PENINSULA CORRIDOR
JOINT POWERS BOARD
(PCJPB)

STANDARDS FOR
DESIGN AND
MAINTENANCE OF
STRUCTURES

Approved:

Darrell J. Maxey
Chief Engineer

Issaharias Amare
Senior Engineer

Issue Date: 2003
TABLE OF CONTENTS

INTRODUCTION ........................................................................................................... i
  • Purpose
  • Roadway Worker Protection Training
  • Qualification Clause

SECTION A - STRUCTURE DESIGN GUIDELINE

CHAPTER 1: GENERAL INFORMATION AND BACKGROUND

1.1 Application of Guidelines ..................................................................................... 1-1
1.2 Compatibility ......................................................................................................... 1-2
1.3 Design Guidelines, Codes, Manuals, Standards, and Specifications ............... 1-2
1.4 General Guidelines for Grade Separations ......................................................... 1-3
1.5 Distribution ........................................................................................................... 1-3
1.6 Background and History of Caltrain ..................................................................... 1-3
  1.6.1 History
  1.6.3 Caltrain Milestones
  1.6.4 Caltrain Improvements
1.7 Caltrain Organization .......................................................................................... 1-11
  1.7.1 PCJPB
  1.7.2 Contract Operator (Amtrak)
  1.7.3 PCJPB Construction Contractors
  1.7.4 Union Pacific Joint Facilities
  1.7.5 Caltrain Organization Chart
1.8 Rules and Regulations ......................................................................................... 1-13
  1.8.1 Related Rules, Regulations, and Standards by Caltrain
  1.8.2 Contract Operator Agreement between PCJPB and Amtrak
  1.8.3 General
  1.8.4 Agreement for Operation and Capital Third Party Support
  1.8.5 Appendix “A” Through “S” to Contract Requirements
  1.8.6 Rules, Regulations, and Procedures Controlled by the Contract Operator
1.9 Applicable Federal Rules, Regulations, Instructions and Standards Related to
    Maintenance and Construction on the Railroad .................................................... 1-15
  1.9.1 Federal Railroad Administration Regulations
  1.9.2 Occupational Safety and Health Administration (OSHA) Part 1910 Gen
    Industry
  1.9.3 Occupational Safety and Health Administration (OSHA) Part 1926
    Construction
1.10 Applicable State Rules, Regulations, Instructions and Standards Related to
    Maintenance and Construction on the Railroad ................................................... 1-16
  1.10.1 California Public Utilities Commission (CPUC) General Orders (GO)
1.11 Other Standards and References ...................................................................... 1-16
  1.11.1 Manual of Uniform Traffic Control Devices (MUTCD)
1.12 Training Requirements ....................................................................................... 1-17
  1.12.1 General
  1.12.2 Training Requirements
  1.12.3 Maps
CHAPTER 2: Design Guideline for RAILROAD BRIDGES AND UNDERPASSES

2.1 General Requirements ......................................................... 2-1
2.2 Superstructure Selection Type .................................................. 2-1
2.2.1 List of Preferred Structure Type ............................................. 2-1
2.3 Structural Design Requirements ................................................. 2-3
2.3.1 Layout .............................................................................. 2-3
2.3.2 Bridge Skew ........................................................................ 2-3
2.3.3 Design Loads for Railroad Bridges ......................................... 2-3
2.4 Clearances ............................................................................ 2-11
2.4.1 General .............................................................................. 2-11
2.4.2 Vertical Clearances ................................................................. 2-11
2.4.3 Horizontal Clearances ............................................................. 2-11
2.5 Special Provisions ................................................................. 2-15
2.5.1 Concrete Structures ............................................................... 2-15
2.5.2 Steel Structures ................................................................. 2-15
2.5.3 Ballast Deck Bridge Structures ............................................ 2-15
2.5.4 Railroad Electrification ......................................................... 2-15
2.6 Substructure ........................................................................ 2-20
2.6.1 General Layout ..................................................................... 2-20
2.6.2 Geotechnical Investigation ................................................... 2-20
2.6.3 Foundation Types ................................................................ 2-20
2.7 Construction Specifications ....................................................... 2-26
2.8 Miscellaneous ..................................................................... 2-26

CHAPTER 3: Design Guideline for GRADE SEPARATIONS OVER RAILROAD (OVERPASSES)

3.1 General Requirements ............................................................ 3-1
3.2 Superstructure ..................................................................... 3-1
3.3 Clearances .......................................................................... 3-3
3.3.1 Permanent Clearances ....................................................... 3-3
3.3.2 Temporary Construction Clearances ................................... 3-3
3.4 Special Provisions .................................................................. 3-5
3.4.1 Drainage and Erosion Control .............................................. 3-5
3.4.2 Utilities ............................................................................. 3-5
3.4.3 Lighting ............................................................................ 3-5
3.4.4 Railroad Electrification ....................................................... 3-5
3.5 Substructure ........................................................................ 3-7
3.6 Construction ....................................................................... 3-8
3.7 Miscellaneous .................................................................... 3-9

CHAPTER 4: Design Guideline for SEISMIC DESIGN

4.1 Performance Criteria ............................................................... 4-1
4.1.1 Bridge Classifications ......................................................... 4-1
4.1.2 Performance Expectations .................................................. 4-1
4.2 Ground Motion Levels .............................................................. 4-3
4.3 Analysis Procedures ............................................................... 4-4
4.3.1 Additional Modeling and Analysis Considerations ................. 4-4
STANDARDS FOR DESIGN AND MAINTENANCE OF STRUCTURES

TABLE OF CONTENTS

4.4 Demands on Structure Components ................................................. 4-6
  4.4.1 Displacement Demand
  4.4.2 Force Demand
4.5 Capacities of Structure Components .............................................. 4-6
  4.5.1 Material Properties
  4.5.2 Reinforcing Steel
  4.5.3 Concrete
  4.5.4 Structural Steel
  4.5.5 Component Plastic Moment Capacity
  4.5.6 Component Plastic Hinge Rotational Capacity
  4.5.7 Column Shear Capacity
  4.5.8 Joint Internal Forces
  4.5.9 Hinge/Seat Capacity
  4.5.10 P-Δ Effects
  4.5.11 Effects of Live Load on Displacement Capacity
4.6 Demand vs. Capacity .................................................................. 4-9
  4.6.1 Local Displacement Ductility
  4.6.2 Capacity Based Performance
4.7 Seismic Design Procedures ......................................................... 4-10
4.8 Ductility Provisions .................................................................. 4-10
4.9 Seismic Risk (under development) .................................................. 4-10

CHAPTER 5: Design Guideline for PEDESTRIAN UNDERPASS

Purpose ......................................................................................... 5-1
5.1 General Requirements for Design of Pedestrian Underpasses ............. 5-1
  5.1.1 Design Considerations
5.2 Pedestrian Underpasses Type Selection ......................................... 5-2
5.3 Structural Design of Pedestrian Tunnels ........................................ 5-5
  5.3.1 Loading
  5.3.2 Surcharge
  5.3.3 Racking Analysis – Seismic Effect
  5.3.4 Design Requirements
5.4 Special Provisions ....................................................................... 5-11
  5.4.1 Waterproofing
  5.4.2 Drainage
5.5 Construction of Pedestrian Underpasses ....................................... 5-14

CHAPTER 6: Design Guideline for PEDESTRIAN OVERPASS

(not included/under development)

CHAPTER 7: Design Guideline for CULVERTS

(not included/under development)

CHAPTER 8: Design Guideline for RAILROAD SIGNAL POLES

(not included/under development)

CHAPTER 9: Design Guideline for RETAINING WALLS

Purpose ......................................................................................... 9-1
  9.1 General Requirements ........................................................... 9-1
  9.1.1 Design Considerations
STANDARDS FOR DESIGN AND MAINTENANCE OF STRUCTURES

TABLE OF CONTENTS

9.2 Retaining Wall Type Selection .................................................. 9-1
  9.2.1 Factors for Selecting Retaining Wall Types
9.3 Structural Design Requirements .................................................. 9-3
  9.3.1 Wall Design Heights
  9.3.2 Loads
  9.3.3 Retaining Wall Stability
  9.3.4 Abutment Stability
9.4 Clearances ............................................................................. 9-11
9.5 Special Provisions ................................................................. 9-11
  9.5.1 Railroad Electrification
  9.5.2 Utilities
  9.5.3 Drainage
  9.5.4 Mechanically Stabilized Embankment (MSE)
  9.5.5 Crib Walls
  9.5.6 Bulkhead / Cantilever Systems
  9.5.7 Tieback Anchored Piles

CHAPTER 10: Design Guideline for MISCELLAEOUS STRUCTURES
(not included/under development)

CHAPTER 11: Design Guideline for STRUCTURE DESIGN SUBMITTAL PROCEDURES
11.1 General .............................................................................. 11-1
11.2 Design Submittals, Master List ............................................... 11-1
  11.2.1 Conceptual Design Level
  11.2.2 Preliminary Design Level
  11.2.3 In-Progress Design Level
  11.2.4 Pre-Final Design Level
  11.2.5 Final Design Level
  11.2.6 Bid Documents
  11.2.7 Bid Period Addendum Documents
  11.2.8 Conformed Contract Documents for Construction
  11.2.9 As-built Documents
11.3 Submittal Quantities .............................................................. 11-4
  11.3.1 Conceptual Design Level
  11.3.2 Preliminary Design Level
  11.3.3 In-Progress Design Level
  11.3.4 Pre-Final Design Level
  11.3.5 Final Design Level
  11.3.6 Bid Documents
11.4 Construction Requirements for Structures ................................. 11-6
  11.4.1 Construction Management
  11.4.2 Construction Submittals
  11.4.3 As-built Submittals

SECTION B - STRUCTURE MAINTENANCE GUIDELINE

CHAPTER 12: BRIDGE MAINTENANCE AND INSPECTION
(not included/under development)

- Bridge Rating
- Annual and Detailed Inspection (Procedures and Forms)
- Emergency Inspection: Seismic, Fire, Flood, Collision, etc. (Procedures and Forms)
- Maintenance Procedures
- Inventory of Available Bridge Material

SECTION C - REFERENCES

COMMENTARY ................................................................. C-1
(Sections as needed for clarification, explanations, examples, and reference)
C.1 GENERAL INFORMATION AND BACKGROUND
C.2 Design Guideline for RAILROAD BRIDGES AND UNDERPASSES
C.3 Design Guideline for GRADE SEPARATIONS OVER RAILROAD
   (OVERPASSES)
C.4 Design Guideline for SEISMIC DESIGN
C.5 Design Guideline for PEDESTRIAN UNDERPASS
C.6 Design Guideline for PEDESTRIAN OVERPASS
   (not included/under development)
C.7 Design Guideline for CULVERTS
   (not included/under development)
C.8 Design Guideline for RAILROAD SIGNAL POLES
   (not included/under development)
C.9 Design Guideline for RETAINING WALLS
C.10 Design Guideline for MISCELLANEOUS STRUCTURES
C.11 Design Guideline for STRUCTURE DESIGN SUBMITTAL PROCEDURES
   (not included/under development)

REFERENCE DOCUMENTS .............................................. R-1
- Caltrain Documents
- Guidelines, Codes, and Standards
- Articles, Publications, and Reports

APPENDIX A: REFERENCE PCJPB TRACK STANDARDS
- PCJPB Standards TS-1025 – Roadbed Sections for Wood Tie Track Construction
- PCJPB Standards TS-1030 – Roadbed Sections for Concrete Tie Construction
- PCJPB Standards TS-1035 – Roadbed Sections for Wood Tie Track in Paved Areas
- PCJPB Standards TS-1040 – Concrete Grade Crossing

APPENDIX B: PCJPB ENGINEERING STANDARDS FOR EXCAVATION SUPPORT SYSTEMS
- Figure 2.1, Railroad Zone of Influence

APPENDIX C: CLEARANCE DIAGRAMS
- PCJPB Track Standards TS-9160 – Clearance Envelope Requirements
- PCJPB Signal Standards G-180.STD – Clearance of Structures
- UPRR Standard Minimum Operating Clearances
- AREMA Figure 28-1-2, Railway Bridges
APPENDIX D: CALIFORNIA PUBLIC UTILITIES COMMISSION
- General Order 26-D
- General Order 118

APPENDIX E: FEDERAL RAILROAD ADMINISTRATION

APPENDIX F: AREMA LIVE LOAD MOMENTS, SHEARS, AND REACTIONS
- AREMA Table 15-1-17, Maximum Moments, Shears and Pier (or Floor Beam) Reactions for Cooper E 80 Live Load or Alternative Live Load

APPENDIX G: EQUIVALENT E80 LOAD FOR EQUIPMENT
- 100 Ton Car
- 110 Ton Car
- 125 Ton Car
- 4-PCJPB Locomotives
- PCJPB 1 Locomotive + 5 Passenger Cars
- SD-45 Freight Locomotive

APPENDIX H: MOMENT AND SHEAR RATING OF EQUIPMENT

APPENDIX I: LOCOMOTIVES AND PASSENGER CARS
- Locomotive MP36PH – 3C
- Locomotive F40PH – 3C
- Locomotive F40PH – 2C (BLC)
- Locomotive F40PH – 2 (Overhauled in 1999)
- Bombardier Bi-Level Cab and Trainer Car
- Gallery Cars
- Budd Cars
- Caboose
- Locomotive GP40-2
- Locomotive SD45-2

APPENDIX J: AREMA & CALTRANS SEISMIC DESIGN GUIDELINES, 2002

APPENDIX K: METRIC CONVERSION FACTORS
INTRODUCTION

Purpose

The Peninsula Corridor Joint Powers Board (PCJPB) has developed a Capital Improvement Program (CIP) for improvements over the next 20 years. Portions of the CIP document envision replacement and/or rehabilitation of several of the existing structures and railroad bridges on the corridor. Additionally, there are plans to eliminate at-grade railroad crossings at various locations on the corridor by constructing grade separation structures among other projects involving structures.

The Structures Design Guidelines are based on existing guidelines, regulations, specifications, codes, documents, best industry practices, and recommended issues relevant to the operations of the PCJPB facilities. The intent is to provide project design guidelines to help guide PCJPB designers and consultants working on projects related to PCJPB facilities in providing uniformity in design along the PCJPB corridor.

The PCJPB operations will continue to expand with an increase in rail traffic along this corridor. An expansion in track capacity is under construction (N-CTX and S-CTX), electrification of the PCJPB operations is proposed, and the State of California is proposing high-speed rail along the corridor for the future. Currently there are 80 trains a day operating on the corridor with plans to increase this to 120 trains a day by the year 2004. Due to the volume of rail traffic and the desire to maintain passenger operations schedules it is anticipated that only limited work windows (mostly nights and weekends) will be allowed to construct new facilities where the main line tracks are anticipated to be encroached upon by construction activities.

The PCJPB operations and their contract operator will provide passenger service while freight rail traffic will continue to be operated along the corridor by the Union Pacific Railroad per agreement.

The guidelines for each structure type have been developed to address preferred design types, types of loads, load combinations, load application, structure material strength and properties, and define requirements for structure type selection.

Roadway Worker Protection Training (RWP Training)

Working near Caltrain tracks can be dangerous and the PCJPB's first priority is for safety along their corridor. All Consultants, Designers (including surveyors, geotechnical, and other sub-consultants), Contractors, and employees that will be performing services that require them to enter PCJPB operating right-of-way are required to be trained and currently certified in the PCJPB Roadway Worker Protection Training program before entering the property. Details regarding training and certification are available from the PCJPB. The adoption of this safety procedure is prescribed by the Federal Railroad Administration (FRA) in 49 CFR 214 - Railroad Workplace Safety.

Qualification Clause

The information prepared herein is presented as a general guide and will be used under the direction of PCJPB by qualified and experienced engineering consultants or staff. In that
regard the PCJPB requires that qualifications of the lead designer or designer in responsible charge of railroad bridge projects have performed 5 years of qualifying railroad bridge design and construction, have a current membership in the American Railway Engineering and Maintenance-of-Way Association (AREMA), and preferably be involved current AREMA committees.

The guidelines are not intended as a substitute for, formal design criteria code application, or the professional experience and judgement of the design professional performing specific services for PCJPB. Each consultant's use of the guidelines will be tailored to the unique tasks and circumstances associated with a particular site or project.

Data presented in the guidelines is representative and is not intended to be exhaustive, precise, or useful for every application. By using the guidelines the user assumes all responsibility for its use. PCJPB and the contributors to this document do not assume or accept any responsibility or liability, including liability for negligence, for errors or oversight, for the use of the guidelines in preparing engineering plans or designs.

ACKNOWLEDGEMENT

It would be impossible to acknowledge each of the individuals who contributed to the development of these standards. However, recognition is due to the significant contribution the following participants had in the development of these Standards for Design and Maintenance of Structures.

Darrell Maxey
Zecharias Amare
Patrick Casey
Simon Kim
Roger Boraas
Ken Kirshling
Regina Pau

Peninsula Corridor Joint Powers Board
Peninsula Corridor Joint Powers Board
HNTB Corporation, Oakland
HNTB Corporation, Oakland
HNTB Corporation, Denver
Canadian National Railway, Formerly HNTB Corporation, Seattle
HNTB Corporation, Oakland
CHAPTER 1

GENERAL
CHAPTER 1
GENERAL INFORMATION & BACKGROUND

1.1 Application of Guidelines

These guidelines and procedures provide for a uniform basis for the structural design criteria for the Peninsula Corridor Joint Powers Board (PCJPB) – Caltrain projects. Structure items included in this guide include railroad bridges and underpasses, pedestrian underpasses and overpasses, retaining walls, and other miscellaneous structures. Where there are cases of special design types, special projects or large-scale projects encountered that are not specifically covered by these guidelines, the designer shall bring them to the attention of PCJPB to determine the applicable criteria to use.

These guidelines also provide some rules, regulations and standards of practice for all personnel performing design, maintenance, and construction on PCJPB owned or maintained track and closely related facilities. The manual is intended to be used and applied by employees of the PCJPB staff, the Contract Operator (Amtrak) as well as construction contractors, PCJPB engineering consultants, and any other parties involved in supervising or directly performing design, construction, maintenance or inspection of track owned or maintained by the PCJPB.

The Union Pacific Railroad (UPRR) operates over the PCJPB corridor and in certain instances the guidelines and standards of the UPRR will govern the design. The designer shall discuss with the PCJPB where and if the UPRR requirements will govern.

The design of a structure owned or maintained by an agency other than the PCJPB shall be in accordance with the standards used by that agency, except where the following conditions exist. If the structure encroaches onto the PCJPB right-of-way or the structure could potential impact or pose a restriction to the PCJPB’s full use of its right-of-way for operating purposes the PCJPB shall be contacted for the guidelines that apply.

These design guidelines shall be used in conjunction with other applicable governmental rules and regulations and manuals of practice. Some of these other regulations and rules are listed in Sections 1.9 through 1.12 in this chapter. If these guidelines conflict with the application of another guideline or code, the conflict shall be brought to the attention of the PCJPB for resolution.

These guidelines and procedures serve as recommended practice and do not substitute for engineering judgement and sound engineering practice. Unless specifically noted otherwise in these guidelines and procedures, the latest edition of guidelines, codes,
regulations, and standards that are applicable at the time the design is initiated shall be used. If a new addition or an amendment to a guideline, code, regulation, or standard is issued before the design is completed, the design shall conform to the new requirements to the extent presented or required by the agency enforcing the requirement. Specific exceptions may apply in special cases.

Any variances to the guidelines and procedures must be approved by PCJPB prior to use in the design. Application for change of guidelines and procedures and other questions should be submitted in writing with full details pertaining to the issues to:

Chief Engineer
PCJPB – Caltrain
1250 San Carlos Ave. – P.O. Box 3006
San Carlos, CA 94070-1306

1.2 Compatibility

These guidelines shall be used in a way that they are compatible with the other PCJPB guidelines, standards, and operations in effect. These PCJPB documents and operations include:

- PCJPB Guideline for Excavation Support Systems
- PCJPB Communication/Signal Engineering Standards
- PCJPB Track Standards (Engineering Standards)
- PCJPB Standards – Volume I and Volume II
- PCJPB Standard Operating Procedures (SOP) for Maintenance and Construction (includes requirements for operations after an Earthquake)
- Caltrain Timetable
- PCJPB Station Facility Guidelines
- PCJPB Electrification Standards
- PCJPB CADD Standards
- PCJPB Policy on High and Low Risk Underground Facilities Within the PCJPB’s Right of Way

1.3 Design Guidelines, Codes, Manuals, Standards, and Specifications

The primary structural design guideline to be used in the design of PCJPB structures shall be the American Railway Engineering and Maintenance-of-Way Association (AREMA) - Manual of Railway Engineering (latest edition) as may be modified by these guidelines. All designers doing work that is related to PCJPB structures, operations, or right-of-way shall have the latest edition of this document.

Other governing guidelines, codes, manuals, and specifications are listed below:

- Federal Railroad Administration (FRA) 49 CFR 213 - Track Safety Standards
- California Public Utilities Commission (CPUC) General Orders
- Caltrans Bridge Design Specifications (BDS)
Note: The Caltrans Bridge Design Details Manual, the Caltrans Memo to Designers Manual, and other Caltrans Manuals that have sections on railroad structure design shall have their use verified with the PCJPB staff prior to incorporating those provisions in the design. A determination will be made on which sections are applicable to the PCJPB project.

1.4 General Guidelines for Grade Separations

The PCJPB prefers overhead highway crossings to underpasses where practical. When overhead highway crossings or underpass highway crossings are planned it is preferable to not change the alignment or elevation of the existing main tracks. Considerations for track alignment and grade changes shall be discussed with the PCJPB for input on the impact to rail operations and the impacts during the construction phase. The PCJPB is planning for a four-track alignment along the corridor; the designer shall make provisions in designing new facilities to accommodate the future proposed four-track alignment.

Agencies intent on designing or constructing grade separations passing over or under the tracks and/or property of the PCJPB should consult with the PCJPB Chief Engineer early in the planning stage to verify the design requirements given herein and to determine the requirements regarding train operations within the corridor. Construction affecting train service should be avoided or minimized. If impacts to operations are unavoidable, impact time and duration must be approved by PCJPB and the project design and construction sequencing must be approved by PCJPB. The following listing provides some of the issues that the PCJPB will be concerned with during design:

- Design requirements for structures and including track alignment and grades
- Permanent impacts to train operations
- Construction impacts to train operations (temporary)
- Construction staging & sequencing

The requirements addressed in this guideline should be followed for all structures over or under the PCJPB tracks or structures constructed on PCJPB property. Compliance with the requirements herein will expedite the review and approval of project submittals.

1.5 Distribution

The PCJPB Standards for Design and Maintenance of Structures manual is distributed to PCJPB staff, contract operator staff, consultants, and contractors whose responsibilities include design, construction, and maintenance of the PCJPB track, structures, and right of way.

1.6 Background and History of Caltrain

1.6.1 History

Passenger service on the peninsula corridor began on Oct. 18, 1863 under the authority of the San Francisco and San Jose Railroad Company. Prophetically, some $600,000 of the original $2 million capital stock issue was owned by the
voters of San Francisco, San Mateo and Santa Clara counties following a three-county election in 1861.

In 1870, the San Francisco and San Jose Railroad Company was acquired by the firm that was eventually consolidated into the Southern Pacific Railway. Southern Pacific double-tracked the line in 1904, and operated passenger service in the corridor successfully until after World War II. Changing commute patterns impacted Southern Pacific along with private carriers all over the country, and after protracted struggles with the state Public Utilities Commission on fares and service levels, Southern Pacific petitioned to abandon passenger service in 1977.

The three Peninsula counties stepped into the breach with a temporary Fare Stabilization Plan -- partially subsidizing commuter tickets -- that reversed a long pattern of declining ridership and set the stage for state sponsorship of the Peninsula Commute in 1980. From 1980 until mid-year 1992, Caltrans contracted with Southern Pacific to provide passenger service in the corridor, sharing operating subsidies with San Francisco, San Mateo and Santa Clara counties. The state assumed sole responsibility for station acquisitions and
other capital improvements until the service resulted in formation of the Peninsula Corridor Joint Powers Board (PCJPB) in 1987. The PCJPB agreed to assume operating responsibilities for Caltrain effective July 1, 1992, and to shoulder 100 percent of the operating subsidy a year later.

In December 1991, the PCJPB purchased the rail right of way from San Francisco to San Jose. The PCJPB secured trackage rights to Gilroy for another $4 million. Union Pacific Railroad, which merged with Southern Pacific in 1996, retains rights to operate freight service along the corridor. To replace Southern Pacific as the commute operator, the PCJPB signed Amtrak, the national passenger rail corporation, to a three-year agreement with two one-year options beginning July 1, 1992. In November of 2001, Amtrak was awarded a 5-year contract to continue commute service for the PCJPB.

Contract oversight is provided by SamTrans, as the administrative arm of PCJPB. Caltrans deeded 26 stations, 20 diesel locomotives and 73 bi-level passenger cars to the PCJPB in 1993. Many of locomotives and gallery cars have been rebuilt or replaced over last five years.


- 77 miles of mainline track between San Francisco and Gilroy
- 80 scheduled weekday trains
- 34 stations, most have parking
- 48 grade crossings between San Francisco and San Jose
- 38 grade crossings between San Jose and Gilroy
- Push / pull operation
- Top train speed of 79 miles per hour
- Each train consist can handle 24 bicycles
- Average daily ridership over 32,000 passengers
- 23 locomotives, 73 cars, including 21 cab cars
1.6.3 Caltrain Milestones

- December 2002
  
  Awarded a $39 million construction contract for 3 projects along the Caltrain right of way. The project is known as the South CTX.

- July 2002
  
  Temporarily discontinued train service on weekends for a 20 month period to facilitate CTX Project construction.

- April 2002
  
  Awarded a $64 million construction contract for 6 projects along the Caltrain right of way. *The project is known as the North CTX.*

- November 2001
  
  Awarded a five year contract for Operation of Commuter Rail Service and Construction Support Services

- March 2000
  
  Inaugurated special service to Pacific Bell Park for San Francisco Giants baseball games.

- November 1999
  
  Opened the new, relocated Hayward Park station in San Mateo.

- May 1999
  
  Approved the Rapid Rail Plan, an $836 million rehabilitation electrification program.

- April 1999
  
  Opened the San Antonio station in Mountain View. Added weekday trains, bringing the weekday total to 68.

- January 1999
  
  Awarded a $54 million construction contract for 30 projects along the Caltrain right of way. The project is known as the Ponderosa.

- December 1998
  
  Caltrain receives the first of three new locomotives. A celebration was held at Caltrain's Fourth and King Streets station in San Francisco to honor the completion of the interior station renovation.
- August 1998
  Began selling 10-ride tickets via the internet.

- March 1998
  Twenty new passenger cards ordered, six of which are cab cars. Also ordered 101 state-of-the-art ticket vending machines.

- July 1997
  Caltrain increases service: six weekday trains and two Saturday trains. Caltrain also introduces a new logo.

- June 1996
  Caltrain records the highest annual ridership since 1958 -- 7.4 million.

- Nov. 24, 1995
  The number of bicycles allowed per train increases to 24 making Caltrain the least-restrictive and most accessible rail system to bicyclists in the country.

- July 1995
  Caltrain becomes accessible to passengers in wheelchairs.

  The Redwood City Transit Center, serving Caltrain and SamTrans bus passengers, is dedicated.

- Dec. 8, 1994
  Dedication ceremony is held to mark the completion of the reconstruction and restoration of the San Jose terminal, which is renamed "San Jose Diridon Station."

- Sept. 17, 1994
  Burlingame station marks 100th anniversary with a community fair.

- June-July 1994
  Some 170,000 people take Caltrain to and from World Cup soccer games at Stanford University.

- January 15-16, 1994
  Peninsula Corridor Joint Powers Board celebrates 130 years of continuous passenger service between San Francisco and San Jose at an open house marking the 130th anniversary of the Santa Clara depot. It is the oldest continuously operating train station in California.
• September 1992

Bicycles are allowed on Caltrain under a pilot program.

• July 1, 1992

The Peninsula Corridor Study Joint Powers Board becomes the Peninsula Corridor Joint Powers Board with Amtrak as contract operator. San Mateo County Transit District provides administration and contract oversight.

Weekday service is increased from 54 to 60 trains.

Tamien station opens in San Jose.

Service is extended to Gilroy.

• December 1991

The Joint Powers Board purchased rail lines in San Mateo and Santa Clara counties. The JPB secured trackage rights to Gilroy for another $4 million, with an option to acquire half the right of way in the future. Union Pacific retains rights to operate freight service in the corridor.

Right of way is purchased from Southern Pacific Transportation Company for $220 million.

• 1988

San Carlos station celebrates its centennial.

Two additional locomotives and ten more cars are purchased.

• 1987

Peninsula Corridor Study Joint Powers Board is formed.

• June 1985

The first of 63 new gallery cars equipped for push-pull operation go into service, along with 18 new F40PH diesel-electric locomotives (each named after a city on the line).

• October 1981

Train schedules are extensively modified and several "reverse commute" trains are added. Total number of weekday trains increases from 44 to 46.

• July 1, 1980

The new agreement takes effect, with Caltrans assuming responsibility for the Peninsula Commute Service.
• 1979

The 1909 wood-frame/stucco Redwood City station is damaged in a fire and replaced by a trailer.

• 1977

Southern Pacific petitions the state Public Utilities Commission (which says "no") and then the Interstate Commerce Commission to discontinue the Peninsula Commute Service. A bitter fight follows. After long months of negotiation, the three counties through which the Peninsula Commute Service runs and the California Department of Transportation (Caltrans), reach an agreement with Southern Pacific. SP would become the contractor and the public agencies would cover most of the operating costs.

• 1976

San Mateo's old station is torn down to make way for a parking structure.

• June 23, 1975

Fourth and Townsend Streets terminal opens in San Francisco.

• May 1, 1971

Amtrak takes over operation of the nation's intercity passenger trains. The northern terminal of the Coast Daylight to Los Angeles is changed to Oakland from San Francisco. Southern Pacific's Del Monte, which ran from San Francisco to Monterey, is discontinued. As a result, commuter trains become the only rail passenger service between San Francisco and San Jose.

• 1965

The grade separation is built at Hillsdale Boulevard in San Mateo.

• June 1955

The first of ten "gallery cars" are delivered to Southern Pacific. The cars, which provide more seating, are an instant success, and in January 1956, Southern Pacific orders 21 more. A final order of 15 is placed in 1968.

• Early 1950's

Diesel locomotives begin to appear in the Peninsula Commute Service.

• December 1935

A new terminal opens on Cahill Street in San Jose.
1915
San Francisco terminal moves to Third and Townsend streets. The station has been built to handle crowds for the Panama Pacific International Exposition.

1870
San Francisco and San Jose Railroad is absorbed into Southern Pacific.

Jan. 16, 1864
The line is completed to San Jose. Within a short time, two trains operate each way weekdays between San Francisco and San Jose. The San Francisco terminal initially is located at 18th and Valencia streets.

October 1863
Regular service between San Francisco and Mayfield (now California Avenue in Palo Alto) begins. The trip takes two hours. At Mayfield, passengers have to board a stagecoach to get to San Jose.

1860
San Francisco and San Jose Railroad incorporates. Financing for a railroad between those cities comes from three counties -- San Francisco, San Mateo and Santa Clara.

January 1851
A line connecting the trading center of San Francisco with California's first state capital, San Jose, was proposed.

1.6.4 Caltrain Improvements

The PCJPB has a very aggressive capital improvement plan to upgrade and improve the physical plant. The plan will upgrade the route to a modern facility with continuous welded rail, new concrete and wood ties, CTC signaling and many other improvements to the stations, bridges and right of way. The annual capital expenditure is approximately $100 million.

The plan calls for major capacity expansion with additional main tracks, additional and improved grade separations, improved station and terminal facilities, a new equipment maintenance facility and potential extensions. Caltrain is also planning for electrification of the route. Additionally, the Caltrain corridor and tracks may be incorporated into the future California high-speed rail system.
1.7 Caltrain Organization

1.7.1 PCJPB

The Peninsula Corridor Joint Powers Board is a state-authorized joint powers authority controlled by the three counties where Caltrain operates—San Francisco, San Mateo, and Santa Clara Counties. For administrative purposes, San Mateo County’s transportation agency, SamTrans, provides administrative and staff support for PCJPB. The PCJPB has a relatively small staff and performs much of its engineering, construction, maintenance and operations with the assistance of consultants and contractors.

1.7.2 Contract Operator (Amtrak)

The contract operator (Amtrak) operates, maintains, and dispatches PCJPB trains and performs basic track, signal, and structure inspection and maintenance. Amtrak supports the substantial amount of construction and third-party work along the corridor, primarily by providing flagging and watchmen. Amtrak also performs small construction tasks such as rebuilding yard tracks and replacing road crossings. The PCJPB in conjunction with the contract operator is responsible for coordinating these activities.

1.7.3 PCJPB Construction Contractors

PCJPB construction contractors perform a wide variety of tasks, including renewals such as track, bridge, station and signal construction and reconstruction.

1.7.4 Union Pacific Joint Facilities

The Union Pacific Railroad (UPRR) operates local freight service on PCJPB, and has joint facility arrangements in a number of other locations. In general, the UPRR owns and maintains Track No. 1 from CP Coast to CP Lick and all freight tracks off the main tracks from San Francisco to Lick.

1.7.5 Caltrain Organization Chart

The following chart illustrates the organization and agencies involved in the Caltrain operation.
Caltrain Organization

Key Departments and Individuals for Construction & Maintenance

San Francisco County
San Mateo County
Santa Clara County

Peninsula Corridor Joint Powers Board
(Owner of Caltrain)

Nine Member Governing Board—3 From Each County

San Mateo County Transit District (Samtrans) Caltrain Managing Agency

Chief Executive Officer

Chief Operating Officer
Chief Development Officer
Chief Engineer
Director of Capital Project Development
Engineering
Project Managers

Rail Safety Manager
Chief Administrative Officer

Chief Financial Officer
Chief Communications Officer

Field Construction Managers & Inspectors

Construction Contractors

Manager of Field Construction Support
Manager of Track & Structures Maintenance (ADE)
Manager of Signal & Communications Maintenance

Manager of Support Mgr (ASM)
1.8 Rules and Regulations

The PCJPB and other railroads rely on a variety of documents and standards to design, construct, operate, and maintain the property. The following sections and the accompanying chart outline most of the involved documents.

1.8.1 Related Rules, Regulations, Specifications, and Standards by Caltrain

<table>
<thead>
<tr>
<th>Document Name</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Safety Plan</td>
<td>SSP</td>
</tr>
<tr>
<td>On-Track Safety Plan (Roadway Worker Protection)</td>
<td>RWP</td>
</tr>
<tr>
<td>Standard Procedures for Track Maintenance &amp; Construction</td>
<td>SP/TM&amp;C</td>
</tr>
<tr>
<td>Standard Track Plans corridor</td>
<td>STP</td>
</tr>
<tr>
<td>Communication/Signal Engineering Standards</td>
<td>CSES</td>
</tr>
<tr>
<td>Communication/Signal Design Standards</td>
<td>CSDS</td>
</tr>
<tr>
<td>Excavation Support Systems</td>
<td>ESS</td>
</tr>
<tr>
<td>Station Design Manual</td>
<td>SDM</td>
</tr>
<tr>
<td>Electrification Design Standards</td>
<td>EDS</td>
</tr>
<tr>
<td>Standard Contract Documents for Construction Contracts</td>
<td>EDS</td>
</tr>
<tr>
<td>Project Specific Construction Specifications and Plans</td>
<td>SSWP</td>
</tr>
<tr>
<td>Site Specific Work Plans</td>
<td>SSWP</td>
</tr>
<tr>
<td>Project Specific Construction and Maintenance Agreements for Other Contractors (Third Parties) on Caltrain</td>
<td>DMS</td>
</tr>
</tbody>
</table>

1.8.2 Contract Operator Agreement between PCJPB and Amtrak

1.8.3 General

The PCJPB has assigned maintenance and operations responsibility to an operating contractor, which is currently Amtrak. The contract operator is responsible to maintain, inspect, and operate the system.

1.8.4 Agreement for Operation and Capital Third Party Support

The contract operator also provides support to other PCJPB contractors, primarily in areas more directly related to the daily operation. The contract operator performs some small capital improvements as well.
1.8.5 Appendix “A” Through “S” to Contract Requirements

The following contract provisions describe the M/W portion of operations contractor’s responsibilities. Appendix “G” includes detailed provisions for maintenance of way. The following Appendix’s are listed for reference.

- Appendix “G”—Rail Line Maintenance Standards and Requirements
- Appendix “I”—Other Service Property and Equipment Maintenance Standards
- Appendix “M”—Right of Way Cleanup Standards
- Appendix “P”—Safety Program Requirements
- Appendix “R”—Capital and Third Party Project Support Services
- Chief Engineer’s Special Instructions

1.8.6 Rules, Regulations, and Procedures Controlled by the Contract Operator

<table>
<thead>
<tr>
<th>Document Name</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Code of Operating Rules</td>
<td>GCOR</td>
</tr>
<tr>
<td>General Code of Operating Rules for Maintenance of Way Employees</td>
<td>MWOR</td>
</tr>
<tr>
<td>General Orders</td>
<td>GO</td>
</tr>
<tr>
<td>Maintenance of Way General Orders</td>
<td>MOW/GO</td>
</tr>
<tr>
<td>Amtrak Special instructions for Maintenance</td>
<td></td>
</tr>
<tr>
<td>Caltrain Timetable and Special Instructions</td>
<td></td>
</tr>
<tr>
<td>Amtrak Air Brake and Train Handling Rules</td>
<td></td>
</tr>
</tbody>
</table>
1.9 Applicable Federal Rules, Regulations, Instructions and Standards Related to Maintenance and Construction on the Railroad

1.9.1 Federal Railroad Administration Regulations

The following federal regulations are specifically related to maintenance of way:

<table>
<thead>
<tr>
<th>FRA Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part 213 Track Safety Standards</strong></td>
</tr>
<tr>
<td>Subpart A—General</td>
</tr>
<tr>
<td>Subpart B—Roadbed</td>
</tr>
<tr>
<td>Subpart C—Track Geometry</td>
</tr>
<tr>
<td>Subpart D—Track Structure</td>
</tr>
<tr>
<td>Subpart E—Track Appliances and Track Related Devices</td>
</tr>
<tr>
<td>Subpart F—Inspection</td>
</tr>
<tr>
<td>Appendix A—Maximum allowable Curving Speeds</td>
</tr>
<tr>
<td>Appendix B—Schedule of Civil Penalties</td>
</tr>
<tr>
<td>Appendix C—Statement of Agency Policy on Safety of Railroad Bridges</td>
</tr>
<tr>
<td>Defect Codes for Subparts A-F</td>
</tr>
<tr>
<td><strong>Part 214 Railroad Workplace Safety</strong></td>
</tr>
<tr>
<td>Subpart A—General</td>
</tr>
<tr>
<td>Subpart B—Bridge Worker Safety Standards</td>
</tr>
<tr>
<td>Subpart C—Roadway Worker Protection</td>
</tr>
<tr>
<td><strong>Part 217 Railroad Operating Rules</strong></td>
</tr>
<tr>
<td><strong>Part 219 Control of Alcohol and Drug Use</strong></td>
</tr>
<tr>
<td><strong>Part 220 Railroad Communications</strong></td>
</tr>
<tr>
<td><strong>Part 225 Railroad Accidents/Incidents: Reports Classification &amp; Investigations</strong></td>
</tr>
<tr>
<td><strong>Part 228 Hours of Service for Railroad Employees</strong></td>
</tr>
<tr>
<td><strong>Part 231 Railroad Safety Appliance Standards</strong></td>
</tr>
<tr>
<td><strong>Part 233 Signal Systems Reporting Requirements</strong></td>
</tr>
<tr>
<td><strong>Part 234 Grade Crossing Signal System Safety</strong></td>
</tr>
<tr>
<td><strong>Part 235 Applications to Discontinue a Signal System</strong></td>
</tr>
<tr>
<td><strong>Part 236 Rules and Standards Governing Installation and Repair of Signal and Train Control Systems</strong></td>
</tr>
</tbody>
</table>

1.9.2 Occupational Safety and Health Administration (OSHA) Part 1910 Gen Industry

This section includes the confined space regulations, Part 1910.146.

1.9.3 Occupational Safety and Health Administration (OSHA) Part 1926 Construction

- Subpart E—Personal Protective Equipment
- Subpart K—Welding and Cutting
• Subpart M—Fall Protection
• Subpart N—Cranes, Derricks and Hoists
• Subpart O—Motor Vehicles and Mechanized Equipment
• Subpart P—Excavations
• Subpart X—Ladders
• Subpart Z—T
• Toxic and Hazardous Substances

1.10 Applicable State Rules, Regulations, Instructions and Standards Related to Maintenance and Construction on the Railroad

1.10.1 California Public Utilities Commission (CPUC) General Orders (GO)
• 22-B Report of Accidents on Railroads
• 26-D Clearance on Railroads & Streets
• 72-B Pavement at Railroad Crossings
• 75-C Signs & Warning Devices Protection at RR Grade Crossings
• 88-A Altering Public Railroad Highway Crossings
• 96-A Electrical Transmission
• 118 Walkways Adjacent to Tracks
• 135 Blocking at RR Grade Crossings

1.11 Other Standards and References

1.11.1. Manual of Uniform Traffic Control Devices (MUTCD)

This manual provides standards for traffic control, including striping, signage, and traffic signals.
1.12 Training Requirements

1.12.1 General

In order to supervise or perform a basic level of track or related work on the Caltrain system – the individual whether it be an Amtrak employee, construction contractor employee or similar must know, understand and pass a qualifying examination and have the required "on-the-job-experience" as outlined in the following table.

Additional training may be required.

1.12.2 Training Requirements

<table>
<thead>
<tr>
<th>TRAINING</th>
<th>Amtrak or Contractor Laborer</th>
<th>Amtrak or Contract Operator On Track Equipment Operator</th>
<th>Amtrak Foreman</th>
<th>Amtrak Welder</th>
<th>Construction Contractor Foreman and Superintendents Project Engineers</th>
<th>Capitol Support Management and Non Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Procedures for Track Maintenance &amp; Construction</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Roadway Worker Protection</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>GCOR for MOW</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Flag Protection</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Radio Procedures</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caltrain physical characteristics</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand tools</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Track jacks</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Rail saw</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Rail drill</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Chain saw</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>TRAINING</td>
<td>Amtrak or Contract Operator On Track Equipment Operator</td>
<td>Amtrak Foreman</td>
<td>Amtrak Welder</td>
<td>Construction Contractor Foreman and Superintendent Project Engineers</td>
<td>Capitol Support Management and Non Management</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>--------------------------------------------------------</td>
<td>----------------</td>
<td>---------------</td>
<td>-----------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Tree pruning per National Arborist Association</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Weed eater</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Impact gun</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Oxy-Acetylene Torch</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Thermite Welding</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ultrasonic testing per ASTM E164</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Magnetic particle testing ASTM E709</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>RBM Frog welding/ Spring Rail</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Rail end welding</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Engine burn welding</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Rail pullers</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Hand grinder</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Frog grinder</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Rail destressing</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Switch Adjustment</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Turnout Inspection</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Frog Inspection</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Curve Inspection</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

**ANNUAL FREQUENCY**
<table>
<thead>
<tr>
<th>TRAINING</th>
<th>Amtrak or Contractor Laborer</th>
<th>Amtrak or Contract Operator On Track Equipment Operator</th>
<th>Amtrak Foreman</th>
<th>Amtrak Welder</th>
<th>Construction Contractor Foreman and Superintendents Project Engineers</th>
<th>Capitol Support Management and Non Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANNUAL FREQUENCY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade Crossing Inspection</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Track Level/Chord Measurements</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>FRA 213 Track Standards</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Earthquake response</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Patrols</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bridge Inspection</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert Inspection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tunnel Inspection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curve lubricators</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Hyrail operation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Boom Truck</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On track equipment</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ballast cars</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Backhoe</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Speed Swing</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Undercutter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bucket Truck</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure Washer</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Low railer</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1.12.3 Maps

The following maps are at the end of the section:

- System Map
- San Francisco Terminal
- San Jose Terminal
- Redwood Junction
CHAPTER 2

RAILROAD BRIDGES
AND
UNDERPASSES
CHAPTER 2
RAILROAD BRIDGES AND UNDERPASSES

Purpose

This guideline was created to provide standards and requirements regarding design and construction of new or modified existing grade separation underpass structures that affect the tracks and property of the Peninsula Corridor Joint Powers Board (PCJPB). Design engineers should use these guidelines as the basis for preliminary and final design.

2.1 General Requirements

The primary structural design guidelines to be used in the design of PCJPB structures shall be the American Railway Engineering and Maintenance-of-Way Association (AREMA) - Manual of Railway Engineering (latest edition) as may be modified by these guidelines.

If the detailed requirements are not specifically covered in AREMA then the appropriate section of the current edition of Caltrans Bridge Design Specifications shall be applied. Final determination of the appropriate sections of Caltrans BDS shall be discussed with the PCJPB.

Right of Entry, Right-of-Way encroachment, and Construction and Maintenance (C&M) agreements consistent with PCJPB policy may be required depending on the type of project, who is the lead agency, and to establish the responsibilities of all parties.

The municipality, other public agency, or PCJPB will be required to make application to the California Public Utilities Commission (CPUC) for a new or any modification to a grade separation. The PCJPB staff will support the application, if required, provided that it concurs with their long range planning. If the lead agency is the PCJPB then the designer will be required to provide the exhibit material necessary to accompany the PUC application process.

For submittal requirements, see Chapter 10.

The agency or their representative shall provide the basic information requested on the Underpass Project Sheet to PCJPB at the initial stage of the project. A copy of the Underpass Project Sheet is included in Chapter 10.

2.2 Superstructure Selection Type

Structure type selection shall be discussed with the PCJPB to determine and identify any constraints that may control the design that are not listed in this guideline. Type selection shall at least be based on the following factors to determine the most suitable type of structure for the location:

- Location
- Configuration
- Cost
• Maintainability
• Constructibility
• Impacts on Rail Operations
• Aesthetic Considerations
• Environmental

Grade separation underpass structures built to support railroad tracks shall be ballast deck type structures. Railroad timber open deck type structures shall only be considered for temporary structures or shoofly structures. Railroad direct fixation type structures shall not be considered for the PCJPB corridor for permanent or temporary structures.

Provisions shall be discussed with PCJPB on the need to accommodate additional or future main tracks across the structure for each project. A four track alignment shall be considered as it is part of the future planning for the corridor.

In the design of underpasses the top of rail elevation and alignment are preferred to remain at the existing location. Where it is required that the track grades or alignment be changed do to the circumstances of design, the PCJPB requests that it be consulted and the following considerations be given:

• The change in track grade for both temporary and permanent alignment shall minimize the impact on train operations, adjacent station platforms, parking lots, and railway maintenance access.

• The change in track grade shall minimize the undulating effect on the track profile relative to existing underpasses, future underpasses, or nearby grade crossings.

• The affects of a track grade change that will require an adjustments or relocations to the fiber optic line along the corridor shall be identified and solutions investigated.

During the design process all property and right-of-way requirements shall be identified that will be required for the project. Permanent right-of-way requirements and temporary construction easements shall be brought to the attention of the PCJPB as early as possible.

Simple span structures are preferred over a continuous span type of superstructure for use along the corridor. The use of continuous type superstructures will only be considered when conditions preclude any other solution. Continuous type structures require the approval of the PCJPB Chief Engineer.

Deck type structures are preferred over through type structures. The concrete through trough type of prestressed or post tensioned, simple or continuous structures, are not to be considered.
2.2.1 List of Preferred Structure Type

The following list of superstructure types is listed in priority order as the preferred types for use along the PCJPB Corridor: (1 being the most preferred and 8 being the least preferred)

1. Steel rolled beams (four or more beams per track) with a cast-in-place concrete or steel deck. (See Figure 2.7 at the end of this chapter)
2. Steel plate girders (four or more girders per track) with a cast-in-place concrete or steel deck. (See Figure 2.7 at the end of this chapter)
3. Prestressed concrete box girders (single or double cell) or solid slab girders (no void). (See Figure 2.8 at the end of this chapter)
4. Steel rolled beams or plate girders (two beams/girders per track) with a cast-in-place concrete deck. (See Figure 2.9 at the end of this chapter)
5. Prestressed concrete “AASHTO” type girders with cast-in-place diaphragms and deck. (See Figure 2.10 at the end of this chapter)
6. Cast-in-place concrete box girders, conventionally reinforced. (See Figure 2.11 at the end of this chapter)
7. Post tensioned concrete box girders. (See Figure 2.11 at the end of this chapter)
8. Through type steel structures (girder or truss) with a cast-in-place concrete or steel deck. Although low profile (top flange near the top of rail in height) through plate girders are more desirable than deep through plate girders. (See Figure 2.12 at the end of this chapter)

See the end of this chapter for typical sections (Figure 2.7 through 2.12) of these structure types and other preliminary planning information related to each type. The span depth factor given in the figures is for simple span structures and is provided as a preliminary layout aid in engineering. Final superstructure depth shall be based on AREMA requirements for stress and deflection. The comparative cost ranking is based on the highest cost being a 10 and the lowest cost being a 1.

2.3 Structural Design Requirements

2.3.1 Layout

The project plans involving an underpass structure shall indicate the limits of PCJPB right-of-way and any other public or private right-of-way involved. Locations of all existing and proposed underground and overhead utilities shall be located and indicated. The PCJPB has adopted a modified version of the Caltrans' Policy on High and Low Risk Underground Facilities within Highway Rights of Way in which the Fiber Optic and Railroad Signal and Communication lines have been added to the list of High Risk Facilities. Proposed construction staging and requirements for a temporary bridge structure or shoofly arrangement and design shall be established. All proposed construction shall be designed and staged to minimize the amount of track interference during construction.
Utility lines will not be permitted to be attached to the bridge superstructure unless approved by the PCJPB, except for utilities (i.e. railroad signal and communication lines) that are required for the operation of the railroad. Signal cables may be buried in the ballast across a bridge, but away from the track. Where railroad signal and communication lines are to be attached to the superstructure special mounting provisions (exterior brackets) shall be designed that minimize interference with maintenance and inspection activities of the structure. Existing or future fiber optic lines shall be placed underground and away from the bridge structure. In most cases relocation of existing utilities will be by the owners of the utility. In some instances where the utility line has no other option than to be located on the structure; the PCJPB will handle this situation on a case by case basis. In the case where a utility line is allowed on a structure it may only be attached to the substructure of the bridge and the following requirements apply:

- Utility line must have a minimum separation of 2 feet horizontality from the superstructure
- Utility can not be attached to the superstructure
- Utility can be attached to the pier and abutment caps, if they are extended for that purpose
- There are no penetrations of the abutment, backwall, or wingwall for the utility line.

Other utility lines that are impacted by the bridge construction shall be identified. Impacted utility lines may require relocation, protection, encasement, or a casing.

Bridge deck drainage shall be provided for and directed away from the track roadbed and away from the back of bridge abutments. Bridge deck shall have a minimum of 0.4% grade longitudinally. Natural drainage that occurs toward the bridge ends shall not be allowed to drain onto the bridge deck but shall be intercepted prior to it draining onto a bridge. Drainage patterns for the entire right-of-way shall be considered for the project with all drainage directed away from the tracks.

For a bridge located on a curve alignment, the girders, abutments, and piers shall be positioned with reference to chords.

The year the bridge was constructed and its milepost designation shall be embedded into the face of the concrete backwall where it is readable. Letters to be 6 inches tall. The bridge milepost designation shall also be shown on all the design plans. Contact the PCJPB if you need help in establishing the PCJPB bridge milepost for your project.

Structures shall be designed to accommodate any future shifting or relocation of track within the limits of the bridge deck. Longitudinal members are to be evenly spaced.
Abutment stem walls shall be at least 0.2h in thickness at their base. Columns and piers shall be at least 0.2h in thickness at the base per Figure 2.1. Minimum bridge seat width shall be per AREMA requirements and shall follow the requirements of these standards per Section 2.6.1. All Abutments shall incorporate a back wall to prevent ballast and the abutment backfill material from migrating to the bridge seat.

![Figure 2.1 - Abutment & Column Requirements](image)

Main line track centers for new bridge construction shall be a minimum of 15'. Track centers shall be verified with PCJPB staff prior to design, as there are other track arrangements that need to be considered (such as at station locations, etc.).

Consideration shall be given in the design of the superstructure, abutments, piers, and bridge seats to allow for the future addition of a third and fourth main tracks along the PCJPB corridor. Similarly, the profile of the roadway under the track shall provide the vertical clearance necessary for the future tracks. Requirements for future tracks shall be determined prior to beginning design.

The designer should be aware that the track structure is supported by the bridge structure, the combination of track and bridge movement (deflection) cannot exceed the tolerances in track standards. Refer to Federal Railroad Administration (FRA) 49 CFR – Part 213 Track Safety Standards for requirements on track tolerances. Therefor it is important for the designer to not exceed the deflection requirements established in the AREMA recommendations.

The use of metal inner guard rails is not generally required on the track by the PCJPB. But in some situations the PCJPB may decide that it is prudent to provide guard rails at locations where track alignment, train speed, train density, type of train traffic, and type of structure is such that this additional precautionary
measure is warranted. Typically the types of structures that will be considered for guard rails are:

(a) On tracks of through-span bridges.
(b) On tracks of open floor deck bridges.
(c) On tracks where the centerline is within 10 feet of the support of an overhead or an adjacent structure.
(d) On tracks through tunnels.

2.3.2 Bridge Skew

The preferred angle of crossing and bridge structure relative to the centerline of track is 90-degrees. In cases where a 90-degree crossing cannot be obtained, the maximum skew of a bridge from the 90-degree shall not exceed 30-degrees. Prior approval from the PCJPB shall be obtained for any skew where a 90-degree crossing cannot be obtained. Skews in excess of 15 degrees are not allowed for continuous span structures and require approval of the PCJPB for the skew and the continuous structure.

If concrete structures use transverse tie rods in the end blocks and at interior diaphragms the tie rods are preferred to be perpendicular to the girder, although in some cases upon approval of the PCJPB skewed tie rods may be used. Multiple single cell concrete girders over 45 feet shall be bonded together with an epoxy grout. For steel girder span bridges the transverse diaphragms shall be perpendicular to the girders but staggered across the width of the structure in line with the skew and at the ends of the girder near the bearings a skewed diaphragm may be allowed.

If skewed abutments are approved, support perpendicular to the track alignment at the end of the skewed structure shall be provided. This squaring off of the support shall be an integral part of the abutment as shown in Figure 2.2.
BRIDGE SKEW

FIGURE 2.2 - TRACK PERPENDICULAR TO SUPPORTING STRUCTURE

Each bridge shall have a track transition at the location where the track comes onto the structure whether the bridge is skewed or not. This transition shall be a 12-inch hot mix asphalt concrete (HMAC) underlayment at each bridge approach extending 50 feet from the bridge abutments. There shall be 8 inches of ballast between the HMAC and the bottom of the tie. Across the bridge section there shall be 4-inches of HMAC on the bridge deck and the ballast depth shall remain at 8 inches beneath the tie. In addition the track ties for this transition area shall be 10 feet long. See Figure 2.3.
2.3.3 Design Loads for Railroad Bridge Structures

Underpass bridge structures shall be designed for the loads and loading conditions specified in the appropriate chapter, for the material being considered, of AREMA - Manual for Railway Engineering. For further guidance on the application of loads and their distribution to the structure refer to the Design Sections in AREMA and to its commentary as well as to the Commentary given in these guidelines located after Chapter 11.

Design live load for all structures shall be Cooper E-80 loading as shown in the AREMA recommendations. The Cooper E-80 loading is a bridge loading and special care shall be exercised if this loading is to be used for other applications.

Refer to Figure 2.4 for information on the method to distribute the track load to top of a bridge deck for ballast deck structures.

Provide individual member load tables on the project drawings with the applied impact value and impact percentage shown. Design calculations shall clearly show how the loads and impact values were developed for the design.

All new bridges shall be designed for the seismic provisions for AREMA, Chapter 9 as modified by Chapter 4 of these guidelines.

Refer to the Appendix in this standard for the typical PCJPB Track Roadbed Sections (TS-1025 and TS-1030) and to the previous transition details to develop the minimum and maximum ballast dead load for designing structures. The design shall use a minimum dead load of ballast of 12" (8" of ballast plus 4" of HMAC to be considered as all ballast for loading purposes) plus the depth of a tie. In addition a maximum ballast depth of 30" which includes the tie depth shall be used in design to account for future track raises due to track surfacing. Ballast dead load shall consider the superelevation present on curved track. The type of tie (wood, concrete, steel) used shall be considered in the determination
FOR CONCRETE STRUCTURAL DESIGN:
LATERAL DISTRIBUTION OF LIVE LOAD TO
BRIDGE DECK, PER AREMA CHAPTER 8.2.2.3.C (3)

LONGITUDINAL DISTRIBUTION OF LIVE LOAD TO
BRIDGE DECK, PER AREMA CHAPTER 8.2.2.3.C (2)

FOR STEEL STRUCTURAL DESIGN DISTRIBUTION OF LIVE LOAD SEE AREMA CHAPTER 15
FOR TIMBER STRUCTURAL DESIGN DISTRIBUTION OF LIVE LOAD SEE AREMA CHAPTER 7

TRACK LOAD DISTRIBUTION
FIGURE 2.4
of the dead load. Confirm with PCJPB the rail section and the type of ties (PCJPB prefers concrete ties) and fastening system to be used. Refer to Table 2.1 for suggested dead load values to be used for the calculations. The Commentary provides typical calculations for how the dead load weight of the track structure can be calculated.

**TABLE 2.1 – DEAD LOADS**

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>UNIT WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track rails, inside guardrails &amp; fastenings</td>
<td>200 lb/ LF of track</td>
</tr>
<tr>
<td>Sand, Gravel, or Ballast (including timber track ties)</td>
<td>120 lb/ ft³</td>
</tr>
<tr>
<td>Reinforced Concrete</td>
<td>150 lb/ ft³</td>
</tr>
<tr>
<td>Earthfilling Materials</td>
<td>120 lb/ ft³</td>
</tr>
<tr>
<td>Waterproofing and protective covering</td>
<td>Estimated Weight</td>
</tr>
<tr>
<td>Timber</td>
<td>5 lb/ foot board measure OR 60 lb/ ft³</td>
</tr>
<tr>
<td>Steel</td>
<td>490 lb/ ft³</td>
</tr>
<tr>
<td>Asphalt-mastic &amp; bituminous macadam</td>
<td>150 lb/ ft³</td>
</tr>
<tr>
<td>Granite</td>
<td>170 lb/ ft³</td>
</tr>
</tbody>
</table>

Impact load for the structural material shall be per AREMA recommendations with the following clarification:

- **Steel Bridges** – The impact shall be considered for rolling equipment without hammer blow (freight and passenger cars, and locomotives other than steam).
- **Reinforced Concrete** – The impact load shall be considered for diesel engine impact as listed in Chapter 8, Part 2 of the AREMA Manual.
- **Prestressed Concrete Structures** – The impact load shall be as listed in Chapter 8, Part 17 of the AREMA Manual.

Impact loads shall be applied to the structure per AREMA recommendations and generally be applied as follows:

- **Group I** – Items in which Impact applies:
  1. The superstructure, including steel or concrete support columns, steel tower, legs of rigid frames, and generally those portions of the structure that extend to the main foundation;
  2. That portion of concrete or steel piles above the ground line where they are rigidly connected to the superstructure, as in rigid frames and continuous structures.
  3. That portion of cap or beam and supported piles in a spill through abutment or that are above the invert or roadway surface underneath the bridge.
• **Group II** – Items to which Impact does not apply:
  1. Abutments, retaining walls, wall type piers, and piles;
  2. Foundation piles and footings;

Non-prestressed components of prestressed members shall be designed using the impact formula per AREMA, Chapter 8, Part 2, (e.g. top slabs in prestressed box girders carrying loads in the transverse direction and decks on prestressed girders carrying loads in the transverse direction). The prestressed components shall use the impact formula per AREMA, Chapter 8, Part 17.

Under normal working loads, some composite action may be expected between a concrete deck and its supporting steel members, whether or not special devices are furnished for shear transfer. For design purposes, however, use non-composite action to proportion the supporting steel members for E-65 live, impact, and dead loads and consider composite action for E-80 live, impact, and dead loads. The bottom of the deck slab shall be placed at least one inch (1") below the top of supporting steel members. Composite action may be taken into account when satisfying the deflection-length ratio requirement of AREMA – Chapter 15, Part 1, Section 1.2.5 provided shear transfer devices are installed. For steel decks welded to the top flanges of multiple I beam girders the composite action shall be considered only for deflection and not for the satisfying the strength of the girder.

On ballast deck structures the live load shall be distributed per the AREMA recommendations. See Figure 2.4 for typical load distribution. For precast, prestressed, single or double cell box girders this live load shall not be assumed to be distributed uniformly to all the boxes over the width of the bridge but shall be distributed to the individual box girders per the distribution in the AREMA recommendations. All precast box girders for a structure shall be designed for the same loading condition, taking into consideration that a track could be shifted anywhere on the deck in the future. An example would be for a single-track bridge where there where there are 8 single cell girders side by side in a bridge, but the normal distribution of the load per AREMA recommendation to the top of the girders would be distributed to only 4 of the girders. Therefore each of the 8 girders would be designed for the same loading as one of the girders in the 4 girder distribution of the live load. (In other words each single cell girder would not be designed for the track loading divided by the eight girders.) This requirement exists so that the track can be moved to any location on the bridge deck. It also assumes that no load sharing takes place between girders or that during the life of the structure any bond between that was designed into the girders may have been lost.

### 2.4 Clearances

#### 2.4.1 General

The provisions for clearances along the PCJPB corridor are stated in this standard in the following sections. Consideration shall be given to the requirements of the following documents.
- PCJPB clearances as listed PCJPB Engineering Standards, Foreword, 3 sheets.

- AREMA – Manual for Railway Engineering, Chapter 28, Figure 28-1-2, Railway Bridges.

- Union Pacific Railroad – Standard Minimum Operation Clearances, Standard drawing 0038A. To be used on structures of the UPRR.

- In all cases the absolute minimum clearances stated in the California Public Utilities Commission General Orders (CPUC G.O.) shall be maintained on all structures.

Clearance diagrams shall be clearly shown on the design drawings.

### 2.4.2 Vertical Clearances

Provide sufficient vertical clearance and protection devices above the vehicle roadway surface to shield the railroad structure from collision of oversized and high loads. Projects shall be designed for minimum vertical clearance of 16'-6" for Freeways and Expressways. Minimum vertical clearance for conventional highways and local streets shall be at least 15'-6". The vertical clearance shall be applied to the entire width of the roadway that is available for traffic. Due consideration shall be given to the need to apply overlays to the street surface and the above clearances adjusted accordingly.

All concrete structures shall have a collision impact device installed over the full width of the approaching travel lanes and attached to the bridge soffit (Clearances listed above shall include an allowance for the collision impact device). A suggested detail as shown in Figure 2.5 is to be applied on all new structures. Structures that require retrofit or rehabilitation shall be evaluated for the appropriate detail to use.

![Figure 2.5 - Collision Impact Device](image)

**FIGURE 2.5 – COLLISION IMPACT DEVICE**

All steel structures that do not meet the clearance requirements stated above shall have the bottom flange of the girder constructed of bolted elements (e.g. angles and plates).

All new railroad structures with clearance less than the clearances noted above shall have a sacrificial beam installed across the full width of the approaching...
travel lanes to the structure. Sacrificial beams shall be installed a minimum of 5 feet ahead of the structure and at the same elevation as the soffit of the railroad structure as shown in Figure 2.6. Sacrificial beam shall not carry any railroad loads and shall be anchored sufficiently to the bridge substructure. The sacrificial beam system shall be designed to withstand the impact of a vehicle collision and shall be prevented from falling onto the roadway surface. The sacrificial beam system can have aesthetic treatments as required as long as it does not interfere with the maintenance of the railroad structure. The retrofit of any structure with a sacrificial beam shall be on a case by case basis and in which other clearance options have been explored.

The PCJPB shall be formally notified prior to any resurfacing of the roadway or other work under a railroad structure. The notification shall include sufficient detail to determine if the clearance under the structure or the structure itself will be compromised or not. Final approval from the PCJPB shall be obtained prior to any work being performed.

The owner of the roadway shall be responsible for posting and maintaining structure sign vertical clearances and for any automatic advance street notification system as required.

The design for roadway profiles shall consider the future widening of the railroad bridge structure to accommodate additional tracks along the PCJPB corridor. Consult with the PCJPB to obtain clarification and direction on the PCJPB's future plans.

For structures over waterways the freeboard required shall be per the requirements of the agency that regulates the waterway, but in no case shall the freeboard be less than 2 feet clear above high water as defined by a 100-year flood event. Also, the top of tie elevation of the track shall not be less than 4 feet above the 100-year flood event. If these parameters are not met then an enlarged structure opening or other solution shall be considered. For areas that
LAYOUT OF SACRIFICAL BEAM
involve the San Francisco Bay, such as for the Dumbarton line, the requirements for freeboard shall be handled on a case by case basis.

The preferred vertical clearance above any bridge structure is 25'-6" measured from top of rail. The minimum vertical shall be 24'-6" with an absolute minimum of 23'-6" only allowed under special circumstances.

2.4.3 Horizontal Clearances

The following minimum horizontal clearances on structures, measured from the centerline of track shall be as follows:

- To the face of railing, barrier, or fencing on bridges:
  10'-0" Recommended
  9'-0" Minimum
- On structures at stations:
  Per PCJPB Facilities Guidelines for platforms required for the loading and unloading passengers, etc.

2.5 Special Provisions

2.5.1 Concrete Structures

Substructure concrete shall have a minimum compressive strength of 3600 psi at 28 days.

Superstructure concrete shall have a minimum compressive strength of 4500 psi at 28 days.

Reinforcing Steel shall conform to ASTM A615 or A706 depending on the application. ASTM A706 reinforcing shall be used when detailing for seismic requirements.

When a cast-in-place concrete deck is to be used to retain the ballast on a steel or concrete structure the use of stay in place metal deck forms are not permitted. Stay in place forms do not allow inspection of the placed concrete deck soffit, can trap moisture leading to the corrosion of the steel form, and prevent maintenance and inspection of the bridge deck.

(a) Precast Prestressed Box or AASHTO Girder

Manufacturers of prestressed products shall be certified by the Prestress Concrete Institute Plant Certification Program in Product Group and Category B4.

AREMA does not allow service load tension in prestressed concrete members.

Precast prestressed girders (Single or double cell boxes or AASHTO type) shall be designed with end and interior diaphragms. Interior diaphragms shall be spaced equally across the span length. Diaphragms spacing should not exceed
25 feet center to center. Provide the minimum number of diaphragms per span length as shown:

<table>
<thead>
<tr>
<th>Span Length (in feet)</th>
<th>Number of Interior Diaphragms</th>
</tr>
</thead>
<tbody>
<tr>
<td>35-50</td>
<td>1</td>
</tr>
<tr>
<td>51-75</td>
<td>2</td>
</tr>
<tr>
<td>Over 76</td>
<td>3</td>
</tr>
</tbody>
</table>

Where transverse tie rods are required they shall be installed at the end diaphragm and each interior diaphragm. Minimum size of tie rod shall be 1-¼ inches in diameter. The tie rod assembly including all plates and hardware shall be hot dipped galvanized per ASTM A123 and A153.

Tie rod anchor assembly shall be recessed into the concrete and shall have a minimum of one-inch grout cover.

Strands at the ends of the precast prestressed members shall be cut one-inch minimum into the member and the resulting recessed pocket filled with grout.

Notching the ends of concrete girders or beams should not be considered.

For AASHTO beams the designer shall provide eighteen (18) inches clear between girder bottom flanges of beams to accommodate inspections and repairs.

Precast prestressed concrete box girders with interior voids shall be fabricated with witness holes in the bottom slab. Holes shall be located at the ends and middle of the girder and/or shall be located on either side of interior diaphragms.

(b) Post-Tensioned Concrete Structures

Provisions are included here in case these types are finally selected for the bridge structure type and have approval from the PCJPB. Note that continuous cast-in-place structures are not preferred as previously mentioned in section 2.2.

All post-tensioned concrete structure ducts shall be bonded (grouted).

(i) Simple Span Structures

Precast Post-tensioned simple spans members, shall in any load condition, and during all stages of construction, require that the bottom fiber not develop any tension and the top fiber shall have at least a minimum compressive stress of 100 psi. At no time shall any variance occur either during construction or under any load configuration from these minimum requirements.

(ii) Continuous Span Structures

Post-tensioned, continuous structures shall be designed for a minimum compressive force of 200 psi in the topmost regions of the element, and 50 psi minimum compressive force at lowermost regions of the element in
the positive moment regions of the structure. In the negative moment regions of the structure the requirement will be reversed such that a minimum compressive force of 50 psi will be required in the topmost regions of the element and a minimum compressive force of 200 psi in the lower most regions of the element. These minimum compressive force requirements must be maintained during any stage of construction or any loading case.

2.5.2 Steel Structures

The minimum thickness for structural steel members (except for fillers) is ½ inch, including gusset plates for trusses.

High strength bolts shall be ASTM A325, type III with an allowable shear strength of 13.5 ksi for primary loads and 17.0 ksi for primary plus secondary loads. The minimum high strength bolt diameter is 7/8 inch. Prior approval from PCJBP is required for the use of A490 bolts, or the higher allowable values shown in AREMA.

The allowable bearing pressures on bearing surfaces for steel structures are given in the AREMA recommendations, Chapter 15.

All fracture critical members (FCM) and connections shall be designated on the project plans.

Floor beams shall be a minimum of 18 inches in depth, but must satisfy the stress and deflection requirements given in AREMA.

All exposed portions of the structure shall be designed to be accessible for inspection and maintenance. 18" is preferred clear spacing between flanges on parallel beams having depths greater than 36".

Provisions for permanent jacking locations shall be provided on all steel spans to permit future maintenance of bridge bearings. Jacking locations shall be provided with jacking pads, jacking stiffeners, and connections capable of supporting the applicable dead load of the structure. A minimum of 12 inches shall be provided between the bridge seat and the bottom of any jacking surface to allow for placement of jacks.

All through plate girder and through truss type spans shall have an end floorbeam. Stringers at the end of a floor system, such as in a through truss or through plate girder type, shall be supported by an end floorbeam. Stringers shall not be allowed to be supported on independent bearings at the bridge ends.

All main load carrying steel members subject to tension stress shall meet the recommendation for notch toughness per AREMA.

AREMA recommendations do not use tension field design for steel girder webs.

Welded girders shall not be used where the vertical clearance is less than that stated in the vertical clearance section of these guidelines. If the vertical
clearance is less than that allowed the bottom flange of girders shall consist of bolted construction (e.g. angles and cover plates).

All steel structures shall be painted except where galvanized or weathering steel is used. The PCJPB prefers the use of unpainted weathering steel except in those locations where the environment is not conducive for establishing a stable finish on the steel. A stable finish cannot be established in a corrosive environment such as over brackish water or near a plant emitting chlorides, sulfides, etc. Painting shall conform to the current requirements of AASHTO or Caltrans specifications and recommendations of the Steel Structures Painting Council Manual (SSPC). Paint shall be applied in accordance with the Manufacturer's recommendation or in compliance with the recommendation of SSPC, whichever is most restrictive.

For all steel structures the provisions for quality of workmanship in fabrication require that the fabricator shall be currently certified for the type of structure being fabricated under the AISC Quality Certification Program for Major Steel Bridges (Cbr). Additionally, the fabricator shall currently have the following endorsements if they apply to the type of structure being fabricated, Fracture Critical Endorsement (F) and/or Sophisticated Paint Endorsement (P).

2.5.3 Ballast Deck Bridge Structures

For a tangent single-track bridge structure the width of the deck shall not be less than 20 feet for bridges without separate walkways or grating walkways, measured from inside face of curb to inside face of curb. The clear distance from centerline of track to inside face of curb shall not be less than 10 feet. The minimum ballast trough width from centerline of track may be 7 feet 6 inches if a solid walkway (e.g. concrete) is used which will also include a curb and toe-board incorporated into the walkway.

The top of ballast curb shall be approximately the same elevation as the base of the highest rail plus a minimum of 8 inches. The additional height will accommodate future track raises and must be high enough to keep ballast from spilling over and off the bridge when these track raises are made. In addition other suitable means can be provided to prevent ballast from falling off bridge decks, such as providing additional screening 1'-0" high along the bridge edges.

Walkways shall be provided on both sides of the deck. Walkways shall not be less than 2 feet wide. Where structural members (such as floor beam knee braces) encroach into the walkway area it shall not be considered as an obstruction to the walkway (see CPUC GO 26-D). Ballast walkways are preferred, especially on bridges less than 100' long, to allow for flexibility in future track relocations and to allow placement of signal cables in the ballast section. If necessary and with the PCJPB's concurrence the walkways can be either concrete or metal grating. Ballast decks shall be designed to allow tracks to be moved anywhere on the deck. Ballast retainers and curbs shall not be constructed between tracks, unless they are for temporary use.

Handrails shall be provided on both sides of the deck. Handrails shall be designed to require a minimum of maintenance and not impinge on the minimum
clearance requirements. PCJPB recommends the following types of handrails, which will depend on the location where it is to be installed:

1) Chain link railing (6' high) with a 1" x 1" opening (1" mesh). Suitable for pedestrian overpasses and over freeways.
2) Tubular hand railing. Suitable over local streets and highways.
3) Picket hand railing. Suitable over local streets and highways.
4) 3/8" diameter cable handrail with a minimum of 3 separate cables. Suitable over water courses and local streets.

All ballast troughs shall be sloped transversely not less than 0.5% for drainage. Low points in the ballast trough shall not occur under a track and shall be located not less than 7 feet from the centerline of track. A longitudinal and transverse collection system shall be provided to transfer drainage water off of the bridge structure away from the track roadbed to an approved discharge location.

All composite decks, cast-in-place concrete decks, and steel ballast pans shall be waterproofed when the HMAC underlayment is not provided on the deck. When the HMAC underlayment is used the bridge joints and expansion joints shall be waterproofed (e.g. a possible waterproofing system is the MEL-DEK system manufactured by W. R. Meadows). Structure ballast decks located over roadways or pedestrian walkways shall be waterproofed. Approval from the PCJPB shall be obtained to eliminate the HMAC on bridge decks. All top slabs of precast prestressed concrete structures and concrete decks that do not require waterproofing shall be sealed with an approved concrete sealer. Waterproofing systems shall conform to AREMA recommendations (Chapter 29) and shall be approved by PCJPB.

For ballast deck bridges the transition from the bridge to the track roadbed shall be designed to prevent ballast from spilling over. Ballast shall be prevented from spilling onto the tops of abutments and piers and kept away from bridge bearings. Ballast shall be prevented from spilling onto highways and walkways below bridge structures. Ballast shall be prevented from spilling down the track roadbed embankment behind bridge abutments. Appropriate wingwalls and breast boards shall be provided to contain the ballast at the transition from bridge to track roadbed. Walkway requirements shall be extending off the bridge structure.

2.5.4 Railroad Electrification

PCJPB/Caltrain is planning for future electrification (25kV AC 60Hz) of the corridor. All structures shall provide for a future overhead catenary system. Space for catenary support poles along the right-of-way and on structures shall be provided for. Overhead (vertical) clearance and horizontal clearance shall
comply with the following references; CPUC—GO-26 and GO95, NESC, NEC, and AREMA Chapters 28 and 33.

All concrete superstructures and substructures shall be detailed to mitigate the effects of stray current corrosion of steel reinforcing, prestressing elements, and other steel components. This will require that electrical continuity be provided between all steel elements within each concrete structural component and be run to a central location at time the structure is designed. When the corridor is electrified the central location points will be connected to the corrosion control system. Comply with GO95, AREMA Chapter 33, IEEE, NESC, and NEC provisions for stray current.

2.6 Substructure

The substructure elements shall be designed in accordance with appropriate sections of AREMA and per Caltrans. In addition to this section refer to Chapter 9 Retaining Walls of these guidelines for further information on abutments.

2.6.1 General Layout

The abutments and wingwalls shall be wide enough to support the standard PCJPB track roadbed section (see PCJPB track standard T. S. 1025 and T. S. 1030) from shoulder to shoulder. Abutments/Wingwalls shall provide for the support of the sacrificial beam when required. The abutment width shall be sufficient to provide for a 13-foot shoulder on both sides measured from the centerline of the track. In multiple track areas the minimum track centers shall be considered as 15' for use in determining abutment widths. Track centers and future tracks shall be discussed with PCJPB prior to design. Wingwalls shall be designed to support the PCJPB standard embankment slope shown on the standards PCJPB Track Standards TS-1025 and TS-1030.

Handrails for bridges shall be returned on the backwall of the abutment and/or wingwalls.

Provide a minimum of 12 inches from the edge of the masonry plate or shoe to the edge of abutment or pier seat. Also, a minimum of 12 inches shall be provided vertically between the bridge seat and bottom of all beams and girders to allow for future jacking. If this jacking area is not possible, jacking pockets with a 12" x 12" seat shall be provided in front of the bridge bearing.

Slope top of abutment and pier to drain. If weathering steel is used in the superstructure the top of the abutment or pier seat shall incorporate a method for collecting and disposing of drainage water in order not to stain the exposed face of the abutment or pier.

Piers with two columns or a solid pier wall are preferred over single column piers.
2.6.2 Geotechnical Investigation

Each bridge location shall have an investigation into the soils at a bridge site. Refer to AREMA Manual Chapter 22 for guidance on geotechnical information required for railroad bridges.

Depending on the nature and importance of the bridge work required the designer shall at the least research the existing geotechnical information available. Information may be obtained from the PCJPB or from other public agencies. This is all that may be required for simple structures. For more complex structures and new bridges the investigation may require boring to characterize the nature of the soils and foundation type recommendations at each abutment and pier. It is recommended that at least one boring occur at each abutment and pier location for new structures.

The geotech report shall include an evaluation of the geological formations and soils at the project site. It shall also describe and evaluate any seismic hazards that are present, such as expected ground shaking that can occur and the potential for liquefaction. The report shall give recommendations on the type of foundation suitable for the site and the structure and provide seismic data, such as peak ground acceleration, that should be used. Recommendations shall include the recommended elevations for spread footings, pile type and tip elevations.

The geotech report shall contain any special requirements regarding potential constructability problems including caving, soil compaction issues, variations that may be expected in pile driving, and any groundwater issues, etc. The geotech shall recommend any job specific specification that should be followed as part of the report.

2.6.3 Foundation Types

Structure foundations can generally classified in the following categories: (1) footing foundations (also referred to as spread footings), (2) pile supported foundations (driven or non-driven piles); (3) special foundation types which would include pier columns and tiedowns.

For pile supported foundations, it is the designer’s responsibility to select the pile type consistent with the Foundation Report’s recommendations. Also, the selected pile type should fulfill the requirements for economy, competitive bidding, and availability for the particular conditions prevailing at the site, especially the PCJPB train operating conditions that will occur during foundation installation.

In cases where both footing and pile foundations are applicable, existing field conditions as well as economics will determine the foundation type. While the foundation type selection is primarily determined by the geological nature of the foundation material itself, non-geologic features are considered in the selection and design of structure foundations.
A seal course is frequently specified as a foundation aid when water problems are anticipated. Seal course concrete can be placed under water, the general purpose being to seal the bottom of a tight cofferdam against hydrostatic pressure. This enables dewatering of the cofferdam and construction of the footing "in the dry".

Generally, footing foundations are more economical than pile supported foundations. CIDH concrete piles are the most economical pile supported foundation with steel piles being the most expensive.

Pile type comparisons may be found in Table 2.2.

- **Spread Footing Foundations:**

  Footing foundations transmit design loads into the underlying soil mass through direct contact with the soil immediately beneath the footing; whereas pile supported foundations transmit design loads through pile friction, end bearing or both.

  Since the load bearing capacity of most soils is relatively low, footing areas will be large in relation to the cross section of the supported member, i.e., columns.

  Each individual footing foundation must be sized so that the maximum soil bearing pressure does not exceed the allowable soil bearing capacity of the underlying soil mass. In addition, footing settlement must not exceed tolerable limits established for differential and total settlement as established by the geotech. Refer to Design Manual 7.02 – Foundations and Earth Structures, NAVFAC DM-7.02 for guidance on the settlement of structures. Each footing foundation must also be structurally capable of spreading design loads laterally over the entire footing area.

  Footing foundations can be classified into two general categories: (1) footings that support a single structural member, spread footings, and (2) footings that support two or more structural members, combined footings.

  Also refer to Chapter 9 on retaining walls.
### TABLE 2.2 – PILE TYPES

<table>
<thead>
<tr>
<th>PILE TYPES</th>
<th>DESCRIPTIONS</th>
<th>GEOLOGIC FACTORS</th>
<th>NON-GEOLOGIC FACTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Footing Foundations</td>
<td>Virtually unlimited in use</td>
<td>The soil profile, the location of the water table and any potential fluctuation, and the potential for scour or undermining.</td>
<td>The size and shape of the footing, adjacent structures, and existing utilities</td>
</tr>
<tr>
<td>Drive Piles</td>
<td>Used where foundation material will not support a footing foundation or discourages the use of a Cast-In-Drilled Hole (CIDH) concrete pile. Pile types are precast concrete, steel structural sections, steel pipe and timber.</td>
<td>Soil profile, driving difficulties and corrosive soil problems.</td>
<td>Adjacent structures, existing utilities, required pile length, restricted overhead clearances, accessibility and noise restrictions.</td>
</tr>
<tr>
<td>Non-driven Piles</td>
<td>Consists of CIDH concrete piles and alternative footing design piles, i.e., GeoJet, Tubex, Pin Piles. CIDH piles are extensively used where piles are required and foundation conditions permit their use. The slurry displacement method of construction of CIDH piles is used where driven piles are impractical and ground conditions necessitate its use. Alternative footing design piles are used when conditions warrant their use.</td>
<td>Location of water table and potential fluctuation, and the soil profile</td>
<td>Adjacent structures, existing utilities, restricted overhead clearances and accessibility.</td>
</tr>
<tr>
<td>Special Case: Tiedowns or Tension Piles</td>
<td>Used typically for seismic retrofitting of existing footing where overturning needs to be addressed, or specially needs.</td>
<td>Location of water table and potential fluctuation, and the soil profile</td>
<td>Adjacent structures, existing utilities, restricted overhead clearances and accessibility.</td>
</tr>
</tbody>
</table>

- **Driven Concrete Piles:**

Driven concrete piles come in a variety of sizes, shapes and methods of construction. In cross section, they can be square, octagonal, round, solid or hollow. These piles generally vary in sizes from 10 to 60 inches. They can be either conventionally reinforced or prestressed (most common). They can also be either precast (most common) or they can be cast in driven steel shells. The types of steel shells vary from 10 to 18 inches in diameter for heavy walled pile which are driven directly with the hammer, to thin walled or step-taper pipes.
which are driven with a mandrel. The steel shell may have a flat bottom or be pointed, and may be step-tapered or a uniform section (such as a Monotube pile). Splicing precast concrete piles is difficult, time consuming, and expensive. Hence, when excessively long piles are required to obtain necessary bearing, precast piles may be precluded.

The unit cost to furnish concrete piles is usually lower than the steel equivalent. But this cost is often offset by the requirement for a larger crane and hammer to handle the heavier pile. This is particularly true when there are a small number of piles to drive.

Cast-in-Steel-Shell (CISS) piles are typically large diameter reinforced concrete piles cast in driven steel shells. Because of the large diameter of the driven element, steel shells are typically driven open-ended. The project geotechnical engineer needs to recommend the required soil plug to adequately resist the hydrostatic pressure.

- **Driven Steel Piles:**

  Steel piling includes “H” piles and pipe piles (empty or concrete filled). The pipe section is a standard alternate for precast piles, but is seldom selected. Steel pipe piles for the PCJPB shall be concrete filled and have reinforcing bar cages installed in the pile that run into the pile cap for attachment.

  Although steel piling is relative expensive on a per foot furnish basis, it has a number of advantages. They come in sizes varying from HP 8x36 to HP 14x117 rolled shapes or may consist of structural steel plates welded together. They are available in high strength and corrosion resistant steels. They can penetrate to bedrock where other piles would be destroyed by driving. However, even with “H” piles, care must be taken when long duration hard driving is encountered as the pile tips can be damaged or the intended penetration path of the pile can be drastically deflected. Some of this type of damage can be prevented by using a reinforced point on the pile. Due to the light weight and ease of splicing, they are useful where great depths of unstable material must be penetrated before reaching the desire load carrying stratum and in locations where reduced clearances required use of short sections. They are useful where piles must be closely spaced to carry a heavy load because they displace a minimal amount of material when driven.

  Splice details should be shown in contract plans. Pile welding work requires special attention and various methods can be used to pre-qualify welders who will be performing the work.

  Sometimes “H” piles (and can apply to all pile types) must be driven below the specified tip elevation before minimum bearing is attained. This can present a construction administrative problem (cost) if the length driven below the specified tip elevation is significant. Steel lugs welded to the piles are commonly used to solve this problem.
- **Driven Timber Piles:**

Although rarely used in modern permanent construction, treated timber piles are commonly found in existing railroad trestles, foundations below masonry and concrete piers, and in protective fenders around piers in navigable waterways. Untreated timber piles are still occasionally used for temporary construction, such as shoring and falsework.

Even treated timber is vulnerable to decay, except underground where oxygen is in short supply. Unless protected with some sort of jacket or protective wrap, marine borers in salt or brackish water can damage the piles. On the other hand, timber is inherently resistant to impact loading and fatigue. Treated timber piles may be used for fender systems or temporary construction only.

The maximum allowable bearing capacity of a timber piles is typically limited to around 45 tons, whereas most steel or concrete piles will support at least 75 tons. Timber piles are difficult to splice, and thus are usually used as single unspliced piles under 60 feet in length. They are not suitable where a deeper penetration is required.

Railroads typical have many existing timber pile structures in use and are phasing out timber trestles as funds become available, typically replacing them with precast concrete girder bridges on steel or concrete piles. Many timber trestles are still maintained in service, however. Furthermore, concrete and masonry piers founded on timber piles are very common and continue to perform well because buried piles, practically sealed from an appreciable supply of oxygen, do not decay.

- **Alternative Piles:**

These piles may be used for special applications. They are: the GeoJet Foundation Unit, the Tubex Grout Injection Unit, the Nicholson Pin Pile, and the Soil-Cement Pile. The GeoJet Foundation Unit consists of a structural member inserted into an augured soil cement column. The Tubex Grout Injection Unit is a steel pile with a special cast iron tip filled with concrete surrounded by an injected grout/soil mixture layer. The Nicholson Pin Pile is a bored cast-in-place pile with a reinforcing bar in a grouted hole. Soil-Cement piles have successfully been used in several projects along the PCJPB corridor. Originally used for shoring tunnel walls during cut-and-cover construction for BART and VTA, these piles have performed well in railroad bridge abutments and walls of pedestrian tunnels under PCJPB tracks.

Construction of soil-cement piles on PCJPB projects has been to first run an auger, typically 24 to 42 inches in diameter, into the ground. Cement grout is injected into the soil from nozzles on the auger as it is backed out of the ground, creating a column of mixed soil and grout. An HP pile or wide flange section is vibrated into the mixture while it is still soft. The pile unit becomes functional as part of a retaining wall or as a load bearing pile after the soil-cement mixture gains strength. Depending on the end product a cap can be welded or cast onto the top of several piles.
Cast-in-Drilled Hole Piles:

These piles are simply reinforced concrete piles cast in holes drilled to predetermined elevations. Diameters range from 12 to 126 inches and lengths range from 10 feet to over 120 feet. They are satisfactory in suitable material and are generally more economical than most other types of piling. They are especially advantageous where vibration from a pile driver might damage adjacent structures such as pipelines, etc.

Much experience has been gained with this pile type because of their extensive use in the construction of bridge structures. While they are the most economical of all commonly used piles, their use is generally limited to certain ground conditions.

The ground formation in which the holes for CIDH piles are to be drilled must be of such a nature that the drilled holes will retain their shape and will not cave in when concrete is placed. Because of cave-in and concrete placement difficulties, these piles are not recommended for use as battered piles. Nor are they recommended where groundwater is present, unless dewatering can be done without unreasonable effort and unless concrete can be placed with a casing that is removed during construction or a casing that remains in place (a type of CISS pile). If groundwater or caving conditions are present, the piles can be constructed by the slurry displacement method if permitted in the contract specifications.

2.7 Construction Specifications

Technical Specifications for bridge construction shall comply with the following:
- PCJPB recommendations presented in these guidelines
- AREMA – Manual of Railway Engineering, Volume 2, Structures
- Caltrans Standard Specifications
- Standard Specification for Public Works Construction
- American Association for State Highway and Transportation Officials Specifications

Development of construction specification for PCJPB projects shall follow the format established by CSI.

2.8 Miscellaneous

PCJPB projects shall show all primary dimensions in drawings for bridges and underpass grade separation structures in English units. Projects that require the use of metric units shall indicate all dimensions and design criteria assumptions in dual units on the project general plan sheet. English units are to be shown in parentheses. Primary dimensions refer to but are not limited to the following:

a) Horizontal and vertical clearances.
b) Track spacing, track stationing, and railroad right-of-way.
a) Top of rail elevation over structure and grade profile.
b) Span length, width and depth of superstructure elements.
c) Size and limits for barriers and fences.
d) Location and elevation of underground or aerial utilities and their relocation adjustments if required.

e) Size, elevation and location of pier or abutment footings for spans adjacent to railroad tracks.

f) Size of structure supports (pier or abutment walls, columns).

g) Size and elevations of pier protection walls, if required.

h) Shoring location and limits, if required.

i) Size and location of drainage structures and ditches.

j) Temporary construction vertical or horizontal clearances, if required.

All estimates for bridge construction in addition to the total cost shall have the bridge cost expressed in track feet. Track foot cost shall be computed by the following formula:

\[
\text{Total Railroad Bridge Cost} = \frac{\text{Bridge Length} \times \text{Number of Tracks}}{} 
\]
STEEL BEAMS (MIN 4 PER TRACK)

NO SCALE

SPAN RANGE
0'-50' STEEL ROLLED BEAMS
50'-150' STEEL PLATE GIRDERS
(MIN. 4 BEAMS PER TRACK)

DEPTH (SOFFIT TO T/R)
0.08 x SPAN + 2.90' (CONCRETE DECK)
0.08 x SPAN + 2.45' (STEEL DECK)

ADVANTAGES
* SIMPLE CONSTRUCTION

DISADVANTAGES
* REQUIRES SEPARATE CONCRETE DECK PLACEMENT

NOTES:
1. SHOWN WITH CPF CONCRETE DECK. A STEEL DECK COULD ALSO BE USED.
2. DOUBLE TRACK SHOWN, OTHER TRACK ARRANGEMENTS MAY BE REQUIRED.
3. COST RANK 7/10.

THE MINIMUM DEPTHS SHOWN ARE RECOMMENDED FOR PLANNING STAGE DEVELOPMENT. LESSER DEPTHS MAY BE USED IF AREMA REQUIREMENTS FOR STRESS AND DEFLECTION ARE SATISFIED.

STEEL BEAM SPAN

FIGURE 2.7
NOTES:
1. SHOWN WITH OPTIONAL CONCRETE DECK.
2. DOUBLE TRACK SHOWN, OTHER TRACK ARRANGEMENTS MAY BE REQUIRED.
• IF APPLICABLE, MAY NOT BE REQUIRED ON BRIDGES OVER CREEK AND WITH DOUBLE CELL PRESTRESSED/PRECAST BOX GIRDER.

PRESTRESSED/PRECAST GIRDER SPANS OVER ROADWAYS, PEDESTRIAN UNDERPASS SHALL HAVE A WATERPROOF DECK.

**PRECAST CONCRETE BOX GIRDER**

**SPAN RANGE**
- 0'–20' SOLID SLAB GIRDER (NO VOID)
- 20'–44' DOUBLE BOX GIRDER
- 44'–70' SINGLE BOX GIRDER

**DEPTH (SOFFIT TO T/R)**
0.08 x SPAN + 2.30' (WITHOUT CONCRETE DECK)

**ADVANTAGES**
- SIMPLE CONSTRUCTION
- EASY TO REPLACE
- NO SEPARATE DECK FLOOR REQUIRED
- FALSEWORK NOT REQUIRED DURING CONSTRUCTION.

**DISADVANTAGES**
- HIGHER COST FOR A CONCRETE BRIDGE

THE MINIMUM DEPTHS SHOWN ARE RECOMMENDED FOR PLANNING STAGE DEVELOPMENT. LESSER DEPTHS MAY BE USED IF AERMA REQUIREMENTS FOR STRESS AND DEFLECTION ARE SATISFIED.

**PRESTRESSED PRECAST CONCRETE BOX GIRDER SPAN**
**FIGURE 2.8**
STEEL DECK PLATE GIRDERS (2 PER TRACK)

NO SCALE

SPAN RANGE
50'-150' (2 GIRDERS PER TRACK)

DEPTH (SOFFIT TO T/R)
0.10 x SPAN + 2.90' (CONCRETE DECK)
0.10 x SPAN + 2.45' (STEEL DECK)

ADVANTAGES
• SIMPLE CONSTRUCTION

DISADVANTAGES
• REQUIRES SEPARATE CONCRETE DECK PLACEMENT
• SUPERSTRUCTURE NOT AS REDUNDANT
• FRACTURE CRITICAL DESIGN — CONSIDER BOLTED BOTTOM FLANGE TO WEB DETAIL.
PRECAST CONCRETE BEAMS WITH CAST IN PLACE CONCRETE DECK

NO SCALE

SPAN RANGE
20'-70'

DEPTH (SOFFIT TO T/R)
0.08 x SPAN + 2.90'

ADVANTAGES
- LOW COST
- EASY TO REPLACE

DISADVANTAGES
- REQUIRES SEPARATE CONCRETE DECK AND DIAPHRAM PLACEMENT

NOTES:
1. DOUBLE TRACK SHOWN. OTHER TRACK ARRANGEMENTS MAY BE REQUIRED.
2. COST RANK 4/10.

THE MINIMUM DEPTHS SHOWN ARE RECOMMENDED FOR PLANNING STAGE DEVELOPMENT. LESSER DEPTHS MAY BE USED IF AREMA REQUIREMENTS FOR STRESS AND DEFLECTION ARE SATISFIED.
CONVENTIONAL REINFORCED CONCRETE BOX GIRDERS
CAST-IN-PLACE POST-TENSIONED CONCRETE BOX GIRDERS

NO SCALE

SPAN RANGE
50'-250'

DEPTH (SOFFIT TO T/R)
0.08 x SPAN + 2.30'

ADVANTAGES
• LOW COST
• FAMILIAR CONSTRUCTION
  PROCEDURES IN CALIFORNIA

DISADVANTAGES
• LONG CONSTRUCTION TIME
• Requires Falsework
• Precast preferred by railroads

THE MINIMUM DEPTHS SHOWN ARE RECOMMENDED FOR PLANNING STAGE DEVELOPMENT. LESSER DEPTHS MAY BE USED IF AREA REQUIREMENTS FOR STRESS AND DEFLECTION ARE SATISFIED.

CAST-IN-PLACE CONCRETE BOX GIRDER SPAN CONVENTIONAL REINFORCED

CAST-IN-PLACE POST-TENSIONED CONCRETE BOX GIRDER SPAN

FIGURE 2.11
STEEL THROUGH PLATE GIRDER SPAN

NOTES:
1. STEEL DECK SHOWN, CONCRETE DECK COULD ALSO BE USE.
2. DOUBLE TRACK SHOWN, OTHER TRACK ARRANGEMENTS
   MAY BE REQUIRED.
3. COST RANK 9/10 THROUGH GIRDER
   10/10 THROUGH TRUSS

STEEL THROUGH PLATE GIRDER

NO SCALE

SPAN RANGE
50'-150' THROUGH GIRDER (TG)
150'-500' THROUGH TRUSS

DEPTH (SOFFIT TO T/R)
0.08 x SPAN (MAIN GIRDER, SINGLE TRACK-TG)
0.095 x FLOORBEAM LENGTH (MIN 18") + 2.5' (STEEL DECK-TG)
0.095 x FLOORBEAM LENGTH (MIN 18") + 3.0' (CONC DECK-TG)
7" FOR THROUGH TRUSS

THE MINIMUM DEPTHS SHOWN ARE RECOMMENDED
FOR PLANNING STAGE DEVELOPMENT. LESSER
DEPTHS MAY BE USED IF AREMA REQUIREMENTS
FOR STRESS AND DEFLECTION ARE SATISFIED.

ADVANTAGES
* LOW PROFILE FOR SPAN LENGTH
  (SLIGHTLY HIGHER COST W/CONCRETE DECK)

DISADVANTAGES
* SUSCEPTIBLE TO DAMAGE
* REPLACEMENT SUBJECT TO LONG LEAD TIME
* LIMITED TO ONE TRACK BETWEEN GIRDER
  (TWO POSSIBLE WITH DEPTH INCREASE)
CHAPTER 3
GRADE SEPARATIONS
OVER RAILROADS
(OVERPASSES)
CHAPTER 3
GRADE SEPARATIONS OVER RAILROAD (OVERPASSES)

Purpose

This guideline was created to provide standards and requirements regarding design and construction of new or modified existing grade separation overhead structures that affect the tracks and property of the Peninsula Corridor Joint Powers Board (PCJPB). Design engineers should use these guidelines as the basis for preliminary design and final design.

3.1 General Requirements

Design and construction of overhead grade separation structures shall comply with standard drawing, Figure 3.1.

Changes in railroad horizontal alignment and profile should be avoided unless they can be shown to benefit the railroad. The PCJPB Chief Engineer must approve any alignment or profile changes.

Provisions should be made for a minimum of four tracks along the PCJPB Right-of-Way.

If the overhead structure occurs within curve limits, the minimum track centers, as shown on PCJPB drawings TS-1025 and TS-1030, shall be increased by 2 inches per degree of curve.

Right of Entry, Right-of-Way encroachment and Construction and Maintenance (C&M) agreements consistent with PCJPB policy will be required.

The municipality or other public agency must make application to the California Public Utilities Commission (CPUC) for the grade separation. The PCJPB staff will support the application, if required, provided that it concurs with the PCJPB's future plans.

For submittal requirements, see Chapter 10.

The agency or their representative shall provide the basic information requested on the Overpass Project Sheet to PCJPB at the initial stage of the project. A copy of the Overpass Project Sheet is included in Chapter 10.

3.2 Superstructure

Erection of the superstructure over the tracks shall not interfere with railroad operations unless approved by the Chief Engineer. Precast girders or prefabricated spans are preferred for spans over tracks to minimize track outages (windows).

Fences or other methods shall be provided on both sides of all overhead structures to protect railroad facilities and the safety of railroad employees below from objects being thrown from above by pedestrians or passing motorists.
GRADE SEPARATIONS

GENERAL:
1. FENCING ON THE OVERPASS STRUCTURE SHALL BE REQUIRED, AS SHOWN, ON BOTH SIDES OF EACH STRUCTURE.
2. FENCING, PER PCPB STANDARD FOR ROW FENCE SHALL BE PROVIDED FOR MINIMUM DISTANCE OF 200 FEET EITHER SIDE OF CENTERLINE OF THE OVERPASS ON BOTH SIDES OF RAILROAD ROW.
3. LIGHTS ARE TO BE INSTALLED ON THE UndersIDE OF THE OVERPASS WHERE STRUCTURE SHADOWS WOULD INTERFERE WITH RAILROAD OPERATIONS.
4. CONCRETE SLOPE PAVING SHALL BE REQUIRED ON ALL ABUTMENT SLOPES STEEPER THAN 2 HORIZONTAL TO 1 VERTICAL.
5. PIER PROTECTION IS REQUIRED FOR PIER WITH LESS THAN 25 FEET HORIZONTAL CLEARANCE TO THE NEAREST TRACK. PIER PROTECTION SHALL BE DESIGNED IN ACCORDANCE WITH THE AREA MANUAL FOR RAILWAY ENGINEERING, CHAPTER 6, PART 2.1.5 AND THE PCPB DESIGN GUIDELINES.
6. APPLICANT SHALL BE RESPONSIBLE FOR IDENTIFICATION, LOCATION, PROTECTION AND/OR RELOCATION OF EXISTING UTILITIES. UTILITIES ATTACHED TO THE OVERPASS STRUCTURE MUST BE APPROVED BY PCPB.
7. SHORING SHALL BE DESIGNED AND APPROVED PER PCPB GUIDELINE FOR EXCAVATION SUPPORT SYSTEMS.
8. FALSEWORK SHALL BE DESIGNED AND APPROVED PER AREA, MANUAL OF RAILWAY ENGINEERING CHAPTER 6, PART 28.6.
9. EXCEPTIONS TO THESE STANDARDS MUST BE APPROVED BY PCPB.

CLEARANCES:
1. PERMANENT VERTICAL AND HORIZONTAL CLEARANCES SHALL BE AS SHOWN.
2. VERTICAL CLEARANCE IS MEASURED FROM THE TOP OF THE HIGHEST RAIL IN FINAL TRACK PROFILE. ADDITIONAL CLEARANCE MAY BE REQUIRED IF SAG VERTICAL CURVE EXISTS OR FOR FUTURE TRACK RAISES.
3. HORIZONTAL CLEARANCE IS MEASURED AT RIGHT ANGLES TO THE CENTERLINE OF TRACK. THE CENTERLINE OF TRACK IS PERPENDICULAR TO THE PLANE OF THE TOP OF RAILS.
4. REQUIRED HORIZONTAL CLEARANCES, AS SHOWN, SHALL BE INCREASED 1-1/2" PER DEGREE OF CURVE WHERE THE STRUCTURE IS LOCATED ON A CURVE OR WITHIN 80 FEET OF THE CURVE LIMITS.
5. MINIMUM TEMPORARY CONSTRUCTION CLEARANCES SHALL BE 21'-8" VERTICAL AND 10 FEET HORIZONTAL. OPUC AUTHORIZATION IS REQUIRED FOR VERTICAL CLEARANCE LESS THAN 21'-8".

FUTURE TRACKS:
1. PROVISIONS MUST BE MADE FOR TWO FUTURE TRACKS AS SHOWN.

DRAINAGE:
1. DRAINAGE FROM THE OVERPASS STRUCTURE SHALL BE DIVERTED AWAY FROM TRACKS AND OTHER RAILROAD FACILITIES.
2. EXISTING DRAINAGE SHALL BE MAINTAINED OR IMPROVED.

OVERHEAD GRADE SEPARATION MINIMUM REQUIREMENTS
FIGURE 3.1
The overpass shall have a curved fence eight feet (8') high or straight fence ten feet (10') high on sides with walkway and a combination of barrier rail and fence with a total height of ten feet (10') on sides without walkway.

The Chief Engineer will consider ornamental fencing with a maximum gap of four inches (4") and meeting the minimum height requirements above.

The limits of protective fence shall be the full width of the PCJPB Right-of-Way or a minimum of twenty-five feet (25') beyond the centerline of the outermost track or access road, whichever is greater. Any addition of future tracks may require the lengthening of the safety fences at the expense of the agency.

The limits and types of fences and/or barriers shall be shown on the plans.

The protection and safety of rail operations, train passengers, and PCJPB employees that may be working on the ground beneath the bridge is paramount. The Chief Engineer must approve any variance to the fence requirements above.

Structures over the PCJPB Right-of-Way shall not have any hinges (especially double hinges) located over the tracks, and they shall be avoided within the PCJPB Right-of-Way.

### 3.3 Clearances

Clearances will comply with Figure 3.1, with provisions for future tracks, drainage ditches, etc. Permanent clearances are those that will be in place when construction is completed. Temporary construction clearances are those that may be utilized for short periods during the construction of the structure. Any variation of horizontal or vertical clearances will require approval by the Chief Engineer.

Horizontal clearances are measured at right angles to the centerline of track. The centerline of track is perpendicular to the plane of the top of rails. Vertical clearance is measured from the top of the highest rail in the final track profile.

Special conditions, such as overheads located near passenger stations, may have additional or more restrictive requirements.

### 3.3.1 Permanent Clearances

Permanent clearances shall be correlated with the methods of construction so that temporary construction clearances will not be less than the minimum allowed.

Overhead bridge structures shall provide the specified horizontal and vertical clearances for anticipated future tracks, changes in track centers, and the raising of tracks for maintenance purposes.

The preferred permanent vertical clearance shall be 25'-6" above the top of rail for all tracks and at any location under the structure. The minimum vertical clearance shall be 24'-6" and the absolute minimum vertical clearance shall be
23'-6" and will only be allowed under special circumstances. Minimum vertical clearance must take into account any superelevation of the rails for tracks on curves. Additional vertical clearances may be required for features beyond those shown in the standard drawing.

The recommended horizontal clearance on tracks shall be twenty-five feet (25') to the face of pier support. The minimum horizontal clearance on tracks shall be fifteen feet (15') to the face of a pier protection wall or column. Required horizontal clearances, as shown in Figure 3.1, shall be increased 1-1/2" per degree of curve where the structure is located on a curve or within 80 feet of the curve limits.

The profile of the existing top of rail (one thousand feet (1000') each side of the proposed overhead) should be plotted on the plans. If the track profile has a local sag at the proposed bridge location, the vertical clearance from the top of rail to the bridge should be increased to permit raising the track in order to remove the sag.

The proposed minimum permanent vertical and horizontal clearances, as well as the existing clearances of structures to be rehabilitated or replaced, shall be indicated on the drawings.

Vertical and horizontal clearances shall be adjusted so that the sight distance to railroad signals is not reduced, unless the signals are to be relocated as part of the project.

Horizontal clearances may need to be modified to include access roads, where such roads now exist or the railroad ROW has sufficient width for new roads.

In any case, clearances shall not be less than those required by California Public Utilities Commission (CPUC) General Order 26D (see Appendix).

### 3.3.2 Temporary Construction Clearances

The proposed minimum temporary vertical and horizontal construction clearances known to be required during design shall be indicated on the drawings. If temporary construction clearances are found to be required during construction, the proposed clearances shall be submitted to PCJPB for approval.

Minimum temporary vertical clearance shall be twenty-one feet, six inches (21'-6") above the top of rail for all tracks and at any location under the structure. Minimum temporary vertical clearance must take into account any superelevation of the rails for tracks on curves. For proposed vertical clearance less than 22'-6", the proposing agency will be required to obtain CPUC approval.

Minimum temporary horizontal side clearance from centerline of track shall be ten feet (10'). This distance shall be increased 1-1/2" per degree of curve where the temporary clearance restriction is located on a curve or within 80 feet of the curve limits.
Construction material or equipment shall not be placed less than fifteen feet (15') from the centerline of the nearest track without permission of PCJPB.

3.4 Special Provisions

3.4.1 Drainage and Erosion Control

Maintaining the existing drainage and providing for future drainage improvements is a major concern for PCJPB. Existing track ditches must be maintained at all times.

Drainage plans shall be included with the plans submitted for review. If the proposed project will not change the quantity and/or character of flow in the railroad's ditches and/or drainage structures, the plans shall include a general note stating this. If an increase in current drainage requirements is required, the plans must include hydrologic computations indicating the rainfall intensity and duration of the design storm used and the method of analysis. Where project design calls for the drainage flow to increase through the railroad right-of-way, methods must be developed to carry the additional flow. Drainage ditches or structures shall be designed for a 100-year storm event such that the water surface elevation does not exceed the top of subgrade elevation of the track.

In order to evaluate the impact of the proposed project relative to the existing site drainage, cross sections perpendicular to the centerline of track should be submitted along with the drainage plans. Sufficient cross sections should be submitted to adequately depict the site conditions. One cross section is to be taken along the centerline of the overpass. The existing railroad ditch and the proposed toe of slope for the approach fill should be located on all cross sections.

Approval of the drainage plan does not relieve the submitting agency and/or designer of ultimate responsibility and liability for a satisfactory drainage design.

No scuppers or other deck drains, roadway drainage, catch basins, or other drainage features required by the project are permitted to drain onto PCJPB property. Any variance of this policy must have the approval of the Chief Engineer. If a variance is granted, deck drains and scuppers will not be permitted to discharge water onto the track or access roads. Downspouts attached to the substructure shall be used to convey the water to a storm drain system or the drainage ditches. Erosion protection, such as aggregate or splash blocks must be provided at outlets into ditches. Downspouts shall not be located on the face of piers nearest the track(s).

If any drainage must be conveyed into a railroad ditch, calculations that indicate the ability of the ditch to carry the additional runoff must be provided to the Chief Engineer for approval.

Abutment or approach slopes must include methods to control erosion and prevent material from sloughing into drainage ditches or onto the track. Slopes shall not be steeper than 1.5 horizontal to 1 vertical.
If deck drainage or highway drainage is to be discharged onto the embankment slopes, concrete slope paving must be used. Concrete slope paving is required for slopes steeper than 2 horizontal to 1 vertical. Slope paving shall extend for a minimum of two feet (2') beyond the outside edges of the bridge. Where warranted, the slope paving shall be extended around the ends of the abutment to a line parallel with the tracks. Slope paving shall consist of a prepared subbase and filter fabric with a minimum of four inches (4") thick reinforced concrete placed on prepared sub-base and filter fabric. The toe of slope paving shall terminate at the bottom of the drainage ditch.

The plans shall show all permanent erosion control methods. Temporary erosion control during construction may be shown on the plans or may be submitted by the contractor to the Chief Engineer for approval prior to beginning any grading work.

3.4.2 Utilities

The applicant shall be responsible for identification, location, protection and/or relocation of existing utilities. Utilities to be attached to the overpass structure must be approved by PCJPB. New or modified existing utility crossings or encroachments on PCJPB Right-of-Way must comply with applicable CPUC General Orders and PCJPB Standards and be approved by PCJPB.

The plans shall include identification and location of all existing and proposed utilities. The plans shall indicate parties responsible for installation or modification of utilities.

Approval by the Chief Engineer is required if changes to PCJPB signal, communication or other utility facilities are proposed.

Fiber Optic cables affected by the project will be relocated at the project’s expense.

3.4.3 Lighting

Permanent lighting of the track area shall be provided for new or modified overhead structures exceeding eighty feet (80') of superstructure width. Lighting shall also be provided for structures having widths of less than eighty feet (80') in areas where switching is performed, within one hundred feet (100') of station platforms or where high vandalism or trespassing has been experienced.

Temporary lighting shall be provided for falsework, regardless of the superstructure width, in areas where switching is performed, within one hundred feet (100') of station platforms or where high vandalism or trespassing has been experienced.

Lighting shall, as a minimum, maintain an average of one foot-candle for the area under the structure at the PCJPB tracks. Fixtures shall be installed without reducing the minimum clearances.
Maintenance of lights shall be the responsibility of the agency. Access to perform any maintenance for lights shall be coordinated with the PCJPB.

Structures with separation greater than ten feet (10') from each other shall be considered as independent structures for the purposes of lighting.

3.4.4 Railroad Electrification

PCJPB/Caltrain is planning for future electrification (25kV AC 60Hz) of the corridor. All structures shall provide for a future overhead catenary system. Space for catenary support poles shall be provided for along the PCJPB Right-of-Way and on structures. Overhead, vertical, clearance and horizontal clearance shall comply with the following references: CPUC—GO-26 and GO95, NESC, NEC, and AREMA Chapters 28 and 33.

All concrete superstructures and substructures shall be detailed to mitigate the effects of stray current corrosion of steel reinforcing, prestressing elements, and other steel components. This will require that electrical continuity be provided between all steel elements within each concrete structural component and be run to a central location at time the structure is designed. When the corridor is electrified the central location points will be connected to the corrosion control system. Comply with GO95, AREMA Chapter 33, IEEE, NESC, and NEC provisions for stray current.

3.5 Substructure

Wherever practical, overhead bridge structures shall have all piers and abutments located outside of the railroad right-of-way.

Footings for all piers, columns, walls or other facilities shall be located and designed so that any temporary sheeting and shoring for support of adjacent track or tracks during construction will not be closer than eight feet, six inches (8'-6") from centerline of track. Excavations will not be allowed closer than 8'-6" from centerline of track unless specifically approved by the Chief Engineer.

Pier footings tops within twenty-five feet (25') of the nearest track centerline shall be a minimum of six feet (6') below base of rail. They should not restrict PCJPB from modifying longitudinal drainage systems in the future or from providing unobstructed areas for placing, signal, fiber optic lines or other buried utilities.

The potential for railroad live load on foundations should be investigated when determining pier locations. Drilling of shafts or shoring construction for footings within the influence of track surcharge shall not proceed without the approval from the Chief Engineer. For limits of track surcharge influence refer to PCJPB Standard Drawing Figure 2.1, Railroad Zone of Influence in Appendix.

Pier protection walls or "crash walls" are required when a face of pier is closer than twenty-five feet (25'-0") from the centerline of track. Pier protection walls shall comply with the American Railway Engineering and Maintenance of Way Association (AREMA) Manual of Railway Engineering, Chapter 8, Part 2, Section 2.1.5. Pier protection walls
may be omitted if the piers are shown to be of HEAVY construction. HEAVY construction is defined as piers having a cross-sectional area equal to or greater than that required for the pier protection wall and the larger of its dimensions is parallel to the track.

Piers, abutments, retaining walls or other structures shall be located so that they do not interfere with drainage requirements.

Piers should be located with their primary axis parallel to the track.

3.6 Construction

The contractor must enter into a right of entry agreement with PCJPB prior to entering PCJPB property. Required insurance must be in effect for the duration of the project or as required in the agreement.

Construction schedules, work sequences and erection plans shall be provided to PCJPB for review and approval. If existing structures are to be removed, demolition plans and procedures shall be submitted to PCJPB for review and approval. Approvals by PCJPB must be obtained before any work begins.

At grade crossings of PCJPB tracks will not be allowed unless approved by the Chief Engineer.

Falsework required for the project must meet or exceed the minimum temporary clearance requirements. Falsework shall comply with the requirements of the AREMA Manual for Railway Engineering Chapter 8, Part 28.6. Falsework plans and design calculations shall be stamped by a Registered Professional Engineer and shall be submitted to PCJPB for review and approval.

Shoring and trenching shall be designed and approved in accordance with the PCJPB Guideline for Excavation Support Systems. Shoring for excavations will be required if excavations occur within the “Zone of Influence” as defined in Drawing Figure 2.1, Railroad Zone of Influence in the Appendix. Shoring shall be designed for the track dead load and Cooper E-80 railroad live load. Shoring plans and design calculations shall be prepared and stamped by a Registered Professional Engineer and shall be submitted to PCJPB for review and approval.

Shoring, trenching, pits, etc. within fifteen feet (15') of centerline of track shall be protected by handrails.

Temporary construction clearances less than those allowed in CPUC General Order 26D require approval by PCJPB and CPUC. Approvals are the responsibility of the public agency sponsoring the project.

Safety rail or barriers placed parallel to the tracks may be required to inhibit or prevent accidental incursion into the railroad operating envelope.
3.7 Miscellaneous

Walkways shall be provided adjacent to turnouts and tracks where train personnel are required to work on the ground. Walkways shall conform to CPUC General Order 118 (see Appendix).

Visibility of railroad signals must not be restricted or obscured at any time.

PCJPB Right-of-Way shall be fenced for a minimum of 200 feet on each side of the overpass.

All primary dimensions in drawings for overhead grade separation structures are to be shown in English units. Projects that require the use of metric units shall indicate all dimensions and design criteria assumptions in dual units on the project general plan sheet. English units are to be shown in parentheses. Primary dimensions refer to but are not limited to the following:

a) Horizontal and vertical clearances.

b) Track spacing, track stationing, and railroad right-of-way.

c) Top of rail elevation under structure and grade profile.

d) Span length, width and depth of superstructure elements.

e) Size and limits for barriers and fences.

f) Location and elevation of underground or aerial utilities and their relocation adjustments if required.

g) Size, elevation and location of pier or abutment footings for spans adjacent to railroad tracks.

h) Size of structure supports (pier or abutment walls, columns).

i) Size and elevations of pier protection walls, if required.

j) Shoring location and limits, if required.

l) Size and location of drainage structures and ditches.

j) Temporary construction vertical or horizontal clearances, if required.
CHAPTER 4

SEISMIC DESIGN
CHAPTER 4
SEISMIC DESIGN

4.1 Performance Criteria

This seismic design criteria was established based on a comparison study of the seismic design criteria presented in the American Railway Engineering and Maintenance-of-Way Association (AREMA), Manual for Railroad Engineering, Chapter 9 and the Caltrans Seismic Design Criteria (CSDC). AREMA recommends the use of tri-level seismic design criteria: serviceability, ultimate and survivability, and considers satisfying the serviceability performance criteria (continued operation of trains with possible speed restrictions subsequent to occasional earthquakes) as the main design condition. In contrast, CSDC employs a single-level seismic design criteria, based on the prevention of collapse during a Maximum Credible Earthquake (MCE) for an ordinary standard bridge. See below for the definition of the MCE. (A detailed comparison between AREMA and Caltrans can be found in the Appendix.)

Railroad bridges are typically short simple span bridges, with relatively regular configurations, and are traversed with a continuous track structure; historically they have performed well in previous seismic events. It is believed that load combinations including centrifugal loads, wind loads and lateral loads from heavy equipment other than the load combinations which include seismic load under serviceability level earthquake will likely govern bridge design in the large majority of cases. Additionally, test results from the Strawberry Park Underpass, a steel through girder ballast deck bridge, in Los Angeles has demonstrated that railroad structures may have significant lateral restraint capacity and continuity, although further research and testing needs to be performed to quantify that capacity.

A seismic performance criterion for 'ordinary bridges', the majority of the PCJPB inventory, is to provide no collapse during the MCE. The primary seismic design guidelines to be used in the design of PCJPB structures shall be the Caltrans Seismic Design Criteria (CSDC) and ATC 32 as may be modified by these guidelines. If the detailed requirements are not specifically covered in CSDC and ATC 32, then appropriate sections of the current edition of AREMA shall be applied. Final determination of the appropriate section shall be discussed with the PCJPB.

4.1.1 Bridge Classifications

An important bridge is any bridge satisfying one or more of the following:

- The bridge is required to provide secondary life safety.
- The time to restore functionality to the bridge after closure would create a major economic impact.
- A bridge formally designated important by the PCJPB.

An 'ordinary bridge' is any bridge not classified as an 'important bridge'.

Performance is defined in terms of two types of criteria: the service level of the structure immediately following the earthquake and the extent (or repairability) of
physical damage. Required performance depends on whether a bridge is classified as important or ordinary.

4.1.2 Performance Expectations

All bridges shall be designed to meet the seismic performance criteria given in Table 4.1.

**TABLE 4.1: SEISMIC PERFORMANCE CRITERIA**

<table>
<thead>
<tr>
<th>Ground Motion Level</th>
<th>Ordinary Bridge</th>
<th>Important Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional</td>
<td>Service: Immediate</td>
<td>Service: Immediate</td>
</tr>
<tr>
<td></td>
<td>Damage: Repairable</td>
<td>Damage: Minimal</td>
</tr>
<tr>
<td>Safety</td>
<td>Service: Limited</td>
<td>Service: Immediate</td>
</tr>
<tr>
<td></td>
<td>Damage: Significant</td>
<td>Damage: Repairable</td>
</tr>
</tbody>
</table>

**Notes:**

1. *Functional Evaluation Ground Motion:* This ground motion may be either deterministically or probabilistically assessed. The determination of this event is to be reviewed by a PCJPB approved consensus group.

2. *Safety Evaluation Ground Motion:* This ground motion may be assessed either deterministically or probabilistically. The deterministic assessment corresponds to the MCE. The probabilistic ground motion of the safety evaluation typically has a long return period (approximately 1000 - 2000 years.)

3. *MCE:* The largest earthquake, that is capable of occurring along an earthquake fault, based on current geologic information as defined by the 1996 Caltrans Seismic Hazard Map.

4. *Service Levels:*
   - Immediate: Full access to normal train operating service is available almost immediately following the earthquake.
   - Limited: Limited access (e.g. reduced tracks, light emergency train service) is possible within days of the earthquake. Full service is restorable within a short period of time.

5. *Damage Levels:*
   - Minimal: Essentially elastic performance.
   - Repairable: Damage that can be repaired with a minimum risk of losing functionality.
   - Significant: A minimum risk of collapse, but damage that would require closure to repair.

The safety evaluation earthquake shall conform to what Caltrans currently defines deterministically as the MCE, and has only a small probability of occurring during the useful life of the bridge. The functionality evaluation earthquake is intended to represent an event that has a reasonable probability of not being exceeded (approximately 60%) during the life of the bridge. Since there is no hazard map for these earthquakes that has been developed, the functional evaluation ground motion must be determined on a case by case basis through site-specific studies.
4.2 Ground Motion Levels

ARS curves based on the deterministic approach shall be employed for 'ordinary bridges'. Acceleration values are obtained from the current Caltrans Seismic Hazard Map. The peak acceleration values reported on this map are mean values obtained using the 1996 Caltrans attenuation relationship. The rock spectra are magnitude and distant dependent. The spectral shapes for acceleration values between 0.1g and 0.7g for three magnitude groups are shown in SDC. These spectra are for California type rock and correspond to NEHRP Soil Profile Type B. These curves are a reasonable upper bound of the spectral values obtained using various spectral relationships. Site modification factors have been developed using the soil profile types and soil amplification factors developed at a workshop on how site response should reflect in seismic code provisions. Table 4.2 summarizes the soil profile types, adopted in the 1994 NEHRP Provisions.

**TABLE 4.2 - SOIL PROFILE TYPES**

<table>
<thead>
<tr>
<th>Soil Profile Type</th>
<th>Soil Profile Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Hard rock with measured shear wave velocity vs &gt; 5000 ft/s</td>
</tr>
<tr>
<td>B</td>
<td>Rock with shear wave velocity 2500 &lt; vs &lt; 5000 ft/s</td>
</tr>
<tr>
<td>C</td>
<td>Very dense soil and soft rock with shear wave velocity 1200 &lt; vs &lt; 2500 ft/s, or with either standard penetration resistance N &gt; 50, or undrained shear strength su ≥ 2000 psf.</td>
</tr>
<tr>
<td>D</td>
<td>Stiff soil with shear wave velocity 600 &lt; vs &lt; 1200 ft/s or with either standard penetration resistance 15 &lt; vs &lt; 50 or undrained shear strength su ≥ 2000 psf.</td>
</tr>
<tr>
<td>E</td>
<td>A soil profile with shear wave velocity vs &lt; 600 ft/s or any profile with more than 10 ft of soft clay, defined as soil with plasticity index PI &gt; 20, water content w ≥ 40 %, and undrained shear strength su &lt; 500 psf.</td>
</tr>
</tbody>
</table>
| F                 | Soil requiring site-specific evaluation:  
                        1. Soils vulnerable to potential failure or collapse under seismic loading; i.e. liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils  
                        2. Peat and/or highly organic clay layers more than 10 ft thick  
                        3. Very high plasticity clay (PI > 75) layers more than 25 ft thick  
                        4. Soft to medium clay more than 120 ft thick. |

For structures within 10 miles of an active fault, the spectral acceleration on the CSDC ARS curves shall be magnified as follows:

- Special acceleration magnification is not required for T ≤ 0.5 seconds
- Increase the spectral acceleration for T ≥ 1.0 seconds by 20%
- Spectral acceleration for 0.5 ≤ T ≤ 1.0 shall be determined by linear interpolation.

A site-specific ARS curve is required when a bridge is located in the vicinity of a major fault or located on soft or liquefiable soil and the estimated earthquake moment magnitude \(M_m > 6.5\).
The geotechnical engineer shall provide the following geotechnical data:

- Seismicity
  - Fault distance
  - Earthquake magnitude
  - Peak rock acceleration
  - Soil profile type
- Liquefaction potential
- Foundation stiffness or the soil parameters

The geotechnical engineer will recommend one of the following: a standard 5% damped CSDC ARS curve, a modified CSDC ARS curve, or a site specific ARS curve. The final seismic design recommendations shall be included in the Final Foundation Report.

4.3 Analysis Procedures

Inelastic static analysis shall be performed in both longitudinal and transverse directions for all bridges to obtain the system capacity. The "push over" analysis may be performed in conjunction with elastic dynamic analysis or equivalent static analysis. ("Push over" analysis requires the performance of static nonlinear analysis of a structure which allows monitoring the progressive yielding of a structure, and establishing the "capacity curve." Detailed discussions can be found in ATC 40 and FEMA 273.) In the push over analysis, loads are applied incrementally until the structure has reached ultimate displacements. At each step, changes in the structure's characteristics due to geometric and material nonlinearity are considered. The effect of gravity loads including dead load and a portion of the live load are also considered. Results of this analysis are used to confirm that the structure is capable of accommodating the displacement demands determined from the elastic dynamic analysis.

Inelastic dynamic analysis may be performed for "important bridges." Both geometric and material nonlinearity should be considered. In general, a stick model with lumped mass at the top and five percent of critical damping is appropriate. The maximum response to three representative input motions or the average response to seven such input motions is recommended.

Results from equivalent static analysis or elastic dynamic analysis for orthogonal response spectrum loadings must be combined to obtain design forces and displacements. The results for each orthogonal loading are first obtained by combining the maximum modal responses according to the complete quadratic combination (CQC) rule. The "30 percent rule" is recommended. Three design load cases may be considered, each of which includes 100 percent of the actions for loading in one of the orthogonal directions plus 30 percent of the actions for each of the remaining two orthogonal loadings. When either elastic or inelastic time history analysis is used, 100 percent of the loadings in each of the orthogonal directions are applied simultaneously, and the resulting maximum actions are taken directly from the analysis results.

Displacement demand can be estimated by using the "equal displacement principle," a common assumption for design. In the "equal displacement principle" the peak displacement amplitude for a structure responding inelastically is equal to the peak displacement amplitude calculated for the same structure (same initial period and viscous damping ratio) responding elastically. Modifications to the elastic dynamic analysis in ATC
32 may be considered to better reflect the actual maximum inelastic displacements that are likely to occur during an earthquake.

4.3.1 Additional Modeling and Analysis Considerations

Element Cross-Sectional Analysis

Element cross-sectional properties, including the effective moment of inertia, shall be determined from moment-curvature analysis that considers the effects of concrete confinement and strain hardening of the reinforcement in accordance with MTD 20-4 and Section 5.6 of SDC.

Foundation Flexibility

The effects of foundation flexibility shall be considered in the seismic design and analysis of all bridges. The rotational and translational foundation stiffness modeled in the demand analysis must be compatible with the foundation’s structural and geotechnical capacity. The lateral design of foundations for seismic demands shall consider the relative stiffness between the foundation and the surrounding soil. The effects of anticipated degradation or deposition of material shall be considered in the seismic design of bridges spanning streambeds. Liquefaction, lateral spreading and other seismic phenomena shall also be considered.

Soil-foundation-structure interaction effects can be estimated utilizing the following computer programs: LPILE for a single pile evaluation, GROUP for multiple pile group evaluation, and NFOOT for pile cap/group rotational evaluation. Simple and rational approaches for developing foundation stiffness are preferred. Complex soil-pile interaction approaches are unnecessary for practical design applications.

Boundary Conditions

In cases where the structural analysis model includes only a portion of the whole structure or abutments, the model shall also contain appropriate boundary elements to capture mass and stiffness effects of the adjacent structure and/or abutment.

After completion of the static or dynamic analysis, boundary conditions and element properties shall remain consistent with initial modeling assumptions. Elements designed to remain elastic shall satisfy strength requirements under the loading combinations in CSDC.

Continuous Welded Rail

Where applicable, the effects of continuous welded rail across a structure shall be considered in the evaluation of the structure.

Effects of Live Load on Displacement Demand

Horizontal displacements due to train loads may be neglected and need not be combined with seismic displacement. The train loads shall not be considered as contributing to the system’s ‘dynamic’ mass for the purpose of equivalent static or dynamic seismic analysis.
Train loads generally shall not be considered. Where applicable (e.g. on long
viaducts or specific analysis methods requiring train loads be included), train loads
may be modeled as equivalent distributed loads. Where equivalent distributed loads
are used in the analysis, the Design Engineer shall account for any local or global
effects to the structure due to actual concentrated axle loads.

4.4 Demands on Structure Components

4.4.1 Displacement Demand

The global displacement demand can be estimated for ordinary standard bridges by
linear elastic analysis using effective section properties. Equivalent static analysis
can be utilized for regular bridges with the following characteristics:

- response primarily captured by the fundamental mode of vibration with
  uniform translation
- simply defined lateral force distribution
- low skew

Elastic dynamic analysis can be used for the global displacement demand for all
ordinary standard bridges.

The effects of soil/foundation flexibility as well as p-delta effect shall be included
when performing elastic analyses.

4.4.2 Force Demand

Force demand can be estimated based on internal forces generated when the
structure reaches the collapse limit state, determined by performing the "push over"
analysis. The collapse limit state is defined when a sufficient number of plastic
hinges have formed within the structure to create a local or global collapse
mechanism.

4.5 Capacities of Structure Components

There are two types of structure members: ductile members and capacity protected
members. A ductile member is any member that is intentionally designed to deform
inelastically for several cycles without significant degradation of strength and stiffness under
the demands generated by the MCE. A capacity protected member is any member that is
intentionally designed to behave elastically due to seismic effects.

The local displacement capacity is based on the inelastic moment-curvature section
analysis. The plastic moment capacity of all ductile members shall be calculated based on
expected material properties. Moment curvature analysis derives the curvatures associated
with a range of moments for a cross section based on the principles of strain compatibility
and equilibrium of forces. The moment curvature curve can be idealized with an elastic
perfectly plastic response to estimate the plastic moment capacity of a member's cross
section.

Capacity protected components shall be designed to remain essentially elastic when the
ductile components reach their over-strength capacities.
4.5.1 Material Properties

Material properties for reinforced concrete components shall conform to Section 3.2 of CSDC except specified herein.

4.5.2 Reinforcing Steel

Grade 60 Reinforcing Steel

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus of Elasticity</td>
<td>$E_s = 29,000$ ksi</td>
</tr>
<tr>
<td>Specified minimum yield strength</td>
<td>$f_y = 60$ ksi</td>
</tr>
<tr>
<td>Expected yield strength</td>
<td>$f_{ye} = 68$ ksi</td>
</tr>
<tr>
<td>Specified minimum tensile strength</td>
<td>$f_u = 80$ ksi</td>
</tr>
<tr>
<td>Expected tensile strength</td>
<td>$f_{ue} = 95$ ksi</td>
</tr>
<tr>
<td>Nominal yield strain</td>
<td>$\varepsilon_y = 0.0021$</td>
</tr>
<tr>
<td>Expected yield strain</td>
<td>$\varepsilon_{ye} = 0.0023$</td>
</tr>
<tr>
<td>Ultimate tensile strain</td>
<td>$\varepsilon_{su} = 0.09$ #10 bars and smaller $= 0.06$ #11 bars and larger</td>
</tr>
<tr>
<td>Onset of strain hardening</td>
<td>$\varepsilon_{sh} = 0.012$ #11 bars and smaller $= 0.006$ #14 and #18 bars</td>
</tr>
</tbody>
</table>

At the PCJPB's approval, where the actual reinforcing steel properties are known, they may be used in the seismic evaluation of the structure.

4.5.3 Concrete

Normal weight portland cement concrete properties shall conform to Section 3.2.6 of CSDC. Mander's confined concrete model shall be used in order to determine the stress-strain relationship for confined concrete. (Mander's model permits compression stress-strain relationships for confined concrete applicable to all section shapes and all levels of confinement, and is incorporated in computer program, XSECTION. This model defines the ultimate concrete compression strain by monitoring fracture of transverse confining steel.)

4.5.4 Structural Steel

The strength of structural steel member shall be determined from the Expected Yield Strength, $F_{ye}$, of the member as determined in the following:

$$F_{ye} = 1.1 F_y$$

$F_y$ is the specified minimum yield strength of the grade of steel to be used.

4.5.5 Component Plastic Moment Capacity

Plastic moment capacity of ductile concrete elements shall be calculated by Moment-Curvature (M-Φ) analysis and shall conform to Section 3.3 of CSDC.
4.5.6 Component Plastic Hinge Rotational Capacity

The rotational capacity of any plastic hinge is defined as the curvature in the M-\Phi analysis where the reinforced concrete element first reaches either of the following allowable strain limits:

- Steel tensile allowable strain limit ($\varepsilon_{su}^a$):
  \[ \varepsilon_{su}^a \leq 1.0 \varepsilon_{su} \]

- Concrete confined compressive allowable strain limit ($\varepsilon_{cu}^a$):
  \[ \varepsilon_{cu}^a \leq 1.0 \varepsilon_{cu} \]

4.5.7 Column Shear Capacity

Shear capacity of ductile concrete components shall conform to Section 3.6 of CSDC except that in evaluating shear capacity of existing concrete components, the shear strength reduction factor ($\phi$) shall be taken as 1.0 and no reinforcing steel capacity is assumed for rectangular ties when spaced at 12" (or greater), except where a dense pattern of crossties is present, or 135° seismic hooks are used to close the perimeter ties.

4.5.8 Joint Internal Forces

Moment resisting connections between the superstructure and the column, as well as the pile cap and the column shall conform to the joint design in Section 7.4 of CSDC. Continuous force transfer through the column/superstructure and column/footing joints shall be ensured, particularly for multi-column bent and pile caps. These joint forces require that the joint have sufficient strength to ensure elastic behavior in the joint regions under the effects of the MCE and it shall be determined based on the capacity of the adjacent members, appropriately including over strength factors.

All moment resisting joints shall be proportioned such that the principal stresses satisfy:

- Principal compression (psi): $p_c \leq 0.25 f'_c$
- Principal tension (psi): $p_t \leq 12\sqrt{f'_c}$

Principal tensile stress shall be calculated per Section 7.4 of CSDC. If the principal tensile stress, $p_t$, does not exceed $3.5\sqrt{f'_c}$ psi, the minimum joint shear reinforcement shall be provided.

4.5.9 Hinge/Seat Capacity

Adequate seat length shall be provided to accommodate anticipated seismic displacements and prevent unseating of the structure.

Transverse shear keys shall be provided or strengthened to accommodate the anticipated seismic loads without modification to the existing provisions for thermal movement and vibration characteristics.
4.5.10 P-Δ Effects

P-Δ effects shall conform to the requirements in Section 4.2 of CSDC.

4.5.11 Effects of Live Load on Displacement Capacity

Displacement amplification and column strength reduction due to train live load effects shall not be considered.

4.6 Demand vs. Capacity

The maximum displacement performance criteria is defined as follows:

\[ \frac{\Delta_D}{\Delta_C} \leq 1.00 \]

where:

\( \Delta_D \) = The displacement demand based on the frame model

\( \Delta_C \) = The displacement capacity based on the non-linear static analysis model

4.6.1 Local Displacement Ductility

The local displacement ductility demand, \( \Delta_{d(0)} \), shall be utilized in determining the shear capacity of structural components. \( \Delta_{d(0)} \) is defined as follows:

\[ \Delta_{d(0)} = \frac{\Delta_D}{\Delta_{\Delta(0)}} \]

where:

\( \Delta_D \) = The local displacement demand based on the frame model, after removal of all displacement demands associated with foundation flexibility, rotations, and translations.

\( \Delta_{\Delta(0)} \) = The member idealized yield displacement based on the local frame model.

The displacement ductility demand of following structural elements shall not exceed the target values as specified herein:

Superstructure Girders, \( \Delta_{\Delta(0)} \leq 2.0 \)

Pier Walls (strong direction) and Non-Ductile Elements, \( \Delta_{\Delta(0)} \leq 1.0 \)

The local displacement ductility capacity, \( \Delta_{\Delta(0)} \), shall be utilized in the design of structural elements. \( \Delta_{\Delta(0)} \) is defined as follows:

\[ \Delta_{\Delta(0)} = \frac{\Delta_C}{\Delta_{\Delta(0)}} \]

where:

\( \Delta_C \) = The member idealized displacement capacity.

\( \Delta_{\Delta(0)} \) = The member idealized yield displacement based on the local frame model.
Each new member shall have a minimum local displacement ductility capacity, $\Delta_{d(0)} \geq 3$, to ensure dependable rotational capacity in the plastic hinge region.

### 4.6.2 Capacity Based Performance

To ensure that inelastic deformations occur only in the prescribed ductile elements, the plastic moments and shears of the ductile elements shall be used in the demand/capacity analysis of the non-ductile, capacity-protected elements of the structure. Component over-strength design factors used for the evaluation of capacity-protected elements, shall be applied as specified in Section 4.3 of SDC.

Reinforced concrete capacity-protected elements shall be limited to the nominal moment strength derived at the curvature in the $M-\Phi$ analysis where $\varepsilon_c = 2/3 \varepsilon_{cu}$ or $\varepsilon_s = 2/3 \varepsilon_{sh}$, whichever is reached first.

### 4.7 Seismic Design Procedures

Geometric irregularities shall be avoided in order to avoid complex nonlinear response which cannot be accurately predicted by elastic modeling. Seismic design should achieve the following:

- Balanced frame design
- Sufficient hinge seat width
- Capacity protected superstructure
- Adequate joint shear design for multi-column bents
- Bearings that are easily inspected for damage and replaced or repaired after an earthquake.
- Capacity protected foundations
- Adequate pressure capacity at abutments.

Conform to the most current CSDC.

### 4.8 Ductility Provisions

Conform to Seismic Detailing section of CSDC.

### 4.9 Seismic Risk

Railroad bridges are functionally and behaviorally different from highway bridges and other types of bridges. Due to the very nature of railroad bridges, they have historically performed well in seismic events with minor or no damage. Several factors have contributed to this performance that is unique to railroad bridges, such as the bridges along the PCJPB corridor. First, Railroad bridges are typically very simple in their design and construction. Superstructures are comprised of shorter span lengths, and thus simple span construction methods are utilized more often than continuous spans. Second, the bridges are traversed by a track structure (rail, ties, and in most cases ballast) that functions effectively as a restraint against longitudinal and lateral movement. Third, the types of damage that are permissible for railroad bridges are different from highway bridges and other bridges used by the public. Fourth, the movement of trains along the PCJPB corridor is controllable through signal and communication systems that are not in place on a public
highway system. With this in mind, the PCJPB is concerned with maintaining the reliability of their infrastructure to provide safety for its employees, passengers, customers, and the public at large.

There are many sources of uncertainty in seismic design. The greatest source of uncertainty can be associated with the local seismicity and the expected ground motion characteristics of the site under consideration. The response of a bridge to a seismic event is affected by the characteristics of the underlying soil conditions and the structural dynamic characteristics of the bridge. Also, the methods of analysis used may add to an overall level of uncertainty.

The seismic design of a railroad bridge for maximum ground motions may not be economically feasible, unless there is a severe social need associated with failure of the structure. During the service life of a railroad bridge, it may be subjected to maximum earthquake loads that exceed the desired performance criteria, even when conservative assumptions have been used in design. A certain amount of risk shall be balanced between the probability of the occurrence of large earthquakes and the design costs associated with maximum earthquake events.

Determining the acceptable seismic risk for railroad bridges is complex. Both social and economic impacts must be considered. Some bridges depending on their location, span length, and configuration may vary in the amount of risk acceptable from bridge to bridge. Other factors to consider include: volume and type of train traffic (passenger vs. freight), the value and importance of the bridge, cost of loss of use, and whether the structure is considered part of a lifeline. Some questions that may need to be asked are: 1) Can the PCJPB corridor be shut down for an extended period of time after a seismic event for repairs? 2) Highway systems usually have an alternate route that can be used during repairs. Will bus routes be able to provide alternate service if PCJPB trains aren't operating? 3) How vital will it be to have PCJPB trains operating after a major seismic event? The occupancy rate of the structure should also be considered. While most highway bridges are continuously occupied by vehicles, railroad bridges have a low occupancy rate and the train traffic is controlled by a signal and communication systems which will allow rail traffic to have operations halted until inspections are made.

The previous sections (Sections 4.1 through 4.8) of this chapter have been developed to consider the aforementioned issues over the PCJPB corridor. There may be specific locations, such as along the Dumbarton Line, where these factors should be reviewed and revised as necessary to provide an acceptable seismic design for the bridges.
CHAPTER 5

PEDESTRIAN UNDERPASS
CHAPTER 5
PEDESTRIAN UNDERPASS

Purpose

This guideline was created to provide standards and requirements regarding design and construction of new or modified pedestrian underpass structures that affect the tracks and property of the Peninsula Corridor Joint Powers Board (PCJPB). Design engineers should use these guidelines as the basis for preliminary and final design.

5.1 General Requirements for Design of Underpasses

Design of pedestrian underpasses shall comply with the appropriate parts of the current AREMA Manual for Railway Engineering. Applicable sections of the manual include Chapter 8, Part 2, 5, 16 and Chapter 1, Part 4 among others.

A minimum of 3 feet depth shall be maintained between the bottom of the track tie to the top of the pedestrian underpass.

The minimum compressive concrete strength used for underpasses shall be 3600 psi at 28 days.

Reinforcement for pedestrian underpasses or box shall meet the following requirements:

- ASTM Standard A615 Grade 60, or
- ASTM Standard A706, or
- Welded steel wire fabric ASTM Standard A497

A maximum allowable steel tensile stress of 24,000 psi shall be used in service load design.

5.1.1 Design Considerations

The selection and design of underpasses shall be based on:

- The purpose of the structure (pedestrian, equipment access, etc)
- Stresses and loads to be applied to the top and invert level
- Depth of structure from base of rail to invert level
- Requirements for soil backfill and cover surrounding the structure
- Depth requirements for ballast above the top of the structure
- Alignment and skew angle, if it applies
- Subgrade width and embankment slopes
- Existing soil and foundation conditions
- A 10'-0" vertical inside clearance
5.2 Pedestrian Underpasses Type Selection

A pedestrian underpass, also known as a box or tunnel, is a structure with rectangular shaped openings through an embankment primarily for pedestrian or equipment access. Different types of underpasses that have been proposed to PCJPB include:

(1) **Precast Concrete Box Tunnel** – This type comprises of box sections with tongue and groove joints. The selection of the joint system used is important if the loads are to be distributed across the joint. Post-tensioning can be used between each joint section, over the tunnel length, or a combination of both to resist differential settlement, to promote sealing, and to provide load distribution. Simple and fast installation of the precast concrete sections may be achieved with this type of underpass.

(2) **Soldier Pile Walls with Precast Roof Slab** – Soldier pile walls consisting of augured/soil-cement holes, typically with alternating H-piles as reinforcement, offer little impact to the site until final excavation and roof installation. This structure type resolves differential settlement issues. Multiple components to this installation require longer time to furnish. Soldier piles may also be substituted with secant piles with alternating concrete-filled reinforced and un-reinforced piles. Shoring and over excavation is minimized. Construction is suited for working around railroad tracks in operation.

(3) **Cast-in-place Concrete Tunnel** – Casting the underpass in a series of concrete pours achieves a continuous monolithic structure. Water sealant may be automatically integrated in the mix design or with an outside waterproof membrane. However, extensive construction staging is required, particularly around railroad tracks, to provide ample curing time for the required concrete strength to develop.

(4) **Contech Multi-plate Arch with Interior Facing** – This arch tunnel can be assembled onsite by a Contech contractor and hoisted into place over a weekend closure of railroad operations. The metal sections are assembled nearby and can be lifted into place in a short amount of time. Although the material cost for the Contech arch is the least expensive of the alternatives, significant excavation, shoring, and extensive interior treatments are needed.

(5) **Conspan Arch Pedestrian Underpass with Cast-in-place Footing** -- Cost savings may be achieved by minimizing the on-site labor required for cast-in-place tunnel construction with this method. Footings are formed without special construction techniques and Conspan manufactured precast arches may be set in place quickly. Precast headwalls may also be manufactured to meet project needs.

Refer to Figure 5.1 for typical sections and Table 5.1 for advantages and disadvantages of each structure type. Some structure types may be preferred over others depending on site conditions, material and construction cost, interior aesthetic treatments, utility locations, railroad track operating closure periods, and public preference. Aside from the structure types listed above, PCJPB welcomes other possible alternatives that may be appropriate for a project.
# TABLE 5.1 – ADVANTAGES & DISADVANTAGES OF TUNNEL TYPES

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type 1: Precast Concrete Box Tunnel</strong></td>
<td></td>
</tr>
<tr>
<td>1. Precast quality control</td>
<td>1. Critical excavation &amp; haul needed</td>
</tr>
<tr>
<td>2. Possible completion over weekend closure of railroad</td>
<td>2. Large crane capacity for lifting heavy sections</td>
</tr>
<tr>
<td>3. Possible phased construction</td>
<td>3. Possible leaking &amp; sealant problems between joints</td>
</tr>
<tr>
<td>4. May be jacked under existing tracks</td>
<td>4. Foundation &amp; excavation need to be prepared quickly</td>
</tr>
<tr>
<td></td>
<td>5. Keyed sections require construction in one direction</td>
</tr>
<tr>
<td></td>
<td>6. May require shoring (separate from structure)</td>
</tr>
</tbody>
</table>

| **Type 2: Secant Pile Walls with Precast Roof Slab** | |
| 1. Possible completion over weekend closure of railroad if piles are placed beforehand. | 1. Waterproofing under high water table may be more difficult |
| 2. No shoring required. Secant piles act as shoring | 2. Interior work necessary after weekend closure |
| 3. Less excavation required than other types | 3. Pile alignment needs to be accurate |
| 4. Minimal heavy lifting | 4. Assembly of more components to install tunnel |
| 5. Foundation built-in with pile placement | 5. Specialty sub-contractor required for installation |
| 6. Resolves differential settlements | |
| 7. Can be used as temporary bridge support for track rather than a shoofly | |
| 8. Seals off water intrusion into the excavation | |

| **Type 3: Cast-in-Place Concrete Tunnel** | |
| 1. Watertight seal possible | 1. Forming and shoring required |
| 2. Open excavation and shoring possible | 2. Extensive staging & phased construction necessary |
| 3. No heavy lifting components required | 3. Crossovers required for switching tracks during construction or shoofly |
| 4. Differential settlement not a critical | 4. More time required for construction due to concrete cure time |

| **Type 4: Contech Multi-plate Arch with Interior Facing** | |
| 1. Light section may be lifted in one section | 1. Rapid excavation and haul critical |
| 2. Possible completion over weekend closure of railroad | 2. Extensive finish work required on tunnel interior |
| 3. Compaction requirements may be reduced with cementitious flowable fill | 3. Compaction in 8-12” lifts may be required |
| 4. Phased construction possible | 4. Increased depth of excavation and/or cover required to develop Cooper E80 train loading strength in arch |
| 5. Full length of preassembled tunnel shapes | 5. Buoyancy control may be difficult |
| 6. Additional interior room for drainage and conduit/ Fiber optics placement | |
| 7. Waterproofing may be completed prior to installation | |

| **Type 5: Cast-in-place Footing with Precast Arch Wall & Roof** | |
| 1. Precast quality control of arch | 1. Excavation and haul critical |
| 2. Interior may be aesthetically finished by precaster | 2. May not be possible to complete over weekend closure. |
| 3. Simple footing forms and reinforcement | 3. Cast-in-place footing requires extended cure time |
| 4. Lighter sections to be lifted | 4. Waterproofing more difficult at arch joints |
| 5. Less on-site labor for reinforcing and forming | 5. Shoring required |
5.3 Structural Design of Pedestrian Underpasses

The structure design of pedestrian underpasses shall follow the design requirements of AREMA for the type of materials being considered and the loading provisions for the material selected.

Provisions under the bulleted items of this Chapter should be used as a guideline, in the development of a cast-in-place pedestrian tunnel for conceptual design. A more rigorous analysis and design procedure should be employed for final design.

- Equations in Figure 5.2 may only be used for preliminary and conceptual studies to calculate the loading conditions acting on the tunnel. The pedestrian underpass shall be analyzed as having rigid joints between slabs and walls for a cast-in-place box type of pedestrian underpass, and with the positive and negative bending moments determined by elastic theory.

5.3.1 Loading

(a) Dead Load

Dead loads to be considered for the tunnel design consist of the weight of the track, ballast, and fill on the top slab of the structure. The dead load shall be uniformly distributed to the top surface of the pedestrian underpass.

Lateral earth pressure coefficients shall be recommended by the geotechnical engineer specific to the site to be used in the analysis.

- For preliminary design when data is not available, minimum and maximum earth pressure coefficients (acting laterally) can be assumed to be 0.33 and 1.0, respectively, and checked for both conditions when the equations in Figure 5.2 are used. Lateral pressures shall be distributed uniformly over the height of the pedestrian underpass, equal and opposite in direction.

(b) Live Load

Design live load shall be Cooper E-80.

The lateral live load surcharge for final design shall be developed per recommendations from AREMA by lateral surcharge pressures.

Long-term compaction by traffic may be considered over time, with varying soil moisture content below the pedestrian underpass. Design loading shall be based on a range of soil mass density, earth pressure coefficients and hydrostatic conditions.
For pedestrian underpasses that are designed for track live load, the distributed surcharge of one track shall be considered the same over the full length of the structure within the PCJPB Right-of-Way. The live load shall be treated in the same manner.

- For preliminary design and the use of equations in Figure 5.2, the live load on a pedestrian tunnel shall be distributed accordingly for train loads that are perpendicular to the pedestrian tunnel. No increase in load shall be used for multiple track loadings -- lateral load distribution for one track shall be limited to the track centers of multiple tracks.

- For preliminary design, lateral pressure due to railroad surcharge shall be computed per Figures 5.2.

(c) Impact Load

For final design, the impact loads shall be distributed on the top slab of the pedestrian tunnel, similar to the live load distribution. The sides of the box shall not be affected by impact loading.

Impact loading shall range from 40% of the live load for a cover height of 18 inches, to 0% of the live load for a cover height of 10 feet.

- For preliminary design and the use of equations in Figure 5.2, the live load impact shall be applied as described for final design above.

(d) Seismic Loads

Earthquake loading shall be considered for pedestrian tunnel design. However, tunnels by nature of their function are presumed to be of a design resistant to seismic loads. Any pedestrian underpass regardless of material, including arched shaped or of proprietary designs shall be designed for seismic loading.

The magnitude of the seismic load shall be calculated as a function of the vertical acceleration component of the seismic event. This load is to be applied as a uniform dead load at the centroid of a fill section containing the pedestrian underpass. Risk factors are to be used to determine acceptable values for allowable stresses.

Refer to Chapter 4 of these Standards for specific seismic requirements pertaining to railroad structures.

(e) Hydrostatic Pressure

Due consideration shall be made to high water table situations. The pedestrian underpass shall be designed to resist the effects of buoyancy. A factor of safety of 1.5 shall be applied in buoyancy calculations.
- **Live Load to be Considered:** E-80

- **Loads on Top Slab:**
  
  \[ W = W_{UL} \left(1 + \frac{I}{100}\right) + W_{DL} = \text{Uniform Load in psf} \]

  \[ W_{UL} = \frac{80000 \text{ lbs}}{5 \times L_d} = \text{Uniform Load in psf} \]

  \[ W_{DL} = W_e H + \frac{200}{L_d} + W_s = \text{Uniform Load in psf} \]

  \[ I = \text{From 40\% at } H = 18 \text{ inches} \]

  \[ \text{To 0\% at } H = 10 \text{ feet} \]

- **Load on Walls:**

  \[ P_e = k_e W_e H' = \text{Uniform Load in psf} \]

  \[ P_s = k_s W_e \left( H' + \frac{80000}{5W_eL_d} \right) = \text{Uniform Load in psf} \]

  \[ k_e = 0.33 \text{ min., 1.0 max.} \quad k_s = 0.33 \]

**FIGURE 5.2 – DESIGN OF PEDESTRIAN UNDERPASSES**
• Design Equations for Single Box (per Foot of Pedestrian Underpass Length)

\[
\text{Max } M_B = \frac{Wb^2}{24} \left( \frac{1 + 3k}{1 + k} \right) \quad \frac{P_e h^2}{12} \left( \frac{k}{1 + k} \right) = \text{in lb-ft, use min. value of } P_e
\]

\[
\text{Max } M_A = \frac{Wb^2}{12} \left( \frac{1}{1 + k} \right) + \frac{P_s h^2}{12} \left( \frac{k}{1 + k} \right) = \text{in lb-ft, use max. value of } P_e \text{ or } P_s
\]

\[
V_A = \frac{Wb}{2} = \text{in lbs}
\]

• Design Equations for Double Box (per Foot of Pedestrian Underpass Length)

\[
\text{FIGURE 5.2 (CONTINUED) – DESIGN OF PEDESTRIAN UNDERPASSES}
\]
Max \( M_A = \frac{Wb^2}{12} \left( \frac{1}{1+2k} \right) + \frac{P_L h^2}{6} \left( \frac{k}{1+2k} \right) \) = in lb - ft, use max. value of \( P_e \) or \( P_i \)

Max \( M_A = \frac{Wb^2}{12} \left( \frac{1}{1+2k} \right) + \frac{P_L h^2}{6} \left( \frac{k}{1+2k} \right) \) = in lb - ft, use min. value of \( P_e \)

Max \( M_C = \frac{Wb^2}{12} \left( \frac{1+3k}{1+2k} \right) - \frac{P_L h^2}{12} \left( \frac{k}{1+2k} \right) \) = in lb - ft, use min. value of \( P_e \)

\( V_A = \frac{Wb}{4} \left( \frac{2+3k}{1+2k} \right) + \frac{P_L h^2}{4b} \left( \frac{k}{1+2k} \right) \) = in lbs., use max. value of \( P_e \) or \( P_i \)

\( V_C = \frac{Wb}{4} \left( \frac{2+5k}{1+2k} \right) - \frac{P_L h^2}{4b} \left( \frac{k}{1+2k} \right) \) = in lbs., use min. value of \( P_e \)

Notations:

- \( b \) = Width of box opening
- \( b' \) = Horizontal distance between center lines of box walls
- \( h \) = Height of a box opening
- \( h' \) = Vertical distance between the centerlines of box top and bottom slabs
- \( H \) = Vertical distance from base of rail to top of box
- \( H' \) = Vertical distance from base of rail to center of box opening
- \( I \) = Impact load applied on top of box, as a percentage of \( W_{LL} \)
- \( I_s \) = Moment of inertia of the top slab gross section, per foot of tunnel length
- \( I_w \) = Moment of inertia of the wall gross section, per foot of tunnel length
- \( K \) = Ratio of \( S \) to \( R \)
- \( K_e \) = Coefficient of active earth pressure for embankment fill without surcharge loading
- \( K_s \) = Coefficient of active earth pressure for embankment fill including surcharge loading
- \( L_d \) = Lateral live load distribution length
- \( M_A \) = Maximum negative moment at the exterior corner of the box, per foot of tunnel length
- \( M_B \) = Maximum positive moment at the center of the top slab, per foot of tunnel length
- \( M_C \) = Maximum negative moment in the top slab at the top of the center wall, per foot of tunnel length
- \( P_e \) = Uniformly distributed lateral earth design load acting on the sides of the box
- \( P_s \) = Uniformly distributed lateral earth + surcharge load acting on the sides of the box
- \( R \) = Ratio of \( b' \) to \( h' \)
- \( S \) = Ratio of \( I_s \) to \( I_w \)
- \( V_A \) = Maximum vertical shear in top slab, at the face of support near an exterior corner, per foot of culvert length
- \( V_C \) = Maximum vertical shear in top slab, at the face of support near a center wall, per foot of tunnel length
- \( W \) = Total uniformly distributed load on top of box, combination of \( W_{LL}, W_{DL}, \) and \( I \)
- \( W_{LL} \) = Uniformly distributed live load on top of box
- \( W_{DL} \) = Uniformly distributed dead load on top of box
- \( W_s \) = Mass density of embankment fill (120 lbs/ft^2)
- \( W_e \) = Mass of concrete per square foot of top slab area

FIGURE 5.2 (CONTINUED) – DESIGN OF PEDESTRIAN UNDERPASSES
(f) Combination of Loads and Loading Cases

All elements of the pedestrian underpass shall be designed for a combination of lateral soil, groundwater, and surcharge loads acting in conjunction with vertical dead and live loads. Generally a box type structure is considered a rigid frame and will be designed for the vertical and horizontal earth load together with the combination of vertical live load, horizontal live load, and uplift pressure which give the greatest stresses in the various parts of the structure. See Figure 5.3. Structure shall be checked for construction loading conditions.

Upon request by PCJPB, the underpass shall be designed to accommodate future expansions (i.e. increased horizontal and vertical clearances, special equipment loading besides pedestrians and for the addition of future tracks).

**FIGURE 5.3 – LOADING CONDITIONS FOR DESIGN OF PEDESTRIAN UNDERPASS**
5.3.4 Design Requirements

The same underpass cross-section shall be used throughout the tunnel whenever possible. Consideration shall be given to provide for future tracks.

- For preliminary design the engineer shall design for a minimum thickness of 12 inches for top and bottom slabs, and walls depending on loading conditions and height of cover. Cast-in-place construction may require larger wall and slab thickness to ensure proper concrete placement.

1. Joints

Placement of joints must be carefully considered to minimize vertical and longitudinal movements, especially for long pedestrian underpasses or in sites with high fill material.

All joints shall have water tight joints and be waterproofed.

Joints shall be spaced away from the centerline of track. Due consideration shall be given to assure load transfer across joints.

2. Reinforcement

The Engineer shall provide sufficient transverse reinforcement to satisfy loading requirements. Minimum longitudinal reinforcement in top slabs, bottom slabs, and walls shall be:

- Fill depths ≤ 10 feet 0.4% of concrete cross sectional area
- 10 feet < fill depths ≤ 100 feet Increase proportionally to 1% of concrete cross sectional area

3. Foundation

Pedestrian tunnels shall be placed on well-graded and level foundation surfaces. For precast underpasses, the foundation shall include a minimum of 12-inch deep layer of compacted crushed stone. Where finer compacted material is needed, a sand layer may be used on top of the crushed stone bed. Cast-in-place construction may not need the crushed stone bed foundation. The designer shall provide recommendations for appropriate foundation material. A mud slab may be required under the bottom slab of a tunnel to facilitate construction if ground water and a muddy base are encountered.

5.4 Special Provisions

5.4.1 Waterproofing

Waterproofing around a pedestrian underpass shall prevent water seepage into concrete joints and the interior of the underpass if there is the possibility of a high water table. Waterproofing is required for all PCJPB pedestrian underpasses that may come in contact with any ground water. Based on the maximum groundwater level anticipated, the designer shall recommend the most appropriate sealant method. Refer to AREMA, Chapter 29 for waterproofing requirements and types.
Selection of waterproofing type shall be based on its resistance to oil, diesel agents, and other contaminated materials in the soil if they are present at the site of the tunnel.

In most cases new concrete shall be cured for a minimum of 7 days before applying waterproofing system. Refer to the manufacturer's recommendations for accurate installation of waterproofing.

Different types of waterproofing have been proven to work effectively in railroad environments, such as roll-on waterproofing material or membrane types.

(a) Types of Waterproofing

i. Slurry Coat Crystallization: A layer of slurry coat may be applied to joint surfaces between pours of tunnel elements. Dry powder compounds are applied to concrete in the slurry coat, forming fibrous crystals throughout the pours. The 2.0 lb/sq. yd. slurry coat substance will not deteriorate under normal conditions and not subjected to effects from humidity, ultraviolet radiation, and oxidation. Typical temperatures suitable for the slurry coat range from –32°C to 130°C.

The slurry coat does not require dry weather to crystallize, surface priming or leveling, and may be applied to either negative or positive pressure sides. The crystallization method is applicable to existing concrete structures and precast elements. Manufacturers for slurry coats include XYPEX, VANDEX, SPECON, and others. Designers shall verify vendors and quotes for specific project sites.

ii. Waterproofing Membrane: The most effective method to protect a pedestrian underpass is by providing a waterproofing membrane. Membrane material may be composed of (See Table 5.2):

- bitumen-treated cotton fabric or felt
- butyl rubber or EPDM
- rubberized asphalt with plastic film
- cold liquid-applied elastomeric membrane with a primer.

When the exterior of the underpass has a waterproofing membrane, a protection course shall be applied prior to the placing of backfill. Backfill shall be selected and placed carefully to prevent damage to the waterproofing system. Flexibility and expansion shall be provided in waterproofing membrane at pedestrian underpass joints where deflection may cause stretching in the material.

The designer shall advise PCJPB of potential sealing problems on projects when necessary. Refer to Section 5.2 for using appropriate waterproofing for different structure types. Every effort shall be made to match existing waterproofing system types when widening or retrofitting an existing PCJPB pedestrian underpass.
<table>
<thead>
<tr>
<th>Type</th>
<th>Temperature of Application</th>
<th>Properties</th>
<th>Application Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>BITUMINOUS MEMBRANE</td>
<td>&gt; 50°F (10°C)</td>
<td>• Coal-tar pitch cannot be heated above 300°F</td>
<td>1. Mop the surface at ½ gallon per 100 sq. ft. of surface.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Asphalt cannot be heated above 350°F</td>
<td>2. Layers of felt/fabric will be lapped on with a min. of 12&quot; splice. See AREMA, Ch. 29.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Requires a strip area of 36&quot; long.</td>
<td>3. Apply anti-bonding paper and galvanized metal over expansion joints.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Membrane thicknesses = 0.06&quot;, 0.09&quot;, or 0.12&quot;</td>
<td>4. Patching only by permission of Engineer.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Hardness = 60 ± 10 durometer</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Tensile strength = 1300 psi</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Puncture resistance = 70 lbs.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Refer to AREMA, Chapter 29 for other properties.</td>
<td></td>
</tr>
<tr>
<td>BUTYL RUBBER / EPDM</td>
<td>&gt; 10°F (-12°C)</td>
<td>• Requires a strip area of 36&quot; long.</td>
<td>1. Apply adhesive and roll membrane tightly over surface.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Membrane thicknesses = 0.06&quot;, 0.09&quot;, or 0.12&quot;</td>
<td>2. Clean all seams, laps, and splices. See AREMA, Ch. 29.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Hardness = 60 ± 10 durometer</td>
<td>3. Apply anti-bonding paper and galvanized metal over expansion joints.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Tensile strength = 1300 psi</td>
<td>4. Patch over punctures with minimum 4&quot; overlap.</td>
</tr>
<tr>
<td>RUBBERIZED ASPHALT WITH</td>
<td>&gt; 50°F (10°C)</td>
<td>• Membrane thickness = 0.06&quot;</td>
<td>1. Clean and dry surfaces.</td>
</tr>
<tr>
<td>PLASTIC FILM</td>
<td></td>
<td>• Max. Permeability = 0.1 perms</td>
<td>2. Apply primer at a rate of 100-250 sq. ft. per gallon. Allow primer to dry for an hour.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Min. Puncture Resistance = 40 lbs.</td>
<td>3. Overlap rubber asphalt with plastic film at 2 ½ inches, and with preformed board at 6 inches.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Peel Adhesion = 5.0 lb/inch of width after 7 days dry</td>
<td>4. Apply anti-bonding paper and galvanized metal over expansion joints.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Crack bridging = 100 cycles 0.25&quot;</td>
<td>5. Trowel the perimeter of the membrane with cold applied asphalt mastic.</td>
</tr>
<tr>
<td>COLD LIQUID-APPLIED</td>
<td>Between 32 - 104°F (0 - 40°F C)</td>
<td>• Membrane Thickness = 100 mils</td>
<td>1. Dry all surfaces.</td>
</tr>
<tr>
<td>ELASTOMERIC MEMBRANE</td>
<td></td>
<td>• Adhesion/ Pull off values = 100 psi for concrete, 290 psi for steel</td>
<td>2. Spray membrane fully over all the sides. Brush on touch-up as needed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Min. Tensile Strength = 930 psi</td>
<td>3. Cure fully before covering the surface.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Crack bridging = pass at 25 cycles 0.0625&quot;</td>
<td>4. Put on protective cover (either Portland cement concrete or asphalt plank/panels) to prevent damage from the ballast.</td>
</tr>
</tbody>
</table>
5.4.2 Drainage

The surface of the top slab in contact with the backfill may be sloped towards the sidewalls for drainage. Interior walkway slabs shall be crowned to slope towards the sidewalls and then drained longitudinally and be collected into a drain system.

Pipe drains may be required to be designed in the backfill adjacent to the sidewalls of the pedestrian underpass. Horizontal drainpipes shall be perforated and at least 8 inches in diameter.

Pedestrian underpasses that are located below the adjacent grade shall be provided with a positive method of eliminating water that may seep into the underpass (i.e. pumping system). Discharge of drainage water shall be collected at an approved discharge point.

5.5 Construction of Pedestrian Underpasses

Staging and construction scheduling shall be carefully planned to minimize impact on PCJPB rail service.

The PCJPB's construction windows for projects that will interfere with rail operations shall be limited to weekends (from Friday evening 9 PM through Monday morning 3 AM) and night time work. During this window, active tracks will be non-operational and removed from service. Tracks, ballast, ties and all service-related components shall be replaced for operation prior to the end of the allotted construction window.

When staging is required for construction outside the specified window, special arrangements must be made with PCJPB. Staging may be required particularly for cast-in-place structures to achieve curing strength. One of three staging methods shall be implemented if a project entails weekday construction hours: (1) construction of the structure 15' outside of active railroad traffic, (2) phase construction so one track remains active, or (3) construct a temporary shoofly or bridge to accommodate railroad traffic.

The engineer shall approve all backfill and bedding materials used for underpasses. All backfill and bedding material shall be free from brush and other organic materials. Wet or impervious materials are not to be used for backfill material of PCJPB structures, unless otherwise approved by the engineer.
CHAPTER 6

PEDESTRIAN OVERPASS
CHAPTER 7

CULVERTS
CHAPTER 8

RAILROAD SIGNAL POLES
CHAPTER 9

RETAINING WALLS
CHAPTER 9
RETAINING WALLS

Purpose

This guideline was created to provide standards and requirements regarding design and construction of new or modified permanent retaining walls that affect the tracks and property of the Peninsula Corridor Joint Powers Board (PCJPB). Design engineers can use these guidelines as a basis for design. Abutments are also discussed in this Chapter since soil loading conditions are similar to that of retaining walls. For temporary shoring walls, refer to the PCJPB Guideline for Excavation Support Systems.

9.1 General Requirements

Design of retaining walls shall comply with the appropriate parts of the current AREMA Manual of Railway Engineering. Applicable sections of the manual include Chapter 8, Part 2, 5, 6, 7, 20 and 22 among others.

The addition of future tracks along the PCJPB Right-of-Way shall be explored prior to the design of retaining walls along the tracks. Provisions must be made for at least four tracks along the PCJPB Right-of-Way.

The designer shall base the retaining wall design on soil conditions from available reports or a new geotechnical report shall be generated if warranted. A log of test borings shall accompany the foundation report and the drawing plan set shall include the log of borings.

9.1.1 Design Considerations

The selection and design of retaining walls shall be based on:

- The purpose of the structure
- Stresses and loads to be applied to the wall
- Depth of structure from base of rail to invert level
- Requirements for soil backfill and compaction
- Existing soil and foundation conditions
- Required height of the wall

9.2 Retaining Walls Type Selection

A retaining wall provides lateral support for earth fill, often times supporting live loads adjacent to the soil mass. The different types of retaining walls that may be used along the Caltrain railroad include:

(1) **Gravity Wall** – The gravity wall relies on its weight to for stability. For a concrete gravity wall only temperature steel is required for reinforcement in gravity walls.

(2) **Semi-Gravity Wall** – This type is an intermediate between a gravity wall and a cantilever wall. For a concrete semi-gravity wall some steel reinforcement is needed along the back and lower side of the toe.
(3) **Cantilever Wall** – This type wall utilizes cantilever action to retain the mass behind the wall from assuming a natural slope. A concrete wall of this type will require steel reinforcement is needed for this L-shaped configuration.

(4) **Counterfort Wall** – This type of wall consists of vertically reinforced counterforts laterally supporting a reinforced vertical face slab buried in backfill, which in turn, all supported by a reinforced base slab.

(5) **Buttress Wall** – Buttresses support a vertical face slab, as in counterfort walls, but exposed on the face of the wall rather than buried in the backfill.

(6) **Crib Wall** – Relying on the weight and strength of earth fill, crib walls are comprised of an earth-filled assembly of separate structural units.

(7) **Mechanically Stabilized Earth (MSE) Wall** – More economical, MSE walls are formed by reinforcing the backfill with reinforcement straps.

The designer shall consider site conditions, load demands including seismic, and cost efficiency when selecting the appropriate type of retaining wall to be used. PCJPB prefers designs that are most compatible with railroad operations and that can be constructed with a minimum amount of disturbance to train traffic.

The PCJPB Right-of-Way shall be verified by professional land surveyors, prior to construction of any structure, especially if the wall is located on the property line. Retaining walls along railroad Right-of-Way may require temporary construction easements on adjacent property to facilitate construction. Permitting and easements shall be obtained through the Real Estate Department at PCJPB. The designer shall make every effort to eliminate the acquisition of temporary and permanent easements.

All earth retention structures owned by Caltrain shall be designed in accordance with criteria described in Chapter 8, Part 5 of the most current AREMA Manual, and any special provisions made by PCJPB.

### 9.2.1 Factors for Selecting Retaining Wall Types

Include all appropriate earth retaining systems in the concept design development documents that will promote a selection of a retaining wall system that satisfies the requirements of the PCJPB and the site conditions. Earth retaining systems that lead to cost savings may be most favored. PCJPB will make final decisions on the type of system to be used based on the designer’s recommendations. The following items will be considered in the selection of the retaining wall structure:

- **Cost** – PCJPB generally prefers the most cost-effective alternative for retaining wall structures, yet still meeting height and length design requirements. For construction costs, mechanically stabilized earth walls (MSE) may be less expensive than cast-in-place gravity walls, especially in locations that require additional fill material. Generally, gravity walls are the most basic and common alternative but can become expensive when supporting railroad surcharge loadings (depending on height).
Location – The location of retaining walls will affect operations and constructibility of certain wall types. Walls shall be of a type that will minimize impact to PCJPB operations. When sufficient construction space or access is not permitted, select a wall type that requires the least Right-of-Way acquisition. In most cases, cast-in-place type wall installation may require an additional encroachment off PCJPB property if it is located on a Right-of-Way line. The designer shall inform PCJPB of potential construction easements or permitting requirements necessary for the construction of a retaining wall.

Aesthetic Conditions – Retaining walls for retrofit or widening projects shall match existing aesthetic conditions whenever possible. New structures will conform to the requirements of PCJPB and local City or County agencies. Wall types and aesthetic treatments shall be uniform throughout a project (i.e. cast-in-place walls to resemble the finishing of adjacent, existing MSE wall when visible to the public). Side slopes of the wall shall be graded to provide a pleasing profile.

Maintenance – Costs incurred for maintenance shall be considered when selecting the type of retaining wall structure. Wall types selected shall require minimal maintenance and replacements. For instance, graffiti-free coating spray may be used to minimize graffiti vandalism during the service life of a wall.

Constructability – The construction of walls along the PCJPB corridor are typically constrained by the active operating track and the available Right-of-Way available for construction. Consideration shall be given to the operations of the PCJPB and to minimize any interference with train operations.

9.3 Structural Design Requirements

9.3.1 Wall Design Heights

Retaining wall heights will be designed to provide for future raises in the track. The height for retaining walls shall vary linearly from top of rail (T/R), in relation to the distance away from the centerline (CL) of track (as the distance away from the centerline of track increases, the required height of the retaining wall can decrease). At a 10 feet minimum distance from the centerline of track, the retaining structure shall be at the same elevation as top of rail. The wall height requirement may be reduced to 8 inches below top of rail, at the maximum distance of 13 feet away from the centerline of track. Refer to PCJPB Track Standard TS-1025 and TS-1030 for cross section of track to be used to establish wall heights parallel to the track, greater than 13 feet from centerline of track.

9.3.2 Loads

Pressure loading on the retaining wall is dependent upon the type of structure, the type of fill, and the location of the applied live load.

(a) Live Load

Live loads that may affect the design of earth retention structures consist of trains, street or highway traffic, or other loading combinations. Live loads due to railroad
trains shall be determined per PCJPB's requirements and in most cases Cooper E-80 axle loading shall be used as found in Chapters 8 and 15. The application of the railroad surcharge loading shall be per AREMA Chapter 8, Section 5.3. Highway-traffic live loading shall be applied in accordance with Caltrans Design criteria. Construction loads shall be considered to account for future maintenance operations of the PCJPB.

Other live loads, including those due to structures, shall be analyzed on an individual-case basis and applied either as a uniform surcharge, point load, or line load.

(b) Applied Loading Exclusive of Earth Pressure

Chapter 8, Section 5.3.1 of the AREMA Manual describes other load applications (i.e. superimposed dead loads and live load surcharge) besides earth pressure.

- **Perpendicular to the track** (such as an abutment) – The track loading is uniformly distributed on the ballast over the width of the tie when structures or abutments lie almost perpendicular to the track center. This surcharge loading distribution increases with depth on a 1 horizontal to 2 vertical slope on both sides with surcharge from adjacent tracks not being permitted to overlap.

![Diagram of track perpendicular to supporting structure](image)

**FIGURE 9.1 - TRACK PERPENDICULAR TO SUPPORTING STRUCTURE**

- **Parallel to the track** – When a wall is parallel to the tracks, the surcharge load is distributed uniformly over the width of the tie. Pressures on the retaining wall, \( P_s \) caused by a continuous strip of surcharge load \( q \) (pounds per square foot) can be analyzed by:

\[
P_s = \frac{2q}{\pi} \left( \beta + \sin \beta \sin^2 \alpha - \sin \beta \cos^2 \alpha \right)
\]

where \( \alpha \) and \( \beta \) are defined in **Figure 9.2**.
The Boussinesq pressure distribution for a strip load may be used for all surface surcharge loads. The pressure distribution may be simplified into a rectangular distribution with a magnitude 80% of the maximum Boussinesq pressure or other some other method upon approval of the PCJPB.

**FIGURE 9.2 - TRACK PARALLEL TO SUPPORTING STRUCTURE**

(c) Loading Combinations

Various loads and forces shall be combined in accordance with the most current AREMA Manual. Factored loading shall be used when using the Load Factor Design (LFD), and unfactored loading when using Allowable Stress Design (ASD).
(d) **Forces Acting on Typical Abutment**

- **D** = Dead Load from superstructure
- **L** = Live Load from superstructure
- **W** = Wind Load on structure
- **EQ** = Earthquake (Seismic) Load on structure
- **OF** = Other Forces (including rib shortening, shrinkage, temperature and/or settlement of supports (assume 10% of Dead Load)
- **H** = Height of abutment
- **WC** = Weight of concrete abutment
- **WS** = Weight of soil behind abutment
- **PS** = Lateral Soil Pressure from live load surcharge
- **PE** = Lateral Pressure due to Earth Embankment

*Active Earth Pressure without earthquake is usually taken as H/3. Dynamic Pressure due to earthquake is assumed to be 0.60H from the base. Combined effect is assumed by most engineers to be 0.5H.*

**FIGURE 9.3 – FORCES ACTING ON ABUTMENT**

(e) **Forces Acting on Typical Retaining Wall**

- **WS** = Weight of soil behind retaining wall
- **Pa** = Active Pressure acting on wall, combination of lateral pressures due to earth and live load surcharge
- **Pp** = Passive Pressure acting on wall, may be neglected when computing resistance against sliding.
- **N** = Resultant vertical force
- **O** = Toe of the wall
- **WC** = Weight of concrete wall
- **F** = Friction force along the base
- **B** = Width of the base
- **Xo** = Horizontal Distance to the resultant force
  \[ X_o = \sum M_o / N \]
  Resultant Vertical Force
- **e** = Eccentricity of resultant = B/2 - Xo

**FIGURE 9.4 – FORCES ACTING ON RETAINING WALL**
(f) Backfill Pressure

Backfill may be considered undisturbed ground or fill material behind a retaining structure. Classification of backfill types and their properties that may be found on PCJPB structures are shown in Table 9-1. Types 4 and 5 backfill are generally not allowed by PCJPB, and their use requires approval.

Table 9-1 BACKFILL TYPES & PROPERTIES FOR RETAINING WALLS

<table>
<thead>
<tr>
<th>Type</th>
<th>Backfill Description</th>
<th>Unit Dry Weight (lb/ft$^3$)</th>
<th>lb/SF</th>
<th>Cohesion “C” Angle of Internal Friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coarse-grained soil without admixture of fine soil particles, very free-draining (clean sand, gravel or broken stone).</td>
<td>105</td>
<td>0</td>
<td>33° 42’ (38° for broken tone)</td>
</tr>
<tr>
<td>2</td>
<td>Coarse-grained soil of low permeability due to admixture of particles of silt size.</td>
<td>110</td>
<td>0</td>
<td>30°</td>
</tr>
<tr>
<td>3</td>
<td>Fine silty sand; granular materials with conspicuous clay content; or residual soil with stones.</td>
<td>125</td>
<td>0</td>
<td>28°</td>
</tr>
<tr>
<td>4</td>
<td>Soft or very soft clay, organic silt; or soft silty clay.</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Medium or stiff clay that may be placed in such a way that a negligible amount of water will enter the spaces between the chunks during floods or heavy rains.</td>
<td>120</td>
<td>240</td>
<td>0</td>
</tr>
</tbody>
</table>

Appropriate structural backfill and compaction will be selected based on the design of the engineer. If after conducting geotechnical investigation and existing backfill is unsuitable for abutments or retaining structures, backfill shall be replaced with material appropriate for the structure. Higher quality backfill material that reduces active soil pressure and lateral loading on the structure may be preferred over an elaborate structural solution.

Other provisions and calculations for backfill pressure shall be computed using formulas found in AREMA, Chapter 8, Section 5.3. The Rankine-Coulomb Theory may be used under the following conditions: when backfill is cohesionless, surface of backfill is flat, and either without surcharge or uniformly distributed surcharge loading.

(g) Dynamic Earth Pressure

Dynamic earth pressure due to earthquake shall be considered using the Mononobe-Okabe Theory. The Mononobe-Okabe static analysis takes into account horizontal and vertical inertia forces acting on the soil, with the following assumptions:
(1) The abutment/retaining wall is free to move sufficiently to mobilize the soil strength. If the abutment is rigidly fixed, the Mononobe-Okabe analysis produces very conservative values for soil forces.

(2) The backfill is cohesionless with a friction angle $\phi$.

(3) The backfill is unsaturated to prevent liquefaction.

The active force that results from the Mononobe-Okabe theory is given by:

$$ P_{AE} = 0.5 \gamma H^2 (1 - k_v) K_{AE} $$

where:
- $\gamma$ = unit weight of soil
- $H$ = height of abutment/retaining wall
- $k_v$ = seismic acceleration coefficient in the vertical direction
- $K_{AE}$ = dynamic active earth pressure coefficient = $K_A + 0.75k_h$
- $K_A$ = static active earth pressure coefficient
- $k_h$ = seismic acceleration coefficient in the horizontal direction

Abutments must be designed for seismic loading, whereas other earth retaining structures need not be designed for earthquake loads if they do not support the PCJPB tracks and unless they have the potential to cause damage to essential facilities or other adjacent structures.

9.3.3 Retaining Wall Stability

Stability calculations are required for retaining structures per AREMA Manual, Chapter 8, Section 5.4.1. Earth retaining structures should satisfy all three stability criteria: overturning, sliding, and bearing pressure.

Overturning

Stability against overturning need not be checked if the resultant on the base is located within (1) the middle third of structures situated on soil, and (2) the middle half for structures situated on rock, masonry, or piles. Per AASHTO, overturning factors of safety of 2.0 or 1.5 are required for footings found on soil or rock, respectively.

Sliding

The factor of safety against sliding shall be at least 1.5. Friction resistance between the soil and the wall is calculated as the product of the normal pressure and coefficient of friction. For different subsoils, friction coefficient values may be taken as:

- coarse-grained soil without silt: 0.55
- coarse-grained soil with silt: 0.45
- silt: 0.35
Bearing Pressure

Depending on soil strength and long-term settlement, bearing pressure can vary over the base of retaining structures. A factor of safety of 3 is generally used to achieve stability of the base against bearing capacity failure. Possible bearing pressure distributions acting on the footing, shown on Figure 9.6, shall be used to determine the maximum bearing pressure, $q_{\text{max}}$, while satisfying the following criteria:

$$\frac{R_s q_{\text{ult}}}{FS} \geq q_{\text{max}} \quad (ASD)$$

$$\phi R_s q_{\text{ult}} \geq q_{\text{max}} \quad (LFD)$$

where:
- $q_{\text{ult}}$ = ultimate bearing capacity
- $R_s$ = reduction factor due to inclined loads
- $FS$ = Factor of Safety
- $\phi$ = performance (strength reduction) factor
- $q_{\text{max}}$ = maximum bearing pressure due to unfactored loads (ASD)
- $q_{\text{max}}$ = maximum bearing pressure due to factored loads (LRFD)

These bearing pressure distributions may be caused by permanent or temporary loads, such as wind or seismic, creating an uneven bearing pressure on the footing. The resultant bearing pressure, $N$, is a resultant of the loading conditions related to the eccentricity, $e$. For moment loads on square or rectangular footings, $e = M/P$, where $M$ is the applied moment and $P$ is the applied normal load on the footing.

If $e \leq B/6$ the resultant force acts within the middle one third-point and the eccentricity or applied moment is in the plane of the $B$ dimension only, the minimum and maximum net bearing pressures, $q_{\text{max}}'$ and $q_{\text{min}}'$ on a square, circular, or rectangular footings are given in Figure 9.6 (a) Trapezoidal Distribution.

When $e = B/6$, the resultant force acts at the third-point of the footing and creates a triangular bearing pressure distribution as shown in Figure 9.6 (b) Full Triangular Distribution. ($q_{\text{min}}'$ equals to 0 in the triangular distribution). Both the trapezoidal and triangular distributions are normally accepted in design because compressive stresses are present along the entire base of the footing.

However, if $e > B/6$, the resultant force at the base is outside the middle third-point. The pressure distribution is shown in Figure 9.6 (c) Triangular Distribution. No tension is allowed between the footing and the soil thus resulting in no uplift. Large settlements at the toe and excessive tilting of the footing may result from this loading condition. This type of retaining wall design is not desirable in practice and shall preferably not be used.
(A) TRAPEZOIDAL DISTRIBUTION

\[ q'_{\text{max}} = \frac{P}{B} (1 - \frac{6e}{B}) \]
\[ q'_{\text{min}} = \frac{P}{B} (1 + \frac{6e}{B}) \]

(B) FULL TRIANGULAR DISTRIBUTION

\[ q'_{\text{max}} = \frac{P}{B} (1 - \frac{6e}{B}) \]
\[ q'_{\text{min}} = 0 \]

(C) TRIANGULAR DISTRIBUTION

\[ q'_{\text{max}} = \frac{2P}{3B(0.5 - \frac{e}{B})} \]

ALL PRESSURE DISTRIBUTIONS ARE BASED ON 1 FT. STRIP OF FOOTING. THESE EQUATIONS ARE RECOMMENDED FOR PRELIMINARY DESIGN.

BEARING PRESSURE DISTRIBUTION

FIGURE 9.6
9.3.4 Abutment Stability

When determining the stability for an abutment, the following must be considered:

1. Uplift is prevented on the backside of the footing.
2. The resultant load, being the sum of the lateral earth pressure, abutment weight, and bridge weight, must lie inside the middle third of the base. Live load shall be included also.
3. Embankments shall be safeguarded against ground ruptures, by providing sufficient abutment depth below the ground surface in soils with low shear strength (shown in Figure 9.5 below).
4. The fill behind the abutment is properly drained.

![Abutment Stability Diagram](image)

**FIGURE 9.5 – STABILITY OF ABUTMENT**

9.4 Clearances

PCJPB requires a minimum of 10 feet horizontal clearance from the centerline of track to the interior face of wall of the retaining structure. The absolute minimum horizontal clearance shall be per California PUC 26D requirements.

Preferred vertical clearances shall be at least 25'-6" above top of rail. Minimum vertical clearance shall be 24'-6" with an absolute minimum vertical clearance of 23'-6" allowed only under special circumstances. Attention shall be given to overhead utilities that may be relocated during construction, if located within PCJPB Right-of-Way; there are special CPUC vertical clearance requirements for overhead utility lines (CPUC GO. 95).

Right-of-Way fences shall be a minimum of 6 feet in height. Retaining walls joining fencing shall provide for continuous protection of the Right-of-Way by the 6 foot height limit.

9.5 Special Provisions

9.5.1 Railroad Electrification

PCJPB/Caltrain is planning for future electrification (25kV AC 60Hz) of the corridor. All structures shall provide for a future installation of an overhead catenary system. Space for catenary support poles along the PCJPB Right-of-Way and on structures shall be provided. Overhead vertical clearance and horizontal clearance shall comply with the following references: CPUC GO-26 and GO-95, NESC, NEC, and AREMA Chapters 28 and 33.
All concrete retaining walls shall be detailed to mitigate the effects of stray current corrosion of steel reinforcing, prestressing elements, and other steel components. This will require that electrical continuity be provided between all steel elements within each concrete structural component with provisions to connect the components to a central location. The corrosion control system will be installed at the time of future electrification with connections made to the central location. Comply with CPUC GO 95, AREMA Chapter 33, IEEE, NESC, and NEC provisions for stray current.

9.5.2 Utilities

Utility lines shall not be attached to new retaining structures, except for utilities (i.e. signal lines) that are required for the operation of the railroad. Existing or future fiber optic lines shall be placed underground and away from retaining walls. In most cases relocation of existing utilities will be provided by the owners of the utility. In some instances when the utility line may have to be located on the structure, PCJPB will handle these on a case by case basis. Utility locations need to be verified by qualified land surveyors and by information from respective public utility agencies.

9.5.3 Drainage

Retaining wall drainage shall be provided for and directed away from the track roadbed and away from the back of the wall. Water shall be removed preferably by horizontal drainpipes (larger than 8" diameter) or by weep holes (larger than 6" diameter spaced at maximum 10 feet apart). Drainage patterns for the entire Right-of-Way shall be considered for the project with all drainage directed away from the tracks and to an appropriate outfall.

9.5.4 Mechanical Stabilized Embankments (MSE)

MSE walls shall follow the requirements of AREMA - Chapter 8, Part 7. In addition to the AREMA guidelines the following provisions shall be incorporated into the design:

- The actual applied bearing pressures under the stabilized mass for each reinforcement length shall be clearly indicated on the design drawings.
- Passive pressure in front of the wall mass shall be assumed to be zero for design purposes.
- Due consideration shall be given to the placement of utilities along the railroad within the area of the MSE structure. This can be done by limiting the placement of the MSE reinforcements to a zone below the potential depth of trenching (4 to 6 ft.) or by planning ahead and pre installing conduits to allow for future utility installations.
- Calculations for stresses and factors of safety shall be based on assumed conditions at the end of the design life.
- The design life shall be 100 years for MSE structures unless otherwise directed by the PCJPB.
(a) **MSE that use Metallic Reinforcing Strips**

In the case of MSE that use metallic reinforcing strips the following provisions apply. For determination of the allowable reinforcement tension, the following metal loss rates shall be used:

- Zinc (first 2 years): 15 microns/year/side
- Zinc (subsequent years to depletion): 4 microns/year/side
- Carbon Steel (after depletion of zinc): 12 microns/year/side
- Carbon Steel (from 75 to 100 years): 7 microns/year/side

For maximum allowable tensile stress in steel reinforcements and connections including tie strips, F₁ at the end of the service life, shall conform to the following:

- **Linear Reinforcements (strips)**
  \[ F₁ = 0.55 \, Fₚ \text{ at reduced gross cross section} \]
  \[ F₁ = 0.50 \, Fₚ \text{ at net section of bolted connections} \]

- **Bar Mats and Welded Wire Meshes**
  \[ F₁ = 0.48 \, Fₚ \text{ all sections} \]

It is critical that the longitudinal and transverse wires (bars) be of the same size on any given reinforcement element. \( Fₚ \) used for design shall not exceed 65 ksi. The maximum allowable tension in the reinforcements shall consider any reductions in cross sectional area of reinforcements due to punching, corrosion losses, and shall not exceed 50% of the pullout capacity of the connection devices embedded in the facing panels.

(b) **MSE Structural Backfill**

The select granular backfill material used in MSE structures shall be reasonably free from organic and otherwise deleterious materials and shall conform to the following gradation limits:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 inches</td>
<td>100</td>
</tr>
<tr>
<td>3 inches</td>
<td>75-100</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-15</td>
</tr>
</tbody>
</table>

In addition the backfill shall conform to all of the following requirements:

1. The plasticity index (P.I.), as determined by AASHTO T-90, shall not exceed 6.
2. Soundness – The material shall be substantially free of shale or other soft, poor durability particles. The material shall have a magnesium sulfate soundness loss of less than 30 percent after four cycles, as determined by AASHTO T-104.
3. Electrochemical Requirements – The backfill material shall conform to the following electrochemical requirements:

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirement</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistivity</td>
<td>Minimum 3000 ohm-cm, At 100% saturation</td>
<td>ASTM G-57-78</td>
</tr>
<tr>
<td>pH</td>
<td>Acceptable Range 5-10</td>
<td>ASTM G-51-77</td>
</tr>
<tr>
<td>Chlorides</td>
<td>Maximum 100 ppm</td>
<td>ASTM D-512-88</td>
</tr>
<tr>
<td>Sulfates</td>
<td>Maximum 200 ppm</td>
<td>ASTM D-516-88</td>
</tr>
</tbody>
</table>

All testing reports and a Certification of Compliance certifying that the selected granular backfill material meets these requirements.

4. Backfill shall be compacted to 95% of the maximum density as determined by AASHTO T-99, Method C or D (with oversize correction).

(c) Corrosion

Special attention shall be given to the prevention of corrosion in addition to the items listed above especially if metal strips are used. The MSE wall shall be provided with inspection elements for removal and verification of the rate of corrosion occurring over the life of the wall. Inspection elements are to be clearly and permanently marked on the wall in the facing panels with the following intervals for inspection; 5, 10, 25, 50, 75, and 100 year time periods with a separate inspection element for each year.

Since the railroad roadbeds have a relatively high permeability the MSE reinforcements can be exposed to precipitation and potentially corrosive substances infiltrating through the roadbed. This issue can be resolved by incorporating an impermeable layer connected to lateral drains beneath the sub-ballast but above the level of the reinforcements or strips.

Stray currents from railroad electrification are also of concern to the corrosion of metal reinforcements. Research and studies have shown that there may be a risk of accelerated corrosion for systems that utilize direct current. However, on alternating current systems this is not apparent. Other studies have shown that galvanized reinforcements have been used where direct current systems are present with stray current corrosion being negligible for the following reasons:

1) The individual reinforcement strips are short in comparison to the rails. Thus the electrical potential along the strips is minuscule for collecting stray currents.
2) The reinforcements are electrically discontinuous since the soil reinforcements are discrete linear strips.
3) Reinforcing strips are generally placed perpendicular to the direction of the running rails and the return current flow. This orientation offers the greatest resistance to stray current collection.
4) Use of a high resistivity select granular backfill reduces the tendency for stray currents to flow within the MSE volume.
It is recommended that a firm or expert in the area of corrosion and stray currents be retained to make site-specific recommendations where MSE structures are to be utilized.

9.5.5 Crib Walls

Crib walls is a gravity structure consisting of rigid open shapes filled with granular material. Types of crib walls include:

- **Concrete crib walls** – Max design height of 50 feet. Suitable for coastal areas and higher elevations. The maximum area of reinforcement shall be 0.9% of its gross rectangular cross-sectional area. Minimum compressive strength of 4,250 psi for concrete at 28 days shall be used.

- **Steel crib walls** – Max design height of 36 feet. Suitable for difficult installation sites due to its lightweight and easy transportation.

  Base metal used shall meet chemical composition and zinc composition.

- **Timber crib walls** – Max design height of 22 feet. Aesthetically compatible with rural environment and comparable service life to that of concrete and steel.

For overturning moments, the wall section may be assumed as a rectangle with total height of the crib wall, and depth equal to the distance between the two outside faces of the crib structure.

Provisions for drainage shall be made behind the wall.

Crib walls shall be designed to withstand a differential deflection of 0.015L, where L is the length of the cell measured along the face of the wall.

Other requirements for crib wall design shall be in accordance with AREMA, Chapter 8, Part 6.

Crib walls shall be handled carefully to avoid any damage due to shock or impact. Cracked or damaged members shall be replaced and removed during erection. The interior of the wall shall be filled immediately before the installation of other tier units.

9.5.6 Bulkhead / Cantilever Systems

Bulkhead systems include cantilever pile, sheet pile, tieback anchored pile, or soldier pile walls. Bulkheads are used where excavation is limited by traffic, utilities, or right of way restrictions. Costs of bulkhead walls depend on specified design requirements, site restraints, and aesthetic considerations.

Provisions in AREMA, Chapter 8 for Sheet Pile Bulkheads are based on service load design only. Sheet pile bulkheads shall be designed to be flexible structures that mobilize full active earth pressure and a portion of the passive pressure. A movement of 0.001Hf to 0.002Hf is needed to develop full active pressure in anchored bulkheads, where Hf is the height of the sheet pile above the soil level.
(a) Loading

Bulkheads may be subjected to, but not limited to, the following loads:

- Temporary loads
  - Construction equipment
  - Construction materials
  - Hydrostatic pressure
- Permanent loads
  - Future grading and paving
  - Railroads or highways
  - Structures
  - Material storage piles
  - Snow and earthquake

9.5.7 Tieback Anchored Piles

Tieback walls may consist of: sheet piles with horizontal wales, vertical soldier piles with timber or concrete lagging, reinforced concrete slurry or shotcrete walls.

(a) Loading

Tieback anchor piles shall be designed as beams subjected to the loading of the appropriate lateral pressure diagram. Horizontal wales shall be designed as simple beams loaded by the reactions from the lateral pressure diagram. The level of soil excavation shall provide sufficient bearing capacity to support the tieback force.

Tiebacks form a prestressing system anchored in a drilled hole filled with PCC grout. The prestressing steel design for tieback anchor piles is at a maximum stress of 0.55f_{pu} and jacking load of 0.75f_{pu}, where f_{pu} is the ultimate strength of prestressing steel in lbs/in². The designer shall develop the design force “T,” the force required to resist the design lateral earth pressure. The minimum factor of safety for the tieback force shall be 1.25.

(b) Construction Sequencing

Proper installation of tiebacks is critical to prevent overstressing of each anchor. Over-excavation is a cause of overstressed tiebacks. Precautions shall be made to specify the maximum allowable level of excavation.

When more than two levels of tiebacks are to be used, PCJPB recommends that the lower tieback be lengthened to avoid forming a circular slip plane and causing settlement failure.

Major failures have been known to occur if lagging is not placed simultaneously with the excavation progress.
9.5.8 Conventional Retaining Walls

The base of a retaining wall or abutment footing shall be embedded at least 3 feet below the ground surface in front of the wall face.

The unit shear stress for a horizontal shear key shall not exceed 0.25fc.

Vertical keyed wall expansion joints may be spaced at a maximum of 60 feet apart with appropriate waterproofing.

The minimum compressive strength of concrete to be used for retaining walls shall be 3600 psi at 28 days.

Reinforcement for retaining walls shall meet the following requirements:

- ASTM Standard A615 Grade 60, or
- ASTM Standard A706, or

A maximum allowable tensile stress of 24,000 psi shall be used in service load design for the reinforcing steel.
CHAPTER 10
MISCELLANEOUS STRUCTURES
CHAPTER 11

STRUCTURE DESIGN
SUBMITTAL PROCEDURES
CHAPTER 11
STRUCTURE DESIGN SUBMITTAL PROCEDURES

11.1 General

Prior to the submittal of any project involving PCJPB facilities, it is important that the agency or applicant be familiar with the guidelines and operations of the PCJPB. Any issues with the design guidelines shall be addressed prior to submitting any documents to the PCJPB. Submittals for design and construction of structures and grade separations projects on PCJPB property shall be coordinated and submitted to the PCJPB. To expedite reviews, submittals must be complete, clearly explained and assembled in an orderly manner. Plan reviews will either be preformed by PCJPB staff, an outside consultant, or a combination of both.

All engineering review work required of the PCJPB by a sponsoring agency or firm for design and construction documents for structures, grade separations, construction submittals, falsework, and shoring plans, etc shall be paid for by the applicant or sponsoring agency, thru an agreement with the PCJPB.

All plans for structures on PCJPB Right-of-Way or that affect PCJPB operations shall be approved by the PCJPB staff before construction begins.

The projects covered under these guidelines will require certain agreements, permits, right-of-entry permits, and CPUC applications be prepared, submitted and approved prior to construction.

The California Public Utilities Commission must approve all alterations, relocations, or detours that affect track alignment, grade, or the addition of tracks at grade crossings and grade separations.

11.2 Design Submittals - Master List

Project plan documents submitted for review shall include the following submittals to the PCJPB:

- Conceptual Design Level – Approximately 10-15% design concept
- Preliminary Design Level – Approximately a 30% design completion
- In-Progress Design Level - 60% design completion
- Pre-Final Design Level - 85% design completion
- Final Design Level – 100 % design completion
- Camera Ready Level or Bid Documents
- Bid Period Addendum Documents (required if a PCJPB project)
- Conformed Documents for Construction
- As-Built Documents

11.2.1 Conceptual Design Level - Approximately 10-15% design concept

Conceptual design level shall be presented in a preliminary meeting with the PCJPB to verify form, function and configuration of the project. Typical submittal item for discussion shall be the minimum of a layout plan.
11.2.2 Preliminary Design Level – Approximately a 30% design completion

Preliminary design plan submittal shall be comprised of the layout plans, (including detailed geometry, profiles, typical sections, track and lane configuration), bridge type selection report, and with critical construction issues raised. Preliminary cost estimate to be included as well.

Specific items to be included shall be:

- Plan view of proposed structure and location of all existing facilities and utilities within the operating Right-of-Way. Plan view to indicate span lengths, alignment, skew angle of abutments and piers, site drainage, etc.

- Elevation view indicating the abutment and pier elevations, track elevation to top of rail for existing and proposed, minimum vertical clearance and location, footing elevations, types of footings, locations of utilities and relocations.

- Typical superstructure cross section showing deck and pier outline, horizontal and vertical dimensions of deck structure, rail and ballast structure, waterproofing, deck drainage, track spacing, horizontal and vertical clearances, etc.

- The existing and proposed track profile shall be shown at least 1000 feet beyond the proposed structure in each direction.

- The existing and proposed track and roadway alignment shall be shown. Any proposed shoothy alignment shall be shown. The alignment design data shall be provided.

- General notes shall be shown to indicate the design criteria, construction materials, and construction sequencing. Preliminary plans on construction staging shall be provided.

- Plans shall identify the locations of existing and relocated utilities. It is very likely that there are fiber optic cables buried along the PCJPB Right-of-Way. The identification of the location of the fiber optic cables and there relocation or protection shall be consider part of the project and be addressed in the plans and specifications.

- The structure general plan shall show the location of the shoofly if required and indicate the footprint of the structure and its relation to the shoofly. Minimum clearance distances shall be shown.

- Preliminary hydrology and hydraulic (H&H) reports shall be developed. High and low flow levels shall be determined. Rainfall intensities investigated. Issues on bridge scour and protection are to be investigated.

Allow a minimum of three weeks review time.
11.2.3 In-Progress Design Level - 60% design completion

Intermediate design submittal will typically be comprised of the final layouts, profiles and typical sections, in-progress drainage plans, construction staging and traffic handling plans and impacts, utility layout plans, bridge general plans and foundation plans, Right-of-Way and permit requirements. Include a detailed outline of specifications and an intermediate cost estimate of the project.

Specific items shall include the following if they apply:

- Design of structure including superstructure and substructure.
- Structure details
- Bearing details
- Deck and waterproofing details
- Geotechnical reports and recommendations
- Structural calculations
- Drainage layout and report
- Utility relocations
- Complete track profile and alignment information and supporting data. Also, include shoofly date if applicable.
- Final hydrology and hydraulic report
- Construction sequence and staging. Indicate locations of shoring, falsework, and temporary facilities that may affect train operations.

This submittal may or may not be sent to external review depending on the complexity of the project.

Allow four weeks for review.

11.2.4 Pre-Final Design Level - 85% design completion

Pre-final design submittal shall include complete plans, specifications, and quantities that are essentially complete. Plans shall include engineering seals if required for agency review. Intended use is for formal review, including internal and external agency comments and approvals. At this level an independent check shall be performed.

Specific items shall include the following:

- Completed structural calculations with revisions from the 60% submittal.
- Complete plans to date
- Complete project specifications
- Complete reports as required for project
- Updated cost estimate
- Documented independent check

Allow five weeks for review.
11.2.5 Final Design Level – 100% design completion

Final design submittal shall include all plans, specifications, and cost estimates. Verify that all reviewers' comments have been addressed and incorporated and that the submittal is ready for printing.

Submittal of final contract documents with original signatures. If it is not a PCJPB contract, submit a copy of the bid documents.

Specific items of the submittal shall include the following:

- Final plans and specifications signed and sealed by a register professional engineer in the state of California.
- Final structural calculations signed and sealed by a register professional engineer in the state of California. The designer and the checker shall sign each calculation sheet.
- Final estimates with quantity calculations
- Final reports and data documents signed and sealed by a register professional engineer in the state of California.

Allow three weeks for final review and approval.

11.2.6 Bid Documents

Camera Ready Level or Bid Documents (required if a PCJPB project). Submittal of final contract documents with original signatures, ready for printing.

11.2.7 Bid Period Addendum Documents

Engineers' updates including addenda and changes to the plans, specifications, and estimates and responses to questions required during the bid period (required if a PCJPB project).

11.2.8 Conformed Contract Documents for Construction

Complete set of Plans, Specifications, and Estimate with bid pricing, including all addendum's and changes made during the bid period. This is the record contract documents to be used during construction.

11.2.9 As-Built documents

(See Construction Submittals)

11.3 Submittal Quantities

11.3.1 Conceptual Design Level – Approximately 10-15% design concept

- One full-size print and 5 half-size prints
- Five sets of concept reports
11.3.2 Preliminary Design Level – Approximately a 30% design completion

- One full-size print and 5 half-size prints
- Five sets of preliminary reports, including hydrology and hydraulic, geotechnical, and final bridge type selection reports.
- Five sets of cost estimate

11.3.3 In-Progress Design Level – 60% design completion

- One full-size print and 5 half-size prints
- Five sets of preliminary reports, including geotechnical reports if revised.
- Five sets of final hydrology and hydraulic report
- Five sets of response to 30% comments
- Five sets of specifications outline, estimate, and schedule
- Two sets of preliminary calculations
- Five sets of permit requirements, table, and status of each parcel.
- Five sets of utility impacts table
- Five sets of Right-of-Way requirements table and final easements/ROW descriptions.

11.3.4 Pre-Final Design Level – 85% design completion

- One full-size print, 5 half-size prints, and one reproducible half-size print.
- Five sets of response to 60% comments
- Five sets of specifications, cost estimate, and schedule
- Five sets of design calculations including computer printouts. All computer printouts to be supplemented with notes explaining input and output information.
- Five sets of permit requirements, table, and status of each parcel.
- Five sets of updated utility impacts table
- Five sets of Right-of-Way requirements table and final easements/ROW descriptions if revised.
- Five sets of independent check documents

11.3.5 Final Design Level – 100 % design completion

- One full-size print, 5 half-size prints, and one reproducible half-size print.
- Five sets of response to 85% comments
- Five sets of specifications, cost estimate, and schedule
- Five sets of final reports
- Five sets of revised design calculations

11.3.6 Bid Documents

- Five sets of responses to final design review
- Camera Ready Bid Documents
- Original full size full-size sealed plans, one reproducible full-size print and one reproducible half-size print.
- Electronic data files for drawings and specifications
- Original sealed specifications
- Final engineers cost estimate and schedule
11.3.7 Bid Period Addendum Documents

- Bid period addendum documents (required if a PCJPB project)
- Responses to contractor's questions
- Updated engineers estimate and revisions to plans and specifications as required.

11.3.8 Conformed Contract Documents for Construction

- Conformed plans and specifications documents for construction

11.3.9 As-Built documents

- As-Built Documents (See Construction Submittals)

All submittals shall include information deemed necessary to clarify the design, such as manufacturer's catalogues and brochures.

All plans, reports, calculations, and data listed above shall be submitted to the PCJPB. The designer shall certify that all the contract documents have been verified and checked in accordance with the Quality Assurance Plans of the firm.

11.4 Construction Requirements for Structures

11.4.1 Construction Management

For construction of grade separation underpass structures an experienced Construction Management Team (CM Team) will be required. The team who has been approved by the sponsoring agency and the PCJPB will typically consist of the following, depending on the project size:

- Project Manager
- Resident Engineer
- Construction Inspector

The members of this team will be required to have obtained PCJPB Safety Program for Roadway Worker Protection training and comply with the FRA Bridge Worker Safety Standards.

The team shall be responsible for notifying the PCJPB of significant milestones during the construction process. The following list represents some of the significant construction stages that the PCJPB needs to be present:

- Preconstruction meeting
- Shoofly work for acceptance prior to being placed in service
- Reinforcement and concrete placement
- Erection of steel and precast concrete
- Post tensioning
- Waterproofing and protection board placement for acceptance prior to ballast placement.
- Final inspection and acceptance of the bridge structure
During the course of the construction, PCJPB will make other periodic site visits to verify progress and inspect the work site.

Costs for the Construction Management Team shall be borne by the sponsoring agency.

11.4.2 Construction Submittals

During the construction process for grade separations the PCJPB will require the review of certain contractor submittals in order to avoid interruption to PCJPB operations and to verify the quality of the construction. Some of these submittals are listed below:

- Construction schedule with periodic update
- Site specific workplans (SSWP) pertaining to PCJPB Right-of-Way
- Staging plans involving PCJPB operations
- Shoring plans
- Falsework installation and removal plans
- Temporary drainage facilities
- Contractors or Sub certifications for members being prefabricated
- Material certifications
- Welder certifications
- Shop drawings for steel and concrete members
- Bearings for the structure
- Concrete mix design
- Rebar and Strand certifications and shop drawings
- 28-day concrete strength tests
- Waterproofing system and protection board material and certifications
- Structural steel certifications for fracture critical members and test results
- Foundation construction reports for pile driving, drill shaft construction, or bearing pressure test reports.
- Pile driving hammer information
- Any other shop drawings or working drawings pertaining to the structure on PCJPB Right-of-Way.

The CM Team and designer shall review all contractor submittals. Any issues shall be prior to being submitting to the PCJPB for review and approval. No work shall be performed inside the PCJPB Right-of-Way without prior review and approval. All site specific work plans submitted by the contractor that affect the operations of the railroad shall include a contingency plan for putting the rail operation system back in service in case of an emergency. The contingency plan shall address the stages of construction and may require redundant equipment and personnel be on call to satisfy this requirement.
11.4.3 As-Built Submittal

At the completion of the project's construction, after final acceptance of the project, the PCJPB shall receive the project As-Built documents. As-Built documents shall consist of the following and be signed and sealed by the California Registered Professional Engineer:

- Final As-Built project plans
- Final shop drawings for prefabricated components (structural steel, precast concrete, bearings, etc. and the test reports for these items).
- Final project specifications

As-Built plan submittal shall be full size drawings on mylar and in electronic file format.
1. Location: __________________________
   CITY  COUNTY  STATE

2. Distance from nearest PCJPB Milepost to centerline of bridge: ________________

3. Description of Project: ________________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________

4. Utilities on Railroad Property:

<table>
<thead>
<tr>
<th>COMPANY NAME</th>
<th>RELOCATION Required?</th>
<th>CONTACT PERSON</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. List the at-grade crossings that will be eliminated by the construction of this grade separation.

<table>
<thead>
<tr>
<th>DOT #</th>
<th>MILEPOST</th>
<th>SIGNALS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. How many spans are proposed: _____________________________________________

7. Offset of temporary detour/shoofly alignment: _______________________________

8. Temporary detour alignment
   On Embankment, Trestle, or Both: __________________________________________
9. DRAINAGE:
Describe how drainage from track roadbed is handled:
____________________________________________________________________________________________________________________
____________________________________________________________________________________________________________________
____________________________________________________________________________________________________________________
____________________________________________________________________________________________________________________
____________________________________________________________________________________________________________________

Describe how drainage from the bridge is handled: ______________________________________________________________________
____________________________________________________________________________________________________________________
____________________________________________________________________________________________________________________
____________________________________________________________________________________________________________________
____________________________________________________________________________________________________________________

10. Scheduled Bid Date: _____________________________________________________________________________________________

ALL INFORMATION ON THIS DATA SHEET TO BE FURNISHED BY THE SUBMITTING AGENCY TO THE PENINSULA CORRIDOR JOINT POWERS BOARD.
1. Location: __________________________
   CITY  COUNTY  STATE

2. PCJPB Milepost to Centerline of Bridge: __________________________

3. Description of Project: _______________________________________
   ______________________________________
   ______________________________________
   ______________________________________

4. Utilities on Railroad Property:
   
<table>
<thead>
<tr>
<th>COMPANY NAME</th>
<th>RELOCATION Required?</th>
<th>CONTACT PERSON</th>
</tr>
</thead>
<tbody>
<tr>
<td>__________________</td>
<td>__________________</td>
<td>__________________</td>
</tr>
<tr>
<td>__________________</td>
<td>__________________</td>
<td>__________________</td>
</tr>
<tr>
<td>__________________</td>
<td>__________________</td>
<td>__________________</td>
</tr>
<tr>
<td>__________________</td>
<td>__________________</td>
<td>__________________</td>
</tr>
</tbody>
</table>

5. List the at-grade crossings that will be eliminated by the construction of this grade separation.
   
<table>
<thead>
<tr>
<th>DOT #</th>
<th>MILEPOST</th>
<th>SIGNALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>__________</td>
<td>__________</td>
<td>__________</td>
</tr>
<tr>
<td>__________</td>
<td>__________</td>
<td>__________</td>
</tr>
</tbody>
</table>

6. Minimum horizontal clearance from centerline of the nearest track to face of Pier:
   
   A. Proposed: ________________  B. Existing (if applicable): ________________

7. Minimum vertical clearance above tope of high rail:
   
   A. Proposed: ________________  B. Existing (if applicable): ________________
8. List Piers where crash walls are provided:

<table>
<thead>
<tr>
<th>PIER</th>
<th>DISTANCE FROM CENTERLINE OF TRACK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. Describe how drainage from track roadbed is handled: ________________________

   ________________________
   ________________________

10. Describe how drainage from overhead grade separation is handled: ___________

    ________________________
    ________________________

11. List piers where shoring is required to protect track: ________________________

    ________________________
    ________________________

12. Scheduled Bid Date: ____________________________

ALL INFORMATION ON THIS DATA SHEET TO BE FURNISHED BY THE SUBMITTING AGENCY TO THE PENINSULA CORRIDOR JOINT POWERS BOARD.
# Preliminary Plan Submittal Checklist

**Highway/Street Name:**

**Location (City & State):**

**County:**

**Project No.:**

**Date:**

<table>
<thead>
<tr>
<th>Item</th>
<th>Required Information</th>
<th>Min. Required</th>
<th>As Submitted</th>
<th>Railroad Remarks</th>
<th>A/R</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abutment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Horizontal Clearance (Left) (CL to face)</td>
<td>25'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Horizontal Clearance (Right) (CL to face)</td>
<td>25'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Vertical Clearance (from Top of Rail)</td>
<td>25'-6&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Horizontal Clearance to footing from CL</td>
<td>25'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Depth top of footing below base of rail</td>
<td>6'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Pier Protection wall required for &lt;25'</td>
<td>25'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Shoring required (CL to nearest Pt.)</td>
<td>8'-6&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pier/Bent #</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Horizontal Clearance (Left) (CL to face)</td>
<td>25'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Horizontal Clearance (Right) (CL to face)</td>
<td>25'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Vertical Clearance (from Top of Rail)</td>
<td>25'-6&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Horizontal Clearance to footing from CL</td>
<td>25'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Depth top of footing below base of rail</td>
<td>6'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Pier Protection wall required for &lt;25'</td>
<td>25'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Shoring required (CL to nearest Pt.)</td>
<td>8'-6&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Abutment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Horizontal Clearance (Left) (CL to face)</td>
<td>25'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Horizontal Clearance (Right) (CL to face)</td>
<td>25'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Vertical Clearance (from Top of Rail)</td>
<td>25'-6&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Horizontal Clearance to footing from CL</td>
<td>25'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Depth top of footing below base of rail</td>
<td>6'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Pier Protection wall required for &lt;25'</td>
<td>25'-0&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Shoring required (CL to nearest Pt.)</td>
<td>8'-6&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Peninsula Corridor Joint Powers Board
### OVERHEAD SUBMITTAL CHECKLIST

<table>
<thead>
<tr>
<th>Item</th>
<th>Required Information</th>
<th>Min. Required</th>
<th>As Submitted</th>
<th>Railroad Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A = Approved R = Rejected</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A/R</td>
</tr>
<tr>
<td>Track Requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Existing track centers</td>
<td>Required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Track spreading taken into consideration</td>
<td>Required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Future track centers</td>
<td>15'-0&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety Requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Splashboards/ barrier rail Near Side (NS)</td>
<td>5'-0&quot;3'-6&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Splashboards Far Side (FS)</td>
<td>5'-0&quot;3'-6&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Splashboards limits adequate</td>
<td>R/W to R/W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Fence w/ pedestrian walkway, NS or FS</td>
<td>8'-0&quot; or 10'-0&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Fence w/o pedestrian walkway, NS or FS</td>
<td>10'-0&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Fence limits adequate</td>
<td>R/W to R/W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage Requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Adequate Drainage (Left)</td>
<td>Required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Adequate Drainage (Right)</td>
<td>Required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Drain from Structure/Leaders at Bents</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Access road (25' from CL to face)</td>
<td>25'-0&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>PCJPB R/W shown accurately</td>
<td>Required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>All tracks labeled correctly</td>
<td>Required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Existing utilities overhead / underground</td>
<td>Required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Maximum gap between structures</td>
<td>2'-0&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Lights required for width of structure &gt; 80'</td>
<td>80'-0&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Track profile for 1000' on each side of str.</td>
<td>1000'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Demolition required</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Abutment slope protection</td>
<td>&gt;2:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Temp. construction vertical clearance w/ PCJPB &amp; PUC approval</td>
<td>21'-6&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Temp. construction horizontal clearance w/ PCJPB &amp; PUC approval</td>
<td>12'-0&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Milepost number &amp; direction of increase</td>
<td>Required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### INSTRUCTIONS:
Milepost and direction of Milepost must be shown in the plans. Left and Right is the orientation of structure elements facing in the direction of increasing milepost.

FILL ALL APPLICABLE PARTS OF TABLE ABOVE: In Column "As Submitted" INSERT ALL APPLICABLE VALUES FROM PLANS. For any exception to the minimum requirements on the checklist, a detailed explanation/reason why the minimum requirements cannot be provided.

### PRELIMINARY PLAN REVIEW:
RESOLUTION OF ITEMS NOT MEETING MINIMUM REQUIREMENT SHOULD BE RESOLVED PRIOR TO PLAN SUBMITTAL.

### FINAL PLAN REVIEW:
PRIOR TO STRUCTURE CONSTRUCTION SIGNED FINAL PLANS, SPECIAL PROVISIONS, AND HYDRAULIC CALCULATIONS IF REQUIRED SHALL BE SUBMITTED FOR FINAL REVIEW. IF ALL ITEMS ARE RESOLVED AND PLANS COMPLY, WILL RELEASE STRUCTURE FOR CONSTRUCTION.
CHAPTER 12
BRIDGE MAINTENANCE
AND
INSPECTION
COMMENTARY
COMMENTARY

The purpose of this commentary is to furnish technical explanations, clarifications, and examples for the various Chapters in the Standards for Design and Maintenance of Structures. The numbering of the sections in this Commentary corresponds to the numbering in the Chapters.

C-1. General

C-1.1 Application of Guidelines
C-1.2 Compatibility
C-1.3 Design Guidelines, Codes, Manuals, Standards, and Specifications
C-1.4 General Guidelines for Grade Separations

In regards to PCJPB's preference for overheads, the following is an excerpt from the Caltrans Highway Design Manual, Section 208.9, Railroad Underpasses and Overheads.

"Generally, it is desirable to construct overheads rather than underpasses whenever it is necessary for a highway and railroad to cross. Railroads should be carried over highways only when there is no other reasonable alternative.

Some undesirable features of underpasses are:

(a) They create bottlenecks for railroad operations.
(b) It is difficult to widen the highway.
(c) Pumping plants are often required to drain the highway.
(d) They are likely to lead to cost participation controversies for initial and future construction.
(e) Shooflies (temporary tracks) are generally required during construction.
(f) Railroads are concerned about the structure maintenance and liability costs they incur.

Advantages of overheads are:

(a) Railroads can use most of their right of way for maintenance.
(b) Overheads can be widened at a relatively low cost and with little difficulty.
(c) Less damage may be incurred in the event of a derailment.
(d) Agreements for design and maintenance can be reached more easily with railroads.
(e) Initial costs are generally lower.

The State, the railroads, and the public in general can benefit from the construction of an overhead structure rather than an underpass."
C-2. Design Guideline for RAILROAD BRIDGES and UNDERPASSES

C-2.1 General Requirements
C-2.2 Superstructure Selection Type

Interruptions in service are much more critical for railroads than for highways (alternate routes are not always available); therefore, constructibility and maintainability without interruption to rail traffic are crucial in the design and construction for rail structures. The duration of construction windows required during rail operations will play a significant part in deciding which type of structure to use for each location. The construction staging and the windows that are required during construction should be discussed early with the PCJPB to determine this and other constraints that will control the design. Also, the type of structure will be affected if a shoofly track or temporary structure is available during construction. Another factor to consider is if the structure can be staged to allow for rail traffic to resume on half or a portion of the structure, prior to the full bridge being completed.

Construction must be planned to minimize delay or disruption of PCJPB train schedules and operations. Work that will affect operation will require work during night periods, during off-peak commute hours, or during weekends. Provisions for shooflys, temporary structures, false work and shoring must minimize the extent and severity of slow orders on operations.

Ballast deck structures require less maintenance than open deck or direct fixation type structures. For this reason ballast deck structures are preferred.

Simple span superstructure construction is fast and lends itself to rapid erection, and therefore is preferred. This is a major consideration on high traffic lines such as the PCJPB corridor which can ill afford shutdowns in its operations. Continuous span construction takes longer to construct and will require greater diligence during construction in the inspection and monitoring of bridge construction to maintain quality. Continuous span structures are also more difficult to replace in emergencies than simple spans.

Trough type superstructures are not readily repairable if damaged, and can result in an extended period of time to replace. This out of service time to repair or replace a structure can have an adverse effect on PCJPB operations and its service to their customers.

Aesthetics of the structure will contribute to the selection of the superstructure; however it shouldn't control the decision of the final bridge type. All of the structures on this list can, with some thought, be constructed so that they are aesthetically pleasing. The use of fascia panels, and other architectural treatments can be used to meet the public's aesthetic requirements. However, care must be taken when applying these treatments in that they do not interfere with the inspection and maintenance of the structure.
C-2.2.1 List of Preferred Structure Type

Generally, deck-type structures are preferred over through-type structures, because deck-type structures are less likely to be damaged in a train derailment or by dragging rail equipment.

Structures of steel and precast concrete are preferable because they are fabricated off site and the quality is shop controlled. Also, these types can be constructed rapidly which is an advantage when working around train operations. Steel structures are also preferred because they are readily repairable. Precast concrete structures are close in ranking to steel structures because of their low maintenance, although the use of weathering steel makes this less of an issue. Cast-in-place girders and components, and post-tensioned structures are less desirable because of the additional construction time required on site and the need for diligent on site inspection to assure quality control.

C-2.3 Structural Design Requirements

Differences between Railroad Bridges and Highway Bridges
(courtesy of AREMA Railway Structures Loading Seminar, Course Manual)

(a) The live load to dead load ratio is much higher for a railroad bridge than for a similarly sized highway structure. This can lead to serviceability issues such as fatigue and deflection control governing designs rather than strength.

(b) The design impact load on railroad bridges is higher than on highway structures.

(c) Simple span structures are typically preferred over continuous structures for railroad bridges.

(d) Interruptions in service are typically much more critical for railroads than for highway agencies. Therefore, constructibility and maintainability without interruption to rail traffic are crucial for railroad bridges.

(e) Since the track structure is supported by the bridge, the combination of track and bridge movement cannot exceed the tolerances in track standards. Interaction between the track and bridge should be considered in design detailing.

(f) Seismic performance of highway and railroad bridges can vary significantly. Railroad bridges have performed well during seismic events.

(g) Railroad bridge owners typically expect a longer service life from their structures than highway bridge owners expect from theirs.

(h) Railroad bridges are typically designed to require as close to zero maintenance as possible.

Items for Designers to be Aware of Regarding Railroad Bridge Design
(courtesy of AREMA Railway Structures Loading Seminar, Course Manual)

(a) For steel structures, pay close attention to fatigue design procedures.

(b) Provide support perpendicular to track at end of skewed structures.
(c) For concrete design, pay close attention to load factors and strength reduction factors. Note that reinforced concrete and prestressed concrete requirements have some differences. Also, note differences in the impact factor for reinforced concrete and prestressed concrete.
(d) Remember the 0.25 sq. in./ft. minimum temperature and shrinkage reinforcing steel requirement for concrete structures.
(e) AREMA does not allow service load tension in prestressed concrete members.
(f) Provide member load tables on the drawings.
(g) Be careful when using computer programs for railroad bridge design. Verify that the program is actually following AREMA recommended practice or the specific requirements of the railroad.
(h) Note that AREMA does not use tension field design for steel girder webs.
(i) Communicate with the railroad (PCJPB) about their specific requirements before designing their structures.

C-2.3.1 Layout

The commuter train operations along PCJPB corridor is a high traffic corridor and the scheduled trains have priority over construction projects during the normal workday week. Most of the construction work that is required to take place within 15' feet of the outside rail of the track or has the potential to come within this region (i.e. a tall crane that may topple into the region) will in most cases require a construction window (i.e. a period of time granted where there is protection from train traffic) or be required to be done during night time or weekend hours upon approval of the PCJPB.

Attachments of utility lines to the bridge are not allowed because they interfere with the maintenance of the structure. Items where utility attachments interfere with rail operations on structures include: bridge inspections such as inadequate access to view bridge components, bridge maintenance such as when the bridge needs to be jacked or shored up for repair but the utility prevents it, painting of the structure, or a utility inhibits access to an area that requires repair. Train Operations can be affected by an emergency of an outside agency's utility problem that is attached to a bridge, resulting in a track having to be shut down for repairs to a utility line.

Drainage and water is one of the main causes of track roadbed failure. All drainage shall be adequately provided for and directed away from the tracks.

Some of the track tolerances governed by 49 CFR Part 315 Track Safety Standards are for line, profile, cross-level, and twist. Structures shall be designed such that they will not be a contributing factor to the loss of track tolerances.
The use of metal inner guard rails is used to minimize damage that could occur when a train derailment occurs. Additional information on the details and limits of guard rail installation can be found in the AREMA Manual of Railway Engineering, Chapter 7, Part 3, Section 6.

C-2.3.2 Bridge Skew

Construction of skewed bridges can have a significant impact on the maintenance budget of the PCJPB therefore approval from the PCJPB is required when the design of a skewed bridge is required. The PCJPB may be able to suggest designs that will lessen the skew angle. Skewed bridges over crossings complicate the construction requiring greater detail, inspection, and a more detailed seismic analysis. Also, additional maintenance is required for a skewed bridge.

Abutments need to be squared-off to allow a full railroad tie to be supported. Partial support of a tie skewed across an abutment backwall will not be allowed. Problems can develop if a tie is only partially supported over the abutment. Ride quality will suffer and tie life will be shortened if the tie is not fully supported.

Track transitions are required to equalize the change in vertical stiffness that occurs when the track approach comes on to a structure. If no provisions are provided at transition regions, the track will require frequent maintenance. If this is neglected, it can deteriorate the rail alignment and surface at an accelerated rate. Low track approaches to a bridge will occur when the track transition is not properly accounted for, resulting in poor ride quality and a shortened track life.

C-2.3.3 Design Loads for Railroad Bridges

Various bridge dead loads are shown in the charts below. The PCJPB has included these values to indicate how the dead loads are established for design calculations. Designers shall generate independent calculations based on the specific conditions of the structure being designed. In no case shall the design load be less than that required by AREMA. The dead loads provided in the AREMA Manual are the minimum values to be used in design, however, if the actual loads are greater than the AREMA minimum requirements the actual load shall be used.
### WEIGHT OF TYPICAL BALLAST DECK, SINGLE TRACK, 20' DECK

<table>
<thead>
<tr>
<th>ITEM</th>
<th>WEIGHT (lbs./LF of track)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAIL (136 RE): 136 lbs/linear yd x 2 rails/track x 1 linear yd/3 linear ft.</td>
<td>91</td>
</tr>
<tr>
<td>INSIDE GUARD RAILS: 115 lbs/linear yd x 2 rails/track x 1 linear yd/3 linear ft.</td>
<td>77</td>
</tr>
<tr>
<td>TIES (Neglect, since included in ballast weight for wood ties)</td>
<td></td>
</tr>
<tr>
<td>TIE PLATES (7¾&quot; x 14¾&quot; for rail with 6&quot; base): 24.32 lbs/plate x 1 tie/19.5&quot; x 12&quot;/ft. x 2 plates/tie</td>
<td>30</td>
</tr>
<tr>
<td>SPIKES (5/8&quot; x 5/8&quot; x 6&quot; reinforced throat): 0.828 lbs/spike x 18 spikes/tie x 1 tie/19.5&quot; x 12&quot;/1 ft.</td>
<td>3</td>
</tr>
<tr>
<td>BALLAST* (assume 12&quot; additional over time): Approximately 120 lbs/ft³ x 30&quot; depth x 1 ft./12&quot; x 20 ft.</td>
<td>6000</td>
</tr>
<tr>
<td>WATERPROOFING: Approximately 150 lbs/ft³ x 0.75&quot; depth x 1 ft./12&quot; x 24 ft.</td>
<td>225</td>
</tr>
<tr>
<td><strong>TOTAL WEIGHT:</strong></td>
<td>6432 lbs/ LF</td>
</tr>
</tbody>
</table>

*NOTE: Wood Ties weigh 237 lbs. for a 7"x 9"x 9'-0" long ties and are spaced at 19½" o. c. Concrete Ties weigh 630 lbs. for 8'-3" long ties and are spaced at 24" o. c. 120 lbs/ft³, used in ballast calculation, includes the weight of timber ties. If concrete ties are used, the weight of concrete ties and ballast shall be figured separately. Concrete ties will also transfer higher live loads and impact load through the ballast to the bridge deck structure than wood ties. This shall be considered in the determination of the loads to be applied to the structure during design.*

### WEIGHT OF RAIL, INSIDE GUARD RAILS & RAIL FASTENINGS FOR TYPICAL DECK

<table>
<thead>
<tr>
<th>ITEM</th>
<th>WEIGHT (lbs./LF of track)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAIL (136 RE): 136 lbs/linear yd x 2 rails/track x 1 linear yd/3 linear ft.</td>
<td>91</td>
</tr>
<tr>
<td>INSIDE GUARD RAILS: 115 lbs/linear yd x 2 rails/track x 1 linear yd/3 linear ft.</td>
<td>77</td>
</tr>
<tr>
<td>TIE PLATES (7¾&quot; x 14¾&quot; for rail with 6&quot; base): 24.32 lbs/plate x 1 tie/19.5&quot; x 12&quot;/ft. x 2 plates/tie</td>
<td>30</td>
</tr>
<tr>
<td>SPIKES (5/8&quot; x 5/8&quot; x 6&quot; reinforced throat): 0.828 lbs/spike x 18 spikes/tie x 1 tie/19.5&quot; x 12&quot;/1 ft.</td>
<td>9</td>
</tr>
<tr>
<td><strong>TOTAL WEIGHT:</strong></td>
<td>207 lbs/ LF</td>
</tr>
</tbody>
</table>
**WEIGHT OF RAILS, INSIDE GUARD RAILS, TIES, GUARD TIMBERS AND FASTENINGS FOR TYPICAL OPEN DECK**

(Walkway Not Included)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>WEIGHT (lbs./LF of track)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAIL (136 RE): 136 lbs/linear yd x 2 rails/track x 1 linear yd/3 linear ft.</td>
<td>91</td>
</tr>
<tr>
<td>INSIDE GUARD RAILS: 115 lbs/linear yd x 2 rails/track x 1 linear yd/3 linear ft.</td>
<td>77</td>
</tr>
<tr>
<td>TIES (10&quot; x 10&quot; x 10 ft. bridge ties): 10&quot; x 10&quot; x 10 ft. x 1 ft²/144 in² x 60 lbs/ft³ x 1 tie/14&quot; x 12&quot;/1 ft.</td>
<td>357</td>
</tr>
<tr>
<td>GUARD TIMBERS (4 in. x 8 in.): 4&quot; x 8&quot; x 1 ft. x 1 ft²/144 in² x 60 lbs/ft³ x 2 guard timbers/ft.</td>
<td>27</td>
</tr>
<tr>
<td>TIE PLATES (7¾&quot; x 14¾&quot; for rail with 6&quot; base): 24.32 lbs/plate x 1 tie/14&quot; x 12&quot;/1 ft. x 2 plates/tie</td>
<td>42</td>
</tr>
<tr>
<td>SPIKES (5/8&quot; x 5/8&quot; x 6&quot; reinforced throat): 0.828 lbs/spike x 18 spikes/tie x 1 tie/14&quot; x 12&quot;/1 ft.</td>
<td>13</td>
</tr>
<tr>
<td>MISCELLANEOUS FASTENINGS (Hook Bolts &amp; Lag Bolts) Approx. (2.25 lbs/hook bolt + 1.25 lbs/lag screw) x 2 bolts/tie x 1 tie/14&quot; x 12&quot;/ft</td>
<td>6</td>
</tr>
</tbody>
</table>

**TOTAL WEIGHT:** 613 lbs/ LF

The design Cooper E-80 live load of is a bridge loading, thus the application of this loading to other structures requires special judgement on the part of the engineer. It should be noted that the Cooper train loading does not reflect the actual loading of any equipment in current revenue service on the rail lines in the United States. Therefore, included in the Appendix are the diagrams for the equipment used along the PCJPB corridor for passenger service, and some of the freight equipment. The diagrams give the equivalent Cooper E loading generated by equipment for various span lengths. Upon review of the equipment diagrams, it will become apparent that the loading of this equipment is less than the Cooper E-80 loading that the PCJPB requires for bridge design. The PCJPB requires the use of Cooper E-80 loading because this corridor is required to be able to accept freight service (Union Pacific Railroad has trackage rights), thus their heavier equipment may approach the E-80 loading conditions especially on some shorter span bridges. The E-80 loading is also specified because in the railroad industry heavier locomotives and heavier cars are the trend. Prior to 1967 the Cooper loading used was E-72. It should also be noted that the PCJPB corridor has historically been designated as satisfactory for 315,000 pound (125 ton car) cars. Generally for railroad service, the Association of American Railroads (AAR) has designated three types of rail cars for line weight clearance, 263,000 pound cars (100 ton cars), 286,000 pound cars (110 ton cars) and the 315,000 pound car (125 ton car). The 315,000 pound car has an axle loading of 78,750 pounds. The PCJPB corridor...
from San Francisco to Santa Clara, which has Union Pacific Railroad trackage rights and a weight limit of 315,000 pounds, and from Santa Clara to Lick where PCJPB shares the tracks of the Coast Route with the Union Pacific Railroad, also has 315,000 pound weight limit. The designer should be aware that there are also on-track maintenance-of-way vehicles (i.e. ballast cars, locomotive cranes, and wrecking cranes, etc.) that may have an axle loading greater than the cars shown in the Appendix. There are also specialty cars that shippers use to haul heavy loads that have non-standard axle spacing and axle loads that can cause moments and shears in structures greater than the E-80 loading condition. Additionally, the standard railroad car can be overloaded which is most likely to occur in car types that have bulk lading (gravel, grain, and coal commodities). The magnitudes of overloads may not be significant enough to cause structural problems other than the variations in stress levels, which can result a faster fatigue damage rate.

C-2.4 Clearances
  C-2.4.1 Vertical Clearances
  C-2.4.2 Horizontal Clearances

The 10-foot recommended horizontal clearance on structures has been established by the PCJPB to provide for additional walkway room in the case of an emergency where a train was stopped over a structure. It will provide for access of emergency personnel and the evacuation of passengers safely.

C-2.5 Special Provisions
  C-2.5.1 Concrete Structures
  C-2.5.2 Steel Structures

The use of weathering steel is preferred because it requires less maintenance than painted steel. However, the use of weathering steel requires that special details be taken into consideration during design, in order to prevent concrete and other surfaces from becoming stained by the weathering action of the steel after construction. An example of this is to provide a lip on the concrete abutments and piers to catch rainwater runoff and to provide provisions for drainage of this water to an approved discharge point. Some applications may consider the painting of the ends of girders on weathering steel. In other cases, if the brown weathering patina is considered undesirable aesthetically, then the structure may have only the outside visible edges of the structure painted.

  C-2.5.3 Ballast Deck Bridge Structures
  C-2.5.4 Special Provisions for Railroad Electrification

C-2.6 Substructure
  C-2.6.1 General Layout
  C-2.6.2 Foundation Types
It is important that the foundation designer be familiar with the operating requirements of the railroad. There is only a limited amount of construction periods available during operations thus the foundation recommendations shall consider working around and adjacent to live railroad tracks. The geotechnical specialists will be required to correlate their reports with the final design and vice versa. The recommendation in the geotechnical report shall be consistent with the selected foundation type. As an example, due consideration shall be given in the case of pile driving to evaluate the effects of vibration on adjacent lifeline and other pipelines, and adjacent structures that may or may not be owned by the PCJPB.

C-2.7 Construction Specifications

C-3. Design Guideline for GRADE SEPARATIONS OVER RAILROAD

C-4. Design Guideline for SEISMIC DESIGN

C-5. Design Guideline for PEDESTRIAN UNDERPASS

C-6. Design Guideline for PEDESTRIAN OVERPASS
   (not included/under development)

C-7. Design Guideline for CULVERTS
   (not included/under development)

C-8. Design Guideline for RAILROAD SIGNAL POLES
   (not included/under development)

C-9. Design Guideline for RETAINING WALLS

   C-9.1 General Requirements
   C-9.1.1 Design Considerations
   C-9.2 Selection of Types of Retaining Walls
      C-9.2.1 Factors for Selecting Retaining Wall Types
   C-9.3 Structural Design Requirements
      C-9.3.1 Wall Design Heights
      C-9.3.2 Loads

   (b) Applied Loading Exclusive of Earth Pressure

   The surcharge loading generally will consist of the Cooper E-80 loading conditions (or the E-XX chosen for the design). It is applied vertically at the bottom of tie elevation. It can be determined by taking the maximum axle loads and axle spacing and determining the vertical load to be applied in the Boussinesq strip load equation. Typically this is 4 – 80 kip axles spaced at 5’ off center, which would be 4 x 80k / 4 x 5’ (spacing) x 9’ (tie length) or 1.778 kips per square foot (ksf). It is appropriate to use the 1.778 ksf load in the Boussinesq strip load
equation because the axle loading can occur anywhere along the track (strip) as long as the walls are parallel to the track. It is also appropriate to use the 1.778 ksf surcharge when designing walls perpendicular to the track (e.g. abutments).

C-9.3.3 Retaining Wall Stability
C-9.3.4 Abutment Stability

C-9.4 Clearances
C-9.5 Special Provisions
C-9.5.1 Railroad Electrification
C-9.5.2 Utilities
C-9.5.3 Drainage
C-9.5.4 Mechanical Stabilized Embankments (MSE)
C-9.5.5 Crib Walls
C-9.5.6 Bulkhead Systems
C-9.5.7 Tieback Anchored Piles

C-10. Design Guideline for MISCELLAENOUS STRUCTURES
(not included/under development)

C-11. Design Guideline for STRUCTURE DESIGN SUBMITTAL PROCEDURES

C-11.1 General
C-11.2 Design Submittals, Master List
   C-11.2.1 Conceptual Design Level
   C-11.2.2 Preliminary Design Level
   C-11.2.3 In-Progress Design Level
   C-11.2.4 Pre-Final Design Level
   C-11.2.5 Final Design Level
   C-11.2.6 Bid Documents
   C-11.2.7 Bid Period Addendum Documents
   C-11.2.8 Conformed Contract Documents for Construction
   C-11.2.9 As-built Documents

C-11.3 Submittal Quantities
   C-11.3.1 Conceptual Design Level
   C-11.3.2 Preliminary Design Level
   C-11.3.3 In-Progress Design Level
   C-11.3.4 Pre-Final Design Level
   C-11.3.5 Final Design Level
   C-11.3.6 Bid Documents

C-11.4 Construction Requirements for Structures
   C-11.4.1 Construction Management
   C-11.4.2 Construction Submittals
   C-11.4.3 As-built Submittals

C-12. BRIDGE MAINTENANCE AND INSPECTION
(not included/under development)
REFERENCE DOCUMENTS