JULY 2025

CHAPTER 11

CONSTRUCTION CONSIDERATIONS AND FINAL SUMMARY

Chapter 11: Construction Considerations and Final Summary

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11-1 Construction

The integrity of a shoring system, like any other structure, is dependent upon the adequacy of the design, the quality of the materials used, and the quality of the workmanship. Frequent and thorough inspection of the excavation and the shoring system during all stages of construction must be performed by qualified personnel. An awareness of the changing conditions is essential. The following is a list of common considerations:

1. Check to ensure the Contractor has a current excavation permit from Cal/OSHA. The annual permits are valid from January 1 to December 31 and must be renewed each year. A project permit will be project specific and will be valid during the life of the project.
2. Prior to the beginning of excavation work, become familiar with all aspects of the authorized plans, the location of the work, assumptions made, available soils data, ground water conditions, surcharge loads expected, sequence of operations, location of utilities and underground obstructions, and any other factors that may impact the work at the site. In addition, know who the Contractor has designated as the competent person.
3. Since the primary function of the shoring is the protection of the workers, adjacent property, and the public, it is essential that the inspector be knowledgeable with the minimum safety requirements.
4. Assess all soil being excavated to confirm that it is consistent with the Log of Test Borings and/or with what is contemplated in the excavation plan. Note any differences between the soil anticipated, and what is actually encountered. Discuss the differences with the Contractor.
5. Monitor for changes in the groundwater conditions.
6. As the excavation progresses, be alert for indicators of distress such as the development of tension cracks, or subsidence of soil near the excavation.
7. If the excavation is sloped back without shoring, the need for inspection remains. Sloughing and cave-ins can occur, especially after significant rain events. Confirm that the slope configurations are per the authorized excavation plan.
8. For shored excavations, check that the shoring members size and spacing conform with the authorized excavation plans. The sequence of operations shown on the plans must be followed. Check for full bearing at the ends of jacks and struts and make sure they are secure and will not fall out under impact loads.
9. Review all the materials for quality, integrity, and the strength-grade specified to avoid potential failure of structural elements. Also, check members for visible signs of bending, buckling, and crushing.

10. Manufactured products, such as hydraulic jacks, screw jacks, and trench shields, should be installed and used according to the manufacturer's recommendations.
11. If a ground anchor system is used, the ground anchors must be installed per the authorized plan.
12. When cables are used in conjunction with anchors, they must not be wrapped around sharp corners. Thimbles should be used, and cable clamps installed properly.
13. Surcharge loads need to be monitored so they do not exceed the design loads anticipated for the system.
14. Weather conditions may have an adverse effect on excavations, and some materials, especially clays, may fail due to change in moisture content. Some situations may benefit by protecting the slopes with sheeting or other stabilizing material.
15. Good workmanship makes an excavation safer and easier to inspect. Trouble spots are easier to detect when the excavation is uniform and straight.
16. Vibrations from dynamic loadings, such as vibratory compaction equipment, pile driving, or blasting operations, require additional monitoring of the system.
17. Verify that the Contractor has notified utility owners prior to commencing work if their facilities are within a horizontal distance that is equal to 5 times the excavation depth.

    Underground Service Alert:

811 or 1-800-227-2600	
Northern California (USA)	www.usanorth811.org
Southern California (USA)	www.digalert.org
Statewide	www.call811.com

18. Encourage the use of benchmarks to monitor ground movement in the vicinity of the shoring system before, during, and after excavation. The benchmarks should be monitored for horizontal and vertical displacement. In general, ground settlement accompanies shoring deflection.
19. Egress provisions such as ladders, ramps, stairways, or other means must be provided in excavations 4 feet or over in depth, so that no more than 25 feet of lateral travel is required to exit trench excavations.
20. Adequate protection from hazardous atmospheres must be provided. Air monitoring and other confined space regulations must be followed and documented.
21. Employees must be protected from the hazards of accumulating water, loose or falling debris, or potentially unstable structures.

22. Daily inspections, inspections after storms, and those otherwise required for hazardous conditions are to be made by the Contractor's competent person. Inspections are to be conducted before the start of the work and as needed throughout the shift. The competent person will need to check for potential cave-ins, indications of system failure, and hazardous atmospheres. When the competent person finds a hazardous situation, that person must have the authority to remove the endangered employees from the area until the necessary corrective action has been taken to ensure their safety.
23. Adequate physical barrier protection is to be provided at all excavations. All wells, pits, shafts, etc. must be barricaded or covered. Upon completion of exploration and similar operations, temporary shafts, etc. must be backfilled.

Contractors sometimes propose alternative shoring methods such as wire mesh MSE style walls, "burrito" style retention systems, and other proprietary systems. These will need to be reviewed against the published manufacturer's design criteria and limitations.

11-2 Encroachment Permit Projects

An encroachment permit is required for projects performed by others within State highway right-of-way or adjacent to State highways, including those done under a cooperative agreement, such as a Capital Improvement Project. The Contractor, builder, or owner must apply for and be issued an encroachment permit by the District Permit Engineer.

If the scope of work requires excavation and shoring, plans for this work must accompany the permit application. The plan must be reviewed and authorized by the District Permit Engineer prior to a permit being issued. The Department has an obligation with respect to trenching and shoring work. Be informed of legal responsibilities and requirements; see Chapter 1, *Legal Requirements.*

Although many of the encroachment permit projects are quite simple, some may require complex shoring systems. The District Permit Engineer, on receipt of an application for an encroachment permit, will decide if technical assistance is necessary to review the plan. The plan may be routed to Structure Maintenance, Bridge Design, or Structure Construction for review and commenting.

The plan must conform to all applicable requirements as outlined in Chapter 2, *Cal/OSHA Overview.* It must also conform to the requirements set forth in the permit application. The review process is similar to the process for a typical State contract, except that all correspondence regarding authorization or rejection of the plan must be routed through the District Encroachment Permit Office.

Note that an engineer who prepares shoring plans for an encroachment permit project may not necessarily use the recommended allowable stresses given in this manual. Keep this in mind, when reviewing these types of shoring plans. Acceptance should be based on what is required for a State project (i.e., within the recommended procedures that govern our own improvements), with consideration being given to the background of the Contractor, the work to be done, and the degree of risk involved. Remember, geotechnical engineering is not an exact or precise science.

In order for the State to review and authorize an encroachment permittee's excavation plan or proposed shoring system, a detailed plan of the work to be done must be submitted. At a minimum, the shoring plan must contain the following information:

Encroachment Permit No. (Contractor):

Contractor:	Name, address, phone
Owner:	For whom the work is being done. Include contract number or designation.

Owner Encroachment Permit No.:

Location:	Road, street, highway stationing, etc. indicating the scope or extent of the project.
Purpose:	A description of what the trench or excavation is for (sewer line, retaining wall, etc.).
Soil Profile:	A description of the soil, including the basis of identification, such as surface observation, test borings, observation of adjacent work in the same type of material, reference to a soils investigation report, etc.
Surcharge Loadings:	Any loads, including normal construction loads that are adjacent to the excavation or trench, should be identified and shown on the plans with all pertinent dimensions; examples are highways, railroads, existing structures, etc. The lateral pressures due to these loads will then be added to the basic soil pressures. The minimum surcharge is to be used where not exceeded by above loading considerations.
Excavation/Trenching & Shoring Plan:	The plan for simple excavation work can be in the form of a letter covering the items required. For more complex systems, a complete description of the shoring system, including all members, materials, spacing, etc., is required. The plan may be in the form of a drawing or referenced to the applicable portions of the Construction Safety Orders. In accordance with California Labor Code (CA law), if a shoring system varies from Title 8 of the safety orders, then the shoring plans must be prepared

	and signed by an engineer who is registered as a civil engineer in the State of California.
Manufactured Data:	Catalogs or engineering data for a product should be identified in the plan as supporting data. All specific items and applicable conditions must be outlined on the submittal.
Construction Permit:	Any plan or information submitted should confirm a permit has been secured from Cal/OSHA to perform the excavation work. This is not an authorization of the shoring system by Cal/OSHA.
Inspection:	The Contractor's plan must designate who the competent person on site will be.

The Engineer will review a Contractor's shoring plan in accordance with applicable specifications and the Construction Safety Orders. Deviations from Cal/OSHA or different approaches will be considered, providing adequate supporting data such as calculations, soils investigations, manufacturer's engineering data and references, are submitted. This Caltrans *Trenching & Shoring Manual* is the primary resource available to assist the Engineer during the shoring plan review process.

The District Encroachment Permit Engineer and their staff are responsible for fieldwork inspection. However, there will be occasions where the complexity of the excavation and/or shoring requires assistance from Structure Construction (SC). For major encroachment permit projects, the District may request that SC assigns an Engineer as a representative of the District Permit Engineer. Remember that the administrative or control procedure is different from typical State construction contracts because SC is assisting the District Permit Engineer as a representative of the District Permit Engineer, not the Resident Engineer. Major corrections must be routed through the District Permit Engineer. If there are difficulties with compliance, the District Permit Engineer has the authority to withdraw the encroachment permit, which would have the effect of stopping the work. Close communication between SC and the District Permit Engineer is very important during all phases of the encroachment permit project.

Prior to the start of excavation work, verify that the Contractor and/or owner have all of the proper permits to do the work and have properly notified Underground Service Alert. The work is then monitored to verify that the excavation and/or shoring work is in conformance with the authorized plan.

For more information regarding the encroachment permit process, contact your local District Permit Engineer. Additional resources are found within the Caltrans Traffic Operations Internet page, under Encroachment Permits.

11-3 Ground Anchor Restrained Shoring Systems

Restrained shoring systems are generally considered higher risk due to several factors. The first of these is that these systems are often retaining a greater height of soil. Another risk is the additional elements of the system that must perform as intended and that the sequence of installation and removal affects the loading and performance of the shoring system. There are also risks involved with additional drilling or disturbance below or behind the shoring, such as damaging utilities. This section will focus specifically on ground anchors used as a restraining element.

11-3.01 Engineering Analysis and Construction Sequence

The construction sequence for a restrained shoring system, sheet pile or soldier pile, must be considered when making an engineering analysis. This is true whether the restraint is strutting, a buried anchor block, or a drilled ground anchor. Different loads are imposed on the system before and after the completion of a level of intermediate supports. An analysis for each stage of the system's installation should be performed and an analysis for each stage of support removal during backfilling operations may also be needed.

11-3.02 Components of Ground Anchor Systems

There are many variations or configurations of ground anchor systems. The tension element of a ground anchor may be either prestressing strands or bars using either single or multiple elements. Ground anchors may be alternatively secured against walers or piles.

Figure 11-1 illustrates a typical temporary ground anchor. In this diagram, a bar tendon system is shown; strand systems are similar.

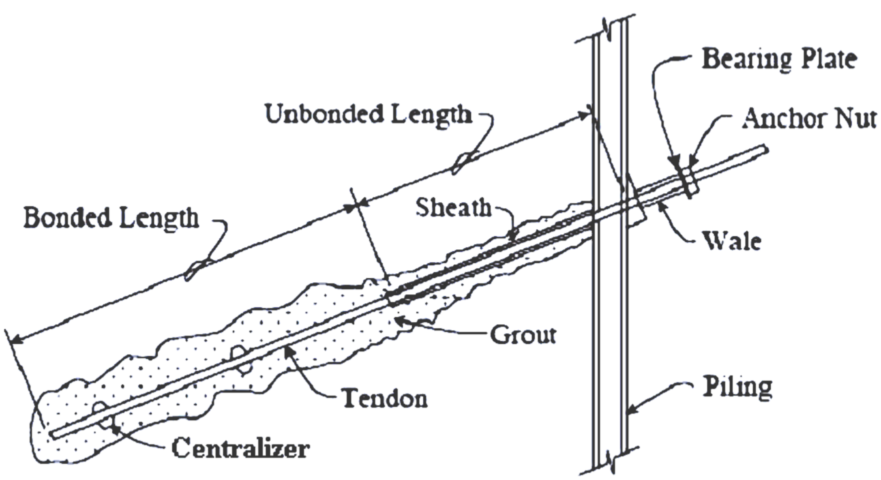

Figure 11-1. Typical Temporary Ground Anchor

The more common components, criteria, and materials used in conjunction with ground anchor shoring systems are listed below:

Piling — Sheet piling and soldier piles. See Chapter 6, *Structural Design of Shoring Systems*, for common materials and allowable stresses.

Waler — These components transfer the resultant of the earth pressure from the piling to the ground anchor. An overstress of 33 percent to the allowable design value is permitted for the walers when proof testing the ground anchor. Anchors for temporary work are often anchored directly against the soldier piling through holes or slots made in the flanges, eliminating the need for walers. Bearing stiffeners and flange cover plates are generally added to the pile section to compensate for the loss of section. A structural analysis of this cut section should always be required.

Tendon — Ground anchor tendons are generally the same high strength bars or strands used in prestressing structural concrete.
The anchorage of the ground anchor tendons at the shoring members consists of (1) bearing plates and anchor nuts for bar tendons, and (2) bearing plates, anchor head, and strand wedges for strand tendons.
The details of the anchorage must accommodate the inclination of the ground anchor relative to the face of the shoring members. Items that may be used to accomplish this are shims or wedge plates placed between the bearing plate and soldier pile or between the wale and sheet piling or soldier piles. For bar tendons, spherical anchor nuts with special bearing washers plus wedge washers, if needed, or specially machined anchor plates may be used.

The tendon should be centered within the drilled hole throughout the entire length. This is accomplished by the use of centralizers (spacers) adequately spaced to prevent the tendon from contacting the sides of the drilled hole or by installation with the use of a hollow stem auger.

Stress — Allowable tensile stress values are based on a percentage of the ultimate tensile strength ($\mathbf{F_{pu}}$) of the anchor. The common value for these are indicated below:

Bars: $\mathbf{F_{pu}} = 150$
Strand: $\mathbf{F_{pu}} = 270$ ksi
(Check manufacturers data for actual ultimate strength.)

Allowable tensile stresses:

At design load: $\mathbf{F_t} \leq 0.6\ \mathbf{F_{pu}}$
At proof load: $\mathbf{F_t} \leq 0.8\ \mathbf{F_{pu}}$
(Both conditions must be checked.)

The relationship between the proof load and the design load can be thought of in this manner: the proof load provides a value that could be considered the maximum value to use for the soil, and the design load applies a safety factor of 1.3 to the proof load.

Grout A flowable Portland cement mixture of grout or concrete encapsulates the tendon and fills the drilled hole within the bonded length. Generally, a neat cement grout is used in drilled holes of diameters up to 8 inches. A sand-cement mixture is used for hole diameters greater than or equal to 8 inches. An aggregate concrete mix is commonly used in very large holes. Type I or II cement is commonly recommended for ground anchors. Type III cement may be used when high early strength is desired. Grout, with very few exceptions, should always be injected at the bottom of the drilled hole. This method ensures complete grouting and will displace any water that has accumulated in the hole.

11-3.03 Ground Anchor

There are several different types of ground anchors. The capacity of a traditional ground anchor depends on a number of interrelated factors discussed later. Alternative anchor products have been developed over the last several years and their analysis would follow the individual published data from the manufacturers. Examples of these include screw anchors, under the product name CHANCE Helical Anchors, and deadman-style anchors, under the product name of Manta Ray Earth Anchors.

The most typical shape of drilled holes for ground anchors is a “straight” shafted drilled hole. Only incidental variations in the sides of the drilled hole are found based on the drilling method and material encountered. Occasionally, a drilled hole will be mechanically enlarged at the end or at multiple points to enhance the ground anchor’s capacity by utilizing a combination of perimeter bond and bearing against the soil, creating a belled hole. A hole with this mechanical widening is referred to as “under-reamed.” This can only be done in soils with sufficient cohesion to prevent collapsing. Figure 11-2 depicts what these drilled holes might look like.

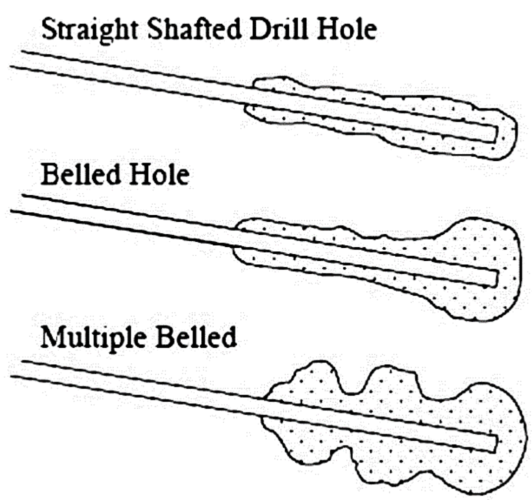

Figure 11-2. Types of drilled hole shapes

The presence of water, either introduced during drilling or existing as ground water, can cause significant reduction in anchor capacity when using a rotary drilling method in some cohesive soils (generally the softer clays).

The grout for a ground anchor is generally placed by tremie or low-pressure grouting methods. High-pressure grouting is seldom used for temporary ground anchor systems, as it is a secondary step, known as post-grouting.

Post-grouting of ground anchors has been used successfully to increase the capacity of an anchor. This method involves the placing of high-pressure grout, 150 psi or higher, in a previously cast anchor. Post-grouting fractures the previously placed anchor grout, disperses new grout into the anchor zone, and expands it. This process compresses the soil and forms an enlarged bulb of grout, thereby increasing the anchor capacity. Post-grouting is done through a separate grout tube installed with the anchor tendon. The separate grout tube will generally have sealed ports uniformly spaced along its length which open under pressure, allowing the grout to exit into the previously formed anchor.

Due to the many factors involved, the determination of anchor capacity can vary quite widely. Proof tests or performance tests of the ground anchors are needed to confirm the anchor capacity. A Federal publication titled *Tiebacks*, the FHWA/RD-82/047 report on ground anchors, provides considerable information for estimating ground anchor capacities for the various types of ground anchors; note that this report may be requested through the Caltrans Transportation Library.

Bond capacity is the ground anchor's resistance to pull out, which is developed by the interaction of the anchor grout (or concrete) surface with the soil along the bonded length.

Determining or estimating the bond (resisting) capacity is a prime element in the design of a ground anchor.

Some shoring designs may include a soils laboratory report, which will contain a recommended value for the bond capacity to be used for ground anchor design. The appropriateness of the value of the bond capacity will only be proven during ground anchor testing.

For most of the temporary shoring work normally encountered, the ground anchors will be straight shafted with low-pressure grout placement. Placement of grout is done with a tube that starts at the bottom of the hole. As grout placement progresses, the tube is extracted, similar to the placement of concrete using a tremie, which utilizes gravity pressure. For these conditions the following criteria can generally be used for estimating the ground anchor capacity.

The determination of the bonded length, $\mathbf{L_b}$, and capacity of the ground anchor is solely the responsibility of the Contractor and is subsequently verified by testing. The Engineer's review of the Contractor's plan must include a check of the unbonded length of the ground anchor. The minimum distance between the front of the bonded zone and the active failure surface behind the wall must not be less than **H/5**. In no case will the minimum distance be less than 5 feet. The unbonded length must not be less than 15 feet. See Figure 11-3 for an illustration of the unbonded length.

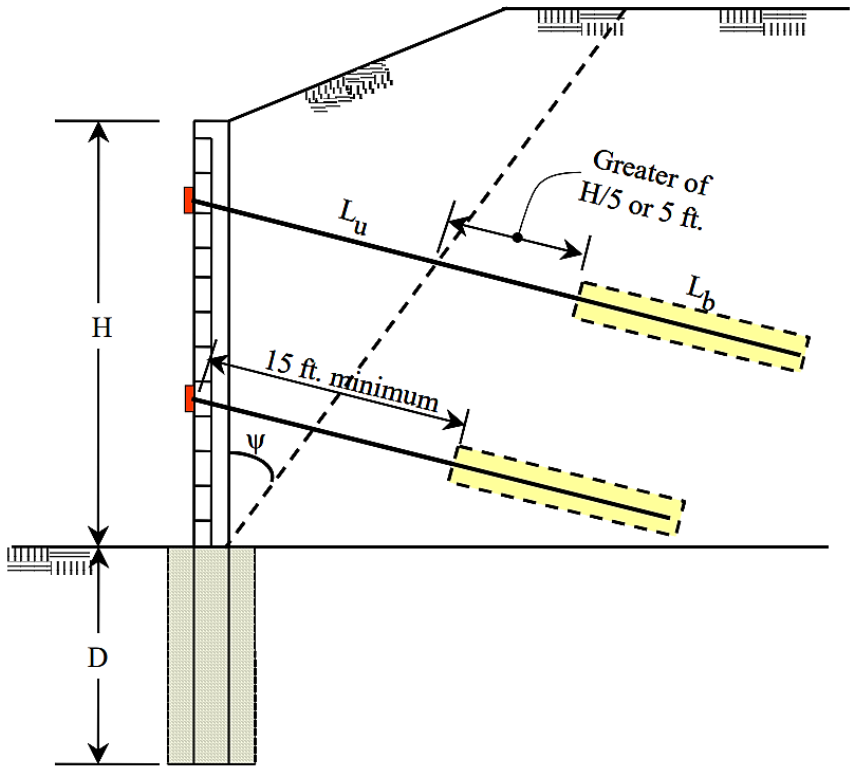

Figure 11-3. Unbonded Length Criteria

The ultimate capacity of the ground anchor is defined as follows:

$$P_{ult} = \pi d L_b S_b$$

Where:

- **d** = Diameter of drilled hole
- L_b = Bonded length of the ground anchor
- L_u = Unbonded length of the ground anchor
- S_b = Bond strength (lbs/ ft^2)
- **Ψ** = Angle between assumed failure plane and vertical. For the Rankine active condition, the angle is $45° - \phi / 2$.

The bond strength for ground anchors depends on the number of interrelated factors listed below.

1. Location – amount of effective overburden pressure above the ground anchor.
2. Drilling method and drilled hole configuration.
3. Strength properties, type, and relative density of the soil.
4. Grouting method and pressure.
5. Tendon type, size, and shape.

Since the bond strength is affected by the Contractor's means and methods, the shoring plans should list the methods they intend to use. The assumed bond strength must be included in the data that is submitted by the Contractor, just as any other soil property, and is preferably included within a geotechnical report. Geotechnical Services staff of the Division of Engineering Services (DES) are available for consultation for concerns or other information regarding bond strength.

11-3.04 Forces on the Vertical Members

Ground anchors are generally inclined; therefore, the vertical component of the ground anchor force must be resisted by the vertical member through skin friction on the embedded length of the piling in contact with the soil and by end bearing. Problems with ground anchor walls have occurred because of excessive downward wall movement when this downward movement was not properly accounted for.

The vertical capacity of the shoring system should be checked, particularly for (1) shoring embedded in loose granular material or soft clays, (2) ground anchors with angles steeper than the standard 15 degrees, and (3) when there are multiple rows of ground anchors. The Engineer is reminded to contact Caltrans Geotechnical Services for assistance when performing a check of the vertical capacity of the shoring elements.

11-3.05 Testing Temporary Ground Anchors

The Contractor is responsible for providing a reasonable test method for verifying the capacity of the ground anchors after installation. Anchors are tested to verify they can sustain the design load over time without excessive movement. The need to test anchors is more important when the system will support, or is adjacent to, existing structures, and when the system will be in place for an extended period of time.

In the Contractor's test methods, the Contractor should consider the degree of risk to the adjacent surroundings and structures when determining the number of ground anchors tested, the duration of the tests, the allowable movement, and the allowable load loss. High-risk situations would include cases where settlement or other damage would be experienced by adjacent facilities. Table 11-1 is a recommended list of minimum criteria for testing temporary ground anchors.

Generally, the shoring plans with ground anchors should include:

1. Ground anchor load testing criteria, which should minimally consist of proof load test values.
2. Frequency of testing (number of anchors to be tested).
3. Test load duration (to capture anchor creep).
4. Allowable movement or loss of load permissible during the testing time frame.
5. The anticipated life of the shoring system.
6. The remedial measures that are to be taken when, or if, test anchors fail to meet the specified criteria.

Pressure gauges or load cells used for determining test loads should have been recently calibrated by a certified lab, they should be clean and not abused, and they should be in good working order. The calibration dates should be determined and recorded. Calibration dates within one year are generally acceptable.

A ground anchor that does not satisfy the testing criteria may still have some value. The Contractor will need to revise the shoring plan to address this. Often the revision will be able to utilize extra capacity of adjacent ground anchors to make up for the reduced value, or an additional ground anchor will be placed to supplement the low value ground anchor.

11-3.05A Proof Testing

Applying a sustained proof load to a ground anchor and measuring anchor movement over a specified period of time is the typical method of proof testing ground anchors. Proof testing may begin after the grout has achieved the desired strength. A specified number of the ground anchors will be proof tested by the method specified on the Contractor's authorized plans (see Table 11-1).

Table 11-1. Recommended Ground Anchor Proof Test Criteria

Test Load	Load Hold Duration	% of Ground Anchors to be Load Tested
Cohesionless Soils Normal Risk 1.2 to 1.3 of Design Load	10 minutes	10% for each soil type encountered
High Risk ≥1.3 Design Load	10 minutes	20% to 100%
Cohesive Soils Normal Risk 1.2 to 1.3 Design Load	30 minutes	10%
High Risk ≥1.3 Design Load	60 minutes	30% to 100%
Adverse conditions When ground water is present or in soft clays	60 minutes for 10 minutes for	10%, and 90% (remaining)

The unbonded length, L_u, of a ground anchor is left ungrouted prior to and during testing (see Figure 11-3) as standard practice. This ensures that only the bonded length, L_b, is carrying the proof load during testing. It is not desirable to have loads transferred to the soil through grout (or concrete) in the unbonded region since this length is considered to be within the zone of the failure wedge and would not contribute to the resisting portion of the system. This also prevents the grout column in the hole from bearing against the wall facing, which would produce erroneous test results.

Forensic investigations on Caltrans specific ground anchors have shown that ground anchors in small diameter holes (6 inches or less) develop most of their capacity in the bonded length despite any additional grout which may be in the unbonded length zone. Regardless, grout in the unbonded zone is to be avoided so there is a clear separation between the wall and the soil restrained, and that of the anchors' bonded zone. This phenomenon is not true for larger diameter ground anchors.

Generally, the Contractor will specify an alignment load of 5 percent to 10 percent of the proof load, which is initially applied to the tendon to secure the jack against the anchor head and stabilize the setup. The load is then increased until the proof load is achieved. Generally, a maximum amount of time is specified to reach proof load. Once the proof load is attained, the load hold period begins. Movement of the ground anchor is normally measured by using a dial indicator gauge that is positioned as shown in Figure 11-4. The dial indicator gauge is mounted on a tripod that is independent of the ground anchor and shoring.

The tip of the dial indicator gauge is positioned against a flat surface perpendicular to the centerline of the tendon; this can be a plate secured to the tendon. The piston of the jack may be used in lieu of a plate if the jack is not going to have to be cycled during the test. As long as the dial indicator gauge is mounted independently of the shoring system, only movement of the anchor, due to the proof load, will be measured. Continuous jacking to maintain the specified proof load during the load hold period is essential to offset losses resulting from anchor creep or movement of the shoring into the supporting soil.

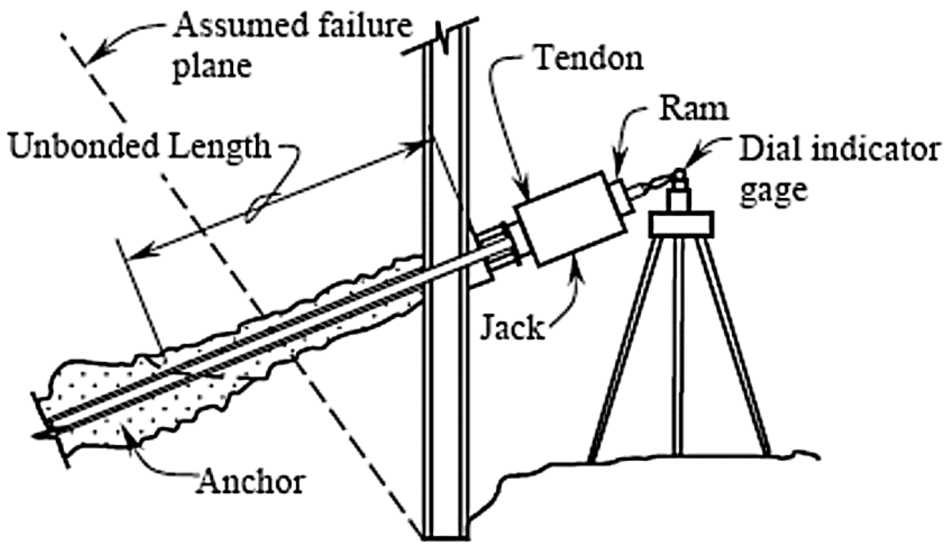

Figure 11-4. Proof Testing Equipment Setup Example

Measurements from the dial indicator gauge are taken periodically during the load hold period in accordance with the Contractor's authorized shoring plan. The total movement measured during the load hold period of time is compared to the allowable value indicated on the Contractor’s authorized shoring plans to determine the acceptability of the anchor.

It is important that the proof load be reached quickly. When excessive time is taken to reach the proof load or the proof load is held for an excessive amount of time before beginning the measurement of creep movement, the creep rate indicated will not be representative. For the creep measurement to be accurate, the starting time must begin when the proof load is first reached.

As an alternative to measuring creep movement with a dial indicator gauge, the Contractor may propose a "lift-off test". A "lift-off test" compares the force on the ground anchor at seating to the force required to lift the anchor head off of the bearing plate. The comparison should be made over a specified period of time. The lost force can be converted into creep movement to provide an estimate of the amount of creep over the life of the shoring system.

Use of the "lift-off test" may not accurately predict overall anchor movement. During the time period between lock-off and lift-off, the ground anchor may creep, or the wall may move into the soil, or both. These two components cannot be differentiated. If the test is done accurately, results are likely to be a conservative measure of anchor movement. Structure Construction recommends the use of a dial indicator gauge to monitor creep rather than lift-off tests.

11-3.05B Performance Testing

Performance testing is similar to, but more extensive, than proof testing. Performance testing is used to establish the movement behavior for a ground anchor at a particular site. Performance testing is not normally specified for temporary shoring, but it can be utilized to identify the causes of anchor movement. Performance testing consists of incremental loading and unloading of a ground anchor in conjunction with measuring movement.

11-3.05C Evaluation of Creep Movement

Long-term ground anchor creep can be estimated from measurements taken during initial short term proof testing. This process involves extrapolating measurements taken during proof testing to determine the anticipated total creep over the period the shoring system is in use; the anchor creep is roughly modeled by a curve which is a logarithmic function of time.

The general formula listed below for the determination of the anticipated long-term creep is only an estimate of the potential anchor creep and should be used in conjunction with periodic monitoring of the wall movement. This formula does not accurately predict anchor creep for soft cohesive soils.

Based on the assumed creep behavior, the following formula can be utilized to evaluate the long-term effects of creep:

General formula for long term creep:

$$\boldsymbol{\Delta_{2-3} = C\left[\log_{10}\left(\frac{T_3}{T_2}\right)\right]} \qquad (11\text{-}3\text{-}1)$$

Where:

$$\mathbf{C} = \Delta_{1-2} \Big/ \left[\log_{10}\left(\frac{T_2}{T_1}\right)\right] \qquad (11\text{-}3\text{-}2)$$

C = Constant determined using the movement from $\mathbf{T_1}$ to $\mathbf{T_2}$. This constant is typically measured in inches. For the period from $\mathbf{T_2}$ to $\mathbf{T_3}$, the value of **C** is already known, and the value of Δ can be calculated with that value of **C**.

$\boldsymbol{\Delta}$ = Creep movement (inches) specified on the plans for times $\mathbf{T_1}$, $\mathbf{T_2}$, or $\mathbf{T_3}$. (or measured in the field)

$\mathbf{T_1}$ = Time of first movement measurement during load hold period. (usually within 1 minute after proof load is applied)

$\mathbf{T_2}$ = Time of last movement measurement during load hold period.

$\mathbf{T_3}$ = Time the shoring system will be in use.

If using a “lift-off test” to estimate the creep movement, the following approximation needs to be made for substitution into the above equation (11-3-2):

$$\boldsymbol{\Delta_{1-2} = (P_1 - P_2)\frac{L_U{}'}{AE}} \qquad (11\text{-}3\text{-}3)$$

Where:

$\mathbf{P_1}$ = Force at seating

$\mathbf{P_2}$ = Force at lift-off

$\mathbf{L_u'}$ = $L_u + \Delta L$

$\boldsymbol{\Delta L}$ = 3 to 5 feet of anchor length necessary for the jack and anchor wedges

$\boldsymbol{\Delta_{1\text{-}2}}$ = Amount of movement during the load hold period.

A = Area of strand or bar in anchor

E = Modulus of elasticity of the strand or bar in anchor

Example 11-1A demonstrates the calculation of long-term creep by Equation 11-3-1 and by the lift-off method in Equation 11-3-3.

11-3.06 Wall Movement and Settlement

As a rule of thumb, the settlement of the soil behind a ground anchor wall, where the ground anchors are locked-off at a high percentage of the design force, can be approximated as equal to the movement at the top of the wall caused by anchor creep and deflection of the piling. Reference is made to Section 7-3 titled *System Deflection* of Chapter 7, *Unrestrained Shoring Systems*.

If a shoring system is to be in close proximity to an existing structure where settlement might be detrimental, significant deflection and creep of the shoring system would not be acceptable. If a shoring system will not affect permanent structures or when the shoring does not support something like a haul road, reasonable lateral movement and settlement may be tolerated.

11-3.07 Lock-off Force

The lock-off force is the percentage of the required design force that the anchor wedges or anchor nut are seated at after seating losses. A value of $\mathbf{0.8T_{DESIGN}}$ is typically recommended as the lock-off force but lower or higher values may be used to achieve specific design needs.

One method for obtaining the proper lock-off force for strand systems is to insert a shim plate under the anchor head equal to the elastic elongation of the tendon produced by a force equal to the proof load minus the lock-off load. A correction for seating of the wedges in the anchor head is often subtracted from the shim plate thickness. To determine the thickness of the shim plate you may use the following equation:

$$\mathbf{t_{shim}} = \frac{\left(\mathbf{P_{proof}} - \mathbf{P_{lockoff}}\right)\mathbf{L_u}'}{\mathbf{AE}} - \mathbf{\Delta L} \qquad (11\text{-}3\text{-}4)$$

Where:

- $\mathbf{t_{shim}}$ = thickness of shim
- $\mathbf{P_{proof}}$ = Proof load (kips)
- $\mathbf{P_{lockoff}}$ = Lock-off load (kips)
- $\mathbf{A}$ = Area of tendon steel (bar or strands) (in^2)
- $\mathbf{E}$ = Modulus of Elasticity of anchor (strand or bar) (psi)
- $\mathbf{L_u'}$ = The unbonded length of the anchor (ft)
- $\mathbf{\Delta L}$ = 3 to 5 feet of anchor length necessary for the jack and anchor wedges

The seating loss for threaded bar systems is much less than that for strand systems and can vary between 0 and 1/16 of an inch.

For strand systems, seating loss can vary between 3/8 and 5/8 of an inch. The seating loss should be determined by the designer of the system and verified during installation. Oftentimes, wedges are mechanically seated, minimizing seating loss and resulting in the use of a lesser value for the seating loss.

After seating the wedges in the anchor head at the proof load, the tendon is loaded, the shim is removed, and the whole anchor head assembly is seated against the bearing plate.

11-3.08 Corrosion Protection

The Contractor's submittal must address potential corrosion of the tendon after it has been stressed.

For very short-term installations in non-corrosive sites, corrosion protection may not be necessary. The exposed steel may not be affected by a small amount of corrosion that occurs during its life.

For longer term installations, grouting of the bonded and unbonded length is generally adequate to minimize corrosion in most non-corrosive sites. Encapsulating or coating any un-grouted portions (anchor head, bearing plate, wedges, strand, etc.) of the ground anchor system may be necessary to guard against corrosion.

For long-term installations or installations in corrosive sites, more elaborate corrosion protection schemes may be necessary. (Grease is often used as a corrosion inhibitor). Figure 11-5 depicts tendons encapsulated in pre-greased and pre-grouted plastic sheaths generally used for permanent installations.

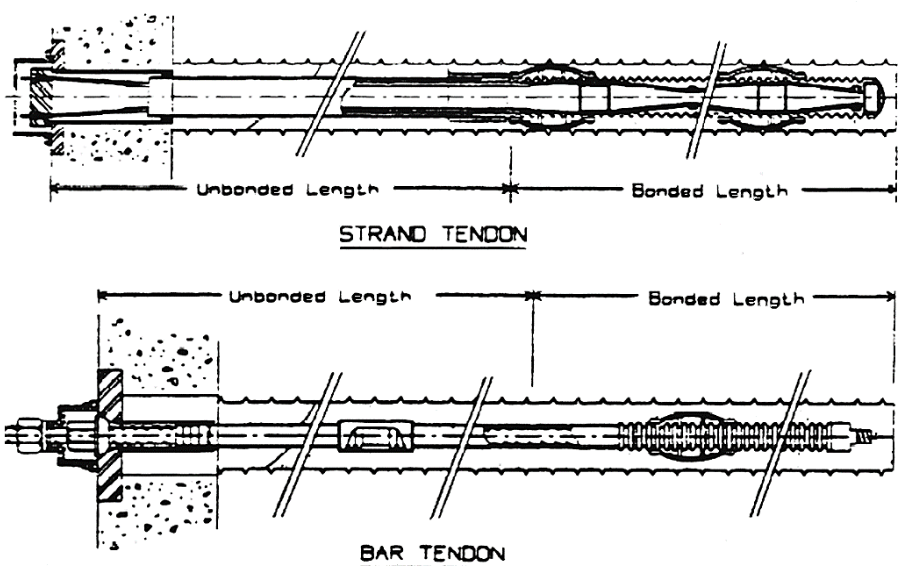

Figure 11-5. Bar or Strand Tendons

11-3.09 General Steps for Checking Ground Anchor Shoring Submittal

1. Review submittal for completeness.
2. Determine $\mathbf{K_a}$ and $\mathbf{K_p}$. In the rare cases where the shoring is not allowed to move sufficiently, determine $\mathbf{K_o}$ in lieu of $\mathbf{K_a}$.
3. Develop pressure diagrams.
4. Determine forces.
5. Determine the moments at the top of the pile above the highest ground anchor.
6. Solve for depth (**D**), for both lateral, and ground anchor force ($\mathbf{T_H}$). Confirm "**D**" is sufficient to resist the vertical loads.
7. Check pile section.
8. Check anchor capacity.
9. Check miscellaneous details.
10. Check adequacy of ground anchor test procedure.
11. Review corrosion proposal.
12. General: Consider effects of wall deflection and subsequent soil settlement on any surface feature behind the shoring wall.

11-3.10 Estimating Long Term Creep

Determine the long-term effects of creep.

11-3.10A Example 11-1A Measurement and Time Method

Given:

The shoring plans indicate that a proof load must be applied in 2 minutes or less, and then the load must be held for ten minutes. The test begins immediately upon reaching the proof load value. Measurements of movement are to be taken at 1, 4, 6, 8 and 10 minutes. The proof load is to be 133 percent of the design load. The maximum permissible movement between 1 and 10 minutes of time is 0.1 inch. All ground anchors are to be tested. The system is anticipated to be in place for 1 year.

Given:

$\Delta_{\mathbf{Allow}}$ = 0.1 inches

$\mathbf{T_1}$ = 1 minute

$\mathbf{T_2}$ = 10 minutes

Solution:

$$T_3 = (1Y)\left(365\,\frac{D}{Y}\right)\left(24\,\frac{H}{D}\right)\left(60\,\frac{M}{H}\right) = 525{,}600 \text{ minutes} \qquad (11\text{-}3\text{-}5)$$

Utilizing Equation 11-3-2 above:

$$C = \frac{\Delta_{1-2}}{\left[\log_{10}\left(\frac{T_2}{T_1}\right)\right]} = \frac{0.1 \text{ inch}}{\left[\log_{10}\left(\frac{10}{1}\right)\right]} = 0.1 \text{ inch} \qquad (11\text{-}3\text{-}6)$$

Estimated long-term creep movement from Equation 11-3-1 above:

$$\Delta_{2-3} = (C)\log_{10}\left(\frac{T_3}{T_2}\right) = (0.1\ )\log_{10}\left(\frac{525{,}600}{10}\right) = 0.47 \text{ inches} \qquad (11\text{-}3\text{-}7)$$

The proof load and duration of test are reasonable and exceed the recommended values shown in Table 11-1. Applying the proof load in a short period of time and beginning measurements immediately upon reaching that load produce meaningful test results which can be compared to the calculated long-term creep movement for the anchor.

If the shoring system were in close proximity to an existing structure that could not tolerate 1/2 inch of wall deflection, the design may not be acceptable. If the shoring will not affect permanent structures or when the shoring does not support something like a haul road, the anticipated movement may be acceptable.

11-3.10B Example 10-1B Lift-Off Load Method

Given:

"Lift-off test" will be performed 24 hours after wedges are seated. The force at seating the wedges will be 83,000 pounds and the lift-off force will be no less than 67,900 pounds.

L_u' = **$L_u + \Delta L$** ≈ 20 ft (which is the unbonded length of 15′ + 5′ for the strand length in the jack)

A = 0.647 in²

E = 28×10^6 psi

T_1 = 1 minute, this is the time until the wedges are seated (at the start of the 24 hours)

Solution:

$$\Delta_{1-2} = (P_1 - P_2)\frac{L_U{}'}{AE} \quad (11\text{-}3\text{-}8)$$

$$\approx \frac{(83{,}000 - 67{,}900)(20)(12)}{(0.647)(28x10^6)} \approx 0.2 \text{ inch} \quad (11\text{-}3\text{-}9)$$

$$C \approx \frac{0.2}{\left[\log_{10}\left(\frac{(24)(60)}{1}\right)\right]} = 0.063 \text{ inch} \quad (11\text{-}3\text{-}10)$$

Estimated long term creep at one year:

T_2 = 24 hours = 1 day (end of the “lift-off test”)

T_3 = 1 year = 365 days

$$\Delta_{2-3} \approx (C)\log_{10}\left(\frac{T_3}{T_2}\right) = (0.063 \text{ inch})\log_{10}\left(\frac{365 \text{ days}}{1 \text{ day}}\right) \quad (11\text{-}3\text{-}11)$$

$\boldsymbol{\Delta_{2-3}}$= **<u>0.16 inch</u>** [from the end of the “lift-off test” (T_2) to the end of the 1 year (T_3)]

11-4 Summary

The Department has an obligation with respect to trenching and shoring work. Be informed of legal responsibilities and requirements (Refer to Chapter 1, *Legal Requirements,* and Chapter 2*, Cal/OSHA Overview*).

Soil Mechanics (Geotechnical Engineering) is not a precise science. Be aware of the effects that assumptions can make. Simplified engineering analysis procedures can be used for much of the trenching and shoring work that will be encountered.

The actual construction work is of equal importance compared to the engineering design or planning. The Contractor and the Engineer must always be alert to changing conditions and must take appropriate action. Technical assistance is available. The Engineer at the jobsite must be able to recognize when assistance is required. The need for good engineering judgment is essential.

Work involving railroads requires additional controls and specific administrative procedures.

The following is a summary of Caltrans requirements and procedures in regard to trenching, excavation, and shoring work:

1. The law (State Statute, §137.6, as discussed in Section 1-4, *State Statutes* of Chapter 1) requires that a California registered engineer review the Contractor's plans for temporary structures in connection with State highway work. Shoring plans are included in this category.
2. The Engineer will ascertain that the Contractor has obtained a proper excavation or trenching permit from Cal/OSHA before any work starts, and that the permit (or copy) is properly posted at the work site.
3. If the trench is less than or equal to 20 feet deep and the Contractor submits a plan in accordance with the standard details found within the Cal/OSHA Construction Safety Orders, it is not necessary to have the plans prepared by a professional engineer. The Engineer will confirm that the Contractor's plan does indeed conform to the applicable standard details found in Cal/OSHA, and need not make an independent engineering analysis.
4. If a trench is over 20 feet in depth, or if the Cal/OSHA standard details are not applicable, the plans must be prepared by a professional engineer.
5. If the Contractor's shoring plan deviates from the Cal/OSHA Construction Safety Orders, the plan must be prepared by a California registered professional engineer and the reviewing engineer will perform an independent engineering analysis.
6. When shoring plans are designed by firms specializing in temporary support systems, soil restraint systems or sloping systems, good engineering judgment is to be used for the review. Shoring designs by such firms may appear less conservative when analyzed using the methods proposed in this manual. Consequently, the shoring plan may need to be reviewed in the manner in which it was designed. Obtain assistance from the SC Falsework Engineer as needed.
7. For any shoring work that requires review and authorization by a Railroad, the SC Falsework Engineer[1] will be the liaison between the project and the Railroad. The Structure Representative will submit the Contractor's shoring plans to SC Sacramento after review. The review should be complete, so that the plans are ready for authorization. The Structure Representative should inform the Contractor of the proper procedure, and the time required for Railroad review and authorization.
8. Any revisions to the shoring plans should be done by the plan originator or by his/her authorized representative.

[1] Caltrans internal use only