** Stephen Metz (Design Team)

**Document Control File Code:**

- **PHC:** Project Director
- **Preparers:** Project Team

**Design Team:**

- **Design Team:** TDC Design Criteria: Design Review Handbook - Chapters 1 to 5

**BackCheck Comment:**

- **Responsibility:** BC - BackCheck Comment
- **Response Time:** 05/13/22
- **Read Time:** 05/13/22
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<td>09/12/16</td>
<td>LDG</td>
<td>Page 8-2 of 5 LDG 09/12/16</td>
<td>Add the term &quot;running&quot; after words: &quot;Concrete ties with rail … shall be used in all special trackwork, in curves with a radius which is less…&quot;</td>
<td>8/5/2022</td>
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<td>09/12/16</td>
<td>LDG</td>
<td>Page 8-2 of 5 LDG 09/12/16</td>
<td>Direct fixation block spacing shall be adjusted between areas of standard fasteners changing track modulus.</td>
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<td>09/12/16</td>
<td>LDG</td>
<td>Page 8-2 of 5 LDG 09/12/16</td>
<td>The terminology in the comment section will be a slight adjustment to ensure that the comment is clearly understood. This comment is considered closed. 8/5/2022 CC</td>
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Previous comment #Cal.003 stated that "embedded track" is not in Caltrain Design.

Cal.026 Chapter 8 Section 8.7 PCG 03/21/22

Cal.023 Chapter 8 Section 8.6.1 PCG 03/21/22

Cal.022 Chapter 8 Section 8.6 PCG 03/21/22

Change to read: "Derailment Containment and Derails" 05/12/22 MJS A Revised as noted 05/13/22 ROK 05/13/22 MM

The responder (PMPC Team) agreed to update per original comment; therefore

Cal.030 Section 8.2.2 HL 10/18/18 LEGACY Comment Cal18.026 - 10 ft concrete ties shall be used for at-grade standard ties are both concrete, the transition ties shall also be concrete. System must be of a proven design, meeting Caltrain Design Criteria and requires that restraining rails be installed in tunnels which covers the entire below

Restraining rails also called Guard Rails, they are also used on curved track, 8.6.1

02/28/22 MJS A

"Standard ties for at-grade crossings are concrete suitable for moisture-prone to provide enhanced load distribution for additional vehicular traffic."

Hydraulic bumping posts must be installed, at minimum, three ties before the end

Revised to read as follows:

new tracks."

..with a Brinell Harness Number of 370 will be used in all special trackwork and

设计师同意按要求修改评论并作出必要更改。No track
designer response was received from Caltrans, thus the comment is considered closed.

设计师同意按要求修改评论并作出必要更改。No track
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设计师同意按要求修改评论并作出必要更改。No track
designer response was received from Caltrans, thus the comment is considered closed.
Project: Frank Blachly (Design Team)  
Name (initials): M. Brunner (CHSRA)  
PMPC Team (mm/dd/yy): RS Back-Check Comment

HSR.002 8.1.1 DMcL 03/22/22 The track gauge will be 4 feet 8.5 inches, not just on tangent track except on tight radius curves. (see Chapter 2, Track Section A- General)  
LEGACY Comment Cal18.031 - Section 8.5.1 Rail Lubrication ( revise first paragraph. Is there a likelihood that this may happen as it is temporary track grade crossings must conform with Caltrain Design Criteria.)

Temporary tracks to support staged construction that will not be in service more than 3 years, and where is it located (also see 9 below), also what type of ties will any temporary rail on the gauge side on all tracks except on tight radius curves where gauge expansion requirements are met in the initial design.  
09/09/22 MS  
10/12/21 CC

09/09/22 MS  
10/12/21 CC

09/09/22 MS  
10/12/21 CC

09/09/22 MS  
10/12/21 CC

The PMF Team met with Caltrain and the Design Team for a C2H held on 9/27/2021 where this issue was reviewed.
Multiple Document Control File Code:

HSR.019 8.5.2 DMcL 03/22/22

HSR.017 8.5.1 DMcL 03/22/22

HSR.016 8.3 DMcL 03/22/22

For the crossovers on the 650 feet radius curve there should be a risk assessment

HSR.015 8.3 DMcL 03/22/22

This section could be rationalized concentrating on the units that will be used.

HSR.020 8.2.7 DMcL 03/22/22

TA.002 Section 8.7, At-Grade Crossings LZ 07/04/22 Sentence needs to be restructured for clarity 09/02/22 MJS A Revised as noted. 9/27/2022 MJS The PMPC Team met with Caltrain and the Design Team for a CRM held on

AFFECTS: Caltrain and CHSRA

needs to follow

could be expanded and the minimum depths added as a minimum 05/12/22 MJS C 05/19/22 MM C 09/02/22 MJS A Revised bullet to read as follows:

(2009).

rails in section 8.6.1 since the term guard rail is sometimes used for restraining

Ballasted track will be used for the at-grade portion of the alignment (Main line, lubricant in case of malfunction or rupture of a hydraulic hose or valve.

include an analysis to ensure the following locations are provided with sufficient

this comment is considered closed. 05/25/22 CC

8/5/2022 CC

8/5/2022 CC

8/5/2022 CC

8/5/2022 CC

8/5/2022 CC

8/5/2022 CC

8/5/2022 CC

10/25/2021 MM MBS did not object to require the comment during affect review of the DTS Design Review Book No. 2 (Draft Final dated 1/3, 2022) and this comment is considered closed.

10/25/2021 MM MBS did not object to require the comment during affect review of the DTS Design Review Book No. 2 (Draft Final dated 1/3, 2022) and this comment is considered closed.

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<td>BRS - Back-check Response Status</td>
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Note: The table above includes tracking information for review comments on a document related to geotechnical investigations and analysis. Each entry includes the reference number, date of the comment, reviewer's initials, the nature of the comment, the responsible party, and the status of the comment as of the final bid date.
characterize the bedrock:

Soil sampling generally about once every 5 feet and at layer changes, with

Agree, will add “about” and switch “can” to “may” in first bullet. Disagree with

The Design Team did not object or reopen this comment during official review of the DTX Design Criteria Book 02 - Draft Final (June 1, 2022) and this comment is considered closed.

This comment is considered closed.

The DTX Design Criteria Book 02 - Draft Final (June 1, 2022) and this reference is used in the 9th Edition, 2019. Recommended update in reference 2015

The response (PSDH) Today agreed to update per original comments therefore this comment is considered closed.

The response (PSDH) Today agreed to update per original comments therefore this comment is considered closed.
This page contains a document related to the Downtown Rail Extension (DTX). It includes a list of comments and responses, with dates and signatures indicating the progress and resolution of issues regarding the project. The comments and responses are organized in a tabular format, with columns for number, reference, ticket number, project number, date, reviewer comment, responsible party, DTX response, and comments. The content discusses various aspects of the project, such as geotechnical data and monitoring, pile capacities, and other technical considerations. The document appears to be a project management tool used to track and manage the feedback and updates from the Design Team. The references to the DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022) indicate that the discussions are based on or related to the project's draft final criteria.
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**GEC.071 Sect 9.5.4, 2nd paragraph YS**

LEGACY Comment: Please clarify. It is noted in the above section is not clear if the condition is a result of the DTX project, ROK - response okay, CC - comment closed.

**GEC.069 Sect. 9.2, GRR YS**

LEGACY Comment: DTX.092 PC

**GEC.068 DC 9.2 PC**

LEGACY Comment: DTX.092 PC

**LEGACY Comment: GEC18.043 - Suggest adding "compensation grouting" to one**

**LEGACY Comment: GEC16.049 - This section is ok and very general. Knowing**

**TJPA want to follow? We should clearly refer to the table (assume it will be in Ch.**

**Please specify the material required from ASCE/SME. Are these referring to**

**The final decision for the inclusion of any material or performance shall be made by the project engineer. Please clarify this.**

**It is noted in the above section is not clear if the condition is a result of the DTX project, ROK - response okay, CC - comment closed.**

**LEGACY Comment: DTX.092 PC**

**LEGACY Comment: DTX.092 PC**

**Please specify the material required from ASCE/SME. Are these referring to**

**The final decision for the inclusion of any material or performance shall be made by the project engineer. Please clarify this.**

**LEGACY Comment: DTX.092 PC**

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**LEGACY Comment: DTX.092 PC**

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**Please specify the material required from ASCE/SME. Are these referring to**

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<td>M &amp; F</td>
<td>I-DRM will not allow erosion drilling to occur as drilling method removes coarse aggregate in highly disturbed samples. No soils for which the most soil conditions can accommodate p300w loads; where not excluded to determine DP.</td>
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<td>M</td>
<td>F</td>
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<td>JL</td>
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<td>S.F</td>
<td>07/06/22</td>
<td>More that &quot;sampling may be removed&quot; but the measure to be the distance from face, sampling, so the sampling is focused on should read &quot;samplng may be removed to...&quot;</td>
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<td>Need to modify the specification to be clear that sampling is focused on the face of the structure.</td>
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<td>Section 9.6, Instrumentation and Measuring Devices</td>
<td>S.F</td>
<td>07/06/22</td>
<td>More to reference to the specifications for additional information, but the Design office forms the basis for qualifications, not for other information</td>
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<td>Need to modify the specification to be clear that sampling is focused on the face of the structure.</td>
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<td>The text includes the dimensions of the instrument (form) to be used and implemented</td>
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<td>10.3.1</td>
<td>RI</td>
<td>R2</td>
<td>A refinement to the seismic design is proposed that would result in a higher peak ground acceleration than the current design.</td>
<td>Y. Sun</td>
<td>04/08/22</td>
<td>Initials Name Initials</td>
<td>05/09/22</td>
<td>Revised as follows: &quot;...ingress of flowing groundwater...&quot;</td>
<td>05/13/22</td>
<td>A</td>
<td>Revised as follows: &quot;...ingress of flowing groundwater...&quot;</td>
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<td>GEC-002</td>
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<td>RI</td>
<td>R2</td>
<td>The design criteria of &quot;displacement ductility ratio of 1.5 must be...&quot; are no requirements in the CBC for peer reviews. Please clarify what the reference to Section 322 peer review requirements in the CBC means.</td>
<td>Joel Pancoast (Caltrain)</td>
<td>05/13/22</td>
<td>A</td>
<td>Revised as follows: &quot;...ingress of flowing groundwater...&quot;</td>
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<td>GEC-003</td>
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<td>The project team was asked to update the PAR with the newer revisions.</td>
<td>Yue Shi (Design Team)</td>
<td>05/13/22</td>
<td>A</td>
<td>Revised as follows: &quot;...ingress of flowing groundwater...&quot;</td>
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<td>GEC-004</td>
<td>10.3.1</td>
<td>RI</td>
<td>R2</td>
<td>Should this be Chapter 13 instead of 10? If so, please make changes in the entire Chapter 13.</td>
<td>Y. Sun</td>
<td>04/08/22</td>
<td>A</td>
<td>Revised as follows: &quot;...ingress of flowing groundwater...&quot;</td>
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<td>GEC-005</td>
<td>10.3.1</td>
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<td>R2</td>
<td>Since CalTrain and HSR allow a displacement ductility ratio of 1.5 (under SEE event), please confirm that the allowable strain limits are compatible with the maximum displacement ductility ratio of 1.5 (under SEE event).</td>
<td>Y. Sun</td>
<td>04/08/22</td>
<td>A</td>
<td>Revised as follows: &quot;...ingress of flowing groundwater...&quot;</td>
<td></td>
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<tr>
<td>GEC-006</td>
<td>10.3.1</td>
<td>RI</td>
<td>R2</td>
<td>Please confirm that under the SEE earthquake, maximum displacement ductility ratio of 1.5 is applicable.</td>
<td>Yue Shi (Design Team)</td>
<td>04/08/22</td>
<td>A</td>
<td>Revised as follows: &quot;...ingress of flowing groundwater...&quot;</td>
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<td>GEC-007</td>
<td>10.3.1</td>
<td>RI</td>
<td>R2</td>
<td>Please confirm that Section 10.3.1 is not 10.3.10.</td>
<td>Yue Shi (Design Team)</td>
<td>04/08/22</td>
<td>A</td>
<td>Revised as follows: &quot;...ingress of flowing groundwater...&quot;</td>
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<td>GEC-008</td>
<td>10.3.1</td>
<td>RI</td>
<td>R2</td>
<td>The file name and number were carried over from previous version (REV 01). Seismic Design will be Chapter 10 in the DTX Design Criteria Revision Book 02. Chapter, section, and subsection numbering have been updated accordingly.</td>
<td>Yue Shi (Design Team)</td>
<td>04/08/22</td>
<td>A</td>
<td>Revised as follows: &quot;...ingress of flowing groundwater...&quot;</td>
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<td>GEC-009</td>
<td>10.3.1</td>
<td>RI</td>
<td>R2</td>
<td>Please confirm that the performance requirements for earthquake load performance in Chapter 3, Design requirements, are unchanged as to how and where the demands are calculated.</td>
<td>Yue Shi (Design Team)</td>
<td>04/08/22</td>
<td>A</td>
<td>Revised as follows: &quot;...ingress of flowing groundwater...&quot;</td>
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<td>GEC-010</td>
<td>10.3.1</td>
<td>RI</td>
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<td>Should note the Chapter 10 of DTX, please make changes to the current Chapter 3.</td>
<td>Yue Shi (Design Team)</td>
<td>04/08/22</td>
<td>A</td>
<td>Revised as follows: &quot;...ingress of flowing groundwater...&quot;</td>
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<td>GEC-011</td>
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<td>The directivity modeling apply to surface structures designed per the building code?</td>
<td>Yue Shi (Design Team)</td>
<td>04/08/22</td>
<td>A</td>
<td>Revised as follows: &quot;...ingress of flowing groundwater...&quot;</td>
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<tr>
<td>GEC-012</td>
<td>10.3.1</td>
<td>RI</td>
<td>R2</td>
<td>The provisions of Chapter 10, Seismic Design will be Chapter 10 in the DTX Design Criteria Revision Book 02. Chapter, section, and subsection numbering have been updated accordingly.</td>
<td>Yue Shi (Design Team)</td>
<td>04/08/22</td>
<td>A</td>
<td>Revised as follows: &quot;...ingress of flowing groundwater...&quot;</td>
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GEC.024 Chapter 13 PC 09/12/16 LEGACY Comment GEC16.081 - OBE design event? 05/20/22 JL A

GEC.020 Ch10.7 Buildings and Surface Facilities JG 04/08/22

preliminary design”.

buildings and surface facilities meets SFBC – i.e., CBC and ASCE7 as specified in

Risk definitions are included in the Threat and Vulnerability Assessment and are

used.

The Design Team did not object or reopen this comment during official review of the DPS Design Center Rev B51 - Draft Final June 1, 2022, and this comment was closed.

8/31/22 UT

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The Design Team did not object or reopen this comment during official review of the DPS Design Center Rev B51 - Draft Final June 1, 22
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**Issues Closed**

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<td>1</td>
<td>Paper 1-2</td>
<td>05/10/22</td>
<td>A. New approach to linear vs. nonlinear response is proposed.</td>
<td>M. J. A.</td>
<td>05/10/22</td>
<td>Confirmed response is satisfactory to TAJPA.</td>
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<td>Paper 1-2</td>
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**Comments Closed**

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<td>Paper 1-2</td>
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<td>M. J. A.</td>
<td>05/10/22</td>
<td>Confirmed response is satisfactory to TAJPA.</td>
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</table>
The Table 10-1 SEE cut-cover concrete compressive strain of 0.006 CHSR criteria is similar and approaches this as the segments are capacity the walls, using specified minimum f'c & phi = 1.0. This is inconsistent with Table 10-1 for FEE (operability) strain limits which, for extreme Event 1a for FEE, T-1b for SEE, or similar). 05/13/22 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 05/13/22 CC This section states "If joints are proposed within the mined tunnel final lining, the phase of design (appears consistent with LA Metro design criteria).
The performance objectives for each earthquake level are presented in Chapter 2, and it is recommended defining what is required for final design.

What is the purpose of including this statement in design criteria? Instead, 10/03/22 MJS The responder (PMPC Team) agreed to update per original comment; therefore, the comment is considered closed.
**Section 10.1 - Determination of the 1/8-Inch Ground Movement**

The purpose of the ZOI is to determine buildings to be assessed. The size of the ZOI is determined by two different methods: the Boscardin and Cording method and the ZOI based on the location of existing underground structures or tunnels. The ZOI shall be revised to reflect Arup’s approach to the zone of influence definitions of zone of influence. See comments in Section 11.1.1.

The ZOI shall be developed for structures such as buildings, supported and supported structures. It needs to define clearly in which buildings or circumstances the designer shall perform SSI interaction (for example, if the damage category of structures are buildings). Also, pile(s) of the adjacent highway super-structures may be founded in Zone C but above an existing underground structures or tunnels which are located in Zone C. Will the DTX alignment exclude these scenarios?

These are taken forward to Stage 2, where more detailed screening of the potential influence.

For example, Stage 1 is a preliminary damage assessment phase. In this stage, the designer shall perform SSI analyses for buildings with damage categories of “Slight” or greater. This needs to be more specific. For example, no additional analyses are required for buildings with damage categories less than “Slight” (or “Low”).

The DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this comment are referenced. The Design Team did not object or reopen this comment during official review of the DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this comment review log.

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The Boscarding and Cording method is mentioned in Section 10.1. Buildings that...

The Design Team did not object or reopen this comment during official review of...

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**Phase:**
Andrew Baltay (Design Team/MJA) (initials)  
**Responders:**
Matt Schreffler (PMPC/Mott MacDonald)  

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**PSRC Response:**
- NA: No response
- Final BRS: Final BRS document
- MM: Modified
- MM: Added
- MM: Removed
- MM: Updated

**Final BRS:**
03/03/22
The column of vertical load: CBS should be revised to read as CBDS.

LEGACY Comment GEC16.066 - Under the sub-heading of Chapter 11-
LEGACY Comment GEC16.065 - Under the sub-heading of 11.2.1.14, "Load
LEGACY Comment GEC16.069 - Under the sub-heading of 11.2.1.15,
02/28/22 NLV A This section has been changed to follow California Bridge Design Specification
02/28/22 NLV A Section changed to use AASHTO LRFD Tunnels Guide Specifications load factors
the DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this
not provide any backcheck response and therefore this comment is considered

8/5/2022 CC
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**Reviewer Comment:**

- Disagree.
- Concrete cover. ROK 05/13/22 MM
- The responder (PMPC Team) agreed to update per original comment. Caltrain did close.

**Final RBD:**

Date (mm/dd/yy)
Section 12.2.1.1 L-R

SRL: 06/18 12.2.1.1 Rad Load Cases - Must see Summary of load levels be included.

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**Phase:** No. Reference By

- **Noel Vivar (PMPC SME/Mott MacDonald)** 2/28/22 (initials) NLV

**Initials:**
- **ACI 533.5R Guide for Precast Concrete Tunnel Segments**
- **Technical Requirements or Specifications**

**Final Comments:**
- **05/26/22 MM Comment response is satisfactory to TJPA. 05/26/22 CC Response response is satisfactory to TJPA.**

**Attachment:**
- **Cal.007 Chapter 11.2.1.1 JP 04/29/22 revise; within the zone of influence, reference chapter 10 05/13/22 NLV.**

**Slight word changes:**
- **ACI 533.5R Guide for Precast Concrete Tunnel Segments**
- **Technical Requirements or Specifications**

**Dates:**
- **04/28/22**
- **05/13/22**
- **05/15/22**
- **05/26/22**
- **06/02/22**
- **06/03/22**
- **06/04/22**
- **06/05/22**

**References:**
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- **Technical Requirements or Specifications**
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<td>Mark issue for future tracking.</td>
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<td>5.4.05</td>
<td>Section 12.3.4, Waterproofing</td>
<td>Y. Sun (Design Team/MJA)</td>
<td>No discussions on waterproofing.</td>
<td>08/02/22</td>
<td>XVL</td>
<td>Review inspection report and recommend area for improvement.</td>
<td>08/02/22</td>
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<td>Section 12.3.5, Waterproofing</td>
<td>Y. Sun (Design Team/MJA)</td>
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<td>Y. Sun (Design Team/MJA)</td>
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<td>08/02/22</td>
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<td>08/02/22</td>
<td>XVL</td>
<td>Not applicable</td>
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**Responder Organization:**
- FW C – Answer provided; no action needed
- AC – Action Code

**Next Steps:**
- Review inspection report and recommend area for improvement.
- Mark issue for future tracking.
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<td>EDC.001</td>
<td>Section 13 Scope, pg. 13-1</td>
<td>KY</td>
<td>12/10/21</td>
<td>Update the references for the general parameters to latest geotechnical reports</td>
<td>Memorandum of Understanding (MOU)</td>
<td>09/30/22</td>
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<td>Section 13, Standards and Guidelines, pg. 13-1</td>
<td>VS</td>
<td>12/10/21</td>
<td>Update for latest standards and add the following: American Concrete Institute (ACI), 2013. ACI 622.1-08: Specification for Structural Steel Buildings.</td>
<td>Memorandum of Understanding (MOU)</td>
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<td>Section 13 Scope, pg. 13-2</td>
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<td>Lattice girders shall have a yield strength of 70ksi&quot;</td>
<td>American Institute of Steel Construction (AISC). 2016. ANSI/AISC 360-16 – Specification for Structural Steel Buildings.</td>
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<td>Section 13.1.2, pg. 13-3</td>
<td>YS</td>
<td>04/08/22</td>
<td>Delete the word “face” as fiberglass dowels may also be used for temporary support.</td>
<td>American Concrete Institute (ACI). 2013. ACI 506.2 – Specification for Shotcrete.</td>
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<td>Section 13.5.3, 2nd Para., Page 11-13 of 19</td>
<td>YS</td>
<td>04/08/22</td>
<td>Add “conforming to ASTM A615&quot; behind “Lattice girders shall have a yield strength of 70ksi”</td>
<td>American Institute of Steel Construction (AISC). 2016. ANSI/AISC 360-16 – Specification for Structural Steel Buildings.</td>
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<td>American Institute of Steel Construction (AISC). 2016. ANSI/AISC 360-16 – Specification for Structural Steel Buildings.</td>
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<td>PC</td>
<td>09/12/16</td>
<td>LEGACY Comment GEC18.064 - There are no criteria for TBM or segmental lining</td>
<td>American Institute of Steel Construction (AISC). 2016. ANSI/AISC 360-16 – Specification for Structural Steel Buildings.</td>
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<td>LEGACY Comment GEC16.079 - Add a sub-section describing Tunnel Portals requirements</td>
<td>American Institute of Steel Construction (AISC). 2016. ANSI/AISC 360-16 – Specification for Structural Steel Buildings.</td>
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<td>LEGACY Comment GEC16.080 - Need to make sure TJPA and JA (design team) agree with the load sharing concept, and if yes, the method to analyze load sharing.</td>
<td>American Institute of Steel Construction (AISC). 2016. ANSI/AISC 360-16 – Specification for Structural Steel Buildings.</td>
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<td>American Institute of Steel Construction (AISC). 2016. ANSI/AISC 360-16 – Specification for Structural Steel Buildings.</td>
<td>09/30/22</td>
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<td>American Institute of Steel Construction (AISC). 2016. ANSI/AISC 360-16 – Specification for Structural Steel Buildings.</td>
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<td>Understood. Can we/should we add a load-sharing concept to the bid documents and/or only the temporary support?</td>
<td>American Institute of Steel Construction (AISC). 2016. ANSI/AISC 360-16 – Specification for Structural Steel Buildings.</td>
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<td>09/12/16</td>
<td>Originally responses for TBM tunnels had been found in the temporary support section.</td>
<td>American Institute of Steel Construction (AISC). 2016. ANSI/AISC 360-16 – Specification for Structural Steel Buildings.</td>
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<td>American Institute of Steel Construction (AISC). 2016. ANSI/AISC 360-16 – Specification for Structural Steel Buildings.</td>
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<td>American Institute of Steel Construction (AISC). 2016. ANSI/AISC 360-16 – Specification for Structural Steel Buildings.</td>
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<td>American Institute of Steel Construction (AISC). 2016. ANSI/AISC 360-16 – Specification for Structural Steel Buildings.</td>
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<td>03/22/22</td>
<td>MSH</td>
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<td>GEC - Project Geotechnical Engineer Report, Part II Soil and Rock Characterization for Bicycle Tunnel Design of the Caltrans Innovation Station at San Francisco International Airport</td>
<td>03/22/22</td>
<td>GEC</td>
<td>According to the current plan, the MJA's Characturization of Tunnelling PSIC will be included in the final GEC - Comment closed.</td>
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<td>GDC-107 sec. 12</td>
<td>RC</td>
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<td>MSH</td>
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<td>GEC - Project Geotechnical Engineer Report, Part II Soil and Rock Characterization for Bicycle Tunnel Design of the Caltrans Innovation Station at San Francisco International Airport</td>
<td>03/22/22</td>
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<td>03/22/22</td>
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**Notes:**
- **PSIC Response**
  - **A**: Actionable
  - **B/S**: Background and Site
  - **DP**: Discussion Points

**Final R/S**
- **DP**: Dispersed for further review and may be included in the final GIR. Comment closed.
- **SM**: Updated for additional comments. Updated for editorial comments. Updated for additional comments. Updated for additional comments. Updated for additional comments.
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<td>GEC.034 Sect. 12.8.1.3, 3rd bullet YS</td>
<td>Legacy Comment GEC.034 Sect. 12.8.1.3, 3rd bullet YS</td>
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<td>2-1, 3.1.4.3.2</td>
<td>Cal.009 Chapter 13 - 13.5.2 BZ 04/21/22</td>
<td>Geotechnical engineer to approve selected factors of safety. 05/03/22</td>
<td>DP A Revised as noted. 05/16/22 ROK 05/16/22 MM The responder agreed to update per original comment; therefore</td>
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<td>2-1, 3.1.4.3.2</td>
<td>Cal.008 Chapter 13 - 13.2 BZ 04/21/22</td>
<td>Revise font to lower case; revise sentence to clarify subsections. 05/02/22</td>
<td>DP A Revised as noted. 05/16/22 ROK 05/16/22 MM The responder agreed to update per original comment; therefore</td>
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<td>5</td>
<td>2-1, 3.1.4.3.2</td>
<td>Any design guideline/criteria for tunnel waterproofing? 08/19/22</td>
<td>DP C Yes, agreed we should address that. 05/04/22 ROK No further comment. 05/04/22 CC</td>
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<td>6</td>
<td>2-1, 3.1.4.3.2</td>
<td>Cal.010 Chapter 12 BZ 10/18/18</td>
<td>Revision of the DTX Design Criteria and will become an action item to carry during the next phase of design. The comment will be considered closed for this revision. 05/04/22</td>
<td>ROK 05/04/22 CC</td>
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<td>7</td>
<td>2-1, 3.1.4.3.2</td>
<td>Cal.007 Chapter 12 BZ 04/21/22</td>
<td>Modification second bullet to read as follows: &quot;Need for face support, pre-support, or shotcrete? Pre-support or shotcrete may now be used to pre-support grouted anchor tubes. It may not be a required practice. The design will need to be reviewed for face support and shotcrete. This comment is considered closed. 05/16/22</td>
<td>CC 05/16/22</td>
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**Note:** The above table represents a summary of comments and actions taken on the project document. Each comment is referenced with a specific date to indicate when it was reviewed or updated.
HSR.001 Section 13.1, p. 2 SK 03/28/22 Suggest deleting “temporary” and reword to say “used for initial support and final lining”.

HSR.004 Section 13.1.6, p. 5 SK 03/28/22 Gasket material specifications should be provided like ASTM C920, ASTM D412, the final lining. Some load combinations applied to final lining involve long-term aggregates, admixtures, etc. Shouldn’t design ground loads be given in the Geotechnical Baseline Report?

A Revised as noted 05/16/22

05/03/22 DP

A Revised as noted 05/16/22

05/16/22 CC

The comment will be considered closed for this revision of the DTX Design.

05/16/22 CC

"Precast tunnel lining segments must include perimeter gaskets conforming with the specification..."

08/19/22 CC

The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.
1. Review a summary of the load sharing between the tunnel support and the initial support.

   - Review the summary of the load sharing and comment on the feasibility of transferring the load to the initial support system.

2. Evaluate the groundwater load acting upon the tunnel and the thickness of the initial support shotcrete.

   - Based on the evaluation, determine if the thickness of the initial support shotcrete is significant and share the concept in practice.

3. Compare dewatering or pumping hundreds/thousands of gpm with infiltration and discuss the additional/allowable criteria.

   - The previous version of the DTX Criteria did allow load sharing between the tunnel support and the initial support.

4. Summarize the magnitude of the joint movement, based on the work done to indicate the magnitude of the joint movement.

   - The responder (PMPC Team) agreed to update the information provided in the reference document.

5. Review the comments made during the review process and the current status of the load sharing.

   - The responder (PMPC Team) agreed to update the comments per the original comment.

6. Summarize the current status of the load sharing and the next steps.

   - The responder (PMPC Team) agreed to update the comments per the original comment.

7. Discuss the impact of spiling or other rock reinforcement on the tunnel and its support system.

   - It seems like load sharing with the initial support system could be utilized to safely transfer some of the load.

8. Summarize the VE savings through load sharing with the initial support system.

   - The responder (PMPC Team) agreed to update the comments per the original comment.

9. Discuss the load sharing process and any potential challenges.

   - The responder (PMPC Team) agreed to update the comments per the original comment.

10. Summarize the current status of the load sharing and the next steps.

    - The responder (PMPC Team) agreed to update the comments per the original comment.

11. Review the comments made during the review process and the current status of the load sharing.

    - The responder (PMPC Team) agreed to update the comments per the original comment.

12. Summarize the current status of the load sharing and the next steps.

    - The responder (PMPC Team) agreed to update the comments per the original comment.
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<td>13.4.2 All references are from Chapter 13 subchapter b.</td>
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<td>D.L.</td>
<td>PMPC Team is taking action.</td>
<td>10/04/22 MJS</td>
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The responder (PMPC Team) recognizes that critical facilities must be designed for 100-year floodplains which are considered closed.
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<td>14.1.3.2</td>
<td>B3</td>
<td>09/08/21</td>
<td>GEC.007 14.1.3.3 - Platform level</td>
<td>Suggest removing “are complete” from sentence as it is unnecessary.</td>
<td>A</td>
<td>N</td>
<td>10/12/21</td>
<td>A</td>
<td>N</td>
<td>POS-confirmed updates</td>
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<tr>
<td>18/C/B</td>
<td>14.1.3.2</td>
<td>B3</td>
<td>09/08/21</td>
<td>GEC.019 14.6.3.2 - Design Features RV 04/08/22</td>
<td>Note: HD commercial grade were used in Phase 1 due to initial costs and maintenance costs with little perceived benefit by using transit-grade equipment. A variance may be requested by the design team, if needed.</td>
<td>A</td>
<td>N</td>
<td>10/12/21</td>
<td>A</td>
<td>N</td>
<td>POS-confirmed updates</td>
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<td>14.1.3.2</td>
<td>B3</td>
<td>09/08/21</td>
<td>GEC.011 14.4.6.6 - Reflectance, ¶1-2 RV 04/08/22</td>
<td>Suggest a less restrictive description “bright and light-colored” to allow flexibility in the design aesthetic.</td>
<td>A</td>
<td>N</td>
<td>10/12/21</td>
<td>A</td>
<td>N</td>
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<td>14.1.3.2</td>
<td>B3</td>
<td>09/08/21</td>
<td>GEC.010 14.4.6 - Materials and finishes, ¶1 RV 04/08/22</td>
<td>Suggest adding note “wherever possible without major modification to existing building structure at which point code required minimum clear headroom.”</td>
<td>A</td>
<td>N</td>
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<td>A</td>
<td>N</td>
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<td>GEC.005 14.1.3.2 - Public Restrooms, ¶1-2 RV 04/08/22</td>
<td>Suggest similar note as above (comment #3)</td>
<td>A</td>
<td>N</td>
<td>10/12/21</td>
<td>A</td>
<td>N</td>
<td>POS-confirmed updates</td>
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<td>14.1.3.3</td>
<td>B3</td>
<td>09/08/21</td>
<td>GEC.004 14.1.3.3 - Design of finishes, ¶1 RV 04/08/22</td>
<td>Revise to read as “Metal panels should be designed to reduce the visual impact of staircase landings.”</td>
<td>A</td>
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<td>10/12/21</td>
<td>A</td>
<td>N</td>
<td>POS-confirmed updates</td>
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<td>14.1.3.3</td>
<td>B3</td>
<td>09/08/21</td>
<td>GEC.014 14.6.1.3 - Headroom, ¶1-1 RV 04/08/22</td>
<td>Revise sentence to read as follows: “Escalators must be heavy-duty, commercial grade with the following design features:”</td>
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<td>N</td>
<td>10/12/21</td>
<td>A</td>
<td>N</td>
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<td>14.1.3.3</td>
<td>B3</td>
<td>09/08/21</td>
<td>GEC.013 14.6.1.3 - Stairs, ¶1-2 RV 04/08/22</td>
<td>The suggested reduction selection requires evaluation and confirmation that long term performance and maintenance benefits are not minimized with use of transit-grade equipment. A variance may be requested by the design team, if needed.</td>
<td>A</td>
<td>N</td>
<td>10/12/21</td>
<td>A</td>
<td>N</td>
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**Notes:**
- The Design Team did not object or reopen this comment during official review of the DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022), and this comment is considered closed.
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- The Design Team did not object or reopen this comment during official review of the DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022), and this comment is considered closed.
GEC.036 20.3 DF 10/01/18 LEGACY Comment GEC18.103 - It's the understanding modification of the between the existing 4th & Townsend Surface Station with the new UG Station to to the new Fourth & Townsend Station will be maintained but there is NO direct LEGACY Comment GEC16.095 - Add elevator machine rooms are required to 02/28/22 AG A See 2016 comment #90; Removed last bullet point: "Direct connections to and from DTX scope covered designing the modifications to comment is considered closed. 05/16/22 CC comment is considered closed.

The Design Team did not object or reopen this comment during official review of the 8/5/2022 CC

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Note: The above table represents a portion of the document's content, focusing on a specific section. The document includes detailed comments and responses related to various aspects of a project, with dates indicating when the comments were made or updated. The table format is used to organize the information for clarity and easy reference.
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| 1   | Cal.001 Chapter 14 BZ 04/21/22 | OA | Cal.001 Chapter 14 BZ 04/21/22 reconcile chapter number with section 1.6 Design Criteria Organization; renumber | 04/21/22 | MM | A | No change | 05/25/22 | OA | CC | Reference section added. 05/25/22.
| 2   | Cal.006 Chapter 14 - 14.2.1 BZ 04/21/22 | OA | Cal.006 Chapter 14 - 14.2.1 BZ 04/21/22 coordinate subsection numbering 05/13/22 ROK 05/16/22 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 05/16/22. |
| 3   | Cal.020 Chapter 14 - 14.6.3.2 BZ 04/21/22 | OA | Cal.020 Chapter 14 - 14.6.3.2 BZ 04/21/22 reference | 05/13/22 MM | A | To be revised by PMPC Team 05/16/22 ROK 05/16/22 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 05/16/22. |
| 4   | Cal.012 Chapter 14 - 14.2.2 BZ 04/21/22 | OA | Cal.012 Chapter 14 - 14.2.2 BZ 04/21/22 omit 'assumed' 05/13/22 ROK 05/16/22 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 05/16/22. |
| 5   | Cal.004 Chapter 14 - 14.1.3.3 BZ 04/21/22 | OA | Cal.004 Chapter 14 - 14.1.3.3 BZ 04/21/22 platform elevation requirements for Caltrain and CHSR rail cars; restart list at a. 05/13/22 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 05/16/22. |
| 6   | Cal.003 Chapter 14 - 14.1.3.3 BZ 04/21/22 | OA | Cal.003 Chapter 14 - 14.1.3.3 BZ 04/21/22 approval for nonstandard design. "at the end of the paragraph. | 05/13/22 MM | A | To be revised by PMPC Team 05/16/22 ROK 05/16/22 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 05/16/22. |
| 7   | Cal.002 Chapter 14 - 14.1.3.3 BZ 04/21/22 | OA | Cal.002 Chapter 14 - 14.1.3.3 BZ 04/21/22 approval for nonstandard design. "at the end of the paragraph. | 05/13/22 MM | A | To be revised by PMPC Team 05/16/22 ROK 05/16/22 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 05/16/22. |
| 8   | Cal.001 Chapter 14 BZ 04/21/22 | OA | Cal.001 Chapter 14 BZ 04/21/22 approval for nonstandard design. "at the end of the paragraph. | 05/13/22 MM | A | To be revised by PMPC Team 05/16/22 ROK 05/16/22 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 05/16/22. |
| 9   | Cal.001 Chapter 14 BZ 04/21/22 | OA | Cal.001 Chapter 14 BZ 04/21/22 approval for nonstandard design. "at the end of the paragraph. | 05/13/22 MM | A | To be revised by PMPC Team 05/16/22 ROK 05/16/22 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 05/16/22. |

**PMPC Team Actions**

- **Cal.001 Chapter 14 BZ 04/21/22**: No change.
- **Cal.006 Chapter 14 - 14.2.1 BZ 04/21/22**: Coordinate subsection numbering.
- **Cal.020 Chapter 14 - 14.6.3.2 BZ 04/21/22**: Reference.
- **Cal.012 Chapter 14 - 14.2.2 BZ 04/21/22**: Omit 'assumed'.
- **Cal.004 Chapter 14 - 14.1.3.3 BZ 04/21/22**: Platform elevation requirements for Caltrain and CHSR rail cars; restart list at a.
- **Cal.003 Chapter 14 - 14.1.3.3 BZ 04/21/22**: Approval for nonstandard design.
- **Cal.002 Chapter 14 - 14.1.3.3 BZ 04/21/22**: Approval for nonstandard design.
- **Cal.001 Chapter 14 BZ 04/21/22**: Approval for nonstandard design.

**Reviewer Comments**

- **Cal.001 Chapter 14 BZ 04/21/22**: Approve for nonstandard design.
- **Cal.006 Chapter 14 - 14.2.1 BZ 04/21/22**: Coordinate subsection numbering.
- **Cal.020 Chapter 14 - 14.6.3.2 BZ 04/21/22**: Reference.
- **Cal.012 Chapter 14 - 14.2.2 BZ 04/21/22**: Omit 'assumed'.
- **Cal.004 Chapter 14 - 14.1.3.3 BZ 04/21/22**: Platform elevation requirements for Caltrain and CHSR rail cars; restart list at a.
- **Cal.003 Chapter 14 - 14.1.3.3 BZ 04/21/22**: Approval for nonstandard design.
- **Cal.002 Chapter 14 - 14.1.3.3 BZ 04/21/22**: Approval for nonstandard design.
- **Cal.001 Chapter 14 BZ 04/21/22**: Approval for nonstandard design.
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<td>Section 20.1.2</td>
<td>10/18/22</td>
<td>Platform length: The standard platform length shall be 875 feet to accommodate a 10-car consist.</td>
<td>MM</td>
<td>Updated text accordingly.</td>
<td>05/16/22</td>
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<td>Platform length: The standard platform length shall be 875 feet to accommodate a 10-car consist.</td>
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Phase:

HSR.023 14.6.1.1 JRD 04/15/22 LOS needs to consider two way movement - consider one way stair flows to improve.

HSR.026 14.6.3.7 JRD 04/15/22 Size elevators to ensure the can move the train headway disabled population based.

HSR.013 14.4.2 JRD 04/15/22 As both stations are underground how will natural light be maximized? 05/23/22 A KC

HSR.011 14.2.1.1 JRD 04/15/22 List missing HSR signage 05/23/22 MM A Will add "HSR signage, where applicable" 05/23/22 MM The responder (PMPC Team) agreed to update per original comment; therefore this

HSR.003 14 - General JRD 04/15/22 Will TVM and Fare Control for HSR be by HSR Train Operator (TO) or will DTX general comment - do not use should, would, could, may, or consider, those words do statement in references for elevators and escalators - they should be considered 05/25/22 OA A APTA reference has been added. 05/26/22 ROK 05/26/22 MM The responder (PMPC Team) agreed to update per original comment; therefore this

...
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| 1.8 | HSR-030 | Section 20.3 | HSR.030 | HSR.030 Section 20.3, HSR.035 Table 20.4 | 7/04/22 | B | why would DTX provide bus operator facilities at 4th/Townsend? Is this even in the 20-9 MBr 10/01/18 | 10/05/22 | A | Revised sentence for clarity/intent. 10/05/22 | LZ | During CRM with SF CTA on 10/5 - it was agreed the approach was logical and the disagree points noted for further clarification. Disagree, the criteria reads "Bus operator facilities may also need to be provided, but the exact location is to be determined after discussion with the SF CTA."

The responder (PMPC Team) met with commentor for a CRM on 10/5 and the comment is considered closed.
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<td>05/17/22</td>
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<td>A. Added the shaded box text of section 15.1</td>
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<td>The main floor location text and growth rate (and country) not seen due to redlining.</td>
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<td>05/17/22</td>
<td>NS</td>
<td>The main floor location text in shaded boxes: &quot;In addition to data presented in Table 15.1, the Design Fire Size is shown in Table 15.1.” The Design Fire Size requires after the data: &quot;In addition to the data presented in Table 15.1, the Design Fire Size is shown in Table 15.1. instead of using the new criterion indicated in the Program’s Chief Risk and Resilience Assessment.”</td>
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<td>09/30/22</td>
<td>MJS</td>
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Legend:
- **PDLC**: Project Design & Construction
- **R/P**: Remote/Partial
- **NS**: New Submission
- **LZ**: Legend
- **JB**: John Bumanis
- **MJS**: Matt Schreffler
- **OK**: Open for Comment
- **KYT**: Kyritsis
- **TS**: Townsend Street Station
- **LY**: Lyonnaise
- **Davidson**: Davidson
- **V1**: V1
- **V2**: V2
- **V3**: V3
- **V4**: V4

Notes:
- The initial sentence reads: "Design fire sizes are shown in Table 15.1." The revised sentence is: "The main floor location text and growth rate (and country) not seen due to redlining."
Preferred maximum is 2000 fpm. 2500 fpm will be considered if site limit does not allow.

It would be beneficial if the number and locations of stalled trains were defined.

It’s our understanding that the maximum air velocity in ducts, plenums, and shafts

GEC.014 16.1.3 Emergency Operations CU 07/01/22 Cite NFPA 130 requirements for coordination with signal system

Vapor exit mode is a safeguard against potential post-fire conditions. Please verify that vapor exit mode is considered.

A requirement for the "cold flow" simulations could be directly exposed to a fire. Add requirement for redundancy, (e.g. extra operating jet fan(s).

This conflicts with sections 16.2.2.1 and 16.2.4.1 that discuss heated and natural ventilation.

This section essentially describes emergency ventilation operating in a single point extract mode of operation.

So the designer should evaluate, using engineering analysis, the need for relief dampers based on criteria in the following content.

The Design Team did not object or reopen this comment during official review of the DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this comment for current version of DTX Design Criteria and carry forward the topic address comment in section 16.2.2.1 and 16.2.4.1. Revised as noted.

1) Section 16.1.6.2 discusses by-pass dampers but does so in the context of temperature control, relief, and exhaust. Since both stations will be mechanically ventilated during normal operations, additional by-pass dampers and shafts are not required to accommodate air exchange between the stations and for exhaust. Please verify. 2) Since both stations will be mechanically ventilated during normal operations, additional by-pass dampers and shafts are not required to accommodate air exchange between the stations and for exhaust. Please verify. Partial extract mode operation is not recommended. Please verify that partial extract mode operation is considered.

This may not be feasible with the current system. In addition, the total heat rate considered by SFMTA are higher than what is being referred to in the narrative.

The criteria language - comment is considered closed.

The project is required to be NFPA 130 compliant, therefore this requirement is implied. ROK Concur 05/16/22 CC

This topic requires further discussion - potential conflict still exists.

CRM held with John B., Nader S., and Matt S. on 10/6/22 - Agreed to modify criteria language - comment is considered closed.

The Design Team did not object or reopen this comment during official review of the DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this comment for current version of DTX Design Criteria and carry forward the topic address comment in section 16.2.2.1 and 16.2.4.1. Revised as noted.

m/s.

What requirements for air exchange through by-pass dampers, other than those for temperature control, relief, and ventilation, are required? If single extract mode is anticipated in a particular location this content shall be reviewed.

This may not be feasible with the current system. In addition, the total heat rate considered by SFMTA are higher than what is being referred to in the narrative.

This may not be feasible with the current system. In addition, the total heat rate considered by SFMTA are higher than what is being referred to in the narrative.

What requirements for air exchange through by-pass dampers, other than those for temperature control, relief, and ventilation, are required? If single extract mode is anticipated in a particular location this content shall be reviewed.

This conflicts with sections 16.2.2.1 and 16.2.4.1 that discuss heated and natural ventilation.

NFPA 130 paragraph 7.2.6.1 "The criteria language - comment is considered closed.

This conflicts with sections 16.2.2.1 and 16.2.4.1 that discuss heated and natural ventilation.

This is the San Francisco Bay Area Region Report”. SME has approved this comment for current version of DTX Design Criteria and carry forward the topic address comment in section 16.2.2.1 and 16.2.4.1. Revised as noted.

Amanda Kaku (PMPC/HCI)
### Table: Mechanical System Modifications

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**Design Criteria**
- The maximum temperature is 10 degrees above ambient temperature.
- The cold water requirements at station platforms.
- During congested operations.

**Architectural Considerations**
- The ceiling height will be determined by the structural/enclosure design. The ceiling height required will be based on the maximum allowable ceiling height for each level. The maximum ceiling height will be 12 ft.

**Note:**
- The ceiling height will be determined by the structural/enclosure design. The ceiling height required will be based on the maximum allowable ceiling height for each level. The maximum ceiling height will be 12 ft.
Phase: Project: (initials) Date
Responders Total Comments 50
Responder Organization: NS
PMPC Team

Cal.001 Chapter 16 JP 04/29/22 reconcile chapter number with section 1.6 Design Criteria
Organization;

Cal.004 Chapter 16.2.6.12 JP 04/29/22 include; Non-essential mechanical systems in conformance with the seismic
TA.014 Section 12.9, Watertightness and TA.012 Section 16.3.3.1, Fixtures LZ 07/04/22 Specify type of flush valves to be used. Suggest automatic 09/20/22 NS A Revised as noted 10/07/22 MJS The responder (PMPC Team) agreed to update per original comment; therefore

Fans, last sentence before "Jet Fans" Train Recovery Operations LZ 07/04/22 Mentions that maintenance operations will be by dies el powered equipment.

LZ 07/04/22 States the acceptable materials for flexible duct connectors 09/20/22 NS C Industry standard is that specific materials shall be selected by the designer based this comment is considered closed.

LZ 07/04/22 States "Do not include provisions for stand-by fans". Explain why 09/20/22 NS A Sentence deleted. 10/06/22 MJS The responder (PMPC Team) agreed to update per original comment; therefore

"Consider the forces caused by the weight and motion of the fluid, water hammer
Revised sentence to read as follows:
recovery operations.

seismic requirements are included in Ch. 10.

this comment is considered closed.
this comment is considered closed. 10/07/22 CC 10/06/22 CC 10/11/22 CC 05/17/22 CC 05/16/22 CC
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<td>GEC.019</td>
<td>18.2.2 OCS Wire Particulars SRA 08/03/22</td>
<td>Subsection numbers in first sentence need updated. 09/13/22 MJS A Revised as noted 10/04/22 MJS</td>
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<td>Wire sizes should be updated to the sizes/types included in the design drawings</td>
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<td>05/18/22 MJS A Revised as noted 8/5/2022 MJS</td>
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<td>General comment: Update chapter references and table numbers</td>
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<td>The sentence about Absolute Minimum Clearances should be removed since this pole and structure&quot; it becomes a general OCS clearance requirement and loses the original intent of the requirement.</td>
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18.6 Signals and Train Control

**HSDR.009 Chapter 18, 18.6 Signals and Train Control** - Traction Current Return AC 04/22/22

Train Control / Signaling AC 04/22/22

from this section 05/18/22 MJS A Section 18.6 revised to following.

18.6 Signals and Train Control (includes first Train detection equipment should be, where possible, immunized against traction perspective.

constraints to allow HSR services to run on the DTX from a train control requirements within the DCM for incorporating HSR design requirements or

Revised Chapter 15 “Scope” as follows:

“In addition to provisions for impedance bonds, train detection equipment must requirements of the signals communications interface between HSR and Caltrain maintenance facilities”

Revised section 9.2 - Geotechnical Reporting, under subheading “Geotechnical DTX Design Criteria.

“The DTX design, through a series of traction power load-flow and power supply

“The DTX PTC must be fully integrated with Caltrain’s existing PTC system.”

Added the following sentence:

structure (see CHSRA DVR_0011) where 21'-6” TOR to BOS has been approved.

05/18/22 MJS Designer agreed to comply with comment and made necessary change. No back-10/04/22 MJS The responder (PMPC Team) agreed to update per original comment; therefore 05/25/22 CC
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<td>Cal.001 Chapter 18 UM 04/29/22 Design should include Chapter 28 Communications Criteria from PCEP</td>
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Notes:

- RD: Request for comment
- RS: Response Status
- BRS: Backcheck Response Status
- ROK: Response with comments meeting and/or resolution
- MJS: Meghan Murphy, AECOM
- MBr DE: Designer to evaluate
- LZ: Comment agreed and will comply
- CC: Comment closed
- ROK: Response okay
- SRA: Steve Adkins (Design Team/Parsons)
- RB: Rick Bartholomew (Caltrain)
- SJC: Andrew Clapham (CHSRA)
- RD: Rusty Dudley (Caltrain)
- MMPC Team: Meghan Murphy (PMPC/AECOM)
- UP: Uhila Makoni (Caltrain)

Document Control File Code:
- Document date: 4/6/2022
- Initials: Steve Adkins (Design Team/Parsons), Rick Bartholomew (Caltrain), Andrew Clapham (CHSRA), Rusty Dudley (Caltrain)
- Document control file code: (if applicable)
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<td>Start-up criteria for the PCEP design criteria which referenced the DTX Design Criteria once solidified.</td>
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<td>Update the systems related submittals to ensure Caltrain's needs are met. If a criteria becomes available, it will be</td>
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**Summary:**
The Design Team did not object or reopen this comment during official review of the design criteria. The comment is considered closed.
This page contains a table with the following columns: **Reference**, **Date (mm/dd/yy)**, **Reviewer Comment**, **Responsible/Owner/Party**, **PDNC Response**, **RSC Back-Check Comment (if applicable)**, **Date (mm/dd/yy)**, **Response Status/Complete**, **PDNC Additional Response/Date (if applicable)**, and **File Number**.

The table entries include comments and responses related to various sections of a document, such as:

- **Reference** (e.g., "HSR.001 Section 19.4")
- **Date (mm/dd/yy)** (e.g., "05/06/22")
- **Reviewer Comment** (e.g., "Request clarification of what purpose test facilities are for.")
- **Responsible/Owner/Party** (e.g., "Meghan Murphy (PMPC/AECOM)")
- **PDNC Response** (e.g., "Alerted per instructions.")
- **RSC Back-Check Comment (if applicable)** (e.g., "This comment is considered closed.")
- **Response Status/Complete** (e.g., "Complete.")
- **PDNC Additional Response/Date (if applicable)** (e.g., "10/11/22")
- **File Number** (e.g., "T-25.0.0 Ref 2022.02")

The comments and responses cover various aspects of the document, including safety, grounding, and bonding requirements, among others. The table format helps organize the feedback and responses into a structured manner, allowing for easy tracking and follow-up on the document's revisions.
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<td>DM/L</td>
<td>CHSRA</td>
<td><a href="mailto:douglas.mcleod@hsr.ca.gov">douglas.mcleod@hsr.ca.gov</a></td>
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<tr>
<td>Eric A. Scotson</td>
<td>EAS</td>
<td>CHSRA</td>
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<td>Fletcher Waggoner</td>
<td>FW</td>
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<tr>
<td>James Deane</td>
<td>JD/JRD</td>
<td>CHSRA</td>
<td><a href="mailto:james.deane@hsr.ca.gov">james.deane@hsr.ca.gov</a></td>
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<tr>
<td>M. Bowers</td>
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<td>Paul Hediditch</td>
<td>PHP/DH</td>
<td>CHSRA/CHSRA</td>
<td><a href="mailto:paul.hediditch@hsr.ca.gov">paul.hediditch@hsr.ca.gov</a></td>
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<td>Tony Hargisay</td>
<td>TH</td>
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<td>XX Banko</td>
<td>XB</td>
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<td>Phase: 2</td>
<td>Date: 06/22</td>
<td>PMPC Team</td>
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**Table 7-8** - Change tolerances to +- 0.125 for Ballasted and Direct Fixation track.

**Table 7-10** - the listed minimum horizontal clearance for CAHSR is 9ft3in this is incorrect. Please advise where this figure was derived.

**Environmental Requirements:** Be beneficial to have projected ambient absolute. These values do not align with the working values for CAHSR, please these should differ.

**Guideway Geometrics HSR:** In October 2018 a Basis of Design Memo was approved by Caltrain and CAHSR which outlined the Caltrain Design Criteria in Sections 1, 4, 5.2. These amendments were submitted but have since been removed from the DTX Design Criteria and will become an action item to carry forward.

**Guideway Geometrics HSR**

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**Transbay Program**

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<tbody>
<tr>
<td>06/22</td>
<td>BCC</td>
</tr>
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**Environmental Requirements:** The tunnel cross section plan shows the tunnel on tangent track except on tight radius curves where gauge widening may be required.
This chapter focuses on existing structures that may be affected by excavation. The chapter begins with a discussion of the current state of the existing structures and the issues faced by the designers and contractors. The chapter then discusses the potential for damage to the existing structures and the measures that can be taken to mitigate this risk. The chapter concludes with a discussion of the lessons learned from previous projects and the steps that can be taken to ensure the safety of the existing structures during the design and construction phases. The chapter includes detailed recommendations for the design and construction of the structures and provides a comprehensive list of references for further reading. The chapter is intended for engineers and contractors involved in the design and construction of new transit facilities and is intended to provide a guide for the successful completion of the facility. The chapter is divided into several sections, each focusing on a specific aspect of the existing structures. The sections include:

1. Introduction
2. Existing Structures
3. Design Considerations
4. Construction Considerations
5. Lessons Learned
6. Recommendations
7. References
19. Fire Life Safety

This section requires that the design train fire size and growth rate conform to the fire heat release rates mandated by RVA criteria. This Table presents information (e.g. MW for trash) that isn’t in the criteria. This Table is intended to provide a snapshot of the system currently designed and the designer should evaluate, using engineering analysis, the need for relief shafts based on their requirements in addition to temperature control.

10/06/22 BZ  

The responder (PMPC Team) has agreed to incorporate subsurface generator locations in the General Electric Code. The comment will be considered a du jour comment for the current version of DTX Design Criteria and will become an action item during the next phase of design.

10/06/22 CC

This topic requires further discussion.

10/06/22 AR

This topic requires further discussion.

10/06/22 AR

What requirements for air exchange through bypass dampers, other than those for temperature control and pressure transient control? Please elaborate.

10/06/22 CC

What requirements for air exchange through bypass dampers, other than those for temperature control and pressure transient control? Please elaborate.

10/06/22 CC

Bypass dampers shall be designed to allow air exchange through bypass dampers. In addition to temperature control and pressure transient control, additional bypass dampers and shafts may be required to control occupants exiting through by-pass dampers. Please verify. 2) Also, additional bypass damper requirements and scope will need to be determined and agreed upon between PAR, CSRA, and the responders during the next phase of design.

10/11/22 LZ

In addition to temperature control, relief shafts may be required to control pressure transient phenomena. In addition, the designer should evaluate, using engineering analysis, the need for relief shafts based on their requirements in addition to temperature control.

10/06/22 CC

The interfacing capabilities of Caltrain are not currently captured explicitly in the Transbay Program. The Final Risk and Vulnerability Assessment is being rebranded as the Threat and Vulnerability Assessment (TVA) and is currently in the process of being updated. The Final Risk and Vulnerability Assessment (TVA) and Vulnerability Assessment (TVA) are not currently captured explicitly in the Transbay Program. Additional bypass dampers and shafts may be required to control pressure transient phenomena. In addition, the designer should evaluate, using engineering analysis, the need for relief shafts based on their requirements in addition to temperature control.

10/06/22 CC

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GEC.001 Section 1.2 BP 11/30/21 Townsend Station length noted as 875ft. With stair structures now at each end of the station.

GEC.012 Section 1.6.2.3 RCCo 09/12/16

GEC.010 Section 1.1 PC 09/12/16

GEC.008 Section 1.7.3.2 CU 11/29/21 Add "FRA" to U.S. DOT bullet point.

GEC.007 Section 1.7.1 CU 11/29/21 State regulations (e.g. CPUC) should be second bullet point.

GEC.015 Page 1-1 of 9 LDG 09/12/16 LEGACY Comment GEC16.007 - Add bullet to describe work from Mariposa Street to Caltrain Yard.

GEC.014 Page 1-7 of 9 SM 09/12/16 LEGACY Comment GEC16.006 - 1.2 DTX Project Description needs to be updated to reflect the TJPA-approved DTX project description.

GEC.013 Section 1.2 BP 11/30/21 Added 2 new bullets:

1. Environmental and Engineering Technical Memos

2. Design Criteria

Page 1-7 of 9 SM 09/12/16 LEGACY Comment GEC16.005 - Operator standards for California High-speed rail stations, bridges, buildings, and miscellaneous structures are lumped under "cut-and-cover structures." It is probably not intended. Please revise to clarify.

Page 1-7 of 9 SM 09/12/16 LEGACY Comment GEC16.010 - Correct title for General Order No. 72-B: clarifying.

Page 1-7 of 9 SM 09/12/16 LEGACY Comment GEC16.004 - Add SF Planning "Better Street Plan" guidelines.

Page 1-7 of 9 SM 09/12/16 LEGACY Comment GEC16.003 - The pedestrian connector is called out under 1.5, Interface Coordination, as it is part of the DTX project, but no longer part of the DTX program.

Page 1-7 of 9 SM 09/12/16 LEGACY Comment GEC16.002 - The Design Team did not object to this revision during official reviews of the DTX Design Criteria. The Design Team did not object to this revision during official reviews of the DTX Design Criteria. The Design Team did not object to this revision during official reviews of the DTX Design Criteria. The Design Team did not object to this revision during official reviews of the DTX Design Criteria. The Design Team did not object to this revision during official reviews of the DTX Design Criteria. The Design Team did not object to this revision during official reviews of the DTX Design Criteria.
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<td>Page 2 of 9</td>
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<td>AEC</td>
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<td>AG</td>
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**Actions:**
- **RD**: Responder did not respond
- **ROK**: Responder okay
- **CC**: Comment closed
- **RD+ROK**: Responder did not respond and will comply
- **RD+CC**: Responder disagrees but reasons not valid
- **ROK+CC**: Responder okay but comments not valid
- **RD+RD**: Responder did not respond and will not respond
- **ROK+ROK**: Responder okay and will not respond
- **CC+CC**: Comments closed and will not respond

**Document Control File Code:**
- **DIP**: Document is approved and ready for use
- **DIP+RD**: Document is approved and ready for use with revisions
- **DIP+ROK**: Document is approved and ready for use with revisions
- **DIP+CC**: Document is approved and ready for use with revisions

**Legacy Comment:**
- **GEC16.011**: General Order No. 75-D: Regulations governing standards for warning devices for environmental and engineering technical memos periodically throughout project lifecycle to ensure references, codes and standards, Stanislaus County, Calif. Department of Transportation.
- **GEC18.007**: The DTX shall accommodate connection to the existing guideway systems.

**Legacy Comment GEC18.007:**
- **Add**: The DTX shall accommodate connection to the existing guideway systems.

**Legacy Comment HSR18.088:**
- **General Comment**: 10/28/21 MJS A See comment response to HSR18.073 05/13/22 ROK 05/13/22 MM The responder (PMPC Team) agreed to update per original comment; therefore the comment is considered closed.

**Legacy Comment HSR18.088:**
- **General Comment**: 10/28/21 AG A Revised title. 08/05/22 BCC Not corrected on p 18-19/14/2022 MJS Revised in Chapter 18, Codes and Standards.

**Legacy Comment GEC16.011:**
- **Correct title for General Order No. 75-D:**
  - Chapter 1 - Overview - Part 1.7.2, 1.7.3, and 1.8.3. Need to ensure all current regulations governing standards for warning devices for environmental and engineering technical memos periodically throughout project lifecycle to ensure references, codes and standards, Stanislaus County, Calif. Department of Transportation.

**Legacy Comment HSR18.088:**
- **General Comment**: 10/28/21 MJS A See comment response to HSR18.073 05/13/22 ROK 05/13/22 MM The responder (PMPC Team) agreed to update per original comment; therefore the comment is considered closed.

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<td>RCU</td>
<td>Check that all documentation has been approved by DFS and DFS has approved all applicable documents prior to release.</td>
<td>09/30/22</td>
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<td>RCU</td>
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<td>City Codes (as applicable)</td>
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<td>Confirm that all applicable city codes have been reviewed and any required changes have been made.</td>
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<td>Confirm that all applicable city codes have been reviewed and any required changes have been made.</td>
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The responder (PMPC Team) answered the inquiry, no change required - comment 09/27/22 CC

The responder (PMPC Team) answered the inquiry, no change required - comment 10/03/22 CC

The order of this list of precedence will be revised as follows: 09/27/22 CC

This comment is considered closed. 10/03/22 MJS

The responder (PMPC Team) answered the inquiry, no change required - comment 10/03/22 CC

The responder (PMPC Team) answered the inquiry, no change required - comment 10/03/22 CC

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<th>Action COD</th>
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<th>Comments (Content changes made)</th>
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<td>Chapter 2; 2.1.2.b CU</td>
<td>04/26/22</td>
<td>MM</td>
<td>ROK</td>
<td>Have minimum headways and dwell times below been coordinated?</td>
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<td>GEC.002</td>
<td>Chapter 2; 2.3.2.a CU</td>
<td>04/26/22</td>
<td>MM</td>
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<td>Include Mass Light rail operations</td>
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<td>Chapter 2; 2.5 para. 1 CU</td>
<td>04/26/22</td>
<td>MM</td>
<td>ROK</td>
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<td>Section 2.3.1</td>
<td>09/12/16</td>
<td>PC</td>
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<td>Section 2.3.2.c</td>
<td>09/12/16</td>
<td>CFW</td>
<td>ROK</td>
<td>LEGACY Comment GEC18.017 - Update: EMU's only, 10 car trains, 875' train length.</td>
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<td>ROK</td>
<td>LEGACY Comment GEC18.014 - Update dwell times 4/6/2022 AG A In-line dwell time removed, verify Caltrain values in table. 8/5/2022</td>
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<td>GEC.014</td>
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CHUKWUMA UOMO (Design Team/Parsons)

MATT SCHREFFLER (PMPC/Mott MacDonald)

DOWNTOWN RAIL EXTENSION (DTX)

PAUL HEBDITCH (CHSRA)

4/6/2022

Date

JD

PCG

Document Control File Code:

GEC.026 2.8.3 DF

GEC.029

Demands, Page 2-7 of 9

CU LEGACY Comment GEC18.021 - 4/6/2022 AK A What specific language should be added? Needs further coordina
tion/alignment

GEC18.027 - Owner's Requirements; Signals and Train

LEGACY Comment GEC18.023 - Confirm status quo 'no specific sustainability
to 26767255040547429995483120916077147879877957737307555770223406933343244372382949653437223526576164830079886447736221531292339157817988635351765670323950666291645429326664412485253308016574537341599744x82810 to 27114017561642718001647405997434724584845501792691421680800195695132565906595890995877198775800528633857013896308127830742295398657225552540182110111343911552318874317223798937060148172363934562516992x82624

however, it is TJPA's expectation that some amount of art will be included in the

Station as TJPA has an extensive art program at the Salesforce Transit Center;
## DTX Design Criteria DRAFT Book Revision 02 - Chapter 02, Owner's Requirements

### Responders Organization:

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<td>EM DE – Designer to evaluate</td>
<td>AC</td>
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### Description:

1. **Responder Organization**
   - RCCo C – Answer provided; no action needed
   - PAR - Parsons internal
   - EM DE – Designer to evaluate

2. **Action Code**
   - AC

3. **Description**
   - Permanent and temporary modifications to existing crossings.
   - 10-car consists will be operated during the peak service, for a total length of 200 cars.

### Revisions:

- **Revised to read as follows:**
  - The Fourth and Townsend Street Station shall accommodate Caltrain and high-speed rail.

### Comments:

- **PMPC Team will update criteria consistent with Caltrain Design Criteria (Third Edition), dated August 31, 2020 [pp 1-9]:**
  - Caltrain's backup facility in San Jose.'
| No. | Reference | Date (month/day/year) | Respondible Party | PEP Response | BRS Bkgm/Daniel Comment of (if applicable) | Date (month/day/year) | Responsible Party | PEP Additional Response/Test Steps | Final Bkgm/Date
|---|---|---|---|---|---|---|---|---|---
| 1 | Appendix 7, para 7.4.3.1 | 5/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 9/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 11/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 1/16/2022 MM | ROK |
| 2 | Appendix 7, para 7.4.3.2 | 5/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 9/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 11/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 1/16/2022 MM | ROK |
| 3 | Appendix 7, para 7.4.3.3 | 5/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 9/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 11/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 1/16/2022 MM | ROK |
| 4 | Appendix 7, para 7.4.3.4 | 5/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 9/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 11/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 1/16/2022 MM | ROK |
| 5 | Appendix 7, para 7.4.3.5 | 5/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 9/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 11/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 1/16/2022 MM | ROK |
| 6 | Appendix 7, para 7.4.3.6 | 5/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 9/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 11/16/2022 MM | The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed | 1/16/2022 MM | ROK |
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8/5/2022 CC
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**Reviewer Organization:** Preliminary Engineering

**Responder Organization:** Downtown Rail Extension (DTX) Design Criteria DRAFT Book Revision 02 - Chapter 03, Safety and Security
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| Karen Saux (PMPC/Mott MacDonald) | Brad Pollock (Design Team/Parsons) | }
## Traffic Management Plan (TMP)

The Traffic Management Plan (TMP) is a document that outlines strategies for managing traffic during construction activities. It includes guidelines for traffic control, access to businesses, and other logistical considerations to ensure safety and minimize disruptions. The TMP is developed in collaboration with various stakeholders, including city agencies, construction companies, and the community.

### Key Components
- **Geometric Design**: Ensuring that the design of roads and streets is safe and efficient for both drivers and pedestrians.
- **Traffic Control Plan**: Strategies for managing traffic flows, including the use of signs, signals, and other devices.
- **Access Management Plan**: Ensuring that access to businesses and other facilities is maintained throughout the construction period.
- **Public Information Plan**: Communicating with the public about construction activities and their impacts.

### References
- **GEC.010**, Page 5-2, Section 5.1.2, (Table 5.2) QM 09/12/16
- **GEC.009**, Section 5.1.2,
- **GEC.008**, Section 5.1.1,
- **GEC.006**, 5.6.2 - Access
- **GEC.004**, 5.2.1.1 - Geometric Design
- **GEC.003**, Chapter 5, Codes and Standards
- **GEC.016**, Section 5.6

### Comments and Revisions
- **GEC16.026**, Benchmark HT0685: revise Northing to 37 47.
- **GEC16.029**, "If vertical clearance is limited between road surface and top of utilities (less than 3 feet), provision will be made for armoring.
- **GEC18A.003**, The CPUC General Orders
- **GEC18A.002**, The intro paragraph cites a Maintenance and Protection of Traffic Plan. Please clarify whether this is meant to be a stand-in statement that should follow specific utility requirements as well.

## Table of Review Comments

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### Additional Information
- **Editorial Changes**
  - Add San Francisco Public Works (SFPW) Standard Specifications
  - Add CPUC General Orders
  - Add San Francisco Public Utilities Commission Design Guidelines & Standards
  - Add NGS online database (i.e., City Transit, Intercity, Articulated, etc.)

---

For further details, please refer to the full document and comments review log.
### Review Comment Sheet

**Transbay Program**

**Downtown Rail Extension (DRE)**

**10/28/21**

**Karen Saux (PMPC/Mott MacDonald)**

**Charles Felder (Design Team/CHS)**

**Amanda Kaku (PMPC/HCI)**

**Q. Mehirdel (Design Team)**

**Luis Zurinaga (SF CTA)**

**M. Brunner (CHSRA)**

---

**Responder Organization:**

**PMPC**

**Reviewer Organization:**

**PMPC**

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### Summary

- **Total Comments:** 32

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### Notes

- **ROK:** reviewer (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.
- **CC:** reviewer (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.
### Preliminary Engineering

**Document date:** 10/28/2021

**Reviewer:**
- Karen Saux (PMPC/Mott MacDonald)
- Charles Felder (Design Team/CHS)
- Q. Mehirdel (Design Team)

**Commenters:**
- MBr
- QM
- AK
- MM

### Review Team

- **PMPC Team**
  - Matt Schreffler (PMPC/Mott MacDonald)
  - Paul Hebditch (CHSRA)
  - S. Leidy (Design Team)

### Comments Closed

- 32

### Total Comments

- 32

### % Complete

- 100%

### Responder Organization:

- MJS

### Reviewer Organization:

- MM

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*Note: This document contains recommendations and responses related to the Downtown Rail Extension (DTX) project. The comments refer to specific sections of project documentation, including sections related to velocity, freeboard, and trainsets. The responders have agreed to update or provide additional information to address the comments.*
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<td>The minimum required clearance between pavement and top of utility is owner-specific based on utility (electrical, gas, water, etc.). The appropriate owner-specific criterion references/resources should be identified in chapter 6.</td>
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<td>John Updike (PMPC)</td>
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<td>Vertical Chimney, Table 7-11 (Incomplete Combined Criterion)</td>
<td>UT</td>
<td>09/20/22</td>
<td>See bar C Letter to Track concern to dry rig of ground platform 5'-4&quot;</td>
<td>09/20/22</td>
<td>SRB</td>
<td>N</td>
<td>Reresult as issued</td>
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<td>09/20/22</td>
<td>See bar C Letter to Track concern to dry rig of ground platform 5'-4&quot;</td>
<td>09/20/22</td>
<td>ADR</td>
<td>N</td>
<td>Revised notation to be continued with remaining design criteria</td>
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<td>DFC-35</td>
<td>Section 7-2.4 Haze Contact</td>
<td>UT</td>
<td>09/18/22</td>
<td>A 24″ (610mm) ASME Schedule 40 #304L SS pipe shall be installed between the black color chimney and the compacted soil to protect the chimney from impact damage.</td>
<td>09/26/22</td>
<td>SRB</td>
<td>A</td>
<td>Awaiting test &amp; inspection o/s fertilizer.</td>
<td>09/26/22</td>
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<td>DFC-36</td>
<td>Chimney, Page 7-11</td>
<td>UT</td>
<td>09/18/22</td>
<td>7.2.4.2.1.3 (P) Remove/думал 350mm diameter LDPE corrugated pipe from 5'-4&quot; to 5'-6&quot;</td>
<td>09/26/22</td>
<td>SRB</td>
<td>N</td>
<td>Awaiting test &amp; inspection o/s fertilizer.</td>
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<td>DFC-37</td>
<td>Table 7-11</td>
<td>DP</td>
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<td>7&quot; (175mm) and 8&quot; (200mm) C/D/R (8&quot;) pipe for new cover. A 7&quot; (175mm) pipe shall be installed parallel to the compacted soil C/D/R (8&quot;) pipe.</td>
<td>09/26/22</td>
<td>ADR</td>
<td>N</td>
<td>Design should consider every variation of both C/D/R and C:D:R.</td>
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<td>DFC-38</td>
<td>7.2.1.3 Revised Alignment</td>
<td>MR</td>
<td>09/18/22</td>
<td>Revised comments in this Paragraph Since there are no conditions described in 7.2.1.3 involving existing terrain, they are described in referenced C/D/R sections.</td>
<td>09/18/22</td>
<td>SRB</td>
<td>A</td>
<td>Awaiting test &amp; inspection o/s fertilizer.</td>
<td>09/18/22</td>
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### Project: Review Comment Sheet

**Phase:** Request Comment Sheet

**Reviewers:**
- Frank Blachly (Design Team)
- Keith Abey (Design Team)
- James Deane (CHSRA)

**Date:**
- 05/12/22

**Actions:**
- A: Responder agrees and will comply
- B: Responder disagrees for reasons noted
- C: No response or no action needed
- D: Designer to evaluate

**PHMC Comments:**

**Date (month/day/year):**
- 05/12/22

**PHMC Response:**

**Date (month/day/year):**
- 05/12/22

**Red BDS:**
- CC

---

**Subject:**
- 7.2.1.2.2 Track Spacing on Curves (currently 7.2.6)

**Description:**
- "The maximum authorized speed for passenger trains within the limits of the project, The final track design will ultimately dictate maximum authorized speeds (MAS) of passenger trains. The responder (PMPC Team) has confirmed that the criteria is correct as stated; no change is necessary.

**Date:**
- 05/12/22

**Responsible Party:**
- MHS

---

**Subject:**
- 7.2.1.2.2 Track Spacing on Curves (currently 7.2.6)

**Description:**
- "Center will be tangent with the exception of track T-26 in the transit center, however, that platform face will be tapered.

**Date:**
- 05/13/22

**Responsible Party:**
- MHS

---

**Subject:**
- 7.2.1.2.2 Track Spacing on Curves (currently 7.2.6)

**Description:**
- Table 7.45 - "Between point of switch of turnout" we have an Absolute value of "20'

**Date:**
- 05/13/22

**Responsible Party:**
- MHS

---

**Subject:**
- 7.2.1.2.2 Track Spacing on Curves (currently 7.2.6)

**Description:**
- Geometry and a maximum unbalanced superelevation of 3 inches. Refer to the Caltrain Design Criteria, Chapter 7.2.6 for more information regarding speed through curves.

**Date:**
- 05/13/22

**Responsible Party:**
- MHS

---

**Subject:**
- 7.2.1.2.2 Track Spacing on Curves (currently 7.2.6)

**Description:**
- however, that platform face will be tapered.

**Date:**
- 05/13/22

**Responsible Party:**
- MHS

---

**Subject:**
- 7.2.1.2.2 Track Spacing on Curves (currently 7.2.6)

**Description:**
- Between point of switch of turnout.

**Date:**
- 05/13/22

**Responsible Party:**
- MHS
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<td>HL</td>
<td>10/18/18</td>
<td>Eric A. Scotson (CHSRA)</td>
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<td>Revised Reference with Caltrain Design Criteria (TSR), dated August 31, 2018, Chapter 3, Table 4.1, Length of Spiral</td>
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<td>The responsible (PHFU) Team agreed to update the original comment to be consistent with Caltrain Design Criteria. Caltrain did not provide any backcheck response and therefore this comment is considered closed.</td>
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<td>10/18/18</td>
<td>Eric A. Scotson (CHSRA)</td>
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<td>A maximum radius of 150 ft shall be used for the minimum radius of spiral. (Caltrain Design Criteria)</td>
<td>10/22/18</td>
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**Notes:**
- R: Requested upgrade and will supply
- K: Requested design for seasonal well
- C: Concurrent proposals, no action needed
- H: Design to evaluate

**Document Control File Code:**
- HSR: Rock-check Response Notes
  - HSR.007 subheading 7.2.1 DMcL 03/16/22
  - HSR.015 subheading 7.2.7.2 DMcL 03/16/22
  - HSR.010 subheading 7.2.2 DMcL 03/16/22
  - HSR.009 subheading 7.2.1.2 DMcL 03/16/22
  - HSR.001 All references DMcL 03/15/22

**Team:**
- PMPC: PMPC Team
- CHSRA: CHSRA
- MJS: MJS
- CC: CC

**Comments:**
- AFFECTS: Caltrain Curvature. The Design Criteria should pick on method of measurement for radii and Agree with the formula for calculating the minimum radius of curve, however the superelevated.
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The values provided in the DTX criteria for minimum horizontal clearances are derived from HSR.035 CAHSR/PG/006 PG, which states the following: The 10' horizontal clearance to tunnel crown is list as 24ft6in desirable. recycled figure was being derived.

The CHSRA vehicle dynamic envelope (VDE) is the controlling clearance envelope to twenty-four (24) inches. This CHSRA vehicle dynamic envelope (VDE) is the controlling clearance envelope to twenty-four (24) inches derived from CPUC GO 26-D, Section 9, which states the following:

The CHSRA vehicle dynamic envelope (VDE) is the controlling clearance envelope to twenty-four (24) inches derived from CPUC GO 26-D, Section 9, which states the following:

10/12/22 CC

05/13/22 CC

05/13/22 CC

05/13/22 CC

05/13/22 CC

05/13/22 CC

05/13/22 CC

05/13/22 CC

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| SM 03/17/22 | GEC.001 | Chapter 08 - Trackwork SM | 03/17/22 | See tracked changes and review comments in “Chapter GEC.001 Section 8.1.3 - Direct Fixation, ¶1-1 CU 03/17/22 This contradicts section 8.1.4 above. 05/19/22 MM 
A Agree. Removed reference to three ties. 08/05/22 ROK 8/5/2022 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. | | | | | | | | | |
| SM 03/17/22 | GEC.002 | Section 8.1.3 - Direct Fixation | 03/17/22 | See tracked changes and review comments in “Chapter GEC.002 8.1.3 - Direct Fixation, ¶1-1 CU 03/17/22 This contradicts section 8.1.4 above. 05/19/22 MM 
A Agree. Removed reference to three ties. 08/05/22 ROK 8/5/2022 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. | | | | | | | | | |
| SM 03/17/22 | GEC.006 | Section 8.2.2 - Concrete Ties | 03/17/22 | This contradicts section 8.1.4 above. 05/19/22 MM A Agree. Removed reference to three ties. 08/05/22 ROK 8/5/2022 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. | | | | | | | | | |
| SM 08/05/22 | GEC.008 | Section 8.5.1 - Rail Lubrication | 03/17/22 | The 2018 SEIS/EIR. Text has been updated to reference this document. 08/05/22 ROK 8/5/2022 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. | | | | | | | | | |
| SM 08/05/22 | GEC.009 | Section 8.5.2 - Bumping Posts | 03/17/22 | “three ties” applies for ballasted track 05/19/22 MM A Agree. Removed reference to three ties. 08/05/22 ROK 8/5/2022 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. | | | | | | | | | |
| SM 08/05/22 | GEC.010 | Section 8.6.2 - Derailment Containment | 03/17/22 | Where is this requirement (required mitigation) defined? 05/19/22 MM C The 2018 SEIS/EIR. Text has been updated to reference this document. 08/05/22 ROK 8/5/2022 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. | | | | | | | | | |
| SM 08/05/22 | GEC.014 | Section 8.3 - Special Trackwork (Turnouts) | 03/17/22 | The design of grade crossing track may conflict with Caltrans Design Manual. Ref to section 4.2.3.4 and section 4.7.1. 08/05/22 ROK 8/5/2022 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. | | | | | | | | | |
| SM 08/05/22 | GEC.016 | Section 8.5.1 - Rail Lubrication | 03/17/22 | “three ties” applies for ballasted track 05/19/22 MM A Agree. Removed reference to three ties. 08/05/22 ROK 8/5/2022 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. | | | | | | | | | |
| SM 08/05/22 | GEC.017 | Section 8.5.2 - Bumping Posts | 03/17/22 | “three ties” applies for ballasted track 05/19/22 MM A Agree. Removed reference to three ties. 08/05/22 ROK 8/5/2022 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. | | | | | | | | | |
| SM 08/05/22 | GEC.018 | Section 8.6.2 - Derailment Containment | 03/17/22 | Where is this requirement (required mitigation) defined? 05/19/22 MM C The 2018 SEIS/EIR. Text has been updated to reference this document. 08/05/22 ROK 8/5/2022 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. | | | | | | | | | |
| No. | Reference | Date (mm/dd/yy) | REC-026 Section 3.2.1 Page 5.3.1 | E2 Back-check comment | OPEN - requires comment closure meeting and/or resolution | GEC.026 Section 8.1.3
Direct fixation block spacing shall be adjusted between areas of standard fasteners per comment GEC.038 response.
Criteria per comment GEC.038 response.
Standard
subballast. Many projects call for filter fabric be tween subballast and roadbed. 02/28/22 AG A Replaced “specifications” with “Manual of Railway Engineering”. 08/05/22 ROK 8/5/2022 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 10/2/2022 CC
8/5/2022 CC |
Phase: DTX Design Criteria DRAFT Book Revision 02 - Chapter 08, Trackwork

LDG
CU
Review Team PMPC Team Review Team PMPC Team

Bin Zhang (Caltrain)

% Complete 100%

PCG DE – Designer to evaluate
Responsible

AC – Action Code

Date

Review Team

GEC.045 8.5.1 Rail Lubriation CU 07/05/22

Cal.012 Chapter 8 Section 8.2.4 PCG 03/21/22 add: "....standard timber tie sections, wood tie or concrete tie to direct fixation

Cal.016 Chapter 8 Section 8.3 PCG 03/21/22 Remove No. 11 and No. 15 turnouts, they are not Caltrain standard turnouts 05/13/22 MM A Revised as noted 05/13/22 ROK 05/13/22 MM The responder (PMPC Team) agreed to update per original comment; therefore

as XXX or equivalent

"....and be installed to lubricate both ends of each curve on all tracks at the specification and be pretested for internal defects 05/09/22 MJS A

welded within the project limits 05/09/22 MJS A

monitoring, electronic type functioning system, and provide containment of the lubricant in case of accidental release of lubricant".

Revised section as follows:

15.1.8 Table 8.2.2 - Deliverable Trains, sections conforming to AREMA Manual for Railway Engineering and Caltrain Standards."

this comment is considered closed. 05/25/22 CC

this comment is considered closed.

this comment is considered closed. 05/13/22 CC

this comment is considered closed. 05/13/22 CC

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this comment is considered closed. 05/13/22 CC

05/24/22 CC

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05/24/22 CC
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<th>Issue (s) Described</th>
<th>Date Identified</th>
<th>Date Resolved</th>
<th>Responsibility</th>
<th>ERP</th>
<th>Comments</th>
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<td>5.2.3</td>
<td>Section 5.2.3.1</td>
<td>Provisions in the railroad crossing area are not adequate in terms of visibility, approach, and stopping distance.</td>
<td>06/15/18</td>
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<td>Designer agreed to comply with comment and made necessary changes. No final checklist response was received from Libs, therefore this comment is considered closed.</td>
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<td>06/15/18</td>
<td>06/15/18</td>
</tr>
</tbody>
</table>

**Design Criteria Rev Book 02 - Draft Final (June 1, 2022)** and this comment is considered closed.
HSR.002 8.1.1 DMcL 03/22/22 The track gauge will be 4 feet 8.5 inches, not just on tangent track except on tight

HSR.010 8.2.3 DMcL 03/22/22 Is the last paragraph required, i.e. where is the likely to be a change in track
Transbay Program
Downtown Rail Extension (DTX)
Review Comment Sheet

Total Comments
Comments Closed
% Complete

Downtown Rail Extension (DTX)
Preliminary Engineering
DTX Design Criteria DRAFT Book Revision 02 - Chapter 08, Trackwork
2/28/2022

Project:
Phase:
Document name:
Document date:

Document Control File Code:

109
109
100%

Reviewer Organization:
Responder Organization:

Reviewers
Name
Frank Blachly (Design Team)
L. Godbold (Design Team)
Chukwuma Umolu (Design Team)
Rick Bartholomew (Caltrain)
Douglas McLoud
Luis Zurinaga (SF CTA)

Initials
FB
LDG
CU
RB
DMcL
LZ

Matt Schreffler (PMPC/Mott MacDonald)

MJS

Name
David Fung (Design Team/Robin Chiang & Co.)
Stephen Metz (Design Team)
Pedro Gutierrez (Caltrain)
Bin Zhang (Caltrain)
M. Brunner (CHSRA)

Initials
DF
SM
PCG
BZ
MBr

Meghan Murphy (PMPC/AECOM)

MM

Multiple
PMPC Team

AC – Action Code
A – Responder agrees and will comply
B – Responder disagrees for reasons noted
C – Answer provided; no action needed
DE – Designer to evaluate

RS – Response Status
ROK – response okay
BCC – Back-check comment

BRS - Back-check Response Status
CC - comment closed
OPEN - requires comment closure meeting and/or resolution

Responders

Review Team

PMPC Team

By
(initials)

Date
(mm/dd/yy)

Reviewer Comment

Date
(mm/dd/yy)

Responsible
Responder

AC

HSR.011 8.2.4.and 8.2.5

DMcL

03/22/22

Where is the location that ballasted track will be required. I feel that the 2 sections
could be expanded and the minimum depths added as a minimum

05/12/22

MJS

C

HSR.012 8.2.6

DMcL

03/22/22

Is there any special trackwork on ballasted track

05/13/22

MM

DE

HSR.013 8.2.8

DMcL

03/22/22

Is Other Track Material the correct heading to use for this section

05/12/22

MJS

03/22/22

Fastening systems have already been mentioned with concrete ties and should be
removed from this sub section. Don't see fastening systems as OTM or System
Safety and Reliability

05/12/22

03/22/22

This section could be rationalized concentrating on the units that will be used.
Perhaps a table showing type and location.

05/12/22

No.

Reference

HSR.014 8.2.8.1

HSR.015 8.3

HSR.016 8.3

DMcL

DMcL

DMcL

03/22/22

HSR.017 8.5.1

DMcL

03/22/22

HSR.018 8.5.1

DMcL

03/22/22

HSR.019 8.5.2

DMcL

03/22/22

HSR.020 8.2.7

DMcL

03/22/22

For the crossovers on the 650 feet radius curve there should be a risk assessment
carried out for its suitability to be positioned on the curve.
Its section 5.8, not 5.9 and this should mention that the lubricators will be
positioned in accordance with the manufacturer. I do not think that AREMA
should be mentioned as the manufacturer would have had to get their product
accepted for use by AREMA.
AFFECTS: Caltrain and CHSRA
Are the tracks bi-directional here as a lubricator would be required at both ends
and this needs to be stated if so.
AFFECTS: Caltrain and CHSRA
Will each platform track have a bumping post at the termination of the track and
will a risk assessment be carried out as to the position of these beyond the end of
the train stop. Is there not a design criteria for Bumping Posts that the designer
needs to follow
AFFECTS: Caltrain and CHSRA

Ballasted track will be used for the at-grade portion of the alignment (Main line,
Maintenance of Way, and Turnback Track) except for at-grade crossings at 16th
Street and Mission Bay Drive.
These sections refer to Caltrain Design Criteria and the specific sections that
describe the Caltrain requirements.

Back-Check Comment
(if applicable)

PMPC Team
Date
(mm/dd/yy)

Responsible
Party

8/5/2022

MJS

PMPC Additional Response/
Next Steps

CHSRA did not object or reopen this comment during offical review of the DTX
Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this comment
review log.

Review Team
Date
(mm/dd/yy)

Final BRS

8/5/2022

CC

05/13/22

CC

05/13/22

CC

8/5/2022

CC

8/5/2022

CC

8/5/2022

CC

05/13/22

ROK

05/13/22

MM

A

Renamed Section header title to "Track Material Performance Requirements"

05/13/22

ROK

05/13/22

MM

MJS

B

Agreed that fastening system is already mentioned, but this subsection is
discussing safety and reliability.

8/5/2022

MJS

MJS

C

A table is of little benefit at this stage with minimal information.

8/5/2022

MJS

8/5/2022

MJS

8/5/2022

MJS

CHSRA did not object or reopen this comment during offical review of the DTX
Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this comment
review log.

8/5/2022

CC

05/12/22

MJS

B

CHSRA has already agreed to the absolute minimum radius of curvature (650') as
stated in DVR_0001. The curved crossover in the 650 radius curve is for Caltrain
use-only as it provide access to the Caltrain platform.

05/25/22

MM

A

Agree, lubricators must be installed per manufacturer's requirements. AREMA
provides recommended practices, not standards.

05/19/22

MM

A

Updated text per recommendation.
Agree. Replaced text to provide a performance standard in line with the CHSRA
criteria as follows: "Bumping posts must be designed to protect passengers and
crew on the train, adjacent trains, and the platforms in the event of an over-run.
The design must consider the track configuration, maximum likely speed, and
rolling stock characteristics."
CHSRA platforms are high platforms which mitigate need for guard rail.
Restraining rail will be used in the transit center. Will allow the use of restraining
rails in section 8.6.1 since the term guard rail is sometimes used for restraining
rail, will clarify terminology in the Design Criteria for the purpose of this project
as follows:
"restraining rails provide a narrow flangeway (1 5/8") to avoid derailment of a
train through a tight radius curve (typically radius less than 500'). Guard rails are
located further away from the running rails (10" gap) and attempt to control the
movement of a derailed train. Guard rail typically are installed at raised portions
of track or at the approaches to tunnels or structural elements that need
protection."
The 25 feet length was included in the original release of the DTX Design Criteria
(2009).

The responder (PMPC Team) acknowledged original comment; therefore this
comment is considered closed.
The responder (PMPC Team) agreed to update per original comment; therefore
this comment is considered closed.
CHSRA did not object or reopen this comment during offical review of the DTX
Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this comment
review log.
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Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this comment
review log.

05/19/22

ROK

05/19/22

MM

The responder (PMPC Team) agreed to update per original comment; therefore
this comment is considered closed.

05/19/22

CC

05/19/22

ROK

05/19/22

MM

The responder (PMPC Team) agreed to update per original comment; therefore
this comment is considered closed.

05/19/22

CC

05/25/22

ROK

05/25/22

MM

The responder (PMPC Team) agreed to update per original comment; therefore
this comment is considered closed.

05/25/22

CC

05/19/22

MM

A

What is the significance of placing guard rails at the end of CAHSR platforms and
not others. Will a continuous check rail (restraining rails) not do the same job.
Where did the 25 feet length come from ?
AFFECTS: CHSRA

05/12/22

MJS

A

05/19/22

MM

C

Section has been updated to reference Caltrain Design Criteria Chapter 2 - Track,
Part D - Special Trackwork. There are at-grade maintenance-of-way and turnback
tracks that are part of the DTX project.

8/5/2022

MJS

CHSRA did not object or reopen this comment during offical review of the DTX
Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this comment
review log.

8/5/2022

CC

Locations referenced in first paragraph. The at-grade interlocking will be updated
to provide a connection to both the DTX tracks and the Fourth and King Station.

8/5/2022

MJS

CHSRA did not object or reopen this comment during offical review of the DTX
Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this comment
review log.

8/5/2022

CC

05/09/22

MJS

Designer agreed to comply with comment and made necessary change. No backcheck response was received from CHSRA, thus the comment is considered closed.

05/09/22

CC

9/27/2022

MJS

The PMPC Team met with Caltrain and the Design Team for a CRM held on
9/27/2022 where this isue was resolved.

9/27/2022

CC

9/27/2022

MJS

The PMPC Team met with Caltrain and the Design Team for a CRM held on
9/27/2022 where this isue was resolved.

9/27/2022

CC

HSR.021 8.6.2

DMcL

03/22/22

HSR.022 8.7

DMcL

03/22/22

What reconfiguration will be happening and at what Grade Crossing

05/19/22

MM

C

MBr

10/01/18

LEGACY Comment HSR18.045 - 8.3 Special Trackwork (Turnouts and
Crossovers) CHSR trainsets cannot utilize No 8 & No. 9 turnouts

02/28/22

MJS

A

Section 8.3,
8-4

RS

Yes, the design is still being progressed, but there is special trackwork on ballasted
track.

Is there an actual requirement for derails based on the location for this project
bearing in mind what their function is for. (CFR 213.357 states that each track
other than a main track which connects to class 7,8 or 9 main track shall be
equipped.)
AFFECTS: Caltrain and CHSRA

HSR.023

Review Team
Date
(mm/dd/yy)

PMPC Response

Turnouts No. 8 and No. 9 will not be used for mainline tracks nor for any CHSRAtrain movements. Revised bullet to read as follows:
05/09/22

ROK

"No. 8 and No. 9 lateral turnouts may be used in yard and non-revenue tracks
where only Caltrain rolling stock will operate."

TA.001

Section 8.5.1, Rail Lubrication
(First bullet)

LZ

07/04/22

Refers to approach to the DTX between 7th and Townsend sts. Should be
"approach to the 4th and Townsend station", since the section between 7th and
Townsend is already part of the DTX

09/02/22

MJS

A

Revised section as follows:
"Train-activated rail lubricators must conform with AREMA (Volume 1 – Track,
Chapter 5, Part 5, section 5.9 Wayside Lubrication of Rail on Curves and the
manufacturer’s recommendations. The design and location of lubricators must and
include an analysis to ensure the following locations are provided with sufficient
lubrication to be installed at both ends of each curve on all tracks to lubricate the
following locations to prevent excessive rail wear and provide noise abatement:
•Curved approach to the DTX between Seventh and Townsend streets
•Curved transition between Townsend and Second streets
•Throat structure approach to the Transit Center
directionRail lubricators located below grade must be designed to support remote
monitoring, electronic type functioning system, and provide containment of the
lubricant in case of malfunction or rupture of a hydraulic hose or valve.

TA.002

Section 8.7, At-Grade Crossings

LZ

07/04/22

Sentence needs to be restructured for clarity

09/02/22

MJS

A

Revised as noted.

30 of 83


| No. | Reference | Date created | Date modified | Recipient Comment | Data source | PSID | Response 
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<tr>
<td>1.1.1</td>
<td>Rock Exploration, “Initial”</td>
<td>03/17/22</td>
<td>03/17/22</td>
<td>“Bedrock is encountered...”</td>
<td>GEC.022</td>
<td>RA</td>
<td>Agree, check to “...on-going and never be...”</td>
<td>§4-1 JF 03/17/22</td>
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<tr>
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<td>Rock Exploration, “Initial”</td>
<td>03/17/22</td>
<td>03/17/22</td>
<td>“If it is recurrent it may be on-going and never be &quot;complete&quot;...”</td>
<td>GEC.022</td>
<td>RA</td>
<td>Agree, check “...in Bay Mud.”</td>
<td>§1-1 JF 03/17/22</td>
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<tr>
<td>1.1.3</td>
<td>Core Logging in Soil and Rock, “Initial”</td>
<td>03/17/22</td>
<td>03/17/22</td>
<td>“If it is recurrent it may be on-going and never be &quot;complete&quot;...”</td>
<td>GEC.022</td>
<td>RA</td>
<td>Agree, check “...may be more costly than it is worth...”</td>
<td>§2-1 JF 03/17/22</td>
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<tr>
<td>1.1.4</td>
<td>Core Logging in Soil and Rock, “Initial”</td>
<td>03/17/22</td>
<td>03/17/22</td>
<td>“If it is recurrent it may be on-going and never be &quot;complete&quot;...”</td>
<td>GEC.022</td>
<td>RA</td>
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<td>§3-1 JF 03/17/22</td>
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<td>1.1.5</td>
<td>Geology</td>
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<td>03/17/22</td>
<td>“If it is recurrent it may be on-going and never be &quot;complete&quot;...”</td>
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<td>RA</td>
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<td>§4-1 JF 03/17/22</td>
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<td>GEC.022</td>
<td>RA</td>
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<td>§5-1 JF 03/17/22</td>
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<td>Geology</td>
<td>03/17/22</td>
<td>03/17/22</td>
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<td>RA</td>
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<td>§6-1 JF 03/17/22</td>
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<td>03/17/22</td>
<td>03/17/22</td>
<td>“If it is recurrent it may be on-going and never be &quot;complete&quot;...”</td>
<td>GEC.022</td>
<td>RA</td>
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<td>§7-1 JF 03/17/22</td>
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<td>1.1.9</td>
<td>Geology</td>
<td>03/17/22</td>
<td>03/17/22</td>
<td>“If it is recurrent it may be on-going and never be &quot;complete&quot;...”</td>
<td>GEC.022</td>
<td>RA</td>
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<td>§8-1 JF 03/17/22</td>
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<td>“If it is recurrent it may be on-going and never be &quot;complete&quot;...”</td>
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<td>Agree, check “...may be more costly than it is worth...”</td>
<td>§10-1 JF 03/17/22</td>
</tr>
</tbody>
</table>

**Note:** The table above represents a summary of comments and responses related to preliminary engineering and rock explorations as of 03/17/22. Each comment and its response are indicated with corresponding dates and references. The text is truncated for brevity, focusing on key points of discussion and resolution. Further details can be found in the original documents linked in the comments. The table is designed to facilitate understanding of the discussions and decisions made regarding preliminary engineering and rock explorations at the time specified.
|-----|-----------|----------|-----|-------------|-----------------|------------------|--------------|---------|-------|------------|
| 174 | 9.2 - Geotechnical Reporting | 05/17/22 | ROK | The Design Team did not object or reopen this comment during official review of the DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this document
| 175 | | | | | | | | | | |
| 176 | 9.2 - Geotechnical Reporting | 05/17/22 | MM | The Design Team did not object or reopen this comment during official review of the DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this document
| 177 | | | | | | | | | | |
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| 216 | 9.2 - Geotechnical Reporting | 05/17/22 | MM | The Design Team did not object or reopen this comment during official review of the DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this document
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<th>Response</th>
<th>Date (sent)</th>
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<td>GEC-16.048</td>
<td>PC</td>
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<td>This section is ok and very general. Knowing</td>
<td>05/04/22</td>
<td>N</td>
<td>R-K</td>
<td>05/04/22</td>
<td>MM</td>
<td>N</td>
<td>For the above (FDSH), agreed to update per original comment. The Caltrain did not provide any feedback response and therefore the comment is considered closed.</td>
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<td>GEC-16.049</td>
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<td>Please specify the recommendations from ASCE/SME. Are these referring to spacing, strength, and bond strength of soil nail and rock anchor design? The responder (PMPC Team) agreed to update per original comment.</td>
<td>05/04/22</td>
<td>N</td>
<td>R-K</td>
<td>05/04/22</td>
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<td>For the above (FDSH), agreed to update per original comment. The Caltrain did not provide any feedback response and therefore the comment is considered closed.</td>
<td>05/04/22</td>
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<td>Similar comment to GEC-16.048.</td>
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<td>R-K</td>
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<td>N</td>
<td>For the above (FDSH), agreed to update per original comment. The Caltrain did not provide any feedback response and therefore the comment is considered closed.</td>
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<td>For the above (FDSH), agreed to update per original comment. The Caltrain did not provide any feedback response and therefore the comment is considered closed.</td>
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<td>All references to GBR shall be prepared for the mined tunnel.</td>
<td>05/04/22</td>
<td>N</td>
<td>R-K</td>
<td>05/04/22</td>
<td>MM</td>
<td>N</td>
<td>For the above (FDSH), agreed to update per original comment. The Caltrain did not provide any feedback response and therefore the comment is considered closed.</td>
<td>05/04/22</td>
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<td>05/04/22</td>
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<td>6</td>
<td>GEC-16.053</td>
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<td>All references to GBR shall be prepared for the mined tunnel.</td>
<td>05/04/22</td>
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<td>R-K</td>
<td>05/04/22</td>
<td>MM</td>
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<td>For the above (FDSH), agreed to update per original comment. The Caltrain did not provide any feedback response and therefore the comment is considered closed.</td>
<td>05/04/22</td>
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<td>All references to GBR shall be prepared for the mined tunnel.</td>
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<td>R-K</td>
<td>05/04/22</td>
<td>MM</td>
<td>N</td>
<td>For the above (FDSH), agreed to update per original comment. The Caltrain did not provide any feedback response and therefore the comment is considered closed.</td>
<td>05/04/22</td>
<td>CC</td>
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<td>PC</td>
<td>CC</td>
<td>All references to GBR shall be prepared for the mined tunnel.</td>
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<td>N</td>
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<td>05/04/22</td>
<td>MM</td>
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<td>For the above (FDSH), agreed to update per original comment. The Caltrain did not provide any feedback response and therefore the comment is considered closed.</td>
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<td>CC</td>
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<td>R-K</td>
<td>05/04/22</td>
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<td>N</td>
<td>For the above (FDSH), agreed to update per original comment. The Caltrain did not provide any feedback response and therefore the comment is considered closed.</td>
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<td>Date (modified)</td>
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<td>Date (modified)</td>
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<td>Final RFS</td>
<td>Comment</td>
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<td>New Step/Communication</td>
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<tr>
<td>0403.001</td>
<td>3.1.1 - Salinity</td>
<td>SLP</td>
<td>03/08/22</td>
<td>A DRD flow test allows carrying drilling to test the distance at which various equipment or processes can be operated without disturbing the sample. This step is appropriate for most soil conditions except those where the formation is too weak to transmit the test force. The test is an acceptable method for determining if the sample is disturbed or not.</td>
<td>03/08/22</td>
<td>M &amp; S</td>
<td>B</td>
<td>ROK</td>
<td>a</td>
<td>03/08/22</td>
<td>M</td>
<td>The respondent (ROK) noted that the sampled sediment is not disturbed and that the sample is representative.</td>
<td>03/08/22</td>
<td>EC</td>
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<tr>
<td>0403.001</td>
<td>3.10.1 - Groundwater</td>
<td>SLP</td>
<td>03/08/22</td>
<td>The other groundwater samples are not discussed in this chapter. For various reasons, injection, and water table conditions.</td>
<td>03/08/22</td>
<td>M</td>
<td>C</td>
<td>ROK</td>
<td>a</td>
<td>03/08/22</td>
<td>M</td>
<td>The respondent (ROK) agreed with the reviewer and that the sample is not disturbed and that the sample is representative.</td>
<td>03/08/22</td>
<td>EC</td>
<td></td>
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<tr>
<td>0403.001</td>
<td>3.11.2 - Geotechnical requirements</td>
<td>SLP</td>
<td>03/08/22</td>
<td>The other geotechnical requirements are not discussed in this chapter. For various reasons, injection, and water table conditions.</td>
<td>03/08/22</td>
<td>M</td>
<td>a</td>
<td>ROK</td>
<td>a</td>
<td>03/08/22</td>
<td>M</td>
<td>The respondent (ROK) agreed with the reviewer and that the sample is not disturbed and that the sample is representative.</td>
<td>03/08/22</td>
<td>EC</td>
<td>03/08/22</td>
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</tbody>
</table>
Reviewer Organization:

Cal.001 Chapter 9 JP 04/29/22 experience qualification for the geotechnical engineer of record 05/20/22 MJW A GEOR will require approval by the TJPA who will establish the experience

Cal.018 Chapter 9.6 JP 04/29/22 refer to design parameters established in Section 10.2 05/20/22 JL C Not sure what the reviewer is referring to for referencing.

Cal.015 Chapter 9.4 JP 04/29/22 reference standard or guideline used for factors of safety 05/20/22 JL A

Cal.006 Chapter 9.1.2 JP 04/29/22 revise; 'alternative sampling techniques must' 05/20/22 MM A

04/29/22 Parsons; geotechnical reports

05/20/22 will revise 9.4 Excavation Base Stability as follows. Depth, and locations of…“for modulus determination” to “for modulus or resistivity determination"

reference list. Slate's seismic hazard report is not needed as reference for...
**Item No.** and **Reference**

<table>
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<tr>
<td>5.1.01</td>
<td>Section 9.1.1, Soil Exploration and Testing (DPE)</td>
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<td>Section 9.1.1, Soil Exploration and Testing (DPE)</td>
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<td>Section 9.1.1, Soil Exploration and Testing (DPE)</td>
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<td>5.1.05</td>
<td>Section 9.1.1, Soil Exploration and Testing (DPE)</td>
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<td>5.1.06</td>
<td>Section 9.1.1, Soil Exploration and Testing (DPE)</td>
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</table>

**Responder:**

- Martin J. Walker (PMPC SME/Mott MacDonald)
- Meghan Murphy (PMPC/AECOM)
- Luis Zurinaga (SF CTA)
- Mitch Fong (CHSRA)

**Review Team:**

- PMPC Team
- Review Team PMPC Team
- Review Team PMPC Team
- Review Team PMPC Team

**Responder Comments:**

- It is still unclear if the specifications will be prescriptive or model specs for a PDB. Agree, reference to specification removed to avoid disrupting order of precedence. 10/03/22 MJS
- See response (PMPC) Tent agreed and addressed the original comment therefore is considered closed. 10/03/22 CC
- The responder (PMPC) agreed and addressed the original comment therefore it is considered closed. 10/03/22 CC
- It is still unclear if the specifications will be prescriptive or model specs for a PDB. Agree, reference to specification removed to avoid disrupting order of precedence. 10/03/22 MJS
- The responder (PMPC) tent agreed and addressed the original comment therefore is considered closed. 10/03/22 CC
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- The responder (PMPC) agreed and addressed the original comment therefore is considered closed. 10/03/22 CC

**Date/Time:**

- 09/01/22 - 10/03/22

**PMPC Response:**

- The responder (PMPC) tent agreed and addressed the original comment therefore is considered closed. 10/03/22 CC
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**PMPC Additional Response:**

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<td>04/08/22</td>
<td>Jongwon Lee</td>
<td>Section 1617.11.1-1.3.8 of CBC refers to Section 322 of CBC</td>
<td>No. A – Responder agrees and will comply</td>
<td>ROK</td>
<td>05/13/22</td>
<td>DCC-001 Ch 10.1, Page 13-4 of 12 YS 04/08/22</td>
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<td>DCC-002</td>
<td>04/08/22</td>
<td>Henry Chang</td>
<td>Since CalTrain and HSR allow displacement ductility ratio of 1.5 (under SEE event). Please confirm that under the SEE earthquake, maximum displacement ductility ratio of 1.5 may be used, if desired, to account for the higher ground motions during these events.</td>
<td>No. MM – Revised section to include clarification</td>
<td>ROK</td>
<td>05/13/22</td>
<td>DCC-002 Ch 10.1, Page 13-4 of 12 YS 04/08/22</td>
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<td>DCC-004</td>
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<td>J. Gebelein</td>
<td>Since CalTrain and HSR allow displacement ductility ratio of 1.5 (under SEE event). Please confirm that under the SEE earthquake, maximum displacement ductility ratio of 1.5 may be used, if desired, to account for the higher ground motions during these events.</td>
<td>No. MM – Revised section to include clarification</td>
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05/09/22 MJS C
Please confirm that the performance objectives for each earthquake level presented in Chapter 10.3.3 are consistent with the building code. Since CalTrain and HSR allow displacement ductility ratio of 1.5 (under SEE event). Please clarify if shear capacities shall be calculated as per CalTrain and HSR. Also, the upper 30-meter...
not used by practitioners nowadays.

1 is 2010 instead of 1999 listed. Uniform Building Code 1997 is referenced but supported on the below grade structure, such as station entrances. The referenced...evaluation earthquake (SEE) and functionality evaluation earthquake (FEE) will...hence, we need to ensure that design of...will make sure the design be fully compliant with the prescriptive...https://sfdbi.org/administrative-bulletins). Hence, we need to ensure that design of...Will remove reference to UBC code. 8/5/2022 MJS

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No. | Reference | Date (mm/dd/yy) | Responsible | Project | Comment
--- | --- | --- | --- | --- | ---
1 | Section 01 | 04/21/22 | JL | Preliminary Engineering | Review & reconcile with section 1.6 Design Criteria
2 | Section 02 | 04/22/22 | JL | Preliminary Engineering | New details on the soil-structure analysis
3 | Section 03 | 05/09/22 | ROK | Preliminary Engineering | Please review the soil-structure analysis
4 | Section 04 | 05/13/22 | CC | Preliminary Engineering | This comment is considered closed.

Date Comments
- 04/21/22: Review & reconcile with section 1.6 Design Criteria
- 04/22/22: New details on the soil-structure analysis
- 05/09/22: Please review the soil-structure analysis
- 05/13/22: This comment is considered closed.

Summary
- Review & reconcile with section 1.6 Design Criteria
- New details on the soil-structure analysis
- Please review the soil-structure analysis
- This comment is considered closed.
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<td>F. Waggoner</td>
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<td>The section states “the performance objectives for each sub-structure level are summarized in Table 10.3.”</td>
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<td>2000</td>
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<td>The event of a rupture of the lining and waterproofing system.”</td>
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<td>Apparently this Chapter used to be 13, but now 10. Section 13.1.1: Structural SSI). For the SEE, how does this approach allow cut/c over strain prediction</td>
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<td>08/22/22</td>
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Note: The comments are closed as of 05/16/22. Comments considered closed as of 05/16/22: CC.

05/03/22 JL A
10/05/22 CC
04/16/22 UC
04/19/22 CC
04/19/22 CC
04/26/22 CE
08/26/22 CE
08/26/22 CE
08/26/22 CE
08/26/22 CE

The response (PDMS) for this comment is satisfied with the original comments. Therefore, this comment is considered closed.
The walls, using specified minimum f'c & phi = 1.0

The section states "If joints are proposed within the mined tunnel final lining, the CHSR strain limits are also bar size dependent (i.e.: #10 bar & smaller, #11 bar &...

Joint shear capacity shall be evaluated and compared to shear demands.

10/05/22 CC

Displacement ductility limit considered as 1.4.
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<td>Section 10.4.4 - Factors of Safety for Earth Retaining Structures under Seismic Loading</td>
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<td>Clarify if B/6 eccentricity limit applies for both FEE or SEE.</td>
<td>ROK</td>
<td>Agree, revision confirmed.</td>
<td>05/24/22</td>
<td>NLV A Limits have been redefined for both FEE and SEE.</td>
<td>ROK</td>
<td>Agree, revision confirmed.</td>
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</table>
The Boscarding and Cording method is mentioned in Section 10.1. Buildings that have

According to email from Matt on March 11, the ZOI will be modified to ¼".

Two different definitions of ZOI are used. Figures 10-1 and 10-2 may need to be removed

For example, Stage 1 is a preliminary damage assessment phase. In this stage, the
determination of using underpinning should be based on the detailed analysis anyway.

Clear criteria for when SSI interaction would be required. The TJPA should be on record that it does not expect Parsons to perform SSI interaction in its current review. The SSO contractor will have to update it and take ownership of it when the time comes.

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According to email from Matt on March 11, the ZOI will be modified to ¼".

All elevation data may not be transported for all utilities within the DTX. This criteria itself phrasing the damage assessment criteria i.e., Boscarding or Cording, is still unclear. Adequate criteria should be developed for this section.

For example, Stage 1 is a preliminary damage assessment phase. In this stage, the analysis of the allowable settlement is determined by empirical methods, the damage category is assessed, and buildings are color-coded using this method. The color coding system contains red, yellow, and green levels. Buildings that are colored green do not require the SSI analysis. Buildings that are colored yellow are in need of further analysis, while red buildings require SSI analysis.

For example, Stage 1 is a preliminary damage assessment phase. In this stage, the analysis of the allowable settlement is determined by empirical methods, the damage category is assessed, and buildings are color-coded using this method. The color coding system contains red, yellow, and green levels. Buildings that are colored green do not require the SSI analysis. Buildings that are colored yellow are in need of further analysis, while red buildings require SSI analysis.

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The Boscarding and Cording method is mentioned in Section 10.1. Buildings that have

This needs to be more specific. For example, no additional analyses are required

It is not captured in these figures.

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Cal.024 Chapter 11 Section 11.2.1; Cal.009 Chapter 11.2 JP 04/29/22 Cut-and Cover Structure heading for next subsection, number accordingly 05/25/22 MM A Revised as noted 05/25/22 MM The responder (PMPC Team) agreed to update per original comment; therefore.

Cal.004 Chapter 11.1.2 JP 04/29/22 As defined in section 10.2 05/25/22 MM A Revised as noted 05/25/22 MM The responder (PMPC Team) agreed to update per original comment; therefore.

Cal.023 Chapter 11.3 JP 04/29/22 Summary estimates shall be submitted to the TJPA for review 05/25/22 MM A

Cal.001 Chapter 11.1.1 JP 04/29/22 Geotech review 05/25/22 MM A Revised as noted 05/25/22 MM The responder (PMPC Team) agreed to update per original comment; therefore.
Noel Vivar (PMPC SME/Mott MacDonald)  Downtown Rail Extension (DTX)  Load Surcharge (LS) (Minimum
12.1.2 - Concrete Reinforcing Steel, (ASCE) MB 03/03/22 Is the version required if above says the latest edition? 05/13/22 NLV A Agree. Will remove the version from ASCE. Change complete. 8/5/2022 MJS

Page 13-14 of 22 AEB 03/17/22 Suggest updating the cast-in-place substructure/superstructure concrete and
bullet (2019 SFBC) MB 03/03/22 Is the version required if above says the latest edition? 05/13/22 NLV B Disagree. Crack width control, in addition to the waterproofing system, is an integral part of achieving design life goals. 8/5/2022 MJS

Margaritte Bello (Design Team)  Amanda Kaku (PMPC/HCI)

The Design Team did not object or reopen this comment during official review of the DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this comment review log.

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**Phase:**

**FW C – Answer provided; no action needed**

**GEC.020 Chapter 11 PC 09/12/16 LEGACY Comment**

GEC.16.056 - Add a sub-section describing Underground Transient Loads, F - including seismic loads, from buildings should be considered for cut-and-cover and cover structures. It is probably not intended. Please revise to clarify.

Sentence referenced states to ignore the top 2 feet of backfill when calculating the DTX Design Criteria Rev Book 02 - Draft Final (June 1, 2022) and this does not provide any backcheck response and therefore this comment is considered 8/5/2022 CC.

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**DTX Program**

**Review/Approval Sheet**

**Document Control File Code:**

**R.E.C. - Check/Review Status:**

- R: Required document for current task
- E: Submit for current task
- C: Check/Review document in current task

**R.E.C. - Additional Response/Task:**

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**LEGACY Comment GEC16.068**
- Under the sub-heading of 11.2.1.15, "Sliding": The provision to disregard 3 ft. of earth above the base slab for sliding and Caltrans Seismic Design Criteria for more information.

**LEGACY Comment GEC16.065**
- Under the sub-heading of “11.2.1.14, "Load Sliding": The provision to disregard 3 ft. of earth above the base slab for sliding and Caltrans Seismic Design Criteria for more information.

**LEGACY Comment GEC16.063**
- Under the sub-heading of "11.2.1.13, "Stability": The provision to disregard 3 ft. of earth above the base slab for sliding and Caltrans Seismic Design Criteria for more information.

**LEGACY Comment GEC16.062**
- Under the sub-heading of "11.2.1.12, "Design": The provision to disregard 3 ft. of earth above the base slab for sliding and Caltrans Seismic Design Criteria for more information.

**LEGACY Comment GEC16.061**
- Under the sub-heading of "11.2.1.11, "Stability": The provision to disregard 3 ft. of earth above the base slab for sliding and Caltrans Seismic Design Criteria for more information.

**LEGACY Comment GEC16.060**
- Under the sub-heading of "11.2.1.10, "Stability": The provision to disregard 3 ft. of earth above the base slab for sliding and Caltrans Seismic Design Criteria for more information.

**LEGACY Comment GEC16.059**
- Under the sub-heading of "11.2.1.9, "Stability": The provision to disregard 3 ft. of earth above the base slab for sliding and Caltrans Seismic Design Criteria for more information.

**LEGACY Comment GEC16.058**
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**LEGACY Comment GEC16.057**
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**LEGACY Comment GEC16.056**
- Under the sub-heading of "11.2.1.6, "Load Sliding": The provision to disregard 3 ft. of earth above the base slab for sliding and Caltrans Seismic Design Criteria for more information.

**LEGACY Comment GEC16.055**
- Under the sub-heading of "11.2.1.5, "Load Sliding": The provision to disregard 3 ft. of earth above the base slab for sliding and Caltrans Seismic Design Criteria for more information.

**LEGACY Comment GEC16.054**
- Under the sub-heading of "11.2.1.4, "Load Sliding": The provision to disregard 3 ft. of earth above the base slab for sliding and Caltrans Seismic Design Criteria for more information.

**LEGACY Comment GEC16.053**
- Under the sub-heading of "11.2.1.3, "Load Sliding": The provision to disregard 3 ft. of earth above the base slab for sliding and Caltrans Seismic Design Criteria for more information.

**LEGACY Comment GEC16.052**
- Under the sub-heading of "11.2.1.2, "Stability": The provision to disregard 3 ft. of earth above the base slab for sliding and Caltrans Seismic Design Criteria for more information.

**LEGACY Comment GEC16.051**
- Under the sub-heading of "11.2.1.1, "Stability": The provision to disregard 3 ft. of earth above the base slab for sliding and Caltrans Seismic Design Criteria for more information.
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**Note:** The above table represents a portion of the document's review process, detailing the comments, responses, and dates for various reviewers. The table includes columns for Reference, Reviewer, Date, Reviewer Comment, Data, and PDRC Response. Each entry indicates the reviewer's initials, the date of the review, and the specific feedback or action taken on the document. The PDRC Response column indicates whether the comment was resolved (R) or required further action (N).
### Table: CCHSRA Design Criteria

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### Notes:
- **PSID:** Project Sponsor Identification
- **RIC:** Responsible Party Identification

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**Conclusion:**
- The review process includes multiple rounds of review and response, with initial comments and changes being addressed by various reviewers.
- The final steps involve the resolution and closure of comments, with emphasis on maintaining clear communication and ensuring that all necessary actions are taken.
- The involvement of different organizations and teams highlights the collaborative nature of this project, ensuring that all aspects are thoroughly reviewed and addressed.
<table>
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<th>No.</th>
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**Legend:**
- **PSRC Response**: Yes response (PSRC) | No response (PSRC)
- **Final Date**: Date when the final response is given
- **Responsible Party**: MM: Project Manager, NLV: New Lane Viaduct
Section 12.5. Bridges

LZ 07/04/22 Bridge criteria to be followed should include Caltrans.

LZ 09/02/22 NLV B CBDS is already referenced in the current copy. Clarification may be needed for the creation of the next step of design.

TA.003 Section 12.1.8. Waterproofing

LRV Models (B. Superimposed Dead Loads)

Earth Surcharge

or other means

seepage through the membrane is allowed. This is the Achilles heel of membrane waterproofing requirements or definition are better suited to a Technical Requirements (LRV Models).

The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 10/11/22 CC

The responder (PMPC Team) met with commentor for CRM on 10/11 and was satisfied.

The responder (PMPC Team) has agreed to define waterstop type and to develop requirements for waterstop type and to develop requirements for a Technical Requirements.

The second bullet under "Scope" has been revised as follows:

The responder (PMPC Team) has agreed to PMPC response; therefore this comment is considered closed. 10/05/22 CC

10/05/22 CC

10/05/22 CC

10/05/22 CC
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<thead>
<tr>
<th>No.</th>
<th>Reference</th>
<th>Date</th>
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<td>120</td>
<td>GEC.008 Ch 13.1.6, Heading, Page 11-4 of 19 YS 04/08/22</td>
<td>05/02/22 DP A</td>
<td>Agreed, ACI 506 is already included. Will add a generic reference to ASTM D7205.</td>
<td></td>
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<tr>
<td>121</td>
<td>GEC.005 Chapter 13 Section 13.1.2, pg. 13-3 YS 12/10/21</td>
<td>05/02/22 DP A</td>
<td>Agree with need for waterproofing/infiltration limits. The waterproofing will reduce potential seepage by taking advantage of the separation between the permanent concrete lining and the temporary screen wall.</td>
<td></td>
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<tr>
<td>122</td>
<td>GEC.003 Chapter 13 References, pg. 13-2 YS 12/10/21</td>
<td>05/02/22 DP C</td>
<td>Understood, however there are areas where the use of shotcrete may be beneficial - such as the 2-3 track transition and within the adit, to offset unique formwork combinations the only thing specific to portals is the area required to prevent ear popping as the train transitions into the smaller space. In our case due to the speed far beyond the portal, the train will be at low enough speed that this shouldn’t be an issue.</td>
<td></td>
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<tr>
<td>123</td>
<td>GEC.009 Ch 13.5.3, 2nd Para., Page 11-13 of 19 YS 04/08/22</td>
<td>05/02/22 DP A</td>
<td>Agree.</td>
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<tr>
<td>124</td>
<td>GEC.011 Section 13.1.11, pg. 11-13</td>
<td>05/02/22 DP A</td>
<td>Agree.</td>
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<tr>
<td>125</td>
<td>GEC.012 Chapter 12 PC 09/12/16 LEGACY Comment GEC16.079 - Add a sub-section describing Tunnel liner design. Things like gasket requirements, segment reinforcing. Segments are difficult to fabricate and are non-standard. Their use is temporary and is dependent on the contract schedule. Should be addressed in the specification.</td>
<td>05/02/22 DP A</td>
<td>Agreed, please note the comment that it is not essential to the design of the DTX. The intent here is that 'appropriate' references may be used. That is left to the discretion of the R&amp;D.</td>
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<tr>
<td>126</td>
<td>GEC.013 Section 12.8.1 PC 09/12/16</td>
<td>05/02/22 DP A</td>
<td>Suggest re-evaluating this requirement.</td>
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<tr>
<td>127</td>
<td>GEC.009 Ch 13.5.3, 2nd Para., Page 11-13 of 19 YS 04/08/22</td>
<td>05/02/22 DP A</td>
<td>Agree.</td>
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</tr>
<tr>
<td>128</td>
<td>GEC.009 Ch 13.5.3, 2nd Para., Page 11-13 of 19 YS 04/08/22</td>
<td>05/02/22 DP A</td>
<td>Agree.</td>
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</tr>
<tr>
<td>129</td>
<td>GEC.009 Ch 13.5.3, 2nd Para., Page 11-13 of 19 YS 04/08/22</td>
<td>05/02/22 DP A</td>
<td>Agree.</td>
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</tr>
<tr>
<td>130</td>
<td>GEC.009 Ch 13.5.3, 2nd Para., Page 11-13 of 19 YS 04/08/22</td>
<td>05/02/22 DP A</td>
<td>Agree.</td>
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<tr>
<td>131</td>
<td>GEC.010 Ch 13.5.4, Page 11-13 of 19 YS 04/08/22</td>
<td>05/02/22 DP A</td>
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<tr>
<td>132</td>
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<td>05/02/22 DP A</td>
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<tr>
<td>133</td>
<td>GEC.003 Chapter 13 References, pg. 13-2 YS 12/10/21</td>
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<td></td>
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<tr>
<td>134</td>
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<td>05/02/22 DP A</td>
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<tr>
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<td>Reference</td>
<td>Issue/ Category</td>
<td>Date identified</td>
<td>Reviewer Comment</td>
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<tr>
<td>GEC.019 DC 12.1 PC</td>
<td>GEC.019 DC 12.1 PC</td>
<td>Date 05/02/22</td>
<td>DPR A</td>
<td>Agreed - added bullet. Requirements for sensitivity analysis are included in GEC.019 DC 12.1 Table has been deleted.</td>
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<td>GEC.019 DC 12.1 PC</td>
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<td>The Scope section has been revised to include the following:</td>
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<td>GEC.020 DC 12.1 PC</td>
<td>Date 05/02/22</td>
<td>MJS A</td>
<td>The Scope section has been revised to include the following:</td>
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<td>GEC.020 DC 12.1 PC</td>
<td>GEC.020 DC 12.1 PC</td>
<td>Date 05/04/22</td>
<td>ROK</td>
<td>According to the current plan, the DFS/04 Characterization Tests will be included in the final DFS/04 document.</td>
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<tr>
<td>GEC.020 DC 12.1 PC</td>
<td>GEC.020 DC 12.1 PC</td>
<td>Date 05/16/22</td>
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<td>GEC.020 DC 12.1 PC</td>
<td>GEC.020 DC 12.1 PC</td>
<td>Date 05/02/22</td>
<td>MJS A</td>
<td>No further comments.</td>
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<td>GEC.020 DC 12.1 PC</td>
<td>Date 05/04/22</td>
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<td>No further comments.</td>
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Note: The document contains a table with various comments and responses from reviewers, indicating revisions to the text. The comments range from technical updates to clarifications and deletions of sections that have already been revised. The table also includes dates for when the revisions were made and the responsible parties for the comments. The final BCR date is included for each entry, indicating the status of the comments and revisions.
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<th>APR Comment</th>
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<td>RS</td>
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<td>Sec. 11</td>
<td>&quot;Required general statement to be added to Sec. 11.&quot;</td>
<td>05/24/22</td>
<td>BCR</td>
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<td>05/24/22</td>
<td>Note revised to add a requirement to the minimum number of spans required for the tunnel.</td>
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<td>RS</td>
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<td>06/30/22</td>
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<td>06/30/22</td>
<td>Note revised to add a requirement to the minimum number of spans required for the tunnel.</td>
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- **PSRC/PSN**: Project System Review Coordinator/Project System Notes
- **BCR**: Best Check Result
- **APR**: Additonal Project Review

### Notes:
- BCR - For best check result, any changes or adjustments are to be made to the PSRC/PSN sheet.
- APR - For additional project review, any changes or adjustments are to be made to the PSRC/PSN sheet.

---

**Issue Commented**

- **RS**: Required changes for review
- **Sec**: Required changes for sec.
- **Note**: Note only

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**Review Team**

- **Review Team**: Review Team
- **PMPC Team**: PMPC Team

---

**Date Commented**

- **05/16/22**: 05/16/22
- **06/30/22**: 06/30/22

---

**BCR**

- **05/24/22**: 05/24/22
- **06/30/22**: 06/30/22

---

**APR**

- **05/24/22**: 05/24/22
- **06/30/22**: 06/30/22

---

**BCR Comment**

- **No further comment**: No further comment
- **Note revised to add a requirement to the minimum number of spans required for the tunnel**: Note revised to add a requirement to the minimum number of spans required for the tunnel.

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**APR Comment**

- **Note revised to add a requirement to the minimum number of spans required for the tunnel**: Note revised to add a requirement to the minimum number of spans required for the tunnel.

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**Panel**

- **05/16/22**: 05/16/22
- **06/30/22**: 06/30/22

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**Review Team**

- **PMPC Team**: PMPC Team
- **Review Team**: Review Team

---

**Date Commented**

- **05/16/22**: 05/16/22
- **06/30/22**: 06/30/22

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**BCR Comment**

- **Note revised to add a requirement to the minimum number of spans required for the tunnel**: Note revised to add a requirement to the minimum number of spans required for the tunnel.

---

**APR Comment**

- **Note revised to add a requirement to the minimum number of spans required for the tunnel**: Note revised to add a requirement to the minimum number of spans required for the tunnel.
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<td>0001</td>
<td>HSR.001</td>
<td>13.1</td>
<td>03/28/22</td>
<td>S. K.</td>
<td>Suggest deleting &quot;temporary&quot; and reword to say &quot;used for initial support and final...&quot;</td>
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<td>0002</td>
<td>HSR.010</td>
<td>13.2.11</td>
<td>03/28/22</td>
<td>S. K.</td>
<td>Section 13.2.11, p. 7 SK 03/28/22</td>
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<td>HSR.015</td>
<td>13.5.1</td>
<td>03/29/22</td>
<td>S. K.</td>
<td>Section 13.5.1, p. 11 SK 03/29/22</td>
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</table>

**FYI:**
- HSR.001 Section 13.1, p. 2 SK 03/28/22
- HSR.010 Section 13.2.11, p. 7 SK 03/28/22
- HSR.015 13.5.1, p. 11 SK 03/29/22

Operations (i.e. fire, blast loading, etc.) which would not be relevant load...


**Project:** CK

**Review Team:**

**HSR.029 13.5.4 EA 04/19/22**

**How much movement does an interface joint have to be designed for? Chapter 10**

Consider a condition whereby the ground load is taken by the initial support but some of it should be effective for long-term ground support. This requirement mentions some dynamic modeling but it is not clear how this should be done.

Since 2009. We've since realized through practical application, that the load sharing between the initial support and ground support is crucial. In June 1, 2022 Section 13.5.4 states "Load sharing between the initial support and ground support is crucial."
<table>
<thead>
<tr>
<th>Reference</th>
<th>No.</th>
<th>Date (mm/dd/yy)</th>
<th>Comment:</th>
<th>Responsible</th>
<th>PMPC Response</th>
<th>Date (mm/dd/yy)</th>
<th>Back-Check Comment (if applicable)</th>
<th>Date (mm/dd/yy)</th>
<th>Responsible</th>
<th>PMPC Additional Response / New Topic</th>
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<tr>
<td>TA.006</td>
<td>12.48</td>
<td>06/19/22</td>
<td>No design requirements exist in the chapter, with one exception.</td>
<td>DP</td>
<td>Final Structure should be defined in Section 6.1.1 Environmental Requirements. There’s no need to rework this.</td>
<td>09/02/22</td>
<td>DP</td>
<td></td>
<td>09/30/22</td>
<td>LZ</td>
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<tr>
<td>TA.006</td>
<td>13.4.2</td>
<td>06/19/22</td>
<td>All references to bored tunnel retracted.</td>
<td>DP</td>
<td></td>
<td>09/02/22</td>
<td>DP</td>
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<tr>
<td>TA.005</td>
<td>13.2.7.2</td>
<td>05/22</td>
<td>The requirement that the design must not result in collapse may be in conflict with</td>
<td>DP</td>
<td></td>
<td>10/04/22</td>
<td>CC</td>
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<tr>
<td>TA.004</td>
<td>13.1.6</td>
<td>07/04/22</td>
<td>No precast tunnel segments. This whole section is for TBM.</td>
<td>DP</td>
<td>Agreed. See response to TA.001</td>
<td>10/05/22</td>
<td>MJS</td>
<td>The responder (PMPC Team) met with commentor for a CRM on 10/5 and agreed the approach was logical.</td>
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<td></td>
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<tr>
<td>TA.003</td>
<td>3.8 Fixed DFAA</td>
<td>06/13/22</td>
<td>The design of the road was modified and a 10-year FEMA project.</td>
<td>DP</td>
<td></td>
<td>10/04/22</td>
<td>CC</td>
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<tr>
<td>TA.003</td>
<td>3.5.8.1 last paragraph</td>
<td>06/13/22</td>
<td>The final design of the tunnel must be designed for critical facilities and comply with other portions of the project within the 100-year flood plain, the drainage system.</td>
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Phase:

Project:

14.6.3.1 - Space

GEC.018 14.6.3.2 - Design Features,

GEC.004

GEC.008 14.3.1.2 - Platform Level RV 04/08/22 Suggest less prescriptive dimensions for platforms as Caltrain and CHSRA

GEC.013 14.6.1.2 - Width, ¶1-2 RV 04/08/22 Revise second sentence to read as follows: The minimum stair width is 5 feet, unless

GEC.012 14.6.1 - Stairs, ¶2 RV 04/08/22 Note: Train box floor-to-floor levels all exceed 20’ and stairs are used throughout. 05/19/22 OA DE

GEC.011 14.4.6.6 - Reflectance, ¶1-2 RV 04/08/22 Suggest a less restrictive description “bright and light-colored” to allow flexibility in

GEC.010 14.4.6 - Materials and

GEC.009 14.4.6 - Materials and

GEC.003

Phases:

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<td>A</td>
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<td>MM</td>
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<td>List missing HSR signage 05/23/22 MM A</td>
<td>Will add “HSR signage, where applicable” 05/23/22 MM</td>
<td>The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.</td>
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<td>LOS needs to consider two way movement—consider one way stair flows to improve accessibility.</td>
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<td>Size elevators to ensure the can move the train headway disabled population based on average passenger counts for the train headway.</td>
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<td>GEC.008 Paragraph 22.4</td>
<td>08/03/22</td>
<td>GEC.001 Ch 15.2.b Emergency Management</td>
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<td>08/03/22</td>
<td>JRD</td>
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**GEC.011 Chapter 15 - General**

- **Population Size, Table 15.1:**
  - Fire size and growth rate should be based on the design rolling stock and can not be determined arbitrarily based on what is feasible for the current system. The system performance perspectives such as adding micro pp fibers in the concrete mix for the final lining. Should this be required?

- **Transbay Program's Final Risk and Vulnerability Assessment:**
  - This chapter does not provide any requirements of fire resistance for the criteria. The Design Team did not object or reopen this comment during official review of the review log.

- **Multiple CFD analysis modeling:**
  - The responder (PMPC Team) provided clarification to original comment inquiry, no change required - comment is considered closed. 10/06/22 CC.

**GEC.003 15.1 - Design Fire Size**

- **Response:**
  - The responders agree and will comply.

- **Date:**
  - 08/03/22

- **Reviewer:**
  - NS A

**GEC.010 Chapter 22/23-General**

- **Legacy Comment GEC.101.28 - Consider prohibiting embedded fire suppression system piping:**
  - The handrails are located against the tunnel wall, not between the train and the walkway so they will not impede egress.

- **Response:**
  - Noted. Design Criteria can be updated after further discussion considering SES and other requirements.

- **Date:**
  - 08/14/22

- **Reviewer:**
  - MM A

**GEC.004 15.2.b - Emergency Management**

- **Comment GEC.18.108 - Consider prohibiting fire suppression system piping:**
  - This chapter does not provide any requirements of fire resistance for the criteria. The Design Team did not object or reopen this comment during official review of the review log.

- **Response:**
  - Noted. Design Criteria can be updated after further discussion considering SES and other requirements.

- **Date:**
  - 08/14/22

- **Reviewer:**
  - MM A

**GEC.008 Paragraph 22.4**

- **Comment GEC.18.108 - Consider prohibiting fire suppression system piping:**
  - The handrails are located against the tunnel wall, not between the train and the walkway so they will not impede egress.

- **Response:**
  - Noted. Design Criteria can be updated after further discussion considering SES and other requirements.

- **Date:**
  - 08/14/22

- **Reviewer:**
  - MM A

**GEC.013 15.2 Emergency Management**

- **Comment GEC.18.108 - Consider prohibiting fire suppression system piping:**
  - The handrails are located against the tunnel wall, not between the train and the walkway so they will not impede egress.

- **Response:**
  - Noted. Design Criteria can be updated after further discussion considering SES and other requirements.

- **Date:**
  - 08/14/22

- **Reviewer:**
  - MM A

**GEC.014 15.7.1 Walkways**

- **Comment GEC.18.108 - Consider prohibiting fire suppression system piping:**
  - The handrails are located against the tunnel wall, not between the train and the walkway so they will not impede egress.

- **Response:**
  - Noted. Design Criteria can be updated after further discussion considering SES and other requirements.

- **Date:**
  - 08/14/22

- **Reviewer:**
  - MM A
AREMA Manual for Railway Engineering is the third bullet under Codes, Standards

Is NFPA 101 actually used by the CBC?  NFPA 130 defers CBC to Cal.001 Chapter 15 BZ 04/21/22 Reconcile chapter numbering 05/13/22 AK A Chapter numbering will be coordinated during production. 05/16/22 ROK 05/16/22 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

Is there a specific fire detection device that the CBC is using for the SFPP? 05/17/22 ROK 05/17/22 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

Coordinating chapter numbering 05/13/22 AK A Chapter numbering will be coordinated during production. 05/16/22 ROK 05/16/22 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

Is the SFO 2006 Public Address System in use in the project specifications? 08/23/21 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

Coordinate chapter numbering 05/13/22 AK A Chapter numbering will be coordinated during production. 05/16/22 ROK 05/16/22 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed. 05/17/22 ROK 05/17/22 MM The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

With the exception of walkways between tracks, hand rails are to be located opposite of track, adjacent to tunnel wall, and not obstruct egress from trains. 06/21/22 JP 06/30/22 revise 5th bullet; handrails to be located opposite of track, adjacent to tunnel wall, and not obstruct egress from trains. 09/13/22 MJS A Revised as noted. 10/04/22 MJS The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

The list of systems does not have CCTV. 09/13/22 MJS A Revised as noted. 10/07/22 CC The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

Added: • Standpipe System. 06/21/22 JP 06/30/22 revise 5th bullet; standpipes be located... 09/13/22 MJS A Revised as noted. 10/04/22 CC The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

A comment is considered closed. 05/17/22 CC The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

The list of locations where fire detection devices must be installed is very vague statement. Functions that need to be included in the project specifications, not the design criteria. 09/20/22 NS A Revised as noted. 10/07/22 CC The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

Added: • Designer should refer to NFPA 130 for life safety equipment requirements needed in this system. Smoke and heat detectors are approved for pressure/temperature, not for the tunnel structures. 06/21/22 ROK 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.

Added the following paragraph: Full document to the minimum automatically gives a pre-determined filter within the database, which would be included in the project scope. The pre-determined filters will be included in the project and will agree upon specifications during the pre-design phase. 06/21/22 CC Revised as noted; the non-DTX scope of the DTX project must have emergency waiting area(s) for a period no less than the required time of tenability (4 minutes). 05/17/22 CC The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

The list of systems does not have CCTV. 06/21/22 JP 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.

Added: • Public Address System. 06/21/22 JP 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.

Comment HSR18.058 - 22.4.3 Station Deluge System - No reference to deluge systems without additional severe consequences. 05/17/22 CC The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

Comment HSR18.056 - 22.2 Emergency Management - Reference NFPA 14 diagnostics and health monitoring system which included smoke, heat detection system and standpipes be located at station platform tracks? 02/28/22 AK/NS A Revised as noted. 10/07/22 CC The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.

Comment HSR18.057 - 22.4.2 Fire Detection - Designer should refer to NFPA 130 for life safety equipment requirements needed in this system. Smoke and heat detectors are approved for pressure/temperature, not for the tunnel structures. 06/21/22 ROK 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.

Comment HSR18.059 - 22.4.1 Fire Standpipe System. 06/21/22 JP 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.

Comment HSR18.054 - 22.4.0 Fire Alarm System. 06/21/22 JP 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.

Comment HSR18.052 - 22.2.1 Fire Alarm System. 06/21/22 JP 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.

Comment HSR18.051 - 22.2.1 Fire Alarm System. 06/21/22 JP 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.

Comment HSR18.050 - 22.2 Fire Alarm System. 06/21/22 JP 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.

Comment HSR18.049 - 22.2 Fire Alarm System. 06/21/22 JP 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.

Comment HSR18.048 - 22.2 Fire Alarm System. 06/21/22 JP 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.

Comment HSR18.047 - 22.2 Fire Alarm System. 06/21/22 JP 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.

Comment HSR18.046 - 22.2 Fire Alarm System. 06/21/22 JP 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.

Comment HSR18.045 - 22.2 Fire Alarm System. 06/21/22 JP 06/30/22 The DTX scope/budget of the DTX project but are accounted for in contingencies. The precise interface management; therefore this comment is considered closed.
Preferred maximum is 2000 fpm. 2500 fpm will be considered if site limit does not entail any blast or piston action relief shafts. Please verify that piston action relief is not incorporated into the criteria.

This conflicts with sections 16.2.2.1 and 16.2.4.1 that discuss heated and unheated service tunnels. What requirements for air exchange through bypass dampers, other than those for sanitary sewer system.

The criteria in section 23.1.2 states that for tenability and time of tenability for stations and trainways shall be established in the criteria.

This is essentially the same as the 2000 fpm max stated in section 16.1.3 and incorporated into the criteria.

This topic requires further discussion - text still refers to 2000 fpm maximum.

What requirements for air exchange through bypass dampers, other than those for sanitary sewer system.

This is the preferred maximum for evacuation through bypass dampers, other than those for sanitary sewer system. This is considered an action item.

This is the preferred maximum for evacuation through bypass dampers, other than those for sanitary sewer system. This is considered an action item.
### Phase: Preliminary Engineering

**Review Comment Sheet**

**Project:**

**Resident Organization:**

- Elena Lasheras (CHSRA)
- Bin Zhang (Caltrain)

**Responder Organization:**

**Date: 06/24/22**

**PMPC Team:**

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- CHSRA
- CHSRA

**Date Commented:**

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- 06/26/22

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### Calibration 001

Chapter 17 JP 04/29/22: Reconcile chapter number with Section 1.6 Design Criteria Organization.

### Calibration 002

Chapter 17.4.1.1 JP 04/29/22: Insert: Illumination of emergency lighting shall conform to section 17.4.1.6.

### Calibration 003

Chapter 17.4.1.6 JP 04/29/22: Revised as noted.

### Calibration 004

Chapter 17.7.1.3 JP 04/29/22: Removed/deleted.

### Calibration 005

Section 24.4.3.2 BZ 10/18/18: Revised as noted.

### Comments Closed

Total Comments: 14
The OCS for the at-grade portion of the DTX must be a simple catenary system, consisting of wires, insulators, and crossarm structures. The system must be designed to meet the requirements of the 2016 PCEP Design Criteria, as well as any additional standards or regulations that apply.

Horizontal and vertical clearances must conform to the requirements of Section 18.3.3 Clearances, as shown. These clearances ensure safe operation of the system under all defined climatic conditions.

All wires and cables associated with the DTX OCS must match those used for the Caltrain OCS, as specified in the Caltrain OCS Design Criteria.

Disconnect switches, used to isolate sections of the system for maintenance and repair, must be motor operated, capable of remote operation and of local motorized or manual operation, as specified in Chapter 19, Communications. All disconnect switches must be designed and installed to meet the requirements of Section 18.2.7.1 Disconnect Switches.

The 2016 PCEP Design Criteria is the latest version available. A revision of the criteria was recently provided by Caltrain.

To complete the DTX Design Criteria revision, GEC.011 through GEC.015 have been consolidated into new (Rev. Book 02) Chapter 18 - Rail Systems. Chapter 14 - Tunnel Systems and Chapter 17 - Overhead Contact System were previously deleted.

In summary, the DTX Design Criteria revision includes updates to the OCS design to meet current standards, as well as changes to the disconnect switch requirements to ensure safe and efficient system operation. All changes are supported by detailed technical specifications and engineering analyses to ensure compliance with all applicable regulations and guidelines.
Project: Downtown Rail Extension (DTX)

MBr DE – Designer to evaluate

HSR.011 Section 14.2.2.2, paralleling stations, a single 50/25 kV autotransformer shall be assumed, rated at 50/25 kV autotransformer. It is not clear within the DCM whether it is the expectation that CBOSS PTC will have consideration for a broader harmonization of the train control system. The optical static wire is multi-purpose, The fiber optic strands can be used for telecommunications (Section 9.2 - Geotechnical Reporting, under subheading “Geotechnical Design Criteria” states (11.2.3 Electrical Clearances): this comment is considered closed. 10/04/22 CC

05/25/22 CC

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*Responder agrees and will comply  ROK – response okay  CC - comment closed*
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- **Editorial**: Title includes a number one (1) in “1Variable Message Signs” 09/13/22 MJS A Revised as noted 10/04/22 MJS The responder (PMPC Team) agreed to update per original comment; therefore this comment is considered closed.
- **Editorial**: The “Caltrain Design Criteria” include “latest edition” 08/13/22 CC | | |
- **Editorial**: Should the “Caltrain Design Criteria” include “latest edition”? 08/13/22 CC | | |
- **Editorial**: Should the PCEP design criteria be referred to by “issue date”? It will be 08/13/22 CC | | |
- **Editorial**: The criteria was updated based on the PCEP design criteria which referenced the Caltrain's PCEP design criteria. Will 08/13/22 CC | | |
- **Editorial**: Further coordination and data sharing is needed between Caltrain, PMPC, and 08/13/22 CC | | |
- **Editorial**: If a criteria becomes available, it will be included in the next issue of the design criteria. Will 08/13/22 CC | | |
- **Editorial**: The Design Team did not object or reopen this comment during official review of the 08/13/22 CC | | |
- **Editorial**: The Design Team did not object or reopen this comment during official review of the 08/13/22 CC | | |
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The track gauge will be 4 feet 8.5 inches, not just on tangent track except on tight radius curves where gauge widening may be required.

The values have been removed so a horizontal alignment has been made to match the CHSR Alignment. Please review where these figures are located.

Where have the all the values for superelevation in Table 7-3 been taken from as Environmental Requirements: Be beneficial to have projected ambient

Adviser where these values were derived. CAHSR mandated values are 27ft absolute. These values do not align with the working values for CAHSR, please these should differ.

Be the ambient temperature and humidity ranges for the tunnel will be determined through analysis/design work and will definitely occur on the air interface modeling and outdoor/exchange and indoor/dryer systems. It's not certain to include them in our design criteria.

Affect: CHSRA 500 feet they have been used. As we do not know what trainset CAHSR will be using 500 feet and below, however there are times when greater than radius curves where gauge widening may be required. 05/12/22 MJS A

Caltrain publishes updated Caltrain Specifications (end of 2020) (vertical and horizontal). The DTX Design Criteria may need to be updated once Caltrain comments .

2016/2018 included Table 7-3 - Maximum Superelevation. Absolute maximum (living project document). Restraining rails have been added to the PE design on

The responder (PMPC Team) recognizes this topic has been discussed and unnecessary cost given the low MAS (30mph max. within tunnel).

Caltrain Design Criteria, Chapter 2 - Track, Part C - Track, subsections 4.0-4.2. In October 2018 a Basis of Design Memo was approved by Caltrain and CAHSR which contained the Caltrain Design Criteria in Section 2 - Track, OFFICIALS for Caltrans.

Table 7-10 - the listed minimum horizontal clearance for CAHSR is 9ft3in this should read 10ft 8in. 10/12/22 MJS

The last DTX Design Criteria (May 2009) listed this value for CHSR as 8'-3". Requiring 10'-0" clearance (an additional 25") of horizontal clearance on each side to avoid trolley contact conductors between main line double tracks such distance may be increased to 24".

Table 7-10: the listed horizontal clearances for CAHSR should be 8'-3". The CHSR FJ Blended criteria stated 9'-3". The responder (PMPC Team) recognizes this topic has been discussed and unnecessary cost given the low MAS (30mph max. within tunnel).

The responder (PMPC Team) has agreed to provide ambient/design temperature for the project limits and lack of agreement between TJPA regarding applicability for the project handed over and agreement between 70% reporting applicability on both criteria. In that respect CHSRA Design Criteria (living project document).

The PMPC Team has reviewed CHSRA Design Criteria (Rev 5) Chapter 2 - Track. The PMPC Team has reviewed CHSRA Design Criteria (Rev 5) Chapter 23 - Track.

The PMPC Team agrees to carry forward this concept/conflict for further discussion and resolution in the next phase of design. The PMPC Team agrees to consider including light rail requirements.
10. Resistance of Tunnel Structures to Seismic Events

This chapter focuses on the existing issues related to seismic resistance. It discusses the current state of the art and emphasizes the importance of addressing these issues in the design process. The chapter provides guidelines for the selection and implementation of appropriate seismic protection measures for tunnels.

11. Waterproofing of Structures

Waterproofing is a critical aspect of the design process, especially in sensitive areas. The chapter reviews the various types of waterproofing materials and techniques, along with their benefits and limitations. It also emphasizes the importance of proper installation techniques to ensure long-term effectiveness.

12. Tunnels

The chapter on Tunnels is divided into several sections, each focusing on a specific aspect of tunnel design and construction. It covers topics such as design criteria, construction methods, and quality control measures. The chapter also includes case studies and best practices for successful tunnel projects.

13. Platforms

Platform design is crucial for the functionality and safety of the rail transit system. The chapter discusses the various factors that influence platform design, including passenger flow, safety standards, and accessibility requirements. It also provides guidelines for the design of platforms that meet the needs of passengers with disabilities.

14. Summary

The summary chapter provides an overview of the key findings and recommendations from the report. It highlights the importance of collaborative efforts among all stakeholders to ensure the success of the rail transit project. The summary also offers suggestions for future research and development in the rail transit industry.
In review of the ESR, the PMPC team agrees with the design. The design team has an understanding of the requirements within the ESR. The PMPC team has discussed this and has been updated on the current SES/CFD work being performed.

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