California High-Speed Train Project

TECHNICAL MEMORANDUM

Structural Design of Surface Facilities and Buildings TM 2.5.1

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Prepared by PB

for the California High-Speed Rail Authority

System Level Technical and Integration Reviews

The purpose of the review is to ensure:

- Technical consistency and appropriateness
- Check for integration issues and conflicts

System level reviews are required for all technical memoranda. Technical Leads for each subsystem are responsible for completing the reviews in a timely manner and identifying appropriate senior staff to perform the review. Exemption to the system level technical and integration review by any subsystem must be approved by the Engineering Manager.

System Level Technical Reviews by Subsystem:

Systems:	NOT REQUIRED Print Name:	DD Month YY Date
Infrastructure:	*Signed document on file* Fletcher Waggoner	9 Jun 10 Date
Operations:	NOT REQUIRED Print Name:	DD Month YY Date
Maintenance:	NOT REQUIRED Print Name:	DD Month YY Date
Rolling Stock:	NOT REQUIRED Print Name:	DD Month YY Date

Note: Signatures apply for the technical memorandum revision corresponding to revision number in header and as noted on cover.

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ABSTRACT

This technical memorandum provides guidance and requirements for the design of surface facilities and buildings that do not provide the supporting structure for high-speed trains, but are required for the California High-Speed Train Project (CHSTP). These surface facilities and buildings include:

- Elevated and at-grade station structures
- Pedestrian bridges
- Highway bridges
- Freight railway bridges
- Traction power facility enclosures
- Communication facility enclosures
- Above-ground ventilation structures
- Wayside structures and portal equipment rooms
- Maintenance facilities
- Operations and control centers
- Anchored wayside facilities, excluding the Overhead Contact System (OCS) requirements, which are defined in TM 3.2.2 - OCS Structural Requirements

This technical memorandum provides Code of Practice references to be used in design of surface facilities and buildings, and defines specific requirements for application of the Codes of Practice, including wind speed, slipstream effects due to passing trains, temperature variations, and seismic design requirements. This document will also define structural classifications in order to determine the importance factors, return periods, special or unusual live loads, and special design requirements.

Design requirements for structures supporting high-speed trains, such as aerial guideways, bridges, tunnels, cut-and-cover structures, trenches, grade separations, and earth retaining structures are provided in separate Technical Memoranda.

The information included in this document is to be used in conjunction with seismic and geotechnical guidance developed specifically for the high-speed train project.

1.0 INTRODUCTION

Operation and maintenance of the California High-Speed Train Project will require design and construction of surface facilities and buildings. This technical memorandum provides the structural design requirements necessary for the construction and long term serviceability of surface facilities and buildings. The functional requirements for design of these facilities are described in separate Technical Memoranda.

1.1 PURPOSE OF TECHNICAL MEMORANDUM

The purpose of this Technical Memorandum is to provide the rationale for the criteria established for structural design of surface facilities and buildings for the California High-Speed Train Project.

1.2 STATEMENT OF TECHNICAL ISSUE

This technical memorandum presents structural design requirements necessary for the construction and long term serviceability for surface facilities and building structures.

1.3 GENERAL INFORMATION

1.3.1 Definition of Terms

The following technical terms and acronyms used in this document have specific connotations with regard to the California High-Speed Train system.

<u>Authority</u>	California High-Speed Rail Authority
<u>Huts</u>	Small self contained enclosures to protect and secure specialized equipment delivered to the construction site and placed on a constructed foundation

Acronyms

ACI	American Concrete Institute
AISC	American Institute of Steel Construction
AREMA	American Railway Engineering and Maintenance-of-Way Association
AWS	Structural Welding Standards
CBDS	Caltrans Bridge Design Specifications: AASHTO LRFD Bridge Design Specification 4th Edition, 2007, with California Amendments
CBC	2007 California Building Code
CDC	CHST Design Criteria
CHST	California High-Speed Train
CHSTP	California High-Speed Train Project
CL	Collision loads
Com	Communications
CSDC	Caltrans Seismic Design Criteria ver. 1.5
DBE	Design Basis Earthquake
LDBE	Lower-level Design Basis Earthquake
LL	Live Load
LRFD	Load and Resistance Factor Design
MCE	Maximum Considered Earthquake
PCF	Pounds per cubic foot
PSF	Pounds per square foot
SE	Earth settlement effects
SS	Slipstream effects
TAP	Technical Advisory Panel
TCL	Track Center Line
THSR	Taiwan High Speed Rail
TPF	Traction Power Facilities
TPS	Traction Power Substation

1.3.2 Units

The California High-Speed Train Project (CHSTP) is based on U.S. Customary Units consistent with guidelines prepared by the California Department of Transportation (Caltrans) and defined by the National Institute of Standards and Technology (NIST). U.S. Customary Units are officially used in the U.S. and are also known in the U.S. as “English” or “Imperial” units. In order to avoid any confusion, all formal references to units of measure should be made in terms of U.S. Customary Units.

2.0 DEFINITION OF TECHNICAL TOPIC

CHSTP surface facilities and buildings shall be constructed to standards of practice defined within this memorandum. This technical memorandum defines the standards of practice and structural design requirements for the design, construction, and long term serviceability of surface facilities and buildings.

2.1 GENERAL

This Technical Memorandum presents guidance for the structural design of surface facilities and buildings, such as stations and maintenance facilities that do not support high-speed train loads.

For such structures, the California Building Code, California Code of Regulations, Title 24, Part 2, California Building Standards Commission, based on the International Building Code as the standard of practice shall be used. This code, with amendments, is referred to herein as the CBC.

Structures that support high-speed trains, such as aerial guideways, bridges, and underground structures, shall be designed based upon loadings in TM 2.3.2 Structure Design Loads and based upon the seismic performance requirements in TM 2.10.4 Interim Seismic Criteria. For 15% seismic design, TM 2.10.5 Seismic Design Benchmarks shall be used.

Bridges or structures that support pedestrian loadings, not spanning over high-speed rail structures or alignments, shall be designed according to Caltrans Bridge Design Specifications (CBDS), with the seismic provisions of Caltrans Seismic Design Criteria ver. 1.5 (CSDC).

Bridges or structures that support highway loadings, not spanning over high-speed rail structures or alignments, shall be designed according to Caltrans Bridge Design Specifications (CBDS), with the seismic provisions of Caltrans Seismic Design Criteria ver. 1.5.

Bridges or structures supporting freight rail, not spanning over high-speed rail structures or alignments, shall be designed according to American Railway Engineering and Maintenance-of-Way Association, Manual for Railway Engineering, 2009 (AREMA).

2.1.1 CHSTP Design Considerations

Buildings often have more complex structural systems and load path mechanisms than bridge structures. Buildings shall be designed to meet the requirements of the CBC which is a force-based design standard following ASCE 7 standards. The CBC design philosophy provides specific procedures and methodologies for load definition, structural member sizing, connection design, and structural stability evaluation.

For seismic design, the CBC uses a force-based design approach using force reduction factors based upon the particular structural system's ductility characteristics.

For structures that support high-speed trains, seismic performance-based design shall be used as required in TM 2.10.4 Interim Seismic Criteria. Performance-based design is based upon limiting strains and displacements in order to achieve specific performance objectives for design earthquakes. Performance-based design can predict specific damage due to an event.

Force-based and performance-based designs have conflicts in their approach, methodology, and results, thus the two methods shall not be used on different regions of the same structure. If performance-based design is required on part of a structure, then it shall be required on the whole structure.

2.1.2 CHSTP Design Parameters

The design life of surface facilities and buildings critical to continued track operations shall be 100 years per TM 1.1.2 Design Life. To achieve this, special consideration shall be made for corrosion resistance, waterproofing, and concrete creep and shrinkage issues.

The CBC requires selection of parameters for the structural design of surface facilities and buildings, such as occupancy categories, importance factors, seismic design categories, and wind speeds and exposure conditions.

2.2 LAWS AND CODES

Initial high-speed train (HST) design criteria will be issued in technical memoranda that provide guidance and procedures to advance the preliminary engineering. When completed, a Design Manual will present design standards and criteria specifically for the design, construction and operation of the CHSTP high-speed railway.

Criteria for design elements not specific to HST operations will be governed by existing applicable standards, laws and codes. Applicable local building, planning and zoning codes and laws are to be reviewed for the stations, particularly those located within multiple municipal jurisdictions, state rights-of-way, and/or unincorporated jurisdictions.

In the case of differing values, the standard followed shall be that which results in the satisfaction of all applicable requirements. In the case of conflicts, documentation for the conflicting standard is to be prepared and approval is to be secured as required by the affected agency for which an exception is required, whether it be an exception to the CHSTP standards or another agency's standards.

This Technical Memorandum presents guidance for the structural design of surface facilities and buildings, such as stations and maintenance facilities that do not support high-speed train loads.

For such structures, the California Building Code, California Code of Regulations, Title 24, Part 2, California Building Standards Commission, based on the International Building Code as the standard of practice shall be used. This code, with amendments, is referred to herein as the CBC.

Attention is specifically directed to California's Alquist-Priolo Earthquake Fault Zoning Act of 1972, which was passed to mitigate the hazard of surface faulting. This Act stipulates that a geologic investigation be made to define the fault trace, in order to prevent buildings for human occupancy from being constructed over fault traces, as well as defining the required offset from the fault trace.

3.0 SURFACE FACILITIES AND BUILDING DESIGN REQUIREMENTS

This section includes design requirements for the static and seismic design of surface facilities and buildings that do not support or span over high-speed rail structures or alignments.

3.1 GENERAL CODE REQUIREMENTS

The design shall conform to the applicable requirements of the CBC, ACI, AISC, and AWS, except where such requirements conflict with specific CHSTP criteria, which shall govern.

Where surface facilities or buildings support or span over high-speed train structures or alignments, they shall meet the provisions of TM 2.3.2 Structure Design Loads, TM 2.10.4 Interim Seismic Criteria, and TM 2.10.5 Seismic Design Benchmarks.

Since the Alquist-Priolo Act has jurisdiction over buildings via the California Building Code (CBC), design of buildings for the CHST system will be subject to these requirements that do not allow placement of buildings on or immediately adjacent to Holocene faults. Since no other codes exist in California that regulate non-building structures, project-specific criteria and guidelines are included in this document that provide alternative capable fault definitions and guidelines for analysis and mitigation that are not consistent with Alquist-Priolo. The term active faulting has definitions that are specific to the Alquist-Priolo, and thus the term capable fault is provided for these project-specific criteria.

These project-specific guidelines are generally consistent with Caltrans Memo to Designer (CMTD) 20-10, which defines a methodology for surface fault rupture displacement determination. CMTD 20-10 references California Geological Survey (CGS) guidelines for evaluating surface fault hazards, and the methodology by Wells and Coppersmith for estimating fault offset displacements.

3.2 LOAD REQUIREMENTS FOR STATIONS

Elevated and at-grade station structures not supporting high-speed trains shall be subject to CBC requirements, with additional criteria specific to the CHSTP herein.

Station platforms, mezzanines, and aerial pedestrian access ramps shall be subjected to additional criteria specific to the CHSTP herein.

The design of the station structures shall take into account all loadings resulting from the method and route to be taken for the installation, removal and replacement of the various items of plant and equipment. Particular emphasis shall be given to vehicular traffic in the station if there is possible loading in the future.

3.2.1 Dead Load and Superimposed Dead Load

Dead load and superimposed dead load shall include but not be limited to the following:

- Dead weight of all structural members and architectural finishes,
- Dead weight of road surface and of backfill above the structures,
- Dead weight of all surcharge loads,
- Dead weight of all equipment and appurtenances.

Refer to TM 2.3.2 Structure Design Loads for the unit weights of materials.

3.2.2 Train Load

Refer to TM 2.3.2 Structure Design Loads for the train loading.

3.2.3 Roof Load

Roof live load and reduction factors shall be in accordance with the CBC.

3.2.4 Floor Load

Floor live load shall be in accordance with the CBC with no reduction in floor live load, except for parking structures, which shall in be accordance with the CBC.

Station platforms and concourse areas shall be designed for a floor live load of 100 psf.

Emergency and maintenance walkways shall be designed for a floor live load of 100 psf.

Floor live loads on service walkways and sidewalks shall be designed for a live load of 100 psf, or a concentrated load of 1,000 pounds applied anywhere on the walkway and distributed over a 2 feet by 2 feet area.

Access doors at street level shall be designed for a floor live load of 350 psf.

Light storage area floor live load shall be 125 psf. For heavy storage area, floor live load shall be 250 psf.

Areas where cash carts are used shall be designed to accommodate a point live load of 350 pounds per wheel. Wherever station configuration requires that cash carts cross pedestrian bridges, bridges shall be designed to accommodate this live load.

Stairways shall be designed for a floor live load of 100 psf or a concentrated load of 300 pounds on the center of stair treads, whichever is critical. Impact shall not be considered for stairways.

3.2.5 Vehicular Load

Parking areas for automobiles shall be designed to a minimum load as specified in the CBC. Bus load shall be designed to carry HL-93 loading in accordance with CBDS.

Gratings in areas that are subject to vehicular loading shall be designed to carry HL-93 loading in accordance with CBDS.

3.2.6 Miscellaneous Loads

Railings in station platforms, mezzanines and service walkways shall be designed in accordance with the CBC.

Safety railings shall be designed to withstand a horizontal force of 50 pounds per linear foot applied at right angles to the top of the railing. The mounting of handrails and framing of members for railings shall be such that the completed handrail and supporting structure shall be capable of withstanding a load of at least 200 pounds applied in any direction at any point on the top rail. These loads shall not be combined with the 50 pounds per linear foot. For the design of structure components that support train loads and a walkway, the walkway live loads shall not be applied simultaneously with the train loads.

Stationary and hinged cover assemblies internal to high-speed train facilities shall be designed for a minimum uniform live load of 100 psf or a concentrated live load of 1,000 pounds over a 2 feet by 2 feet area. Deflection at center of span under 100 psf load shall not be more than 1/8 inch.

Gratings in sidewalks and in areas protected from vehicular traffic shall be designed for a uniform live load (LL) of 300 psf.

3.2.7 Slipstream Effects from Passing Trains

Refer to TM 2.3.2 Structure Design Loads for slipstream effects from passing high-speed trains.

Where structural elements can also be subjected to wind load, loading due to the slipstream effects from passing trains shall be considered to occur in combination with wind load.

Where trains are enclosed between walls and with a ceiling and deck, the requirements for tunnels shall be considered (see Technical Memorandum 2.4.2 Basic Tunnel Configuration) including the following:

- Minimum cross section area of the through trackway
- Evacuation

- Fire safety
- Medical Health Criteria

In addition, transient air pressure analyses (as in a tunnel ventilation analysis) shall be used to determine the maximum transient air pressure acting on the walls and ceiling. These pressures shall be used for design of elements such as uplift of ceilings or lateral pressure on walls and doors.

3.2.8 Lateral Pressures

Lateral pressure on the structures shall include earth pressure, water pressure, lateral pressure resulting from surcharge loads, seismic forces, wind effects, and transient air pressure from slipstream effects as applicable.

3.2.9 Earth Pressures

Earth pressure on structures shall vary from active earth pressure to earth pressure at rest depending on soil displacement and to what extent movement is restrained. Coefficients of earth pressure shall be calculated based on Rankine's theory. Ka, Ko as used in the following paragraphs are designated as earth pressure coefficients for active (Ka) and at-rest (Ko) conditions.

Design earth pressure shall be determined by considering deformation characteristics of structures and acceptable disturbances on adjacent areas due to structure displacement.

Cohesion shall be taken into account if justified by appropriate soil tests at the location of the structure. However, a minimum earth pressure shall be used with Ka = 0.33 in all cases, unless otherwise specified in the geotechnical reports and recommendations.

For areas where working space is available between the permanent structure wall and the temporary retaining wall, lateral loads on the structure wall shall be calculated according to the material used for backfilling.

3.2.10 Lateral Pressures Resulting from Surcharge

Lateral pressure resulting from vertical surcharge shall be calculated by multiplying vertical loads by the lateral load coefficient K.

Generally, the earth pressures are calculated as active earth pressure. If increased active earth pressure is considered while at rest earth pressure is too conservative for the case, an average of the coefficients of active earth pressure and at rest earth pressure may be used. For example, such earth pressure shall be used for designing counterfort retaining walls.

3.2.11 Seismic Design for Stations

Seismic design of stations shall be meet the requirements of the CBC. The importance factor (ASCE 7 subsection 11.5.1) of 1.5 shall be used. An additional load case shall be considered and evaluated for the Operability Performance Level (OPL) using the Lower-level Design Basis Earthquake (LDBE) with a return period of 100 years. For the OPL the response modification factors shall be equal to 1.0 to provide essentially elastic response. Loads shall be combined as presented in the Load Combinations Table 3.2 in TM 2.3.2 Structure Design Loads using Load Combination Extreme 3 for the LDBE.

Buildings and other structures that are integral to or over guideways supporting high-speed train loadings shall be designed to the performance requirements provided in either ASCE 41 or CSDC to achieve the same performance as the aerial guideway structures as described in TM 2.10.4 Interim Seismic Design.

Where adjacent facilities are located close enough that pounding could occur that could damage the integrity of a station structure during an earthquake, the facility shall have sufficient separation to preclude pounding, or special elements shall be added to dissipate energy to preclude damage to the station structure.

3.2.12 Liquefaction

Evaluation of liquefaction potential shall be in accordance with the guidance in TM 2.9.3 Geotechnical and Seismic Hazard Analysis Guidelines.

3.2.13 Collision Loads in Stations

Columns in stations shall be classified into three groups, according to the following criteria:

GROUP A:

This group consists of all columns where the clearance measured from the Track Center Line (TCL) and relevant conditions are as follows:

(1) ≥ 16.5 feet

(2) < 16.5 feet and within the station platform area provided that the platform is of massive construction and the platform edge is at least 1.25 feet above the level of the nearest rail.

GROUP B:

GROUP B columns are those located in a row of columns which run adjacent and parallel to the high-speed rail track and which do not meet the criteria of GROUP A. All columns in the row are classified as GROUP B, with the exception of the first and last ones. The column row shall include a column protection wall throughout its length.

The column protection wall shall comprise a lower guide wall together with an upper guide beam as shown in **Figure 3.1**. Due to the presence of the column protection wall, the GROUP B columns need not withstand full face collisions, but only grazing impacts by trains that have already been derailed. The lower guide wall and the upper guide beam shall be designed to withstand the impact loads as given in GROUP B below.

GROUP C:

Group C consists of the first and last columns in a row that do not belong to Group A or Group B.

The collision loads for each group of columns, as indicated above, are as follows:

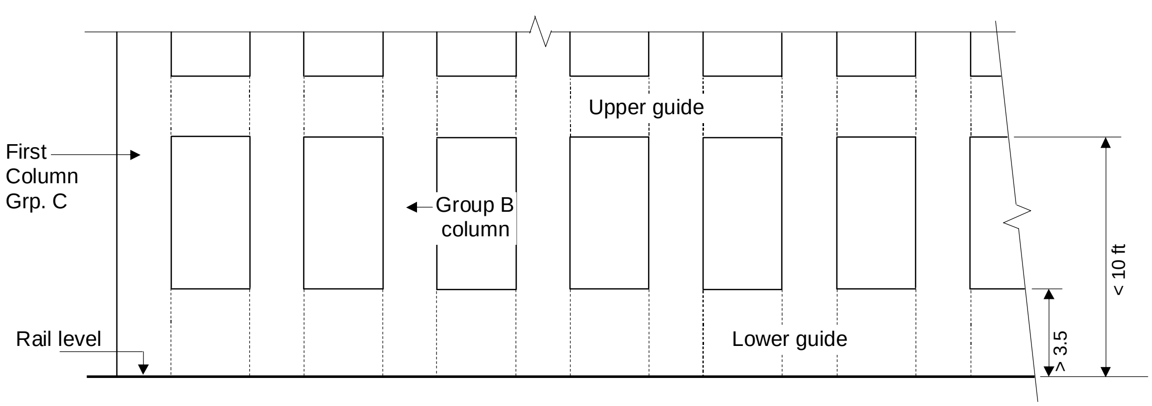

Figure 3.1 - Collision Loads for Each Group of Columns

GROUP A:

No impact forces need be applied.

GROUP B:

Columns and column protection walls shall be designed for one of the following horizontal impact loads, whichever produces the most adverse effect:

Columns shall be designed to resist a 900 kip force parallel with the TCL acting together with a 350 kip force at 90° to the TCL, both 3.5 feet above low rail level and 225 kip force at 90° to the TCL, 10 feet above top of rail.

Lower guide wall shall be designed to resist a 900 kip force parallel with the TCL acting together with a 350 kip force at 90° to the TCL, both 3.5 feet above top of low rail.

Upper guide beam shall be designed to resist a 350 kip force at 90° to the TCL, acting 10 feet above top of low rail.

GROUP C:

Columns shall be designed for one of the following horizontal impact loads, whichever produces the most adverse effect:

- A 2250 kip force parallel with the TCL acting together with an 800 kip force at 90° to the TCL, both 3.5 feet above top of low rail
- A 225 kip force at 90° to the TCL, acting 10 feet above low rail level

Alternatively, a protection device designed to resist the GROUP C impact loads shall be provided at the open face of the column as shown in **Figure 3.2**. The column in this Figure shall be designed for the GROUP B column impact loads.

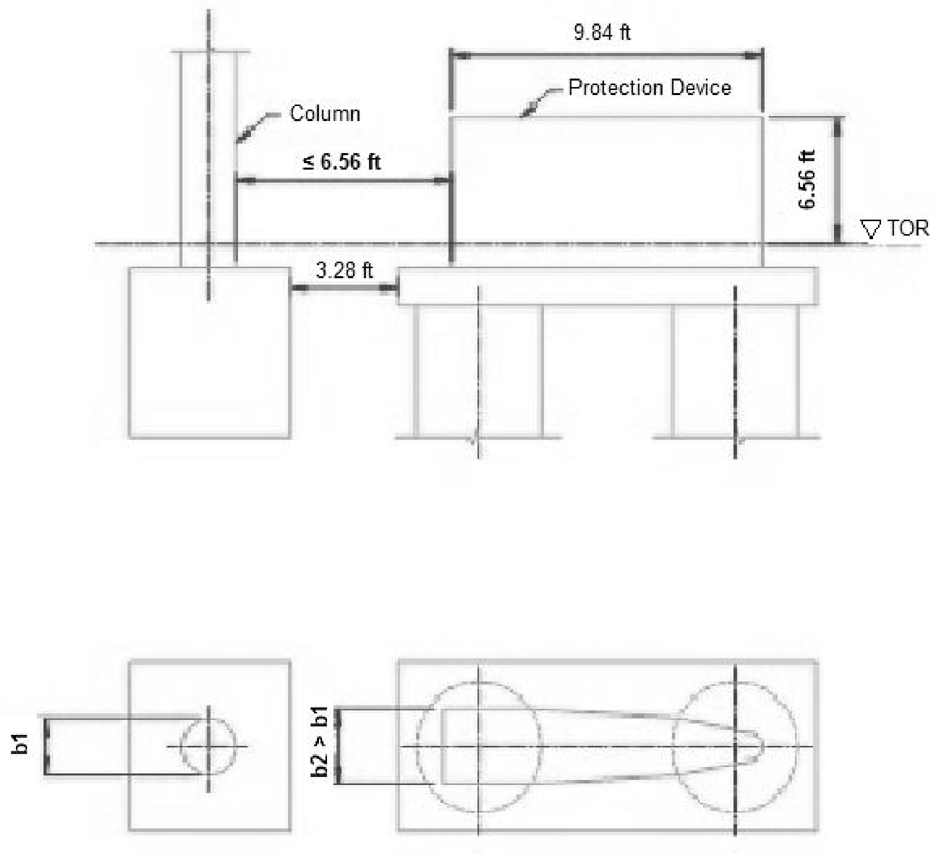

Figure 3.2

3.2.14 Collision Loads on Platforms

Platforms shall be designed to withstand a horizontal impact load of 225 kips applied at 90° to the TCL of the nearest track located anywhere along the platform.

A one foot wide void shall be provided around columns that are within platform areas to prevent transfer of collision loads to the column.

3.2.15 Wind Loads

Wind loads including both windward and leeward sides of buildings and other structures shall be in accordance with the provisions of CBC, with basic wind speed of 80 mph, Exposure C and I_w = 1.15.

3.2.16 Effects of Temperature, Shrinkage and Creep

Effects of temperature, shrinkage and creep shall be considered for structures above ground, as per requirements of the CBC.

3.2.17 Frequency and Vibration Limits

In addition to requirements listed above, station structures shall meet the following requirements for pedestrian comfort:

1. The comfort criteria shall be defined in terms of maximum acceptable acceleration of any part of the station platform or deck occupied by the public.

The following accelerations are the recommended maximum values for any part of the station platform or deck:

- 2.3 ft/s^2 for vertical vibrations
- 0.7 ft/s^2 for horizontal vibrations
- 1.3 ft/s^2 for exceptional crowd conditions

2. A verification of the comfort criteria shall be performed if the fundamental frequency of the deck is less than:

- 5 Hz for vertical vibrations
- 2.5 Hz for horizontal (lateral) and torsional vibrations.

Note: the data used in the calculations, and therefore the results, are subject to very high uncertainties. When the comfort criteria are not satisfied with a significant margin, it may be necessary to make provision in the design for the possible installation of dampers in the structure after its completion. In such cases the designer should consider and identify any requirements for commissioning tests.

3.3 LOAD REQUIREMENTS FOR PEDESTRIAN BRIDGES

Bridges or structures that support pedestrian loadings not spanning over high-speed rail structures or alignments, shall be designed according to Caltrans Bridge Design Specifications (CBDS), with the seismic provisions of Caltrans Seismic Design Criteria ver. 1.5 (CSDC).

3.3.1 Live Load

Pedestrian bridges shall be designed for a live load of 100 psf.

Areas where cash carts are used shall be designed to accommodate a point live load of 350 pounds per wheel.

3.3.2 Frequency and Vibration Limits

Pedestrian bridges or structures shall meet the requirements for pedestrian comfort specified in Section 3.2.17.

3.4 LOAD REQUIREMENTS FOR HIGHWAY BRIDGES

Bridges or structures that support highway loadings not spanning over high-speed rail structures or alignments, shall be designed according to Caltrans Bridge Design Specifications (CBDS), with the seismic provisions of Caltrans Seismic Design Criteria ver. 1.5 (CSDC).

3.5 LOAD REQUIREMENTS FOR RAILWAY BRIDGES

Bridges or structures supporting freight rail not spanning over high-speed rail structures or alignments, shall be designed according to American Railway Engineering and Maintenance-of-Way Association, Manual for Railway Engineering, 2009 (AREMA) and the requirements of the railroad owner and operator.

Seismic design of bridges or structures supporting freight rail not spanning over high-speed rail structures or alignments, shall be designed according to the seismic provisions of Caltrans Seismic Design Criteria ver. 1.5 (CSDC).

3.6 LOAD REQUIREMENTS FOR ANCILLARY STRUCTURES

Ancillary structures for the CHSTP include the following:

- Maintenance buildings
- Operations control centers
- Tunnel ventilation structures
- Portal equipment rooms
- Traction power facilities
- Communication facilities
- Wayside facilities

Ancillary structures not supporting high-speed trains, shall be subject to CBC requirements, with additional criteria specific to the CHSTP herein.

New buildings by private developers representing commercial interests or other public agencies that are planning pedestrian entrance access to CHST facilities must have their designs reviewed and accepted by the Authority on a case-by-case basis. This includes not only plans for physical attachment but also all new construction within the influence zone of the CHST facilities.

3.6.1 Roof Load

Roof live load and reduction factors shall be in accordance with the CBC.

3.6.2 Floor Load

Floor live load shall be in accordance with the CBC with no reduction in floor live load.

Train Control Room shall be designed for a floor live load of 100 psf.

Equipment rooms shall be designed for either the known equipment weight, or a floor live load of 350 psf, whichever governs design.

Electrical equipment rooms, pump rooms, service rooms, storage space, and machinery rooms shall be designed for floor live load of 250 psf, to be increased if storage or machinery loads so dictate.

Fan rooms and battery rooms shall be designed for uniform loads of 350 psf.

3.6.3 Miscellaneous Loads

Safety railings shall be designed to withstand a horizontal force of 50 pounds per linear foot applied at right angles to the top of the railing. The mounting of handrails and framing of members for railings shall be such that the completed handrail and supporting structure shall be capable of withstanding a load of at least 200 pounds applied in any direction at any point on the top rail. These loads shall not be combined with the 50 pounds per linear foot. For the design of structure components which support train loads and a walkway, the walkway live loads shall not be applied simultaneously with the train loads.

Stationary and hinged cover assemblies internal to high-speed train facilities shall be designed for a minimum uniform live load of 100 psf or a concentrated live load of 1,000 pounds over a 2 feet by 2 feet area. Deflection at center of span under 100 psf load shall not be more than 1/8 inch.

3.6.4 Slipstream Effect from Passing Trains

Slipstream effects from passing trains on ancillary structures shall be in accordance with Section 3.2.7.

3.6.5 Lateral Pressure

Lateral pressure on the ancillary structures shall include earth pressure, water pressure, lateral pressure resulting from surcharge loads, seismic forces, wind effects, and transient air pressure from slipstream effects as applicable.

3.6.6 Earth Pressures

Earth pressure effects on ancillary structures shall be in accordance with Section 3.2.9.

3.6.7 Lateral Pressures Resulting from Surcharge

Lateral pressures resulting from vertical surcharge on ancillary structures shall be in accordance with Section 3.2.10.

3.6.8 Seismic Design for Ancillary Structures

Seismic design of ancillary structures shall meet the requirements of the CBC. The importance factor (ASCE 7 subsection 11.5.1) of 1.5 shall be used.

3.6.9 Liquefaction

Evaluation of liquefaction potential shall be in accordance with the guidance in TM 2.9.3 Geotechnical and Seismic Hazard Analysis Guidelines.

3.6.10 Collision Loads on Ancillary Structures

Collision loads on ancillary structures shall be in accordance with Sections 3.2.13 and 3.2.14.

3.6.11 Wind Loads

Wind loads on ancillary structures shall be in accordance with the provisions of CBC, with basic wind speed of 80 mph, Exposure C and I_w = 1.15.

3.6.12 Effects of Temperature, Shrinkage and Creep

Effects of temperature, shrinkage and creep shall be considered for structures above ground, as per requirements of the CBC.

3.6.13 Foundations and Soils Investigations

Foundation and soils investigations shall be in accordance with CBC Section 1802, except as modified by specific geotechnical.

3.7 TEMPORARY SUPPORT OF FACILITIES DURING CONSTRUCTION

Temporary support of CHST facilities during adjacent excavation for new buildings shall be such that at any level, the CHST facilities' lateral displacement shall not exceed 0.001 times its overall height above the bottom of the base slab, but not to exceed 1/2 inches without Authority approval.

Unless otherwise approved by the Authority, the lateral forces used for the design of temporary excavation support shall consider both the static and dynamic loads for which the facility was designed.

Temporary support shall not endanger the safety of any persons or cause damage to any property and shall conform to the requirements for support and underpinning of existing structures.

3.8 AREAS OF POTENTIAL EXPLOSION

Areas of new buildings adjacent to CHST facilities where the public has access or that cannot be guaranteed as a secure area, such as parking garages and commercial storage and warehousing, shall be treated as areas of potential explosion.

NFPA 130, Standard for Fixed Guideway Transit Systems, life safety separation criteria shall be applied that assumes such spaces contain Class-I flammable or Class-II or Class-III combustible liquids. For structural and other considerations, separation and isolation for blast shall be treated the same as for seismic, and the more restrictive requirement shall be applied.

3.9 OTHER ITEMS

3.9.1 Parapets

Where parapets are used, they shall be designed to withstand dead load, wind load, force due to thermal expansion and contraction, shrinkage force, and earthquake forces equal to the full dead load of the parapet acting at the center of mass of the component parts.

3.9.2 Elevators

Surface structures shall be designed for the loads described below:

- Dead load of structure
- Live load of 100 plf applied at the free edges of the frame
- Wind load of 40 psf on windward side
- Elevator rated load capacity
- For traction type elevators, the surface structure shall be designed to support elevator beams. The end reaction of the elevator beams shall be 18,000 pounds minimum. The location of the elevator beams varies with the type of elevator and its relative machine room location. The Designer shall coordinate with elevator manufacturers regarding elevator beam locations.

3.9.3 Escalators

The support elements shall be designed for the end reactions from the escalators.

3.9.4 Elevators, Escalators, and Passenger Conveyors

Structures supporting elevators, escalators, or passenger conveyors shall be designed for the maximum reactions from any of the manufactured units considered for use in the system.

4.0 SUMMARY AND RECOMMENDATIONS

Surface facilities and buildings shall be designed in accordance with the California Building Code, CBC 2007 or current version. The exception is if facilities are in contact with or could cause damage to the guideway structures that could interrupt service. In that case, the facilities shall be designed to the same standards as the aerial, at-grade or underground guideway.

5.0 SOURCE INFORMATION AND REFERENCES

1. Manual for Railway Engineering of the American Railway Engineering and Maintenance of Way Association (AREMA), 2009.
2. AASHTO LRFD Bridge Design Specifications American Association of State Highway and Transportation Officials, 4th Edition, 2007.
3. American Concrete Institute, Building Code Requirements for Reinforced Concrete, ACI 318-05.
4. American Institute of Steel Construction, Steel Construction Manual, Thirteenth Edition.
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21. California High-Speed Train Project Technical 2.10.5 Seismic Design Benchmarks

6.0 SURFACE FACILITIES AND BUILDING DESIGN REQUIREMENTS

This section includes design requirements for the static and seismic design of surface facilities and buildings that do not support or span over high-speed rail structures or alignments.

6.1 GENERAL CODE REQUIREMENTS

The design shall conform to the applicable requirements of the CBC, ACI, AISC, and AWS, except where such requirements conflict with specific CHSTP criteria, which shall govern.

Where surface facilities or buildings support or span over high-speed train structures or alignments, they shall meet the provisions of TM 2.3.2 Structure Design Loads, TM 2.10.4 Interim Seismic Criteria, and TM 2.10.5 Seismic Design Benchmarks.

Attention is specifically directed to California's Alquist-Priolo Earthquake Fault Zoning Act of 1972, which was passed to mitigate the hazard of surface faulting. This Act stipulates that a geologic investigation be made to define the fault trace, in order to prevent buildings for human occupancy from being constructed over fault traces, as well as defining the required offset from the fault trace.

Since the Alquist-Priolo Act has jurisdiction over buildings via the California Building Code (CBC), design of buildings for the CHST system will be subject to these requirements that do not allow placement of buildings on or immediately adjacent to Holocene faults. Since no other codes exist in California that regulate non-building structures, project-specific criteria and guidelines are included in this document that provide alternative capable fault definitions and guidelines for analysis and mitigation that are not consistent with Alquist-Priolo. The term active faulting has definitions that are specific to the Alquist-Priolo, and thus the term capable fault is provided for these project-specific criteria.

These project-specific guidelines are generally consistent with Caltrans Memo to Designer (CMTD) 20-10, which defines a methodology for surface fault rupture displacement determination. CMTD 20-10 references California Geological Survey (CGS) guidelines for evaluating surface fault hazards, and the methodology by Wells and Coppersmith for estimating fault offset displacements.

6.2 LOAD REQUIREMENTS FOR STATIONS

Elevated and at-grade station structures not supporting high-speed trains shall be subject to CBC requirements, with additional criteria specific to the CHSTP.

Station platforms, mezzanines, and aerial pedestrian access ramps shall be subject to additional criteria specific to the CHSTP herein.

The design of the station structures shall take into account all loadings resulting from the method and route to be taken for the installation, removal and replacement of the various items of plant and equipment. Particular emphasis shall be given to vehicular traffic in the station hall if there is possible loading in the future.

6.2.1 Dead Load and Superimposed Dead Load

Dead load and superimposed dead load shall include but not be limited to the following:

- Dead weight of all structural members and architectural finishes,
- Dead weight of road surface and of backfill above the structures,
- Dead weight of all surcharge loads,
- Dead weight of all equipment and appurtenances.

Refer to TM 2.3.2 Structure Design Loads for the unit weights of materials.

6.2.2 Train Load

Refer to TM 2.3.2 Structure Design Loads for the train loading.

6.2.3 Roof Load

Roof live load and reduction factors shall be in accordance with the CBC.

6.2.4 Floor Load

Floor live load shall be in accordance with the CBC with no reduction in floor live load, except for parking structures, which shall in be accordance with the CBC.

Station platforms and concourse areas shall be designed for a floor live load of 100 psf.

Emergency and maintenance walkways shall be designed for a floor live load of 100 psf.

Floor live loads on service walkways and sidewalks shall be designed for a live load of 100 psf, or a concentrated load of 1,000 pounds applied anywhere on the walkway and distributed over a 2 feet by 2 feet area.

Access doors at street level shall be designed for a floor live load of 350 psf.

Storage area floor live loads shall be 100 psf.

Areas where cash carts are used shall be designed to accommodate a point live load of 350 pounds per wheel. Wherever station configuration requires that cash carts cross pedestrian bridges, bridges shall be designed to accommodate this live load.

Stairways shall be designed for a floor live load of 100 psf or a concentrated load of 300 pounds on the center of stair treads, whichever is critical. Impact shall not be considered for stairways.

6.2.5 Vehicular Load

Parking areas for automobiles shall be designed to a minimum load as specified in the CBC. Bus load shall be designed to carry HL-93 loading in accordance with CBDS.

Gratings in areas that are subject to vehicular loading shall be designed to carry HL-93 loading in accordance with CBDS.

6.2.6 Miscellaneous Loads

Railings in station platforms, mezzanines and service walkways shall be designed in accordance with the CBC.

Safety railings shall be designed to withstand a horizontal force of 50 pounds per linear foot applied at right angles to the top of the railing. The mounting of handrails and framing of members for railings shall be such that the completed handrail and supporting structure shall be capable of withstanding a load of at least 200 pounds applied in any direction at any point on the top rail. These loads shall not be combined with the 50 pounds per linear foot. For the design of structure components that support train loads and a walkway, the walkway live loads shall not be applied simultaneously with the train loads.

Stationary and hinged cover assemblies internal to high-speed train facilities shall be designed for a minimum uniform live load of 100 psf or a concentrated live load of 1,000 pounds over a 2 feet by 2 feet area. Deflection at center of span under 100 psf load shall not be more than 1/8 inch.

Gratings in sidewalks and in areas protected from vehicular traffic shall be designed for a uniform live load (LL) of 300 psf.

6.2.7 Slipstream Effects from Passing Trains

Refer to TM 2.3.2 Structure Design Loads for slipstream effects from passing high-speed trains.

Where structural elements can also be subjected to wind load, loading due to the slipstream effects from passing trains shall be considered to occur in combination with wind load.

Where trains are enclosed between walls and with a ceiling and deck, the requirements for tunnels shall be considered (see Technical Memorandum 2.4.2 Basic Tunnel Configuration) including the following:

- Minimum cross section area of the through trackway

- Evacuation
- Fire safety
- Medical Health Criteria

In addition, transient air pressure analyses (as in a tunnel ventilation analysis) shall be used to determine the maximum transient air pressure acting on the walls and ceiling. These pressures shall be used for design of those elements such as uplift of ceilings or lateral pressure on walls and doors.

6.2.8 Lateral Pressures

Lateral pressure on the structures shall include earth pressure, water pressure, lateral pressure resulting from surcharge loads, seismic forces, wind effects, and transient air pressure from slipstream effects as applicable.

6.2.9 Earth Pressures

Earth pressure on structures shall vary from active earth pressure to earth pressure at rest depending on soil displacement and to what extent movement is restrained. Coefficients of earth pressure shall be calculated based on Rankine's theory. Ka, Ko as used in the following paragraphs are designated as earth pressure coefficients for active (Ka) and at-rest (Ko) conditions.

Design earth pressure shall be determined by considering deformation characteristics of structures and acceptable disturbances on adjacent areas due to structure displacement.

Cohesion shall be taken into account if justified by appropriate soil tests at the location of the structure. However, a minimum earth pressure shall be used with Ka = 0.33 in all cases, unless otherwise specified in the geotechnical reports and recommendations.

For areas where working space is available between the permanent structure wall and the temporary retaining wall, lateral loads on the structure wall shall be calculated according to the material used for backfilling.

6.2.10 Lateral Pressures Resulting from Surcharge

Lateral pressure resulting from vertical surcharge shall be calculated by multiplying vertical loads by the lateral load coefficient K.

Generally, the earth pressures are calculated as active earth pressure. If increased active earth pressure is considered while at rest earth pressure is too conservative for the case, an average of the coefficients of active earth pressure and at rest earth pressure may be used. For example, such earth pressure shall be used for designing counterfort retaining walls.

6.2.11 Seismic Design for Stations

Seismic design of stations shall be meet the requirements of the CBC. The importance factor (ASCE 7 subsection 11.5.1) of 1.5 shall be used. In addition an additional load case shall be considered and evaluated for the Operability Performance Level (OPL) using the Lower-level Design Basis Earthquake (LDBE) with a return period of 100 years. For the OPL the response modification factors shall be equal to 1.0 to provide essentially elastic response. Loads shall be combined as presented in the Load Combinations Table 3.2 in TM 2.3.2 Structure Design Loads using Load Combination Extreme 3 for the LDBE.

Buildings and other structures that are integral to or over guideways supporting high-speed train loadings shall be designed to the performance requirements provided in either ASCE 41 or CSDC to achieve the same performance as the aerial guideway structures as described in TM 2.10.4 Interim Seismic Design.

Where adjacent facilities are located close enough that pounding could occur that could damage the integrity of a station structure during an earthquake, the facility shall have sufficient separation to preclude pounding, or special elements shall be added to dissipate energy to preclude damage to the station structure.

6.2.12 Liquefaction

Evaluation of liquefaction potential shall be in accordance with the guidance in TM 2.9.3 Geotechnical and Seismic Hazard Analysis Guidelines.

6.2.13 Collision Loads in Stations

Columns in stations shall be classified into three groups, according to the following criteria:

GROUP A:

This group consists of all columns where the clearance measured from the Track Center Line (TCL) and relevant conditions are as follows:

(1) ≥ 16.5 feet

(2) < 16.5 feet and within the station platform area provided that the platform is of massive construction and the platform edge is at least 1.25 feet above the level of the nearest rail.

GROUP B:

GROUP B columns are those located in a row of columns which run adjacent and parallel to the high-speed rail track and which do not meet the criteria of GROUP A. All columns in the row are classified as GROUP B, with the exception of the first and last ones. The column row shall include a column protection wall throughout its length.

The column protection wall shall comprise a lower guide wall together with an upper guide beam as shown in **Figure 6.1**. Due to the presence of the column protection wall, the GROUP B columns need not withstand full face collisions, but only grazing impacts by trains that have already been derailed. The lower guide wall and the upper guide beam shall be designed to withstand the impact loads as given in GROUP B below.

GROUP C:

Group C consists of the first and last columns in a row that do not belong to Group A or Group B.

The collision loads for each group of columns, as indicated above, are as follows:

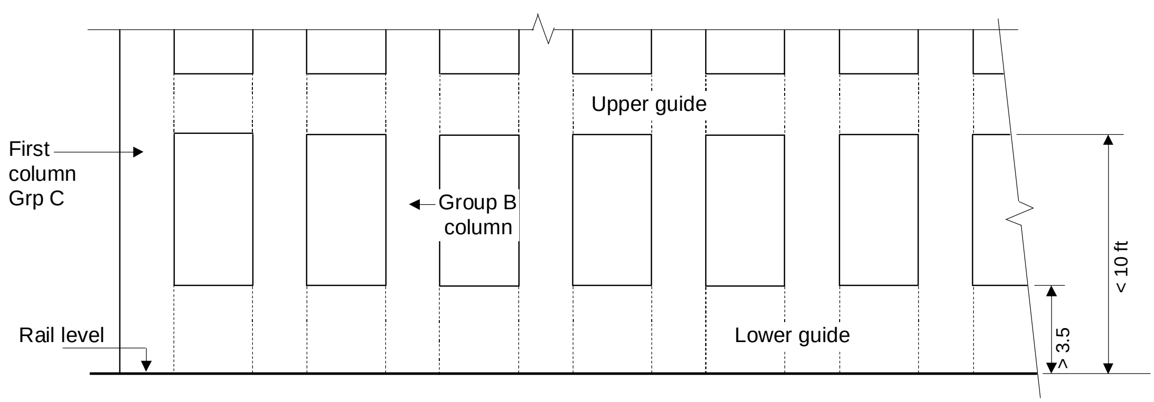

Figure 3.1 - Collision Loads for Each Group of Columns

GROUP A:

No impact forces need be applied.

GROUP B:

Columns and column protection walls shall be designed for one of the following horizontal impact loads, whichever produces the most adverse effect:

Columns shall be designed to resist a 900 kip force parallel with the TCL acting together with a 350 kip force at 90° to the TCL, both 3.5 feet above low rail level and 225 kip force at 90° to the TCL, 10 feet above top of rail.

Lower guide wall shall be designed to resist a 900 kip force parallel with the TCL acting together with a 350 kip force at 90° to the TCL, both 3.5 feet above top of low rail.

Upper guide beam shall be designed to resist a 350 kip force at 90° to the TCL, acting 10 feet above top of low rail.

GROUP C:

Columns shall be designed for one of the following horizontal impact loads, whichever produces the most adverse effect:

- A 2250 kip force parallel with the TCL acting together with an 800 kip force at 90° to the TCL, both acting 3.5 feet above top of low rail
- A 225 kip force at 90° to the TCL, acting 10 feet above low rail level

Alternatively, a protection device designed to resist the GROUP C impact loads shall be provided at the open face of the column as shown in **Figure 6.2**. The column in this Figure shall be designed for the GROUP B column impact loads.

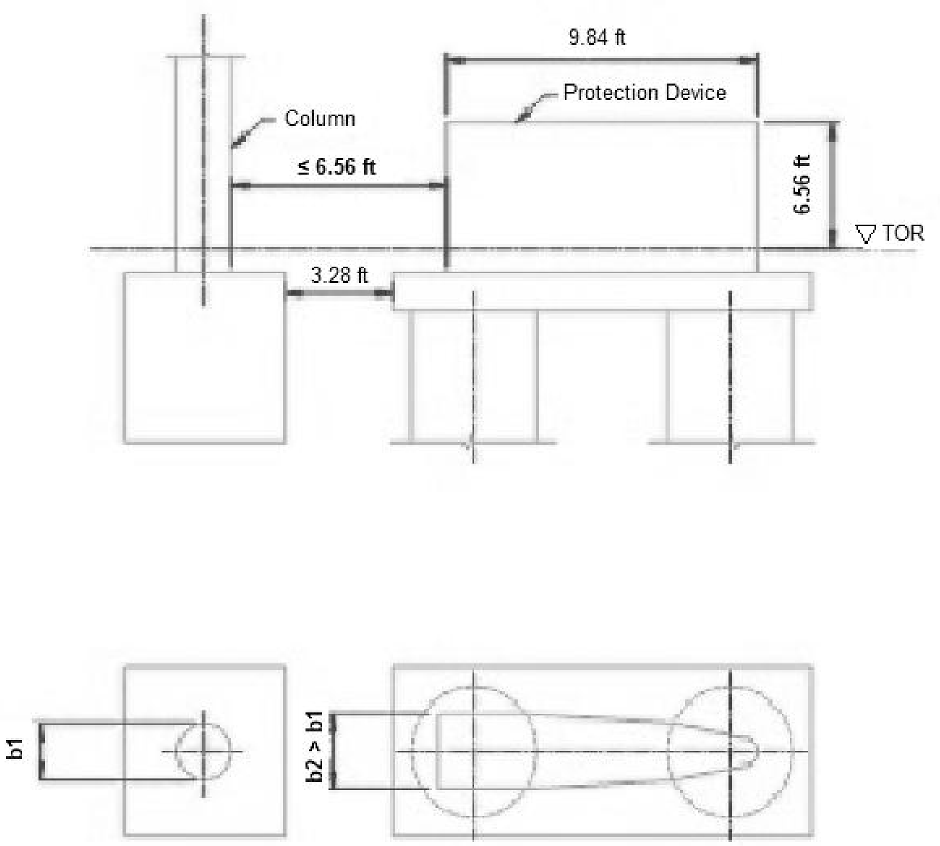

Figure 6.2

6.2.14 Collision Loads on Platforms

Platforms shall be designed to withstand a horizontal impact load of 225 kips applied at 90° to the TCL of the nearest track located anywhere along the platform.

A one foot wide void shall be provided around columns that are within platform areas to prevent transfer of collision loads to the column.

6.2.15 Wind Loads

Wind loads including both windward and leeward sides of buildings and other structures shall be in accordance with the provisions of CBC, with basic wind speed of 80 mph, Exposure C and I_w = 1.15.

6.2.16 Effects of Temperature, Shrinkage and Creep

Effects of temperature, shrinkage and creep shall be considered for structures above ground, as per requirements of the CBC.

6.2.17 Frequency and Vibration Limits

In addition to requirements listed above, station structures shall meet the following requirements for pedestrian comfort:

1. The comfort criteria shall be defined in terms of maximum acceptable acceleration of any part of the station platform or deck occupied by the public.

The following accelerations are the recommended maximum values for any part of the station platform or deck:

- 2.3 ft/s^2 for vertical vibrations
- 0.7 ft/s^2 for horizontal vibrations
- 1.3 ft/s^2 for exceptional crowd conditions

2. A verification of the comfort criteria shall be performed if the fundamental frequency of the deck is less than:
   - 5 Hz for vertical vibrations
   - 2.5 Hz for horizontal (lateral) and torsional vibrations.

Note: the data used in the calculations, and therefore the results, are subject to very high uncertainties. When the comfort criteria are not satisfied with a significant margin, it may be necessary to make provision in the design for the possible installation of dampers in the structure after its completion. In such cases the designer should consider and identify any requirements for commissioning tests.

6.3 Load Requirements for Pedestrian Bridges

Bridges or structures that support pedestrian loadings not spanning over high-speed rail structures or alignments, shall be designed according to Caltrans Bridge Design Specifications (CBDS), with the seismic provisions of Caltrans Seismic Design Criteria ver. 1.5 (CSDC).

6.3.1 Live Load

Pedestrian bridges shall be designed for a live load of 100 psf.

Areas where cash carts are used shall be designed to accommodate a point live load of 350 pounds per wheel.

6.3.2 Frequency and Vibration Limits

Pedestrian bridges or structures shall meet the requirements for pedestrian comfort specified in Section 6.2.17.

6.4 Load Requirements for Highway Bridges

Bridges or structures that support highway loadings not spanning over high-speed rail structures or alignments, shall be designed according to Caltrans Bridge Design Specifications (CBDS), with the seismic provisions of Caltrans Seismic Design Criteria ver. 1.5 (CSDC).

6.5 LOAD REQUIREMENTS FOR RAILWAY BRIDGES

Bridges or structures supporting freight rail not spanning over high-speed rail structures or alignments, shall be designed according to American Railway Engineering and Maintenance-of-Way Association, Manual for Railway Engineering, 2009 (AREMA) and the requirements of the railroad owner and operator.

Seismic design of bridges or structures supporting freight rail not spanning over high-speed rail structures or alignments, shall be designed according to the seismic provisions of Caltrans Seismic Design Criteria ver. 1.5 (CSDC).

6.6 LOAD REQUIREMENTS FOR ANCILLARY STRUCTURES

Ancillary structures for the CHSTP include the following:

- Maintenance buildings
- Operations control centers
- Tunnel ventilation structures
- Portal equipment rooms
- Traction power facilities
- Communication facilities
- Wayside facilities

Ancillary structures not supporting high-speed trains, shall be subject to CBC requirements, with additional criteria specific to the CHSTP herein.

New buildings by private developers representing commercial interests or other public agencies that are planning pedestrian entrance access to CHST facilities must have their designs reviewed and accepted by the Authority on a case-by-case basis. This includes not only plans for physical attachment but also all new construction within the influence zone of the CHST facilities.

6.6.1 Roof Load

Roof live load and reduction factors shall be in accordance with the CBC.

6.6.2 Floor Load

Floor live load shall be in accordance with the CBC with no reduction in floor live load.

Train Control Room shall be designed for a floor live load of 100 psf.

Equipment rooms shall be designed for either the known equipment weight, or a floor live load of 350 psf, whichever governs design.

Electrical equipment rooms, pump rooms, service rooms, storage space, and machinery rooms shall be designed for floor live load of 250 psf, to be increased if storage or machinery loads so dictate.

Fan rooms and battery rooms shall be designed for uniform loads of 350 psf.

6.6.3 Miscellaneous Loads

Safety railings shall be designed to withstand a horizontal force of 50 pounds per linear foot applied at right angles to the top of the railing. The mounting of handrails and framing of members for railings shall be such that the completed handrail and supporting structure shall be capable of withstanding a load of at least 200 pounds applied in any direction at any point on the top rail. These loads shall not be combined with the 50 pounds per linear foot. For the design of structure components which support train loads and a walkway, the walkway live loads shall not be applied simultaneously with the train loads.

Stationary and hinged cover assemblies internal to high-speed train facilities shall be designed for a minimum uniform live load of 100 psf or a concentrated live load of 1,000 pounds over a 2 feet by 2 feet area. Deflection at center of span under 100 psf load shall not be more than 1/8 inch.

6.6.4 Slipstream Effect from Passing Trains

Slipstream effects from passing trains on ancillary structures shall be in accordance with Section 6.2.7.

6.6.5 Lateral Pressure

Lateral pressure on the ancillary structures shall include earth pressure, water pressure, lateral pressure resulting from surcharge loads, seismic forces, wind effects, and transient air pressure from slipstream effects as applicable.

6.6.6 Earth Pressures

Earth pressure effects on ancillary structures shall be in accordance with Section 6.2.9.

6.6.7 Lateral Pressures Resulting from Surcharge

Lateral pressures resulting from vertical surcharge on ancillary structures shall be in accordance with Section 6.2.10.

6.6.8 Seismic Design for Ancillary Structures

Seismic design of ancillary structures shall meet the requirements of the CBC. The importance factor (ASCE 7 subsection 11.5.1) of 1.5 shall be used.

6.6.9 Liquefaction

Evaluation of liquefaction potential shall be in accordance with the guidance in TM 2.9.3 Geotechnical and Seismic Hazard Analysis Guidelines.

6.6.10 Collision Loads on Ancillary Structures

Collision loads on ancillary structures shall be in accordance with Sections 6.2.13 and 6.2.14.

6.6.11 Wind Loads

Wind loads on ancillary structures shall be in accordance with the provisions of CBC, with basic wind speed of 80 mph, Exposure C and $I_w = 1.15$.

6.6.12 Effects of Temperature, Shrinkage and Creep

Effects of temperature, shrinkage and creep shall be considered for structures above ground, as per requirements of the CBC.

6.6.13 Foundations and Soils Investigations

Foundation and soils investigations shall be in accordance with CBC Section 1802, except as modified by specific geotechnical information.

6.7 TEMPORARY SUPPORT OF FACILITIES DURING CONSTRUCTION

Temporary support of CHST facilities during adjacent excavation for new buildings shall be such that at any level, the facilities' lateral displacement shall not exceed 0.001 times its overall height above the bottom of the base slab, but not to exceed 1/2 inches without Authority approval.

Unless otherwise approved by the Authority, the lateral forces used for the design of temporary excavation support shall consider both the static and dynamic loads for which the project facility was designed.

Temporary support shall not endanger the safety of any persons or cause damage to any property and shall conform to the requirements for support and underpinning of existing structures.

6.8 AREAS OF POTENTIAL EXPLOSION

Areas of new buildings adjacent to CHST facilities where the public has access or that cannot be guaranteed as a secure area, such as parking garages and commercial storage and warehousing, shall be treated as areas of potential explosion.

NFPA 130, Standard for Fixed Guideway Transit Systems, life safety separation criteria shall be applied that assumes such spaces contain Class-I flammable or Class-II or Class-III combustible liquids. For structural and other considerations, separation and isolation for blast shall be treated the same as for seismic, and the more restrictive requirement shall be applied.

6.9 OTHER ITEMS

6.9.1 Parapets

Where parapets are used, they shall be designed to withstand dead load, wind load, force due to thermal expansion and contraction, shrinkage force, and earthquake forces equal to the full dead load of the parapet acting at the center of mass of the component parts.

6.9.2 Elevators

Surface structures shall be designed for the loads described below:

- Dead load of structure
- Live load of 100 plf applied at the free edges of the frame
- Wind load of 40 psf on windward side
- Elevator rated load capacity
- For traction type elevators, the surface structure shall be designed to support elevator beams. The end reaction of the elevator beams shall be 18,000 pounds minimum. The location of the elevator beams varies with the type of elevator and its relative machine room location. The Designer shall coordinate with elevator manufacturers regarding elevator beam locations.

6.9.3 Escalators

The support elements shall be designed for the end reactions from the escalators.

6.9.4 Elevators, Escalators, and Passenger Conveyors

Structures supporting elevators, escalators, or passenger conveyors shall be designed for the maximum reactions from any of the manufactured units considered for use in the system.