PENINSULA CORRIDOR JOINT POWERS BOARD

ENGINEERING STANDARDS FOR EXCAVATION SUPPORT SYSTEMS

REVISED JANUARY 1, 2024

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SECTION 1 – INTRODUCTION AND BACKGROUND

1.1 General

These Standards summarize the minimum requirements for temporary excavation shoring systems adjacent to the Peninsula Corridor Joint Powers Board (PCJPB) railroad tracks. The design of permanent retaining walls and other systems of permanent earth retention adjacent to the PCJPB tracks is addressed in the PCJPB Standards for the Design and Maintenance of Structures.

The PCJPB has developed the criteria and requirements specified herein for the protection of their Operating System. Given the risks (including life safety) associated with construction and excavation adjacent to an active railroad supporting both commuter/passenger and freight services, the design requirements and construction restrictions specified herein are typically more conservative than those commonly required by other agencies.

The criteria, information, and analysis methodologies presented in these Standards have been developed in accordance with recognized engineering principles.

1.2 Engineer Qualifications

Excavation shoring designs shall be prepared by a licensed California professional engineer who shall be solely responsible for verifying the accuracy, suitability, and applicability of the information contained in these Standards for any specific project. Excavation shoring systems shall typically be designed by a team composed of a railroad civil engineer who is experienced (a minimum of 5 years) and knowledgeable in the design, construction, operations and maintenance parameters for commuter/passenger and freight railroad systems, and a licensed civil or structural engineer who is experienced (a minimum of 5 years) and knowledgeable in the design and construction of shored excavations adjacent to the railroad.

Submit resumes of the railroad civil engineer and the shoring design engineer to PCJPB for approval. PCJPB's decision is final regarding acceptance of the proposed personnel to perform shoring design. Resumes shall include verifiable experience and provide sufficient detail to demonstrate compliance with the requirements above. Resumes shall detail qualifications and work experience of the personnel and include references from owners and construction management team members from three previous projects of similar scope and complexity.

Review and acceptance of shoring submittals by the PCJPB shall not relieve the contractor and shoring engineer of responsibility for the design and construction of the shoring system, including responsibility for errors and omissions in submittals, and construction deviations from accepted design plans.

1.3 Reference Documents

The following documents are referenced in these Standards:

PCJPB Standards for Design and Maintenance of Structures, latest edition.

PCJPB Standard Procedures for Track Maintenance & Construction (STPMC), latest edition.

American Railway Engineering and Maintenance-of-Way Association (AREMA), Manual for Railway Engineering, latest edition.

State of California Department of Transportation (Caltrans), Trenching and Shoring Manual, latest edition.

Cal/OSHA Standards – California Code of Regulations, Title 8, Chapter 4, Division of Industrial Safety, Subchapter 4, Construction Safety Orders, latest revision.

Pile Buck®, Steel Sheet Piling Design Manual, latest edition.

American Institute of Steel Construction (AISC), Manual of Steel Construction - Allowable Stress Design (ASD), latest edition.

American Concrete Institute (ACI), Building Code Requirements for Reinforced Concrete (AC/ 318), latest edition.

American Welding Society (AWS), D1.1, Structural Welding Code – Steel (AWS D1.1), latest edition.

Post-Tensioning Institute (PTI), Recommendations for Prestressed Rock and Soil Anchors, latest edition.

1.4 Distribution

These Standards are 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.

1.5 Definitions

1.5.1 Railroad Terminology

Fouling of OTS Envelope: The placement of an individual or an item of equipment within the OTS Envelope.

Fouling of Track: The placement of an individual, material or piece of equipment where said item will be struck by passing train or on-track equipment.

On-Track Safety (OTS) Envelope: The space bounded by two imaginary lines, measured 15 feet horizontally from the field side (outside) of the field rail of any track on which trains or on-track equipment operate or may potentially operate. The OTS Envelope also includes the width and length of any active station platform. The boundaries of the OTS Envelope extend from top of rail vertically up infinitely.

Operating System: Includes, but is not limited to, the tracks on which trains and on-track equipment operate or may potentially operate, and in addition any facilities closely related to the operation of the railroad system including signal and communications masts, bridges, poles, cables, and houses, bridges, tunnels, culverts, grade crossings and station platforms.

Railroad Zone of Influence: The zone within which excavation shoring is required to be installed for protection of the railroad. See Figure 2.1.

Site Specific Work Plan (SSWP): An integrated plan and schedule prepared and submitted by the Contractor and approved by the PCJPB that accurately describes and illustrates the manner in which work within the OTS Envelope will be accomplished, the potential impacts on elements of the Operating System and the manner and methods by which these elements will be protected from any potential impact, and/or the manner in which work will be accomplished within PCJPB allotted Work Windows.

Work Window: A period of time with a specific beginning and ending time and duration for which the track, signals, bridges and other Operating System elements within the OTS Envelope are temporarily removed from service or modified in some other manner and train and other operations suspended or modified to allow construction or maintenance to occur. Written authority from the Owner and an approved Site Specific Work Plan (SSWP) are required before a Contractor is granted a Work Window. The Contractor's Work Window shall have specific geographic limits, which are defined in the approved SSWP. Modifications or suspension of train and on-track equipment movements resulting from a Work Window involves written changes to the Railroad's Rules of Train and On-Track Equipment Operations. Work Windows are specified in the Special Provisions sections of the Contract documents for each project.

1.5.2 Shoring Terminology

Deadman (or Deadman Anchorage): A buried or partially buried structure that is utilized as an anchorage for tension rods that restrain a shoring wall. A Deadman anchorage may be provided by soldier piles, sheet piling, or concrete blocks or walls.

Deep Soil Mix Wall: An augered, cement grout soil improvement technique, incorporating soldier pile reinforcement, whereby in-situ soils are mixed in place with cement grout to form a row of overlapped soil-cement columns. These overlapped soil-cement columns are used for both groundwater cutoff and, with soldier piles, as a reinforced-soil diaphragm-type shoring wall.

Diaphragm Wall: A continuous shoring wall comprised of concrete or a mixture of cement and soil (usually with embedded vertical steel members) that is drilled or excavated in place prior to excavation in order to support lateral loads from retained soil and water. Examples of diaphragm walls include deep soil mix walls, secant walls, tangent walls, and slurry walls.

Grouting: Injection of fluid materials into the ground to improve the strength of ground, decrease permeability and prevent water inflows, and/or compensate for ground settlements and movements. Types of grouting include permeation grouting (cement, micro-cement, chemical, etc.), jet grouting, and compaction grouting.

Lagging: Timber boards, planking or sheathing, reinforced concrete planks, or steel plate secured between adjacent soldier piles.

Packing: Steel, wood, concrete or non-shrink grout used to fill gaps and transfer load between the shoring wall and bracing elements.

Preloading: Placement of initial loads in bracing members by jacking and shimming or wedging to assure adequate bearing of connected shoring elements and to reduce ground movements.

Secant Wall: A continuous shoring wall formed by a series of overlapped, concrete-filled drilled piers. A minimum of every other pier is reinforced to span vertically.

Sheet Piling: Vertical steel shapes that are driven into the ground and interlocked with each other to form a continuous wall in order to support lateral loads from retained soil and water.

Slurry Wall: Continuous, reinforced concrete wall constructed by filling a series of discrete trenches with tremie concrete. Tremie concrete displaces bentonite or polymer slurry that is in the trench. The slurry is used to prevent collapse of the trench during excavation for slurry wall placement. The resulting concrete barrier wall retains soil and groundwater on the exterior side of the slurry wall, and permits excavation and removal of soil on the interior side of the wall.

Soil Nailing: A system in which soil nails are typically grouted, untensioned rebars that are installed in drilled holes in order to form a reinforced soil mass. Reinforced shotcrete is applied to the face of the excavation. Shotcreting and nail installation proceed in a top down manner as excavation proceeds.

Soldier Piles: Vertical steel shapes (typically wide flange or HP) installed to support lateral loads from retained soil (and water, if part of a sealed shoring system).

Strut: A brace (compression member) that resists thrust in the direction of its own length.

Tangent Wall: A shoring wall formed by a series of concrete-filled drilled piers that are installed tangent to each other. A minimum of every other pier is reinforced to span vertically.

Tieback (Soil Anchor): A tension element utilized to restrain a shoring wall. A tieback consists of a steel tendon (bar or strands) installed in a drilled hole. The tendon is bonded to the soil over its anchorage length with cement grout. The tendon is tensioned to provide positive restraint to the shoring wall and to reduce wall deflections.

Tremie Concrete: Concrete deposited under water or slurry by means of tremie equipment. The concrete displaces the water or slurry as the concrete is deposited.

Trench Shield or Trench Box: Pre-fabricated structure that is commonly installed to support lateral earth loads for utility installation, and whose walls commonly have no toe embedment into the soils below excavation subgrade. Trench shields are typically installed within pre-excavated slots and/or pushed into the ground as the excavation proceeds.

Wale: Horizontal beam used to brace vertical excavation shoring elements.

1.6 Rules and Regulations

Applicable rules and regulations (Caltrain, Federal, and State) related to the maintenance and construction on the railroad are addressed specifically in Sections 1.5, 1.6, and 1.7 of the PCJPB Standard Procedures for Track Maintenance and Construction (SPTMC).

1.7 Training

Training requirements for individuals who will be supervising or performing track or related work on the Caltrain system are covered in Section 1.8 of the PCJPB Standard Procedures for Track Maintenance and Construction.

1.8 Conflicts

In the event of conflict between the procedures, criteria, and requirements for excavation shoring outlined in these Standards and those of other entities, including Caltrans, California Division of Occupational Safety and Health (Cal/OSHA), local municipalities, etc. the most stringent requirements shall take precedence.

The PCJPB's decisions regarding conflicts shall be final.

SECTION 2 – SHORING ADJACENT TO RAILROAD - GENERAL

2.1 Railroad Zone of Influence and Shoring Requirements

The Railroad Zone of Influence is defined on Figure 2.1. The area below the Influence Line is divided into four zones. Requirements and limitations for excavations and excavation shoring systems within each zone are described in detail on Figure 2.1.

2.2 Exceptions for Minor Construction

At its option, the PCJPB may permit unshored excavation within the Zone of Influence for minor construction that has limited excavation area and is no greater than 5 feet in depth. Further, excavation and backfilling must be completed during a single, uninterrupted period of time during which no train movements will occur on the nearest track. The decision on whether to grant an exception is solely under PCJPB’s discretion, and decision will be final.

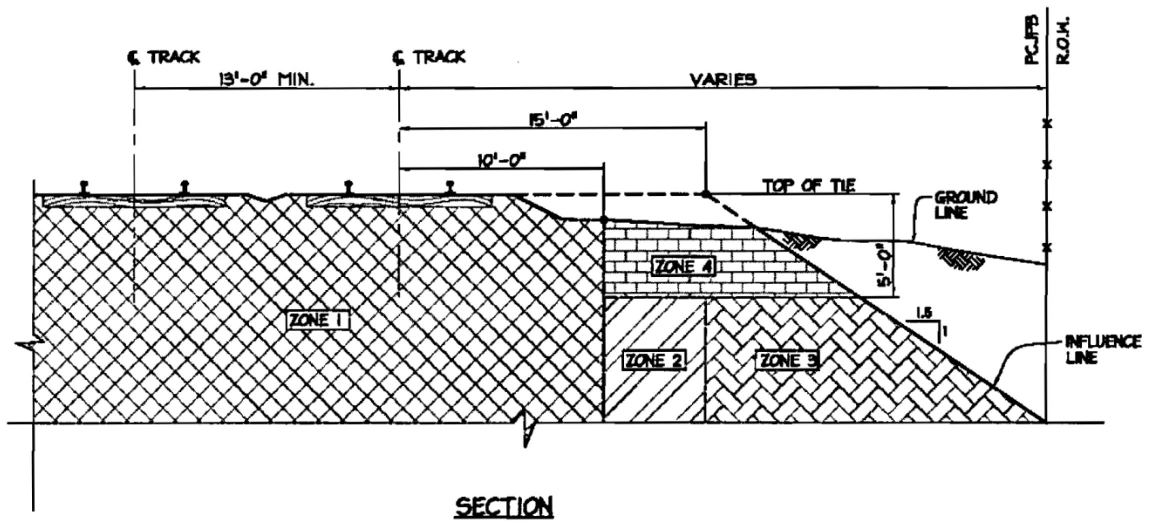
Unshored excavation adjacent to a track will only be allowed in soil conditions that will permit the work to be performed without disturbing the nearest track or the materials supporting the track.

Localized shallow trenching for utility installation and excavations for the installation of precast concrete foundations (such as signal foundations) are examples of cases where exceptions may be granted. Exceptions will be granted on a case-by-case basis by the PCJPB. Factors the PCJPB will consider when assessing whether or not to grant an exception include; the depth of excavation, the length of time required to complete the excavation and backfilling relative to the available window of time between train movements on the nearest track, and the local soil conditions.

2.3 Restrictions on Contractor’s Operations

When operating near active rail tracks, whether on or off PCJPB property, the Contractor’s operations will be constrained as necessary to protect the railroad. In general terms, if Contractor’s operation has the potential to interfere with the safe passage of rail traffic or has the potential to foul the track, restrictions will be imposed on the Contractor’s operations.

FIGURE 2.1 - RAILROAD ZONE OF INFLUENCE



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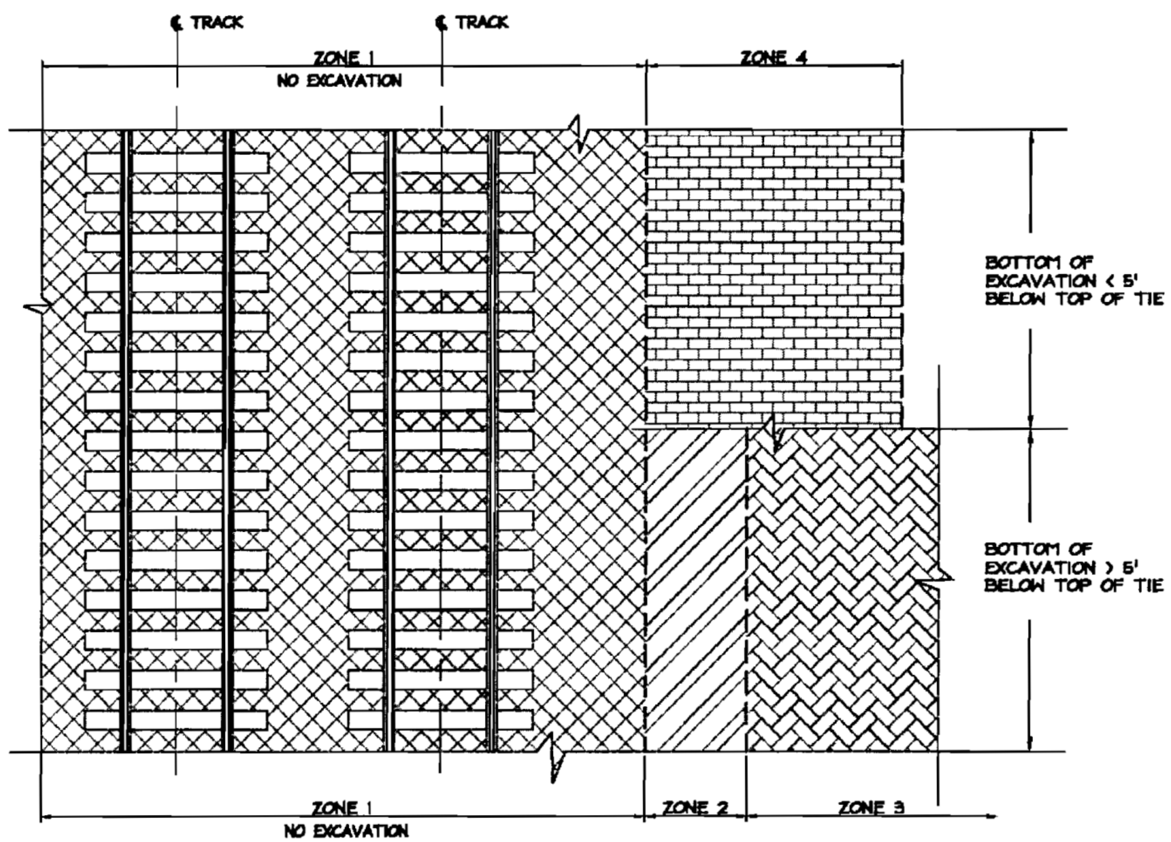


PLAN

ZONE 1:

- **No shoring installation or excavation will be allowed without the written permission of the PCJPB. It is the contractor's responsibility to identify within which zone of influence the shoring will be located. If the temporary excavation is identified to be within zone 1, the contractor should request PCJPB permission prior to the design of the shoring system within zone 1.**
- **Alternates to shored excavations should be utilized when possible. Potential alternates include temporary relocation of the tracks away from the excavation location and the completion of the excavation work during a PCJPB approved track outage.**
- **If excavation is allowed, the shoring system shall be designed for lateral surcharge due to railroad live load. Soldier Piles and lagging will not be allowed.**
- **If excavation is allowed, the shoring system shall be designed in accordance with these Standards.**

ZONE 2:

- **Excavation requires shoring for the protection of the Railroad consisting of continuous shoring walls that are installed prior to any excavation.**
- **Examples of acceptable shoring wall types include interlocked sheet piling or diaphragm walls. Diaphragm wall types include deep soil mix walls; secant pile walls, tangent pile walls and slurry walls.**
- **Soldier piles and lagging will not be allowed.**
- **The Shoring system shall be designed for lateral surcharge due to railroad live load.**
- **The shoring system shall be designed in accordance with these Standards.**

ZONE 3:

- **Excavation requires shoring for the protection of the Railroad.**
- **The shoring system shall be designed for lateral surcharge due to Railroad live load.**
- **The shoring system shall be designed in accordance with these Standards.**

ZONE 4:

- **Excavation requires shoring for the protection of the Railroad.**
- **Lateral surcharge due to railroad live load need not be considered in the shoring design.**
- **The excavation shall be provided with a shoring system that actively supports the sides of the excavation and prevents the excavation faces from raveling or moving. Sloped excavations are not permitted.**
- **Hydraulic and mechanical trench shores with sheeting, trench shields and timber shoring may be utilized; however, installation of the shoring system must be completed before movement of trains is allowed on the nearest track. Windows within which the shoring system installation must be completed shall be coordinated with the PCJPB.**

EXCAVATIONS BEYOND INFLUENCE LINE:

- **Lateral surcharge due to Railroad live load need not be considered in the shoring design.**
- **Sloped excavations are discouraged. (PCJPB may require slope stability analysis for sloped excavations.) Shored vertical excavations are preferred.**
- **Excavations and shoring shall meet OSHA requirements.**

When working within the OTS Envelope (i.e., within 15 feet of the nearest rail of an active track), the Contractor is considered to have the potential to foul the track, regardless of the operation or equipment being used.

The Contractor will still be considered as having the potential to foul the track when working outside the OTS Envelope, depending upon the operation. For example, if the Contractor operates a crane or backhoe whose boom is sufficient in length to foul a track if the boom were in the horizontal position, or if the Contractor is handling long beams or piles that could fall across a track, such an operation would be restricted.

PCJPB shall have sole discretion to determine if the Contractor's operation has the potential to foul a track.

Unless otherwise approved by the PCJPB, the Contractor will not be permitted to perform operations that have a potential to foul the mainline tracks during the weekday commute hours, and must work around the weeknight and weekend train traffic. Upon request, PCJPB will provide a summary of typical train traffic for planning purposes.

The Railroad's Contract Operator will operate Work Trains along the corridor for the Contractors on various Railroad construction projects. The Work Trains transport a variety of equipment and materials for the projects. The time and number of Work Train traffic will vary.

The Contractor's activities that have the potential to foul the tracks (mainline or otherwise) will be suspended during all train movements within the construction limits.

The Contractor will generally be directed by railroad flagmen as to the need to suspend operations. The number of flagmen required will be determined by PCJPB per its review of the Contractor's SSWP.

All shoring work within the OTS Envelope shall be performed in accordance with an approved SSWP.

2.4 Safety Regulations

In addition to safety regulations specific to the railroad, all construction shall conform to the applicable safety provisions of latest Cal/OSHA Standards – California Code of Regulations, Title 8, Chapter 4, Division of Industrial Safety, Subchapter 4, Construction Safety Orders. Construction shall also conform to the applicable California Public Utilities Commission Orders, as well as any other applicable government agency safety regulations.

2.5 Protective Dividers

An appropriate protective divider shall be provided between the construction operations and the Operating System. The divider shall be placed and secured a minimum of 10-feet clear from the centerline of the nearest active track.

Caltrans temporary railing Type K (K-rail) is an acceptable divider.

2.6 Handrails and Walkways

Adequate barrier physical protection shall be provided for all excavations in accordance with Cal/OSHA requirements.

In the event there is insufficient space to place a protective divider as specified in Section 2.5, a handrail shall be provided along the side of the excavation adjacent to the track. Minimum clearance from the centerline of track to the face of handrail shall be 8’-6” on tangent track and 9’-6” on curved track. The preferred minimum clearance is 10’-0”.

Handrails shall be designed in conformance with the requirements of Chapter 15, Section 8.5 “Walkways and Handrails on Bridges” of the AREMA Manual for Railway Engineering.

2.7 Clearances

All elements of the shoring system shall be placed such that they satisfy the clearance requirements specified in CPUC General Order 26-D.

The preferred minimum clearance from centerline of track to fixed objects such as posts, poles, signs, and elements of shoring systems that extend above the top of rail is 10’-0”.

SECTION 3 – PROHIBITED SHORING TYPES

The Contractor shall be solely responsible for the design, construction and performance of the temporary shoring structure with the following restrictions:

Soldier Piles and Lagging: Due to concerns about ground loss during excavation and lagging installation, soldier piles and lagging are not allowed for shoring within Zone 1 (when excavation in Zone 1 is permitted) and Zone 2 of the Zone of Influence.

Soil Nailing: Soil nailing may not be utilized to shore excavations within the Zone of Influence.

Tiebacks: Tiebacks may not be drilled under the tracks without permission of the PCJPB. If permission to utilize tiebacks is granted, the tiebacks must be installed using a method in which the drilled holes for the tiebacks will be fully supported at all times. Supplementary track monitoring requirements may be imposed during the installation of the tiebacks. Tieback testing requirements are specified in Section 8.5.

All of the temporary excavation support system elements should be removed and the excavated area should be backfilled.

SECTION 4 - LOADING ON SHORING SYSTEM

4.1 Design Loads (General)

Lateral loading from the following sources shall be considered in the design of the excavation shoring system:

- Retained Soil
- Retained Groundwater (hydrostatic pressure)
- Surcharge from all applicable sources, including, but not limited to, railroad live load, equipment and vehicles, material stockpiles, structures and improvements, etc.

Additionally, under certain conditions, earthquake (seismic) loading shall be considered. See Section 4.5.

Other sources of load, including centrifugal force from a train, impact loads, thermal loads, and wind loads are typically not required to be considered in the design of excavation shoring. Such loads need only be considered in cases where they are significant. For example, centrifugal forces may need to be considered in the design of an excavation shoring system constructed at a curve over which trains travel at high speeds.

Elements of the shoring system shall also be designed for vertical dead and live loads, as appropriate.

4.2 Soil Loads

4.2.1 Soil Types and the Determination of Soil Properties

Soil types and applicable properties shall be ascertained by taking borings and performing appropriate field and laboratory tests. Sufficient geotechnical exploration shall be performed to establish an understanding of the soil profile for the subject site. In addition to establishing the soil profile, key soil parameters for the design of shoring to be ascertained during exploration include the unit weights and strengths [i.e., the cohesion (c) and angle of internal friction (ϕ)] for the soils.

The design soil properties shall be established by a Registered Geotechnical Engineer, or, alternatively, by a Registered Civil Engineer specializing in geotechnical engineering.

4.2.2 Loading from Retained Soil on Flexible Systems

The loading defined in this section applies to shoring systems that have some degree of flexibility. Shoring types that may be considered flexible include cantilever shoring walls and, in most cases, shoring walls supported by a single level of bracing. The active soil pressure distribution for a flexible shoring system shall be assumed to take the form of an equivalent fluid pressure (EFP); i.e., a triangularly shaped pressure distribution.

EFP values used for shoring design shall be ascertained by a Registered Geotechnical Engineer, or, alternatively, by a Registered Civil Engineer specializing in geotechnical engineering. In no case shall the design active EFP for soil above the groundwater table be less than 30 psf/ft for level retained earth when this approach is used (i.e., the active pressure at any depth shall not be less than 30Y psf where Y is the depth below the ground surface). This minimum EFP value must be increased appropriately when the shoring system is retaining a sloped cut.

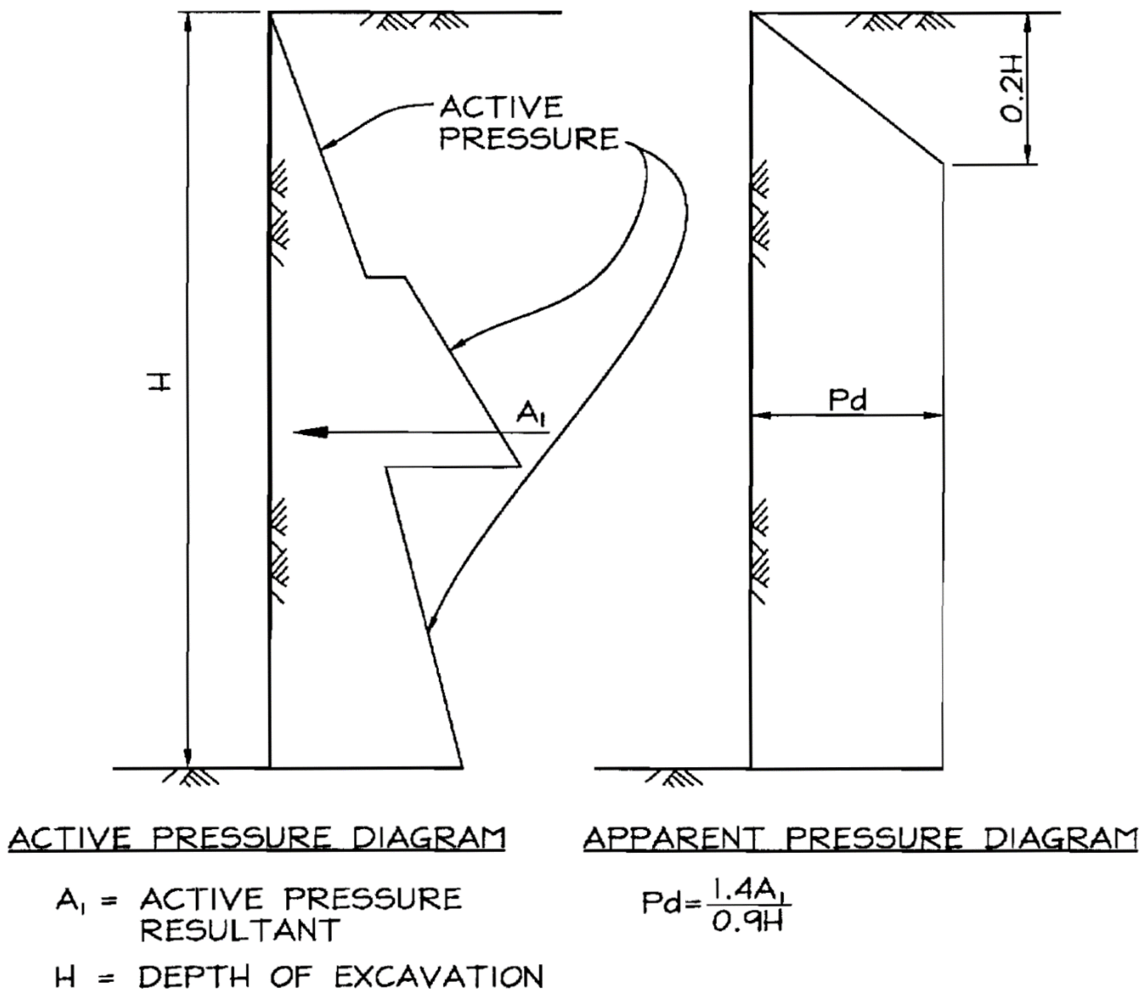
Alternatively, the retained soils may be classified as either Type 2, 3, 4 and 5 in accordance with the soil descriptions in Table 8-5-1 of the AREMA Manual for Railway Engineering. Representative soil properties for each classification are given in Table 8-5-2 of the AREMA Manual for Railway Engineering. The soil properties for the Type 1 classification given in Table 8-5-2 shall not be used. In no case shall the design EFP for soil above the groundwater table be less than 37 psf/ft for level retained earth when this approach is used (i.e., the active pressure at any depth shall not be less than 37Y psf where Y is the depth below the ground surface). This EFP corresponds to Type 2 soil classification. This minimum value must be increased appropriately for the case of shoring that is retaining a sloped cut. EFP values for Type 3, 4 or 5 soils shall be developed based upon the soil properties presented in Table 8-5-2.

4.2.3 Loading from Retained Soil on Restrained Systems

Shoring walls with multiple levels of bracing tend to restrict movements of the soil behind the wall. This restraint alters the soil pressure distribution from that anticipated based on the theory of active loading. “Apparent pressure” diagrams for braced (restrained) shoring systems have been developed by numerous authors. Generalized apparent pressure diagrams suitable for use in both cohesionless and cohesive soils, as well as interlayered soil profiles, can be constructed from active pressure diagrams as shown in Figure 4.1.

Alternatively, a number of diagrams, applicable to either cohesionless or cohesive soils, are presented in Chapter 5 of the Caltrans Trenching and Shoring Manual. These diagrams may be utilized, provided that the resulting loading magnitudes are not significantly less conservative than those determined by the procedure outlined in Figure 4.1.

FIGURE 4.1 – CONSTRUCTION OF AN APPARENT PRESSURE DIAGRAM



When apparent pressure loading is utilized for design, active soil loading developed in accordance with Section 4.2.2 shall be assumed to act below excavation grade.

4.2.4 Passive Resistance

Cohesionless Soil

The passive resistance in cohesionless ($c = 0$) soils shall be determined based upon log-spiral theory (refer to Figure 5(a) in the Pile Buck® Steel Sheet Piling Design Manual). Determination of the coefficient of passive pressure (K_p) is a function of ϕ and the angle of wall friction (δ).

Previous railroad design criteria have required that δ be assumed to be 0° due to dynamic train loading. However, this assumption can produce overly conservative results. In lieu of requiring δ = 0°, at the shoring designer's option, δ_{design} may be assumed to be a maximum of $\delta_{typ}/2$, where δ_{typ} is the wall friction value that would be utilized in the design of typical shoring away from the railroad. In no case shall δ exceed 0.25ϕ.

Cohesive Soil

In cohesive (ϕ = 0°) soil, K_p = 1.0, and the passive resistance is $\gamma_e z+2c$, where γ_e is the effective unit weight of the soil (i.e., the moist unit weight above the water level and the buoyant unit weight below the water level) and z is the depth below excavation grade.

Negative active pressures shall not be utilized to increase the available passive resistance under any circumstances.

C, ϕ Soil

Passive pressure diagrams can be developed for c, cp soils using more complex theoretical expressions. However, it is common to consider a soil stratum as either a purely cohesionless or cohesive soil depending on the soil's predominant physical properties and expected behavior.

Effect of Unbalanced Water Head

In cases where shoring system will retain an unbalanced water head, available passive resistance may need to be reduced to account for upward seepage pressures. Further details regarding the means of evaluating the reduction in passive resistance due to seepage pressures are outlined on page 34 of the Pile Buck® Steel Sheet Piling Design Manual.

4.3 Groundwater Load

Groundwater loading acting on the shoring system shall be based upon the maximum groundwater level that can be reasonably anticipated during the life of the shored excavation.

The design groundwater table shall be established based upon available historical groundwater monitoring (well) data and/or boring data for the subject area. For projects where historical records are not available, the groundwater table utilized for design should be assessed conservatively.

4.4 Surcharge Loads

Lateral pressure acting on the shoring system resulting from the following sources of surcharge loading should be considered in the design of the shoring as appropriate:

- Railroad live load (see Section 5)
- Equipment and vehicles
- Material stockpiles
- Existing structures
- Any other source of surcharge load

Lateral pressure resulting from vertical surcharge loads should be computed in accordance with the equations presented in Chapter 8, Section 20.3.2 of the AREMA Manual for Railway Engineering.

4.5 Earthquake (Seismic) Load

In atypical situations, such as where a shored excavation of substantial length parallels the OTS Envelope or where a shored excavation will remain open for more than 3 months, the PCJPB may require that lateral loading due to earthquake (seismic) shaking be considered. Subway construction parallel to the tracks is an example of a situation where the application of earthquake loading may be appropriate because an extensive length of open excavation may be present at one time.

This issue will be addressed on a project-specific basis by the PCJPB.

4.6 Combination of Loads and Loading Cases

All elements of the shoring system shall be designed for a combination of lateral soil, groundwater, and surcharge loads acting in conjunction with vertical dead and live loads.

Loading conditions during all stages of excavation, support removal and support relocation shall be analyzed. No reduction in loading from that present during the full depth excavation stage shall be assumed for the stages of support removal or relocation.

In situations where loading conditions on opposite sides of an internally braced excavation are not equal, the shoring design shall account for this unbalanced loading condition. The shoring system shall be designed for, and be compatible with, the more heavily loaded side of the excavation.

SECTION 5 - RAILROAD SURCHARGE

5.1 General

All shoring systems supporting excavations within Zones 1, 2 and 3 of the Zone of Influence (see Section 2) shall be designed for lateral pressure due to railroad live load surcharge. Railroad surcharge shall be based on Cooper's E-80 live load. Lateral pressure resulting from railroad surcharge shall be computed using the Boussinesq equation (see Figure 5.1).

Lateral surcharge pressure values for various depths below bottom of tie and distances to centerline of track computed using the Boussinesq equation are provided in Table 5.1.

The values in Table 5.1 were developed for the standard wood tie length (TL) of 9.0 feet. The values developed for the standard concrete tie length (8.25 feet) are not meaningfully different from those presented in Table 5.1.

5.2 Surcharge from Multiple Tracks

Surcharge loading from multiple tracks shall be considered as follows:

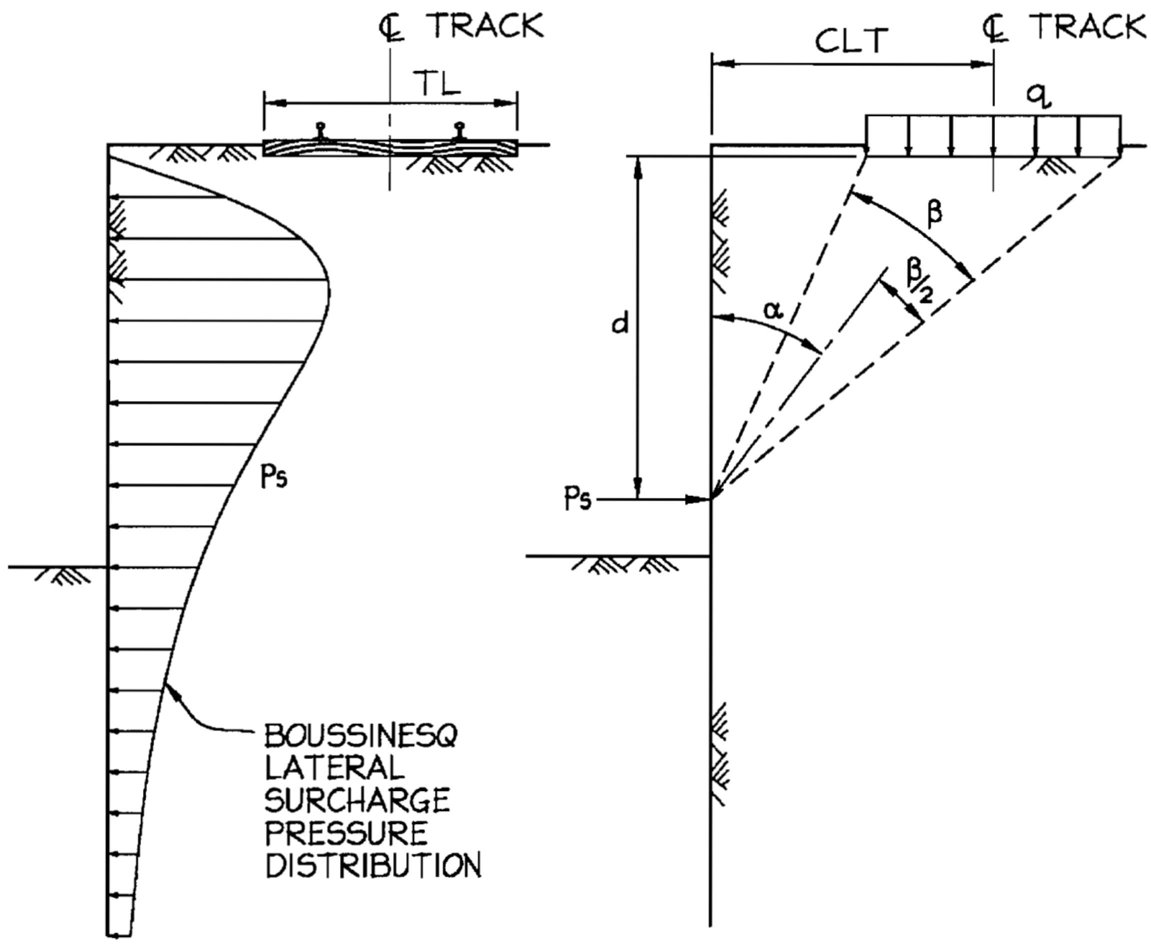
- Two tracks – Full surcharge from both tracks. See example 5.1.
- Three tracks – Full surcharge from two closest tracks combined with 50% surcharge from third track. See example 5.2.
- Four or more tracks – Full surcharge from two closest tracks combined with 50% surcharge from third track and 25% surcharge from fourth track.

Only surcharge from those tracks for which the shored excavation is within the Zone of Influence need be considered.

5.3 Simplified Surcharge Pressure Distribution

In lieu of using the detailed Boussinesq pressure distribution, railroad surcharge pressures may be assumed to have a rectangular distribution with a magnitude equal to 80% of the maximum Boussinesq pressure. See example 5.3.

FIGURE 5.1 – BOUSSINESQ LATERAL SURCHARGE PRESSURE DISTRIBUTION



d = DEPTH BELOW BOTTOM OF TIE
CLT = DISTANCE FROM ℄ TRACK TO FACE OF SHORING WALL
TL = TIE LENGTH
Ps = LATERAL SURCHARGE PRESSURE
q = VERTICAL SURCHARGE PRESSURE

$$P_s = \frac{2q}{\pi}(\beta - \sin\beta\cos 2\alpha)$$

q(E-80) = 80,000/(5TL)

TL = 9' STANDARD WOOD TIE
→ q = 1778psf

TL = 8'-3" STANDARD CONCRETE TIE
→ q = 1939psf

TABLE 5.1 – RAILROAD (E-80) LIVE LOAD LATERAL SURCHARGE

Based on the Boussinesq equation (see Figure 5.1)
d = depth below bottom of tie, surcharge values in psf

d	Distance from centerline of track to face of shoring (feet)																
(feet)	5	6	7	8	8.5	9	10	11	12	13	14	15	16	17	18	19	20
1	1469	974	625	434	370	320	247	197	161	135	114	98	86	75	67	59	53
2	1304	1172	930	719	635	563	450	367	305	257	220	191	166	147	130	117	105
3	1103	1092	983	838	767	701	585	492	418	359	310	271	239	212	189	170	153
4	921	955	924	846	799	750	655	570	496	434	381	337	299	267	240	217	197
5	762	817	828	797	771	741	674	605	541	482	431	386	347	313	283	257	234
6	629	692	724	725	715	699	658	609	558	508	461	419	381	347	317	290	266
7	518	583	627	646	646	642	622	591	553	514	475	438	403	371	341	315	291
8	428	491	539	568	576	580	575	559	535	506	476	444	414	385	358	333	309
9	354	413	462	497	509	518	525	520	507	488	466	441	416	391	367	344	322
10	295	349	396	434	448	460	474	479	474	464	449	431	411	390	370	349	329
11	246	295	340	378	394	407	426	437	439	436	427	415	400	384	367	349	332
12	207	251	293	330	345	359	382	396	404	406	403	396	386	373	360	346	331
13	175	215	253	288	303	317	341	359	370	376	377	374	368	360	350	338	326
14	149	184	219	252	267	281	305	324	338	347	351	352	349	344	337	329	319
15	127	159	190	221	235	248	272	292	307	319	326	329	330	328	323	317	310
16	110	138	166	194	207	220	243	263	280	292	301	307	310	310	308	305	300
17	95	120	146	171	184	196	218	237	254	268	278	285	290	293	293	291	288
18	82	105	128	151	163	174	195	214	231	245	256	265	271	275	277	277	276
19	72	92	113	134	145	155	175	194	210	224	236	246	253	258	261	263	263
20	63	81	100	120	129	139	158	175	191	205	217	228	236	242	246	249	250
21	56	72	89	107	116	125	142	159	174	188	200	211	219	226	232	235	238
22	49	64	79	96	104	112	129	144	159	172	184	195	204	211	217	222	225
23	44	57	71	86	94	101	116	131	145	158	170	181	190	198	204	209	213
24	39	51	64	77	84	92	106	119	133	145	157	167	176	185	191	197	202
25	35	46	58	70	76	83	96	109	122	134	145	155	164	172	179	185	190
26	32	41	52	63	69	75	88	100	112	123	134	144	153	161	168	174	180
27	29	37	47	58	63	69	80	91	102	113	124	133	142	150	158	164	170
28	26	34	43	52	58	63	73	84	94	105	114	124	132	141	148	154	160
29	23	31	39	48	53	57	67	77	87	97	106	115	123	131	139	145	151
30	21	28	36	44	48	53	62	71	80	89	98	107	115	123	130	137	142
31	19	26	33	40	44	48	57	65	74	83	91	100	108	115	122	128	134
32	18	23	30	37	41	44	52	60	69	77	85	93	101	108	115	121	127
33	16	22	27	34	37	41	48	56	64	71	79	87	94	101	108	114	120
34	15	20	25	31	35	38	45	52	59	66	74	81	88	95	101	107	113
35	14	18	23	29	32	35	41	48	55	62	69	76	82	89	95	101	107
36	13	17	22	27	30	33	39	45	51	58	64	71	77	84	90	95	101
37	12	16	20	25	28	30	36	42	48	54	60	66	73	79	84	90	95
38	11	15	19	23	26	28	33	39	45	50	56	62	68	74	80	85	90
39	10	13	17	22	24	26	31	36	42	47	53	58	64	70	75	80	85
40	9	13	16	20	22	24	29	34	39	44	50	55	60	66	71	76	81
41	9	12	15	19	21	23	27	32	37	42	47	52	57	62	67	72	77
42	8	11	14	18	19	21	25	30	34	39	44	49	54	58	63	68	73
43	8	10	13	16	18	20	24	28	32	37	41	46	51	55	60	64	69
44	7	10	12	15	17	19	22	26	30	35	39	43	48	52	57	61	65
45	7	9	12	14	16	18	21	25	29	33	37	41	45	49	54	58	62
46	6	8	11	14	15	17	20	23	27	31	35	39	43	47	51	55	59
47	6	8	10	13	14	16	19	22	25	29	33	37	40	44	48	52	56
48	6	7	10	12	13	15	18	21	24	27	31	35	38	42	46	50	53
49	5	7	9	11	13	14	17	20	23	26	29	33	36	40	44	47	51
50	5	7	9	11	12	13	16	19	21	25	28	31	34	38	41	45	48

TABLE 5.1 – RAILROAD (E-80) LIVE LOAD LATERAL SURCHARGE (CONTINUED)

Based on the Boussinesq equation (see Figure 5.1)

d = depth below bottom of tie, surcharge values in psf

d	Distance from centerline of track to face of shoring (feet)																
(feet)	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
1	48	44	40	37	34	31	29	27	25	23	22	20	19	18	17	16	15
2	95	86	79	72	66	61	57	53	49	46	43	40	38	36	34	32	30
3	139	127	116	106	98	91	84	78	73	68	64	60	56	53	50	47	45
4	179	164	150	138	128	118	110	102	95	89	84	79	74	70	66	62	59
5	214	197	181	167	155	144	134	125	117	109	103	96	91	86	81	77	73
6	244	225	208	193	179	167	156	146	136	128	120	113	107	101	96	91	86
7	269	249	231	215	201	187	175	164	154	145	137	129	122	115	109	104	98
8	288	268	250	234	219	205	192	181	170	160	151	143	135	128	122	116	110
9	302	283	265	249	234	220	207	195	184	174	165	156	148	140	133	127	121
10	311	293	276	260	246	232	219	207	196	186	176	167	159	151	144	137	131
11	315	299	283	269	254	241	229	217	206	196	186	177	168	161	153	146	140
12	316	302	287	274	261	248	236	225	214	204	194	185	177	169	161	154	147
13	314	301	289	276	264	252	241	230	220	210	201	192	184	176	168	161	154
14	309	298	287	276	265	255	244	234	224	215	206	198	189	182	174	167	161
15	302	293	284	274	265	255	246	236	227	218	210	202	194	186	179	172	166
16	293	286	279	271	262	254	245	237	228	220	212	205	197	190	183	176	170
17	284	278	272	265	258	251	244	236	228	221	214	206	199	192	186	179	173
18	273	269	265	259	253	247	241	234	227	220	214	207	201	194	188	182	176
19	262	259	256	252	247	242	237	231	225	219	213	207	201	195	189	183	178
20	250	249	247	244	241	237	232	227	222	217	211	206	200	195	189	184	179
21	239	239	238	236	233	230	227	223	218	214	209	204	199	194	189	184	179
22	227	228	228	227	226	223	221	217	214	210	206	201	197	193	188	183	179
23	216	218	219	219	218	216	214	212	209	206	202	198	195	191	186	182	178
24	205	207	209	210	210	209	208	206	204	201	198	195	192	188	184	181	177
25	194	197	200	201	202	201	201	200	198	196	194	191	188	185	182	179	175
26	184	188	190	192	193	194	194	193	192	191	189	187	184	182	179	176	173
27	174	178	181	184	185	186	187	187	186	185	184	182	180	178	176	173	171
28	165	169	173	175	177	179	180	180	180	180	179	178	176	174	173	170	168
29	156	161	164	167	170	172	173	174	174	174	174	173	172	170	169	167	165
30	148	152	156	160	162	165	166	167	168	168	168	168	167	166	165	164	162
31	140	144	149	152	155	158	160	161	162	163	163	163	163	162	161	160	159
32	132	137	141	145	148	151	153	155	156	157	158	158	158	158	157	156	155
33	125	130	134	138	141	144	147	149	150	152	153	153	153	153	153	152	152
34	118	123	127	131	135	138	141	143	145	146	147	148	149	149	149	149	148
35	112	117	121	125	129	132	135	137	139	141	142	143	144	145	145	145	144
36	106	111	115	119	123	126	129	132	134	136	137	139	139	140	141	141	141
37	100	105	109	114	117	121	124	126	129	131	132	134	135	136	136	137	137
38	95	100	104	108	112	115	118	121	124	126	128	129	131	132	132	133	133
39	90	95	99	103	107	110	113	116	119	121	123	125	126	127	128	129	130
40	85	90	94	98	102	105	109	111	114	116	119	120	122	123	124	125	126
41	81	85	90	94	97	101	104	107	110	112	114	116	118	119	120	121	122
42	77	81	85	89	93	96	100	102	105	108	110	112	114	115	117	118	119
43	73	77	81	85	89	92	95	98	101	104	106	108	110	111	113	114	115
44	69	74	77	81	85	88	91	94	97	100	102	104	106	108	109	111	112
45	66	70	74	77	81	84	87	90	93	96	98	100	102	104	106	107	108
46	63	67	70	74	77	81	84	87	90	92	94	97	99	101	102	104	105
47	60	64	67	71	74	77	80	83	86	89	91	93	95	97	99	100	102
48	57	61	64	67	71	74	77	80	83	85	88	90	92	94	96	97	99
49	54	58	61	65	68	71	74	77	79	82	84	87	89	91	92	94	96
50	52	55	58	62	65	68	71	74	76	79	81	84	86	88	89	91	93

TABLE 5.1 – RAILROAD (E-80) LIVE LOAD LATERAL SURCHARGE (CONTINUED)

Based on the Boussinesq equation (see Figure 5.1)

d = depth below bottom of tie, surcharge values in psf

	Distance from centerline of track to face of shoring (feet)												
d (feet)	38	39	40	41	42	43	44	45	46	47	48	49	50
1	14	14	13	12	12	11	11	10	10	9	9	9	8
2	28	27	26	24	23	22	21	20	19	19	18	17	16
3	42	40	38	36	35	33	32	30	29	28	27	25	24
4	56	53	51	48	46	44	42	40	38	37	35	34	32
5	69	66	62	60	57	54	52	50	47	45	44	42	40
6	82	78	74	70	67	64	61	59	56	54	52	50	48
7	93	89	85	81	77	74	71	68	65	62	60	57	55
8	105	100	95	91	87	83	80	76	73	70	67	65	62
9	115	110	105	100	96	92	88	84	81	78	75	72	69
10	125	119	114	109	104	100	96	92	88	85	82	79	76
11	133	128	122	117	112	108	103	99	95	92	88	85	82
12	141	135	130	124	119	115	110	106	102	98	95	91	88
13	148	142	136	131	126	121	117	112	108	104	100	97	93
14	154	148	142	137	132	127	122	118	114	110	106	102	99
15	159	153	148	142	137	132	127	123	119	115	111	107	103
16	164	158	152	147	142	137	132	128	123	119	115	111	108
17	167	162	156	151	146	141	136	132	127	123	119	115	112
18	170	165	159	154	149	144	140	135	131	127	123	119	115
19	172	167	162	157	152	147	143	138	134	130	126	122	119
20	173	168	163	159	154	149	145	141	137	133	129	125	122
21	174	169	165	160	156	151	147	143	139	135	131	128	124
22	174	170	165	161	157	153	149	145	141	137	133	130	126
23	174	170	166	161	157	153	150	146	142	138	135	131	128
24	173	169	165	161	158	154	150	147	143	140	136	133	129
25	172	168	165	161	158	154	150	147	144	140	137	134	131
26	170	167	164	160	157	154	150	147	144	141	138	135	131
27	168	165	162	159	156	153	150	147	144	141	138	135	132
28	166	163	160	158	155	152	149	146	144	141	138	135	132
29	163	161	158	156	153	151	148	146	143	140	138	135	132
30	160	158	156	154	152	149	147	145	142	140	137	135	132
31	157	155	154	152	150	148	146	143	141	139	136	134	132
32	154	153	151	149	148	146	144	142	140	138	136	133	131
33	151	150	148	147	145	144	142	140	138	136	134	132	130
34	147	146	145	144	143	142	140	138	137	135	133	131	129
35	144	143	142	141	140	139	138	136	135	133	132	130	128
36	140	140	139	139	138	137	136	134	133	132	130	129	127
37	137	137	136	136	135	134	133	132	131	130	129	127	126
38	133	133	133	133	132	132	131	130	129	128	127	126	124
39	130	130	130	130	129	129	128	128	127	126	125	124	123
40	126	127	127	127	127	126	126	125	125	124	123	122	121
41	123	123	124	124	124	124	123	123	122	122	121	120	119
42	119	120	120	121	121	121	121	120	120	119	119	118	117
43	116	117	117	118	118	118	118	118	118	117	117	116	116
44	113	114	114	115	115	115	115	115	115	115	115	114	114
45	109	110	111	112	112	113	113	113	113	113	112	112	112
46	106	107	108	109	109	110	110	110	110	110	110	110	110
47	103	104	105	106	107	107	107	108	108	108	108	108	108
48	100	101	102	103	104	104	105	105	106	106	106	106	106
49	97	98	99	100	101	102	102	103	103	103	104	104	104
50	94	95	97	98	98	99	100	100	101	101	101	102	102

5.4 Application of Surcharge Pressures

Railroad surcharge pressures shall be assumed to act over the full height of the shoring wall (i.e., from the lower of the bottom of railroad ties or the top of shoring wall down to the bottom of the shoring wall).

5.5 Surcharge - Shoring Walls Used as Bridge Abutments

When shoring walls are used as temporary bridge abutments, the design railroad live load surcharge acting on such walls shall be computed in accordance with Chapter 8, Section 5.3.1 of the AREMA Manual for Railway Engineering.

5.6 Combination with Surcharge from Other Sources

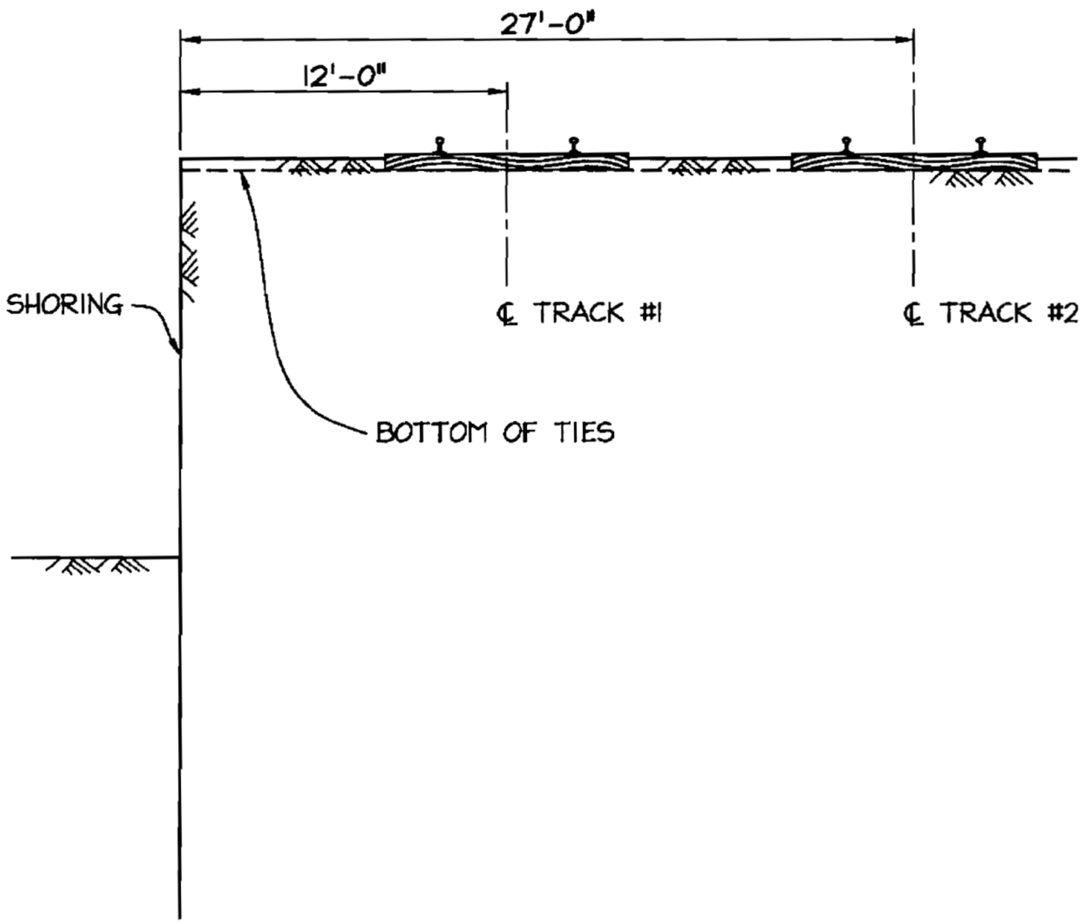
Surcharge from other sources (e.g., heavy equipment, existing structures, etc.) shall be considered in the design of excavation shoring systems as appropriate. Surcharges from other sources shall be added to the railroad surcharge if the surcharge loads can act concurrently.

5.7 Example Problems

EXAMPLE 5.1 - RAILROAD SURCHARGE FROM TWO TRACKS

PROBLEM:

COMPUTE THE LATERAL SURCHARGE PRESSURES ACTING ON THE SHORING WALL BASED ON THE FOLLOWING TRACK GEOMETRY.

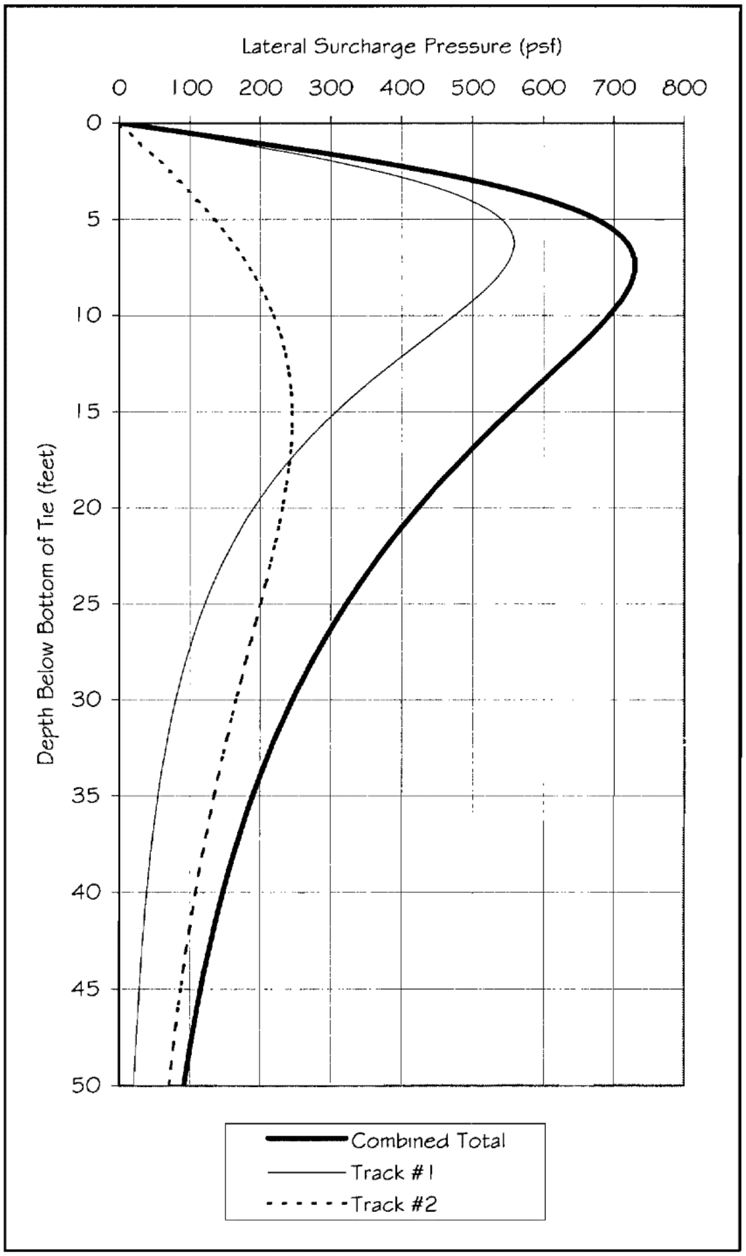


SOLUTION:

Centerline of Track #1 is 12 feet from face of shoring
Centerline of Track #2 is 27 feet from face of shoring

d = depth below bottom of tie
$P_{s,1}$ = lateral surcharge from Track #1
$P_{s,2}$ = lateral surcharge from Track #2
$P_{s,total}$ = combined lateral surcharge from Tracks #1 and #2 = $P_{s,1}+P_{s,2}$

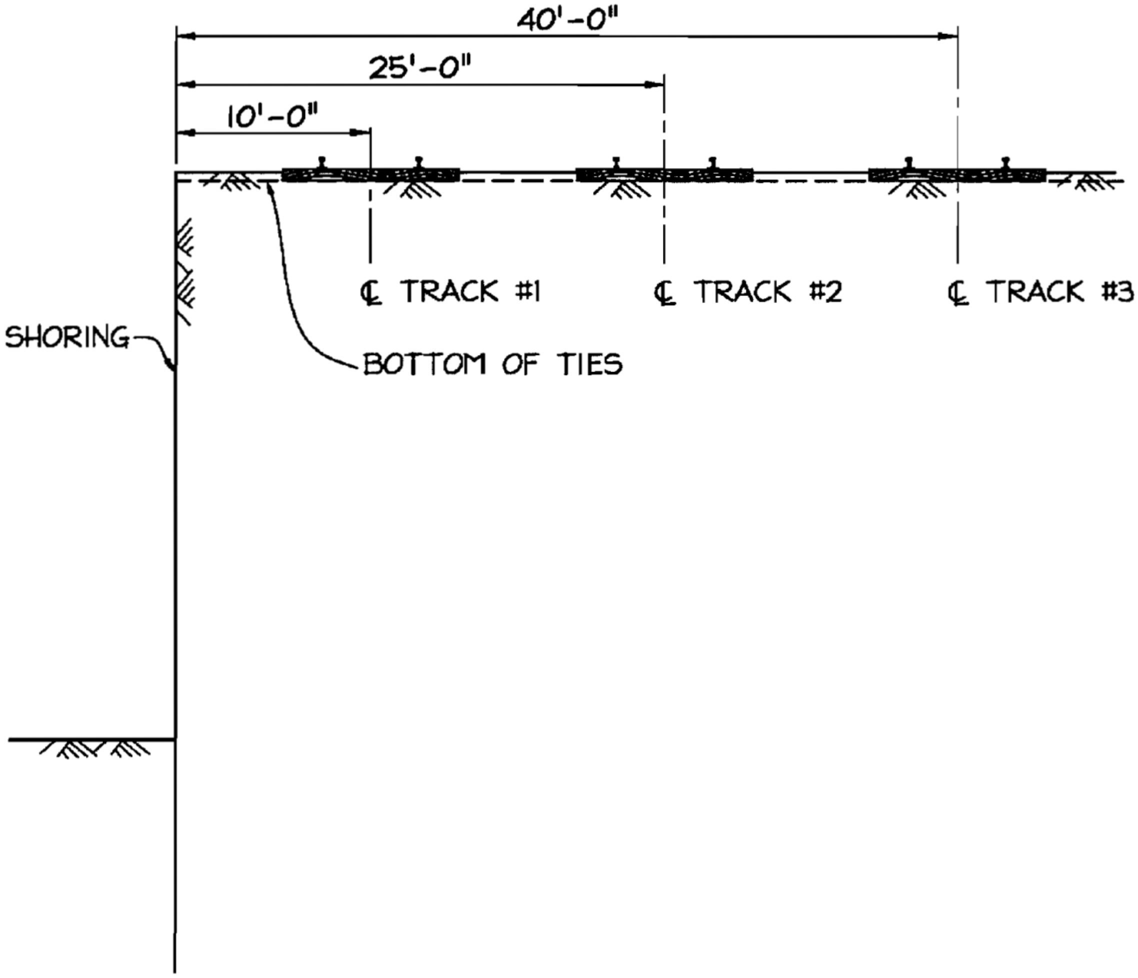
d (feet)	$P_{s,1}$ (psf)	$P_{s,2}$ (psf)	$P_{s,total}$ (psf)
1	161	29	190
2	305	57	362
3	418	84	502
4	496	110	606
5	541	134	674
6	558	156	713
7	553	175	729
8	535	192	727
9	507	207	714
10	474	219	693
11	439	229	668
12	404	236	640
13	370	241	611
14	338	244	582
15	307	246	553
16	280	245	525
17	254	244	498
18	231	241	472
19	210	237	447
20	191	232	423
21	174	227	401
22	159	221	379
23	145	214	359
24	133	208	340
25	122	201	322
26	112	194	305
27	102	187	289
28	94	180	274
29	87	173	260
30	80	166	246
31	74	160	234
32	69	153	222
33	64	147	211
34	59	141	200
35	55	135	190
36	51	129	180
37	48	124	171
38	45	118	163
39	42	113	155
40	39	109	148
41	37	104	141
42	34	100	134
43	32	95	128
44	30	91	122
45	29	87	116
46	27	84	111
47	25	80	106
48	24	77	101
49	23	74	97
50	21	71	92



EXAMPLE 5.2 - RAILROAD SURCHARGE FROM THREE TRACKS

PROBLEM:

COMPUTE THE LATERAL SURCHARGE PRESSURES ACTING ON THE SHORING WALL BASED ON THE FOLLOWING TRACK GEOMETRY.

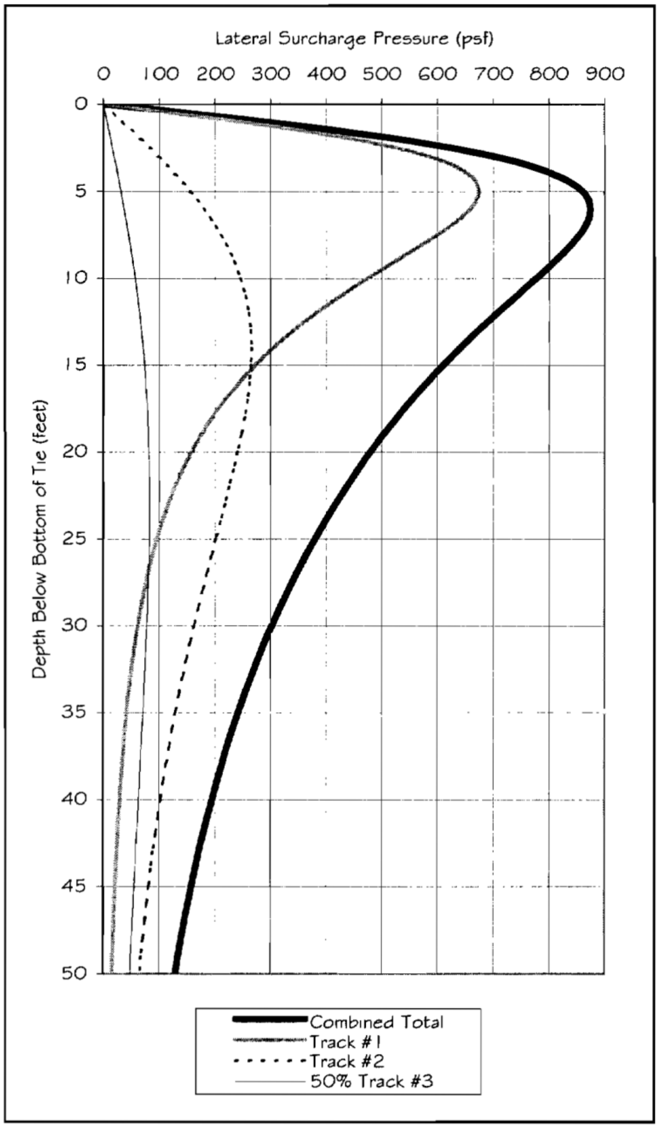


SOLUTION:

Centerline of Track #1 is 10 feet from face of shoring
Centerline of Track #2 is 25 feet from face of shoring
Centerline of Track #3 is 40 feet from face of shoring

d (feet)	$P_{s,1}$ (psf)	$P_{s,2}$ (psf)	$P_{s,3}$ (psf)	$0.5P_{s,3}$ (psf)	$P_{s,total}$ (psf)
1	247	34	13	6	287
2	450	66	26	13	529
3	585	98	38	19	703
4	655	128	51	25	808
5	674	155	62	31	860
6	658	179	74	37	874
7	622	201	85	42	865
8	575	219	95	48	842
9	525	234	105	52	811
10	474	246	114	57	777
11	426	254	122	61	742
12	382	261	130	65	707
13	341	264	136	68	673
14	305	265	142	71	641
15	272	265	148	74	611
16	243	262	152	76	582
17	218	258	156	78	554
18	195	253	159	80	528
19	175	247	162	81	504
20	158	241	163	82	480
21	142	233	165	82	458
22	129	226	165	83	437
23	116	218	166	83	417
24	106	210	165	83	398
25	96	202	165	82	380
26	88	193	164	82	363
27	80	185	162	81	346
28	73	177	160	80	331
29	67	170	158	79	316
30	62	162	156	78	302
31	57	155	154	77	289
32	52	148	151	76	276
33	48	141	148	74	264
34	45	135	145	73	252
35	41	129	142	71	242
36	39	123	139	70	231
37	36	117	136	68	221
38	33	112	133	67	212
39	31	107	130	65	203
40	29	102	127	63	194
41	27	97	124	62	186
42	25	93	120	60	179
43	24	89	117	59	171
44	22	85	114	57	164
45	21	81	111	56	158
46	20	77	108	54	151
47	19	74	105	53	145
48	18	71	102	51	139
49	17	68	99	50	134
50	16	65	97	48	129

d = depth below bottom of tie
$P_{s,1}$ = lateral surcharge from Track #1
$P_{s,2}$ = lateral surcharge from Track #2
$P_{s,3}$ = lateral surcharge from Track #3
$P_{s,total}$ = combined lateral surcharge from Tracks #1, #2 & #3 = $P_{s,1} + P_{s,2} + 0.5P_{s,3}$



EXAMPLE 5.3 - "SIMPLIFIED" RAILROAD SURCHARGE

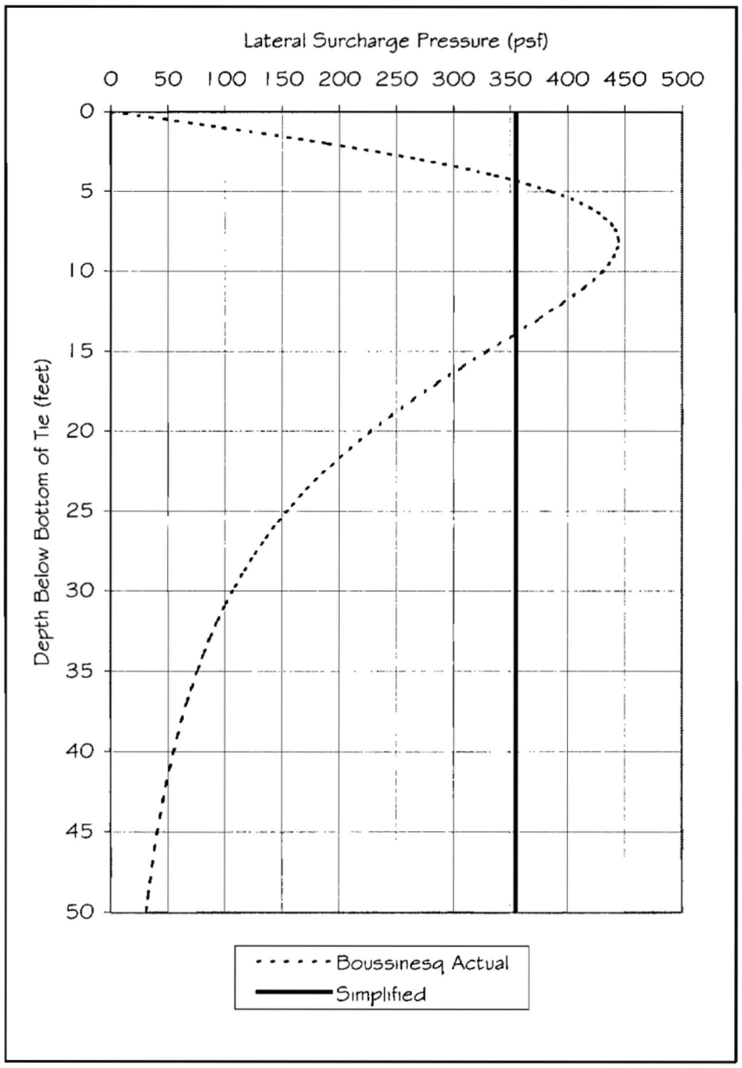
PROBLEM:
DEVELOP THE "SIMPLIFIED" LATERAL SURCHARGE PRESSURE DIAGRAM FOR A SINGLE TRACK WHOSE CENTERLINE IS LOCATED 15 FEET FROM THE FACE OF A SHORING WALL.

SOLUTION:

Centerline of track is 15 feet from face of shoring

d = depth below bottom of tie
P_s = Boussinesq lateral surcharge
$P_{s,simple} = 0.8P_{s,max} = 0.8(444) = 355$ psf

d (feet)	P_s (psf)	
1	98	
2	191	
3	271	
4	337	
5	386	
6	419	
7	438	
8	444	$P_{s,max}$
9	441	
10	431	
11	415	
12	396	
13	374	
14	352	
15	329	
16	307	
17	285	
18	265	
19	246	
20	228	
21	211	
22	195	
23	181	
24	167	
25	155	
26	144	
27	133	
28	124	
29	115	
30	107	
31	100	
32	93	
33	87	
34	81	
35	76	
36	71	
37	66	
38	62	
39	58	
40	55	
41	52	
42	49	
43	46	
44	43	
45	41	
46	39	
47	37	
48	35	
49	33	
50	31	



SECTION 6 - SHORING ANALYSIS METHODOLOGIES

6.1 Continuous Shoring Walls

Continuous shoring walls, such as steel sheet piling and diaphragm walls, are typically analyzed on a longitudinal per-foot-of-wall (unit) basis for the lateral pressures computed in accordance with Sections 4 and 5 of these Standards. The wall is designed for the unit bending moments and shears resulting from the lateral pressures acting on the wall. When the shoring wall is designed to support vertical loads, these loads must be considered in the design as well.

In the case of sheet piling, the structural strength of the wall is provided by sheets themselves. On the other hand, the wide flange sections installed in deep soil mix, secant, tangent, or SPTC (slurry) walls are the primary structural elements for these systems. Rebar reinforced slurry walls are designed as a continuous vertically reinforced concrete wall.

6.2 Soldier Pile Shoring Walls

Soldier pile and lagging walls are analyzed in a somewhat different manner than continuous shoring walls. Soldier pile and lagging walls are not continuous below excavation grade, and the loading acting on the active and passive sides of the wall for the embedded portion of the wall must be constructed to reflect the discontinuous nature of the wall. The "effective width" of the embedded portion of the soldier pile (for both active and passive loading) shall be computed using the "Arching Capability" values given in Section 6.2 of the Caltrans Trenching and Shoring Manual. As for continuous walls, lateral pressures utilized to construct the loading diagrams shall be computed in accordance with Sections 4 and 5 of these Standards.

Soldier piles are designed as vertical beams to resist the bending moments and shears resulting from the lateral loads acting on the piles. Vertical loading (if any) shall be considered in the soldier pile design.

6.3 Analysis of Cantilever Walls

A cantilever shoring wall is typical analyzed based on the assumption that the shoring wall is embedded far enough to assure stability by balancing the rotation moments induced by the loads acting on the two sides of the wall at a point close to the bottom of the wall. The realistic load distribution pattern is shown in Figure 6(b) in the Caltrans Trenching and Shoring Manual. The "Simplified" method illustrated in the Caltrans Trenching and Shoring Manual may be used to design a cantilever shoring wall. The computed to toe embedment depth (referred to as D_0

in the above referenced figures) shall be increased by 20 percent to determine the minimum theoretical toe embedment depth.

A factor of safety for the cantilever wall toe embedment shall be provided. When the theoretical toe embedment depth is computed based on the "unreduced" (factor of safety equal to 1.0) passive resistance, this theoretical embedment depth shall be increased by a minimum of 40% to determine the minimum design toe embedment depth. This 40% increase is provided in addition to the 20% increase required if the "Simplified" method of analysis has been utilized.

Toe embedment depths computed based on passive resistance that has been divided by a factor of safety of 2.0 will also be acceptable, provided that the resulting design toe embedment depth is not significantly less than that computed using the nominal 40% increase in toe depth discussed above.

Analysis utilizing "unreduced" passive resistance should be applied with caution when the shoring wall is embedded in stiff to hard clays, because the computed toe embedment may be unrealistically short. See Section 6.8.1 for minimum toe embedment depths.

6.4 Analysis of Walls with a Single Level of Bracing

Walls supported by a single level of bracing (or a single tier of tiebacks) may be analyzed using the Free Earth Support or Fixed Earth Support Method at the shoring designer's option. Each of these methods is outlined below.

6.4.1 Free Earth Support Method

This method is based on the assumption that the shoring wall is embedded far enough to assure stability, but that the available passive resistance is incapable of restraining the shoring wall sufficiently to induce negative moment in the wall (i.e., there is no reversal of moment below excavation subgrade). The theoretical toe embedment required for stability is determined by statics. The theoretical depth of embedment required is determined by summing moments due to all pressures acting on the shoring wall about the bracing level. The embedment depth is adjusted until the sum of the moments about the bracing level is zero. Moments and shears in the shoring wall and the bracing reaction may be computed after the embedment depth is determined.

6.4.2 Fixed Earth Support Method

This method is based on the assumption that the shoring wall is embedded sufficiently to provide effective "fixity" at the toe of the shoring wall (i.e., the deflected shape of the shoring wall is such that the wall reverses curvature over its embedded length and becomes vertical at its bottom). Unlike the Free Earth

Support Method, moment reversal takes place over the embedded portion of the shoring wall. In comparison to the Free Earth Support Method, the toe embedment computed using the Fixed Earth Support Method would be longer; however, pile moment demand, pile deflection, and the bracing reaction will typically be reduced.

Hand calculating the required toe depth for the Fixed Earth Support Method is not a trivial manner. However, through the use of commonly available structural analysis software, determining the depth of embedment required to produce the appropriate deflected shape of the shoring wall (i.e., effective fixity) is just a matter of iterating the depth of embedment. As for the Free Earth Support Method, moments and shears in the pile, and the bracing reaction may be computed after the theoretical embedment depth is determined.

6.4.3 Factor of Safety for Shoring Wall Toe Embedment

A factor of safety for the shoring wall toe embedment must be provided when either the Free Earth Support Method or Fixed Earth Support Method is used. When the theoretical toe embedment depth is computed based on the "unreduced" (factor of safety equal to 1.0) passive resistance, this theoretical embedment depth shall be increased by a minimum of 40% to determine the minimum design toe embedment depth. (This method should be used with caution when stiff to hard clays provide passive resistance, because the computed embedment depth may be unrealistically short.)

Toe embedment depths computed based on passive resistance that has been divided by a factor of safety of 2.0 will also be acceptable, provided that the resulting design toe embedment depth is not significantly less than that computed using the nominal 40% increase in toe depth discussed above.

See Section 6.8.1 for minimum toe embedment depths.

6.5 Analysis of Walls with Multiple Levels of Bracing

6.5.1 Toe Embedment Depth

The required depth of penetration for a shoring wall supported by two or more levels of bracing shall be determined by one of the following methods:

1. The theoretical toe embedment may be calculated by balancing moments due to all soil, hydrostatic, lateral surcharge, and "unreduced" (factor of safety equal to 1.0) passive pressures acting below the lowest bracing level about the lowest bracing level. The moment capacity of the shoring wall shall be conservatively neglected in this analysis. The depth of penetration is adjusted until the sum of the moments equals zero. The computed theoretical embedment depth shall be increased by a minimum of 40% to determine the minimum design toe

embedment depth. (This method should be used with caution when stiff to hard clays provide passive resistance, because the computed embedment depth may be unrealistically short.)

2. The toe embedment depth may be computed by summing moments as noted above, using passive resistance values that have been reduced by dividing them by a factor of safety of 2.0. No increase in toe embedment is required when this method is used. This method will be acceptable provided that the resulting design toe embedment depth is not significantly less than that computed using the nominal 40% increase in toe depth discussed above.

See Section 6.8.1 for minimum toe embedment depths.

6.5.2 Analysis of Shoring Wall

Moments and shears in the shoring wall shall be computed using beam analysis, assuming that the shoring wall is hinged at all bracing levels except the uppermost. Moments may be reduced to 80% of their computed values for design to account for wall continuity over the bracing locations.

Analysis of the portion of the shoring wall below the lowest bracing level shall be based on statics, including a consideration of all loads acting on the embedded portion of the shoring wall. A fictitious support at or below subgrade shall not be assumed for analysis purposes.

No redistribution of loads or reduction in the demand on the shoring wall due to soil arching shall be assumed.

6.5.3 Determination of Bracing Loads

Bracing loads shall be determined by beam analysis assuming that the shoring wall is hinged at all the bracing levels except the uppermost. The load on the lowest bracing level shall be determined by statics, including a consideration of all loads acting on the embedded portion of the shoring wall. A fictitious support at or below subgrade shall not be assumed for analysis purposes.

6.6 Analysis of Bracing Systems

Unit (per foot) reactions at each bracing level are determined during the analysis of the shoring wall. For shoring walls with soldier piles (e.g., soldier pile and lagging walls, deep soil mix walls, and secant walls) point loads from each pile are computed by multiplying the pile spacing by the unit bracing reactions. On the other hand, bracing loading for sheet piling may be assumed as a horizontal uniform load equal to the unit reactions.

Internal (cross-lot) bracing systems consisting of wales and struts shall be designed to resist the computed bracing loads. Moments, shears and axial loads in the bracing members shall be computed using standard methods of structural analysis.

Tieback or Deadman systems that are used to restrain the shoring walls shall be designed to resist the computed bracing loads.

No redistribution of loads or reduction in the demand on bracing elements due to soil arching shall be assumed.

6.7 Lagging Analysis

Lagging may be designed for a load equal to 60% of the shoring design load (soil and surcharge pressures) to account for soil arching. The lagging members shall be designed as horizontal beams spanning between soldier piles.

In cases where soil arching cannot develop, reduced lagging loads shall not be considered.

Tabulated lagging thicknesses (such as those presented in Table 10-2 of the Caltrans Trenching and Shoring Manual) shall not be utilized.

6.8 General Shoring Requirements

6.8.1 Minimum Toe Embedment

Computed toe embedment depths shall be compared with the following minimum values. In cases where the computed design toe embedment depth is less than that specified below, the minimum toe embedment depth specified below shall be utilized:

- Cantilever walls: Toe depth shall not be less than the height of the retained cut.
- Braced walls less than 20 feet high: Toe depth shall not be less than 6 feet.
- Braced walls 20 feet or more high: Toe depth shall not be less than 8 feet.

6.8.2 Secondary Bracing

Primary elements of the shoring system shall be provided with secondary bracing as required for stability. The secondary bracing elements shall be designed for an axial load equal to 3% of the axial load in the braced member.

6.8.3 Connections

Connections between the various elements of the shoring system shall be designed for tension and shear loads equal to at least 10% of the design compression load transferred through the connection. If the actual shear or tension at a connection is larger than this 10% value, the actual shear or tension load shall be utilized for design.

6.8.4 Stiffeners

Stiffeners shall be provided at shoring member connections when required by the provisions of Chapter K of the AISC, ASD.

6.9 Shoring Deflection

All shoring designs within the Zone of Influence shall include an estimate of shoring deflection. The amount of deflection that occurs will depend upon the soil type, the size of the excavation, the construction methods and quality of workmanship, and the design of the shoring system (including the stiffness of the shoring wall and bracing systems).

At the least, elastic analyses of the shoring system should be performed for the various stages of support installation and removal in order to estimate lateral shoring deflection.

The intent of requiring an analysis of deflection is to provide some assurance that the shoring system will have sufficient stiffness to prevent excessive track movement. See Section 9 for track monitoring requirements and track movement limitations.

The estimated horizontal shoring wall deflection shall be limited to a maximum of 1/2 inch.

SECTION 7 – MATERIAL PROPERTIES AND ALLOWABLE STRESSES

7.1 Steel

7.1.1 General

Steel may be used material, provided that is free from any strength impairing defects.

7.1.2 Structural Steel

Allowable stresses for steel shall conform to the AISC, Manual of Steel Construction – Allowable Stress Design (ASD), ninth edition, 1989, with the following additional constraints for struts:

- Slenderness ratio (L/r) shall not exceed 120.
- Axial stress shall not exceed 12 ksi.

No overstress shall be permitted.

Structural steel for which mill certificates are not available (unidentified steel) shall be designed for allowable stresses no greater than those allowed for ASTM A36 steel.

Bolted and welded connections shall be designed in accordance with the provisions of the AISC, ASD.

7.1.3 Steel Sheet Piling

The maximum allowable flexural stress in sheet piling shall not exceed 65% of the yield strength of the steel.

7.1.4 Prestressed Strand or Rod

If prestressed strands or rod are used as tieback tendons or as tie rods to a Deadman anchorage, the allowable working stress shall not exceed 40% of the guaranteed ultimate tensile strength (G.U.T.S.).

If the strands or rod are used for purposes other than those specified above, the allowable working stress shall not exceed 60% of G.U.T.S.

The shoring designer shall evaluate the potential effects of corrosion on strands and rods. Corrosion protection suitable for the installation environment and anticipated service life shall be provided.

7.1.5 Wire Rope Cable

The allowable working load for wire rope shall be no greater than 25% of the rated breaking strength.

If wire rope connectors with an efficiency of less than 100% are used, the allowable working load shall be taken as no greater than 25% of the rated breaking strength multiplied by the efficiency of the connectors.

Wire rope used as a structural element for more than 30 days shall be galvanized.

7.2 Concrete

Reinforced and plain (unreinforced) concrete shall be designed in accordance with ACI 318. No stress increases or load factor reductions shall be allowed.

7.3 Wood

All wood shoring elements shall be Douglas fir, No. 2 or better.

All wood that will remain in place permanently shall be pressure treated for ground contact use.

Allowable stresses shall be as follows:

- Compression perpendicular to the grain = 450 psi

- Compression parallel to the grain = $480{,}000/(L/d)^2 < 1600$ psi, where
  L = unbraced length of member
  d = lesser cross-sectional dimension of member
  (L and d to have consistent units)

- Flexural stress = 1700 psi*
  *reduced to 1,500 psi for members with a nominal depth of 8 inches or less)

- Horizontal shear = 140 psi

7.4 Other Materials

Allowable stresses for materials other than steel, concrete, and wood will be approved by the PCJPB on a case-by-case basis. Typically, industry-accepted allowable stresses or loads (with no overstress allowances) will be acceptable.

SECTION 8 – SPECIAL CONDITIONS

8.1 Sealed Shoring

Under certain conditions, excavation below the groundwater table will require that a sealed shoring system be utilized. Examples of situations where sealed shoring is needed include, but are not limited to:

- Excavations in permeable soils where dewatering is infeasible or where the quantity of water to be handled and disposed of would be excessive.
- Locations where the groundwater is contaminated.
- Locations where dewatering would result in unacceptable settlement of the surrounding area.

Relatively watertight shoring is most commonly provided using interlocked sheet piling or diaphragm walls.

Where possible, groundwater flow around the bottom of the shoring wall should be prevented by extending the wall into an underlying low permeability soil layer (such as a clay layer). If a low permeability cut off layer is not present, or if it is at such a great depth that penetrating it is not feasible or cost effective, a tremie concrete or grouted seal slab should be considered for the base of the excavation.

In cases where a positive bottom seal is not provided, the potential for piping must be evaluated. See Section 8.3.

8.2 Dewatering

Dewatering can be an effective means of reducing shoring loading and improving shoring stability and constructability.

In cases where dewatering is not precluded by other factors (see Section 8.1), the PCJPB will consider allowing dewatering, provided that it won't cause problematic track settlement. The potential for problematic track settlement to occur will be a function of the site soil profile and the depth to which the site needs to be dewatered. Track settlement in excess of that specified in Section 9.1 may be acceptable if it can be shown that differential track settlements resulting from dewatering will be minimal (i.e., settlements will occur over a broad area). Engineering calculations demonstrating that excessive differential settlement will not occur will be required.

In cases where the performance of the excavation shoring system depends upon the functionality of the dewatering system, the dewatering system shall be fail-safe.

Elements such as an uninterrupted power supply, back-up pumps, and failure alarm signals will be required to guarantee that the dewatering system will never shut down for a period of time that could compromise the stability of the shored excavation.

Dewatering system design shall be performed by a Civil Engineer registered in the State of California with previous experience in the design of the specific type of dewatering system being proposed.

8.3 Bottom Stability

8.3.1 Piping

For excavations in pervious materials, the possibility of piping must be evaluated. Piping occurs when an unbalanced hydrostatic head causes large upward seepage pressures in the soil at and below the bottom of the excavation. The upward seepage pressure reduces the effective weight of the soil below the bottom of the excavation. As a result, the ability of the soil to laterally support the embedded portion of the shoring wall (i.e., passive resistance) is reduced. In the extreme, a quick condition can develop at the bottom of the excavation and large quantities of soil can be transported rapidly from outside to inside the excavation, thereby causing large ground settlements, and possibly even shoring system collapse.

Piping can be controlled by dewatering outside the shoring walls (where allowed) or by making the shoring walls deeper in order to reduce the upward hydraulic gradient. Alternatively, a tremie or grouted slab can be used as a bottom seal.

The potential for piping can be evaluated using procedures outlined in the Pile Buck® Steel Sheet Piling Design Manual. The minimum acceptable factor of safety against piping shall be 1.5. Additionally, a reduction in the available passive resistance due to upward seepage pressures shall be taken if appropriate.

8.3.2 Bottom Heave

In cases where excavations are made in soft (and sometimes medium) clays the potential for bottom heave must be evaluated. Bottom heave occurs when the depth of excavation is sufficient to cause upward movement of material in the bottom of the excavation and corresponding downward displacement of material surrounding the excavation. Heave can result in excessive settlement of the ground retained by the shoring system, and distress or failure of the shoring.

The possibility for heave should be evaluated further in cases when the Stability Number (N_0) exceeds 4, where:

$N_0 = (\gamma H+q)/c$, and

γ = unit weight of soil
H = depth of excavation
q = vertical surcharge pressure
c = cohesive strength of soil

When N_0 exceeds 4, the factor of safety against bottom heave should be computed using procedures outlined in the Pile Buck® Steel Sheet Piling Design Manual. The minimum acceptable factor of safety against bottom heave shall be 1.5.

8.4 Global Stability

When appropriate, shoring systems and sloped excavations shall be demonstrated to be safe against slip circle type failure. Slope stability analyses shall consider the presence of Cooper's E-80 train loading on active tracks.

The minimum factor of safety against slip circle failure of the whole, or any portion of, the shored or sloped cut shall be 1.5.

8.5 Tiebacks

Tiebacks will be allowed only with permission of the PCJPB (see Section 3.1) and where right-of-way limits are sufficient. If tiebacks are permitted they must be installed using a method in which the drilled holes for the tiebacks will be fully supported at all times.

Tiebacks shall be designed in accordance with the procedures and criteria outlined in the Post-Tensioning Institute (PTI), Recommendations for Prestressed Rock and Soil Anchors, with the exception that the allowable stresses for the tieback tendons shall be limited to those values specified in Section 7.1 of these Standards.

All tiebacks shall be load tested. Procedures and acceptance criteria for performance and proof testing shall conform to those given in the Post- Tensioning Institute (PTI), Recommendations for Prestressed Rock and Soil Anchors. The first 3 tiebacks installed and a minimum of 10% of the remaining tiebacks shall be performance tested. All remaining anchors shall be proof tested.

When tiebacks are bonded in fine-grained soils, creep testing shall be done in lieu of performance testing. Creep testing procedures and acceptance criteria shall conform to those given for temporary anchors in the Post-Tensioning Institute (PTI), Recommendations for Prestressed Rock and Soil Anchors.

Tiebacks shall be locked-off at a minimum of 75% and a maximum of 100% of their design load.

8.6 Deadman Anchorages

Under the appropriate conditions the PCJPB may allow shoring walls to be supported using Deadman anchorages located on the opposite side of the tracks from the shored excavation. The proposed location(s) for Deadman anchorages will require the approval of the PCJPB and third party property owners as appropriate.

Deadman anchorage may be provided by soldier piles, sheet piling, or concrete blocks or walls. Deadman anchors shall be designed in accordance with the procedures outlined in the Pile Buck® Steel Sheet Piling Design Manual.

Deadman anchors shall be designed to provide a minimum factor of safety of 2.0 against failure.

Tie rods that pass under the tracks must be electrically isolated from the track. Details of proposed system of electrical isolation shall be submitted.

SECTION 9 - TRACK MONITORING

9.1 Limitation on Track Movement

The PCJPB requires that track horizontal or vertical movement associated with all aspects of shoring and/or excavation shall not exceed 1/2-inch. Remedial measures are required to restrict additional track movement if this limit is exceeded. In addition, track resurfacing will be required if track movement occurs due to shoring and/or excavations.

The track monitoring procedures specified below are intended to confirm that shoring systems are performing in a satisfactory manner, and to identify locations of excessive ground movement so that they can be corrected in a timely manner.

9.2 Minimal Requirements for Track Monitoring

The PCJPB requires that tracks adjacent to excavations within the Zone of Influence be monitored for movement. At a minimum, track movement monitoring shall consist of the following:

- Survey points shall be established and documented at north and south ends of the excavation or shoring limits, Survey stakes may be required at the discretion of the Caltrain engineer.
- Survey points shall be established along all tracks for which the excavation is within the Zone of Influence. The maximum spacing and minimum extent of these points shall be as shown on Figure 9.1. A minimum of three control points shall be established in the area that will not be subject to possible disturbance due to construction activities or railroad operations.
- The surveying method utilized for track monitoring shall be accurate to +/-1/16 inch and shall comply with railroad surveying requirements in this design criteria.
- The horizontal coordinates and elevations of both rails shall be measured at each survey point location in accordance with the following schedule:
    - A baseline reading of coordinates and elevations shall be taken prior to any excavations or installation of any elements of the shoring system. In case where track maintenance activities are performed to correct movements, a new baseline shall be established and its relationship to previous baseline documented.
    - A minimum of two baseline readings showing consistent horizontal coordinates and elevations shall be taken prior to installation of any elements

of the shoring system or any type of the excavation within the zone of influence.

  - Reading shall be taken daily when excavations, shoring installation or removal work is performed within the railroad right of way and within the zone of influence as determined by the engineer.

  - Readings shall be taken twice a week from the time at which shoring installation commences until shoring removal is completed. Supplemental readings may be required if settlements are observed, recorded, or at the request of Caltrain representative on site.

  - Readings shall continue once a week for a minimum of four weeks after shoring removal or excavation work has been completed.

- Initial survey data shall be submitted to the Caltrain engineer prior to any shoring or excavation work. Proceeding reading shall be provided as required per this section. If no additional monitoring is required after completion of work, final readings after the shoring is removed or excavation completed shall be provided as well.

- Survey readings and data shall be documented and provided to Caltrain within 2 calendar days following each survey. Survey data comparison to previous and baseline data should be provided. Caltrain shall be notified immediately of any change in horizontal or vertical change of ¼” or greater.

- The excavation and temporary shoring shall be visually inspected daily by qualified contractor personnel to check for horizontal or vertical movement. Visual monitoring shall be performed more often during performance of critical activities or after rain events.

The monitoring requirements outlined above may be relaxed or waived on a project-specific basis at the discretion of the PCJPB.

9.3 Supplemental Monitoring

The PCJPB reserves the right to require that supplemental monitoring be done for large, atypical, or long-lived shoring projects. Supplemental monitoring may include the use of inclinometers, piezometers, tiltmeters, or other types of monitoring instrumentation. This PCJPB will address this issue on a project-specific basis.

9.4 Remediation Plan

The Contractor shall provide Remediation Plan(s) when the horizontal and/or vertical track movement reaching 1/4-inch. The Remediation Plan(s) shall provide means and methods to mitigate the additional track movement. The Contractor shall immediately discuss the plan with the Railroad or authorized Railroad representative and receive approval confirmation from them.

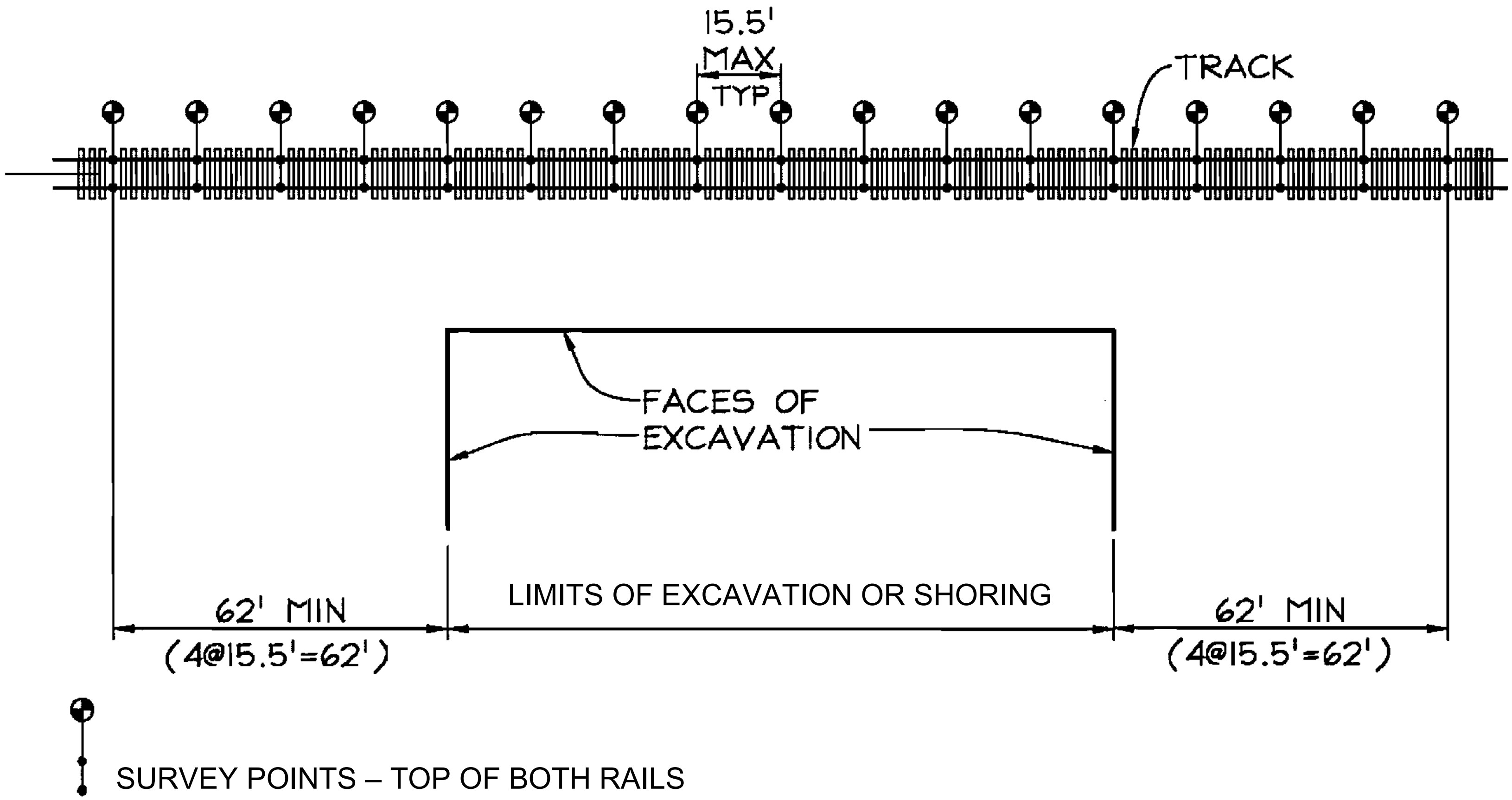
Once the 1/2-inch value is met, all project work shall stop, and the chosen Remediation Plan shall commence. The Contractor shall implement each Remediation Plan with required materials, equipment, and personnel.

9.5 Other

Access for establishing and reading/surveying movement points and monitoring instrumentation shall be coordinated with the PCJPB.

Monitoring readings shall be available for review by the PCJPB.

FIGURE 9.1 – MINIMUM TRACK MOVEMENT MONITORING



SECTION 10 - SUBMITTAL REQUIREMENTS

10.1 General

All drawings and calculations for shoring shall be prepared, sealed, and signed by a Civil Engineer currently registered in the State of California who has previous experience in the design of temporary shoring systems of the type being submitted.

The designer will be responsible for the accuracy of all controlling dimensions as well as the selection of soil design values that accurately reflect the actual field conditions. No shoring installation or excavation within the Zone of Influence will be allowed until the drawings and calculations are reviewed and approved by the PCJPB.

A complete set of drawings and calculations shall be submitted to the PCJPB for review.

A minimum of 30 calendar days should be allowed for the PCJPB's review, provided that all submitted materials are in order.

Approval of the shoring submittal shall not relieve the designer and/or contractor of the ultimate responsibility and liability for the shoring design and construction. Construction Contract Documents, where more restrictive, shall supersede design guideline requirements specified in this Standard.

10.2 Drawings

The shoring drawings must be complete and shall accurately describe the nature of the work. Drawings shall be to-scale.

At a minimum the shoring drawings shall include the following:

- Plan view that includes the following information and meets the following criteria:
    - All of the proposed excavations and distances from centerline of the track(s) to the face of the excavation at relevant locations.
    - All pertinent topographic information.
    - All Railroad systems facilities.
    - All overhead and underground utilities.
    - Railroad stationing and milepost. (The JPB will assist in providing this information.)
    - North arrow.
    - The drawing shall be oriented so that the track alignments are approximately parallel to the top and bottom of the sheet, with the left side of the sheet

oriented toward San Francisco (approximately north} and the right side of the sheet toward San Jose.

- The drawing shall be in U.S. units with a scale no less than 1”=1O’. Acceptable scales include 1”=10’, 1/8”=1’-0”, and ¼”=1’-0”.

- Section view normal to the track(s) showing the shoring system relative to the centerline of the track(s). The section shall show elevations of the track(s), the ground surface, excavation subgrade, and bracing elements. The section shall also show shoring wall embedment depth.
- Arrangement and sizes of shoring elements and details of all connections.
- Specifications for materials and requirements for shoring fabrication and installation.
- Construction sequence(s) detailing all steps in the shoring installation, excavation, and shoring removal.
- Track monitoring requirements (types, locations, reading schedule, etc.) See Section 9 for requirements.

10.3 Design Calculations

Design calculations shall be provided for all elements of the shoring system.

The calculations shall consider each stage of excavation and support removal.

The calculations shall include estimates of shoring deflection, demonstrating that the proposed system will not cause excessive movement of the tracks.

A summary of the soil parameters used in the design shall be included in the calculations, and the source reference for these parameters shall be identified.

10.4 Design Checklist

The shoring designer shall complete and seal and sign a copy of the Design Checklist included in Section 11.1 of these Standards. The completed Design Checklist shall accompany the shoring submittal.

10.5 Other Information

In the event that all or part of the proposed shoring system consists of commercially available, prefabricated elements (e.g., a trench shield), the shoring submittal shall include complete design data for these elements.

10.6 Site Specific Work Plan (SSWP)

The construction of all shoring and excavation work within the OTS Envelope will require the Contractor to submit a Site-Specific Work Plan (SSWP). Refer to the Caltrain Site Specific Work Plan Policy and Procedures at the following link: http://www.caltrain.com/Assets/planning/pdf/SSWP+Policy+and+Procedures.pdf.

The SSWP shall:

- Contain a description of any proposed changes to the Operating System.
- Describe the activities necessary to perform specific shoring work within the OTS Envelope.
- Contain a schedule of the work, including a detailed schedule that indicates the expected hourly progress of each activity that has a duration of one hour or longer. The schedule shall include the time at which all activities planned under the SSWP will be completed.
- Show each activity and where and how it affects the normal operation of the Operating System.
- Include all materials and equipment required to complete the each activity in the SSWP within the allotted time period (window).
- Include contingency plans for putting the Operating System back in operation in case of emergency or in case the Contractor fails to perform and complete the work on time. Contingency plans shall address the various stages of construction and may require redundant equipment and personnel.

The SSWP shall be submitted to the PCJPB at least 6 weeks prior to the start of the work within the OTS Envelope.

The Contractor's construction activities that impact the Operating System including tracks, signals, bridges, stations, and related facilities in active service shall be subject to the following requirements. These requirements shall be addressed in an SSWP.

- Contractor shall provide sufficient personnel, equipment, materials, and all other resources necessary to return the impacted facilities to full service upon the conclusion of the approved Work Window.

- Contractor shall perform the work expeditiously and continuously with no gaps or breaks in the work activities or substantive reductions in the labor force, equipment, and materials necessary to construct, reconstruct, or repair the impacted facility to the full service upon the conclusion of the approved Work Window.

- The size and scope of the impacted facilities within the Operating System (e.g., tracks or signal systems removed) shall not exceed the Contractor's capacity to conservatively return the impacted facility to the required level of service within the approved Work Window.

- The justification for removing both main tracks from service to the extent that Work Train, UPRR freight, and rail bound construction equipment is precluded from through moves for more than three (3) hours.

- Contractor shall take all appropriate and reasonable measures to perform work activities and tasks located outside the Operating System to effectively reduce the amount of time and effort required during the approved Work Window. These appropriate and reasonable measures shall include, but not be limited to, pre-construction and pre-assembly of shoring systems (e.g., trench shields} and pre-staging of shoring materials.

- Backup or Emergency Plan: Contractor shall include in the SSWP backup and/or contingency plan(s) and the necessary resources (labor, equipment, materials, etc.) to assure the Railroad that all appropriate and reasonable measures are available for the return of the impacted facility to full service upon conclusion of the approved Work Window.

- When not in use, materials and equipment shall not be piled, stored, or parked closer than 25 feet horizontally from the centerline of the nearest operating track.

10.7 Construction Verification

The shoring designer (or his authorized designee) shall inspect the as-built shoring system to verify that the system is constructed in accordance with the approved shoring plans. The shoring designer shall provide a letter that shall be submitted to the Railroad confirming that the shoring system has been constructed in accordance with the approved shoring plans.

The number of site visits and the stage or stages of construction at which they shall be performed will be specified by the PCJPB as a condition of approval of the shoring design. The intent will be to have the shoring installation verified by the engineer at the critical construction stages.

SECTION 11 - DESIGN AND REVIEW CHECKLISTS

11.1 Design Checklist

The shoring designer shall complete, seal, sign, and submit the enclosed Shoring Design Checklist with the shoring design submittal.

11.2 Review Checklist

The enclosed Shoring Review Checklist shall be utilized by PCJPB staff or consultants to aid the review of shoring design submittals.

PCJPB SHORING DESIGN CHECKLIST

Project Name/Location: ____________________
Date: ____________________
Shoring Design Firm: ____________________
Contractor: ____________________

Item:	Yes/No/NA	Explain of No or NA
Designer Qualifications		
Designer meets the qualifications shown in Section 1.2?		
Drawings		
1. Drawings to-scale?		
2. Plan view is oriented correctly and shows relative position of shoring/excavation and tracks railroad stationing and mileposts, and all pertinent Operating system facilities (surface and underground)?		
3. Section normal to track(s) shows elevations of track(s), ground surface, excavation subgrade and bracing elements?		
4. Dimensions defining the arrangement of all elements of shoring system provided?		
5. Sizes of all shoring elements provided?		
6. All connections detailed?		
7. Specifications for all materials provided?		
8. Specifications and requirements for fabrication and installation provided?		
9. Construction sequence(s) detailing all steps in the shoring installation, excavation and shoring removal provided?		
10. Track monitoring requirements indicated?		
Design Calculations		
General:		
1. Design calculations provided for all elements of the shoring system?		
2. Calculations for all stages of excavation and support removal?		
3. Shoring designer has verified the accuracy, suitability and applicability of the information and criteria outlined in the Shoring Standards for the specific application being designed?		
Loading:		
4. Soil loading (active and passive) developed in accordance with Section 4.2 of the Shoring Standards?		
5. Groundwater loading developed in accordance with Section 4.3 of the Shoring Standards?		
6. Surcharge loading (other than railroad surcharge) developed in accordance with Section 4.4 of the Shoring Standards?		
7. Seismic loading considered?		
8. Railroad surcharge developed in accordance with Section 5 of the Shoring Standards?		
9. All required loads considered in shoring analysis?		

Page 1 of 2

PCJPB SHORING DESIGN CHECKLIST (CONTINUED)

Item:	**Yes/No/NA**	**Explain of No or NA**
Analysis:		
10. Shoring wall analyzed in accordance with Section 6 of the Shoring Standards?		
11. Bracing loads determined in accordance with Section 6 of the Shoring Standards?		
12. Depth of wall penetration determined in accordance with Section 6 of the Shoring Standards?		
13. Bracing system analyzed in accordance with Section 6.6 of the Shoring Standards?		
14. Lagging analyzed in accordance with Section 6.7 of the Shoring Standards?		
15. Secondary bracing, connections and stiffeners analyzed and provided in accordance with Section 6.8 of the Shoring Standards?		
16. Shoring deflection and settlement estimated in accordance with Section 6.9 of the Shoring Standards?		
Material Properties and Allowable Stresses:		
17. Material properties and allowable stresses in accordance with Section 7 of the Shoring Standards?		
Special Conditions:		
18. Is external dewatering proposed?		
a. If yes, has dewatering been approved by Owner?		
b. If yes, has a settlement analysis (due to dewatering) been provided?		
19. Has the potential for piping been evaluated?		
20. Has potential for heave been evaluated?		
21. Has global stability of the shoring system been evaluated?		
22. Are tiebacks proposed?		
a. If yes, has PCJPB approved their usage?		
b. If yes, are they designed and will they be tested in accordance with Section 8.5 of the Shoring Standards?		
23. Are Deadman anchorages proposed?		
a. If yes, has PCJPB approved their usage?		
b. If yes, has third party approval been granted?		
c. If yes, are they designed in accordance with Section 8.6 of the Shoring Standards?		

____
Shoring Designer Signature

____
Print Name

____
Place Engineering Seal Above

Page 2 of 2

PCJPB SHORING REVIEW CHECKLIST

Project Name/Location: ______________________
Date: ______________________
Name of Reviewer: ______________________

Item:	Yes/No/NA	Explain of No or NA
Designer Qualifications		
Designer meets the qualifications shown in Section 1.1?		
Drawings		
1. Drawings to-scale?		
2. Plan view is oriented correctly and shows relative position of shoring/excavation and tracks railroad stationing and mileposts, and all pertinent Operating system facilities (surface and underground)?		
3. Section normal to track(s) shows elevations of track(s), ground surface, excavation subgrade and bracing elements?		
4. Dimensions defining the arrangement of all elements of shoring system provided?		
5. Sizes of all shoring elements provided?		
6. All connections detailed?		
7. Specifications for all materials provided?		
8. Specifications and requirements for fabrication and installation provided?		
9. Construction sequence(s) detailing all steps in the shoring installation, excavation and shoring removal provided?		
10 Track monitoring requirements indicated?		
Design Calculations		
General:		
1. Design calculations provided for all elements of the shoring system?		
2. Calculations for all stages of excavation and support removal?		
3. Shoring designer has verified the accuracy, suitability and applicability of the information and criteria outlined in the Shoring Standards for the specific application being designed?		
Loading:		
4. Soil loading (active and passive) developed in accordance with Section 4.2 of the Shoring Standards?		
5. Groundwater loading developed in accordance with Section 4.3 of the Shoring Standards?		
6. Surcharge loading (other than railroad surcharge) developed in accordance with Section 4.4 of the Shoring Standards?		
7. Seismic loading considered?		
8. Railroad surcharge developed in accordance with Section 5 of the Shoring Standards?		
9. All required loads considered in shoring analysis?		

PCJPB SHORING REVIEW CHECKLIST (CONTINUED)

Item:	Yes/No/NA	Explain of No or NA
Analysis:		
10. Shoring wall analyzed in accordance with Section 6 of the Shoring Standards?		
11. Bracing loads determined in accordance with Section 6 of the Shoring Standards?		
12. Depth of wall penetration determined in accordance with Section 6 of the Shoring Standards?		
13. Bracing system analyzed in accordance with Section 6.6 of the Shoring Standards?		
14. Lagging analyzed in accordance with Section 6.7 of the Shoring Standards?		
15. Secondary bracing, connections and stiffeners analyzed and provided in accordance with Section 6.8 of the Shoring Standards?		
16. Shoring deflection and settlement estimated in accordance with Section 6.9 of the Shoring Standards?		
Material Properties and Allowable Stresses:		
17. Material properties and allowable stresses in accordance with Section 7 of the Shoring Standards?		
Special Conditions:		
18. Is external dewatering proposed?		
a. If yes, has dewatering been approved by Owner?		
b. If yes, has a settlement analysis (due to dewatering) been provided?		
19. Has the potential for piping been evaluated?		
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21. Has global stability of the shoring system been evaluated?		
22. Are tiebacks proposed?		
a. If yes, has PCJPB approved their usage?		
b. If yes, are they designed and will they be tested in accordance with Section 8.5 of the Shoring Standards?		
23. Are Deadman anchorages proposed?		
a. If yes, has PCJPB approved their usage?		
b. If yes, has third party approval been granted?		
c. If yes, are they designed in accordance with Section 8.6 of the Shoring Standards?		

____
Reviewer's Signature

____
Print Name

Finding:
☐ No Exceptions Taken
☐ Make Corrections Noted
☐ Amend and Resubmit

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