NAXSA®
North American
Excavation Shoring Association

NAXSA DISCUSSION OF TRENCH RESCUE EMERGENCY SHORING

EXISTING PRACTICE AND OSHA 1926 SUBPART P CONFORMANCE

www.naxsa.org

Contents

Introduction

In the unfortunate event of a trench collapse, rescue operations typically fall to local firemen as the first responders. While first responders often utilize similar shoring equipment as that used for construction purposes, trench rescue operations are inherently different than trench excavation and shoring operations. Under construction conditions, trenching and shoring operations have the benefit of being planned and sequenced for the orderly placement of shoring elements in accordance with the requirements set forth in OSHA Subpart P, as well as the manufacturers' specifications for the shoring elements. In comparison, rescue operations are forced into an ad-hoc situation, typically starting with a previously excavated trench that has already caved in. In many cases, these trenches have not been previously shored at all.

With the primary purpose of most pre-manufactured trench shoring systems aimed at the construction market, the issue has arisen that many of the specifications noted in the typical manufacturer's shoring tabulated data does not correspond to rescue situations. In regards to deviations from the specifications, we find that manufacturers are not inclined to rewrite their specifications or issue written approval on allowances for undescribed site-specific uses. More to the point, shoring manufacturers have very little experience or expertise in trench rescue operations, and have little interest in wading into that arena. This has lead to confusion in the rescue community as to whether pre-manufactured shoring equipment, such as hydraulic trench shores, are appropriate for trench rescue scenarios.

In conversations with first responders, this committee finds that the use of typical OSHA excavation methods and equipment are the preference and are commonly used across the United States due to their ease of use and ability for quick deployment where time is of the essence. However, there is uncertainty in whether their use is allowed due to the specialized conditions that first responders are subject to as they attempt their rescue and recovery operations. While certainly faced with unique risks not seen on the typical construction sites, aluminum hydraulic shoring are inexpensive, locally available, and have proven to be effective in rescue and recovery use.

It is the opinion of the NAXSA engineering committee that, while not thoroughly described in the existing tabulated data, the bulk of the uses of these methods and equipment in trench rescue operations are in accordance with OSHA and manufacturers requirements. Due to the unique risks involved with their tasks, it is critical that trench rescue personnel have clear and consistent procedures and rules to apply these shoring methods.

The purpose of this project is to examine from an engineering and OSHA conformance perspective the spot shoring methods used by first responders, and serve as an introduction to allow for further discussion and collaboration in the field of trench rescue. In this document, we will outline the following:

- Describe the use and limitations of hydraulic aluminum shoring methods so that training procedures can be implemented for their proper use and implementation
- Introduce the existing tabulated data for hydraulic aluminum shores
- Provide general engineering practices and procedures to serve as an educational base and point of reference for scenarios that do not clearly conform to manufacturer's tabulated data

This committee would like to thank the members of the South King Fire & Rescue Group for their collaboration and time in educating this committee on current trench rescue tactics. Their first hand knowledge and demonstration of rescue tactics were instrumental in putting this document together and ensuring it would serve its purpose as both an educational and practical reference for first responders.

Trench Rescue Situations and Current Practice

Causes of Excavation Collapse

While soil can come in a multitude of forms, at the most basic level soil consist of small particles packed together. In its natural, unexcavated, and consolidated state, the soil has typically had years to reach a point of equilibrium. Once excavated, it is the imbalance of forces that create the risk of collapse and cave in. In the case of a trench excavation, while the soil is still vertically supported, there is now a lack of horizontal support that must be accounted for that would typically be resolved with shoring equipment. In the absence of shoring, the soil tries to initially support itself through shear strength; through the years of consolidation, the soil particles have packed close enough together that, in order for them to move, they would have to overcome static friction forces between them. This is the reason that, in most cases outside of saturated or runny soils, an excavation can stand open for a time without any means of support. However this ability to stand open is heavily dependent on the soil type and exterior conditions.

In unshored excavations, trench collapse in its simplest form, is caused by (2) main factors: Soil Type and Surcharge Loads.

<u>Soil Type</u>

As noted earlier, soil is made up of particles. What those particles look like, how tightly they are packed together, and how moist they are, all combine to determine how stable the soil will be in an excavation. OSHA has put together a classification system to allow for the identification of types of soil from an excavation perspective, and to aid in the selection of shoring equipment and identify high risk soils. This system will be outlined later in this document.

<u>Surcharge Loading</u>

Surcharge is any vertical load that is imparted on the soil. This loading can come in the form of a spoil pile dumped adjacent to the trench, or as equipment staged next to the edge of the excavation. Any surcharge placed adjacent to an excavation directly adds downward loads to the soil. In weak soils, even the weight of a worker could be a significant surcharge that starts a collapse. As mentioned above, when all the soil has to hold itself up is friction, any addition loading only increases the risk of cave in.

Concerning excavations, OSHA Section 1926 Subpart P outlines the requirements that must be met for worker safety. The OSHA specifications outlining excavation shoring methods and equipment are as follows:

- **Soil sloping and benching systems** OSHA 1926 Subpart P 1926.652(b)
- **Timber Shoring for Trenches** OSHA 1926 Subpart P App C
- **Aluminum Hydraulic Shoring for Trenches** OSHA 1926 Subpart P App D

The instructions and tabulations provided for these shoring elements are primarily directed toward planned excavation shoring applications and not rescue operations. What this means is that this tabulated data comes with some inherent assumptions:

1. Soil type is first identified in accordance with OSHA Subpart P Appendix A, Soil identification
2. If there are more than one shoring type used (sloping, timber, and aluminum shoring) each type shall conform to its specific tabulation and not conflict with the coexisting data.
3. That which is not explicitly shown or described in the tab data still meets the basic requirements of the data but is not clearly described or illustrated in the data

OSHA Subpart P is specific on this as follows:

- 1926.652(c)(2)Option (2)-Designs Using Manufacturer's Tabulated Data.
- 1926.652(c)(2)(i) Design of support systems, shield systems, or other protective systems that are drawn from manufacturer's tabulated data shall be in accordance with all specifications, recommendations, and limitations issued or made by the manufacturer.
- 1926.652(c)(2)(ii) Deviation from the specifications, recommendations, and limitations issued or made by the manufacturer shall only be allowed after the manufacturer issues specific written approval.

Current Status of Trench Rescue

By their very nature, emergency trench rescues are last minute and unplanned affairs, with the responsibility of action primarily falling on the local firefighting agency to perform the rescue and recovery procedures. To their credit, firefighting agencies have worked hard to put together plans and procedures for trench rescue operations, as well as training programs to ensure their own members stay safe. With that said, at the time of publish for this document, there is no conclusive set of national guidelines for first responders to follow. Because of this, each fire district has had to develop their own set of procedures. Due to being readily available and easily used, hydraulic aluminum trench shores are commonly found on trench rescue trucks throughout the United State. Through training classes and inter-agency sharing of information, a rough set of general procedures have developed. Upon arrival at a trench rescue situation, first responders typically:

- Survey the scene and establish control of the work area
- Identify the collapse, as well as areas safe to work and stage equipment
- Verify how many victims there are and their approximate location within the collapse
- Deploy trench shoring equipment and begin stabilizing the necessary areas
- Once the excavation is adequately shored, it is safe for responders to begin entering the excavation and perform rescue/recovery operations

As previously mentioned, while the above are some general procedures that have risen through trial-and-error within the firefighting community, there is no current consensus. With emergency rescue and response far outside the directive of NAXSA, it is beyond the scope of this document to dictate what should be best practices. However, we do hope that it serves as a useful source of information and can better prepare first responders and keep them safe.

Pressures on Trench Shoring Systems

In the design of trench shoring systems, the forces and pressures that must be taken into account can be numerous and complex. As this document is intended to serve as a primer for further discussion within the trench rescue field, it will focus on the two principle sources of pressure in excavation shoring: Soil and Surcharge.

Soil Loading

Soil mechanics, and the analysis used to accurately determine the pressures that will load any given excavation shoring system are exceedingly complex, with numerous factors, variables, and computations necessary to produce an accurate model. For a worker out in the field, there was a need for a simpler, approachable method to reliably identify soils so that workers could stay safe while excavating on job sites. It was for this reason the OSHA soil classifications were created.

The ability of an excavated soil to stand on its own is heavily dependent on the stiffness or density of that soil. As noted earlier, it is the friction forces between the soil particles that resists the weight of the soil once excavated, and therefore resists collapse. This is why an excavation in stiff clay or a very dense sand has the ability to stay open for weeks or even months, while a pit dug in soft or runny material may not even stay open long enough to get shoring in place. This is the reason why the type of soil directly determines what shape the shoring system needs to take. For example, hydraulic trench jacks installed in Type A soil (dense sand or stiff clay) will have a larger spacing between struts than the same system installed in a Type C soil (loose soils).

For soil classifications, OSHA Part 1926, Subpart P, Appendix A defines the types of soil as well as outlines how they shall be identified.

> (1) Classification of soil and rock deposits. Each soil and rock deposit shall be classified by a competent person as Stable Rock, Type A, Type B, or Type C in accordance with the definitions set forth in paragraph (b) of Appendix A.
>
> (2) Basis of classification. The classification of the deposits shall be made based on the results of at least one visual and at least one manual analysis. Such analyses shall be conducted by a competent person trained in methods of soil classification and testing such as those adopted by the America Society for Testing Materials, or the U.S. Department of Agriculture textural classification system.

Steps in Determining Soil Type

All soils have some combination of cohesive, clay particles and non-cohesive granular (ie sandy) particles. The largest percent of particles determines the soil type. If the sample is over 50% clay particles it is cohesive soil. Alternatively, if over 50% of the sample is sandy, granular particles, the soil is classified as granular.

Cohesive soil means clay (fine grained soil), or soil with a high clay content, which has cohesive strength. Cohesive soil does not crumble, can be excavated with vertical side slopes, and is malleable when moist. Cohesive soil is hard to break up when dry, and exhibits significant cohesion when submerged. Cohesive soils include clayey silt, sandy clay, silty clay, clay and organic clay

Granular soil means gravel, sand, or silt, (coarse grained soil) with little or no clay content. Granular soil has no cohesive strength. Granular soil cannot be molded when moist and crumbles easily when dry. Some moist granular soils exhibit apparent cohesion initially, however they tend to crumble as they dry.

Observe samples of soil that are excavated and soil in the sides of the excavation. Estimate the range of particle sizes and the relative amounts of the particle sizes. Soil that is primarily composed of fine-grained material is cohesive material. Soil composed primarily of coarse-grained sand or gravel is granular material.

The following is a physical test that gives us a sense of soil loading that will be encountered:

Thumb penetration. **The thumb penetration test can be used to estimate the unconfined compressive strength of cohesive soils.** (This test is based on the thumb penetration test described in American Society for Testing and Materials (ASTM) Standard designation D2488—''Standard Recommended Practice for Description of Soils (Visual—Manual Procedure).'')

A. **Type A soils with an unconfined compressive strength (UCC) of 1.5 tsf** can be readily indented by the thumb; however, they can be penetrated by the thumb only with very great effort.

B. **Cohesive soil with an unconfined compressive strength (UCC) greater than 0.5 tsf (48 kPa) but less than 1.5 tsf (144 kPa**)

C. **Type C soils with an unconfined compressive strength (UCC) of 0.5 tsf can be easily penetrated several inches by the thumb**, and can be molded by light finger pressure. This test should be conducted on an undisturbed soil sample, such as a large clump of spoil, as soon as practicable after excavation to keep to a minimum the effects of exposure to drying influences. If the excavation is later exposed to wetting influences (rain, flooding), the classification of the soil must be changed accordingly.

The distinction between cohesive and non cohesive is important for rescue work because:

1. Non cohesive soils tend to run and ravel and these conditions signal the need for sheeting between hydraulic or timber shoring elements. If sheeting is needed it must be placed prior to the structural elements of the shoring (ie: hydraulic jacks or struts). When time is of the essence, the decision to leave out the sheeting can mean the difference between rescue and recovery.

2. For cohesive soils when the UCC goes below 0.5 tsf, the soil will have a difficult time staying vertical and may slough or run. A handful of soft clay soil at 0.5 tsf will easily squeeze between the fingers. Soil with a UCC of 0.25 tsf will simply flow between open fingers. Sheeting is always required in the case of Type C soil.

3. Water and muck in the bottom of the trench is not necessarily an indicator of the soil type or strength. Water will flow along the bottom of the trench and can come from other places. Hydrovac work involves water and tends to make a muddy mess. This condition does not force the soil classification to be downgraded to Type C Soil.

Observe the area adjacent to the excavation and the sides of the opened excavation for **evidence of surface water, water seeping from the sides of the excavation,** or the location of the level of the water table.

Surcharge

A surcharge load is any added load that is not coming from the retained soil itself. Surcharge can take any combination of forms. They can be as small as a spoil pile of excavated soil, or as large as a 200 ton crane. The important thing to realize is that surcharge imparts load directly to the soil. This load is then transmitted through the soil and distributed to whatever shoring system is in place. Using a pressure calculation method known as a Boussinesq analysis, it is possible to calculate and graph how much pressure is transmitted from a surcharge load to shoring system.

An example of a Boussinesq analysis output is show in Figure 1. What is important to note is the shape of the surcharge distribution; a distinctive P-shape forms. WAfter analyzing multiple Boussinesq surcharge conditions, some important points are revealed:

- Surcharge pressures have their highest impact at the very top of an excavation, with the pressures dissipating with depth.
- The further away from the shoring edge the surcharge load is placed the less the load on the shoring elements.
- Point loads (crane outriggers, vehicle tires, etc) have a significant impact, with high pressure transmitted horizontally through the soil.

Depth of Excavation H	Surcharge Ps
0	0
0.5	108
1	95
2	48
3	24
4	13
5	8
6	5
7	3
8	2
9	2
10	1
11	1
12	1

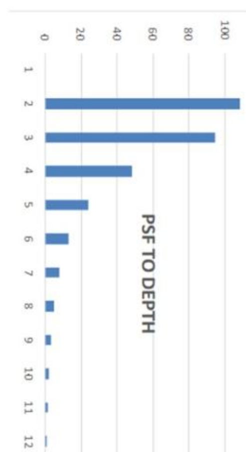


Figure 1: Surcharge Pressure Distribution

With respect to surcharges, some guidelines to follow:

- If possible, move all possible surcharges back away from the edge of the excavation. Distance helps the loads dissipate through the soil before impacting the shoring system
- Distributing point loads so they are distributed over a larger area can help reduce the amount of pressures that are transmitted through the soil.

Trench Rescue: Case Study

The purpose of this analysis is to examine existing rescue shoring practices and determine how they apply to the OSHA and Tabulated Data requirements. We will define a condition and walk through each step of the rescue procedures

Example: A ~4 ft -wide x 12'-deep trench wall has collapsed on a worker. No existing shoring was in place. Only one side of the trench has collapsed. See Figure 2 below.

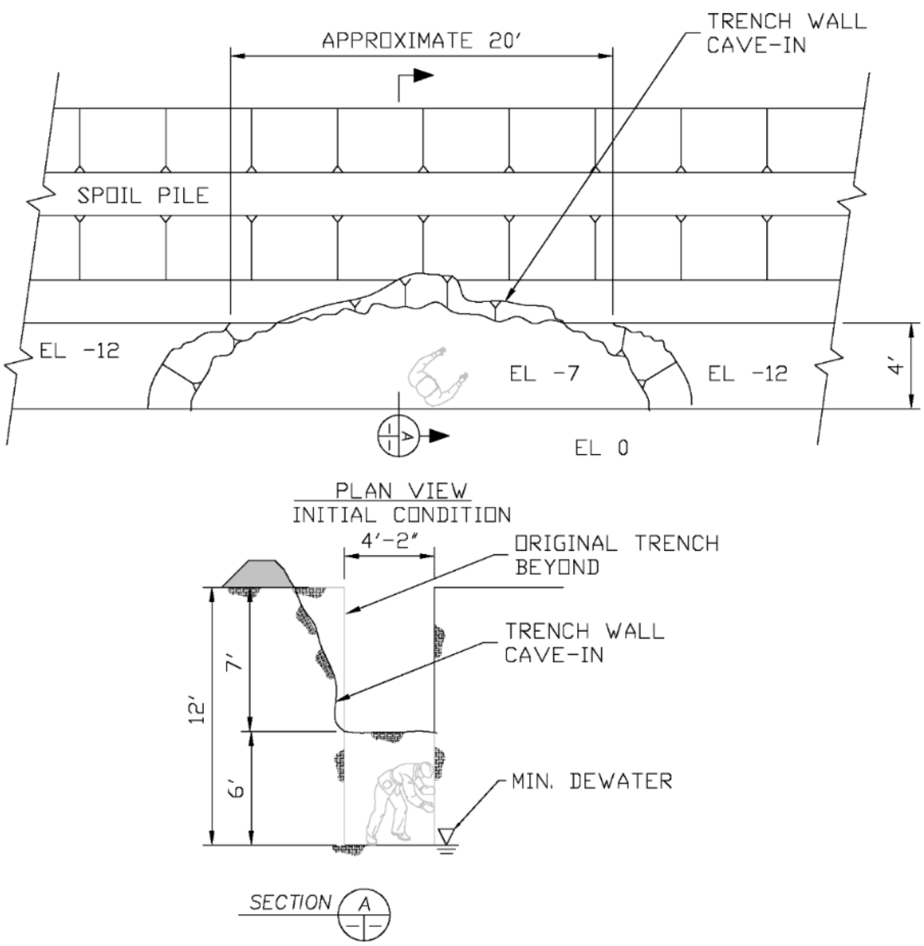


Figure 2-Trench collapse condition

Step 1-Determine Soil Conditions

The first step in determining the correct shoring system, and arguably the most critical, is correctly determining the type of soils present. It is critical to understand that, depending on the soil type, not all shoring methods are suitable. For this example., the soil in the project area is shown in Figure 3.

Figure 3-Soil Condition to be analyzed

In a rescue scenario where responders are showing up after the initial excavation, the first option of observing the soil as it is excavated is typically not an option at all. Therefore, focus should be on either nearby soil piles or on the recently collapsed soil itself.

In the case of the previous outlined example, the particle size of the soil is so small, (clay particles), that they cannot be seen. The visible rock particles are few and far between and not affecting the strength (ability to stand up) of the soil. For the most part, the soil stands up, and has clumps or clods.

For this exercise, assume the thumb could be pushed into the soil but not easily. It could not be squeezed between the fingers. Therefore, the unconfined compression strength is estimated to be less than 1.5 tons/square foot (softer than a Type A soil) but greater than 0.5 tsf (stiffer than a Type C soil). This places it in the OSHA Type B Category

Trench rescue soil classification is critical and must be made rapidly and on the spot. With proper training, a quick analysis in full conformance with OSHA Subpart P Appendix A can be performed within ten minutes.

Step 2-Initial Stabilization & Determination of Shoring Method

Proceed with initial stabilization measures, specifically:

- Delineate the work area
- If necessary, spoil piles should be moved back at least 2 ft from the edge of the trench within the work area
- Provide edge protection and cross trench bridging as necessary
  1926.651(j)(2) Employees shall be protected from excavated or other materials or

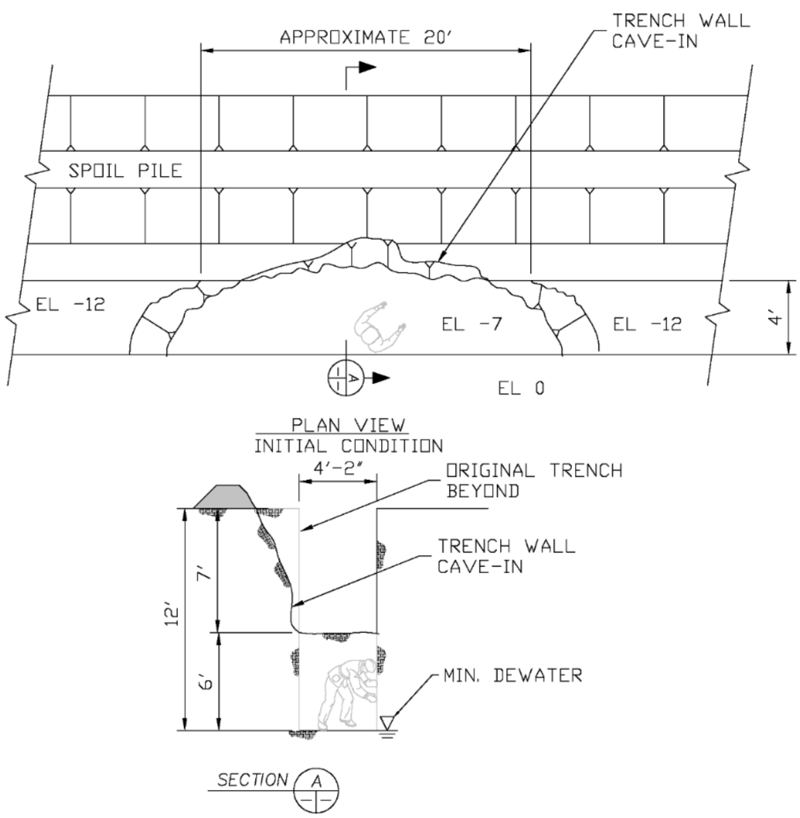


Figure 4: Initial Collapse Condition

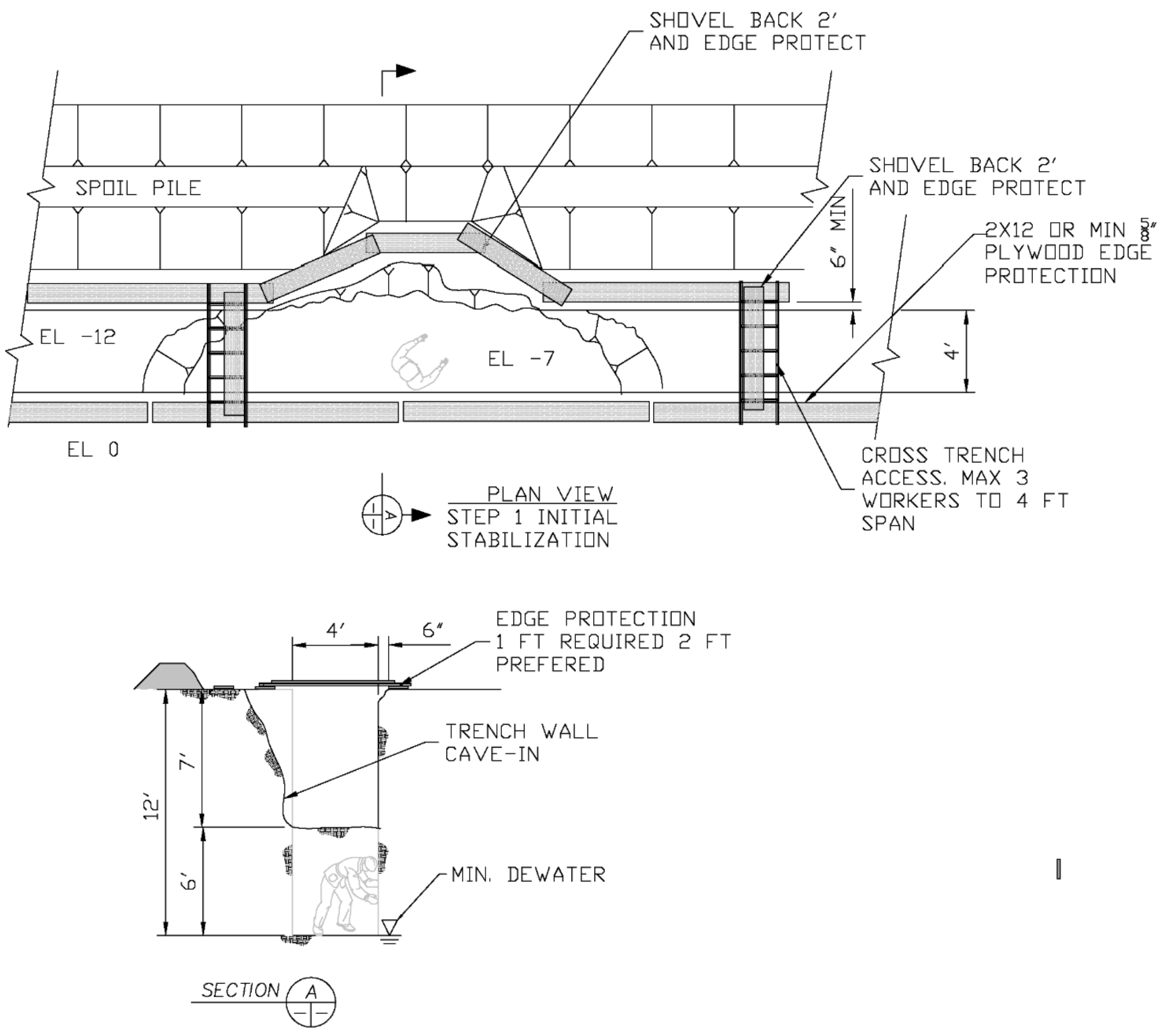


Figure 5: After Initial Stabilization

Decide worker protection system to be used:

Sloping and Benching

By sloping and benching the soil, this alternative essentially removes the unsupported soil from the situation. Since the soil above the collapsed level would no longer require support, this changes the shoring initiation height, quantity of shoring, and required effort from the surface to the level of the collapsed soil. However, this method comes with significant risks:

- Sloping of soil could initiating further collapse
- Potential of striking the victim with heavy equipment
- Possibly undermining surface encumbrances and existing buried facilities

If there is sufficient equipment access and the three risks listed above have been taken into account, the option of sloping soil may save critical time.

Support system based on surrounding surface level to depth of rescue

This is the most commonly use and practiced protection system used, often for the following reasons:

- Even if the first two options are used, a support system will still be required to proceed deeper and reach the recoverable victim depth.
- Shoring equipment and material is common and readily available
- Timber and hydraulic/pneumatic shoring equipment can be pre-supplied and stored on the rescue truck.

For this example, the worker protection system to be utilized will be aluminum hydraulic spot shores.

Step 3-Spot Shoring Installation Procedure.

For spot shoring installation, specific maximum vertical and horizontal spacing requirements are typically outlined by the manufacturer's tabulated data. However, below are general guidelines for aluminum hydraulic shoring installation:

1. Vertical Spacing
    - The first hydraulic cylinder must be within 18" of the surface. Manufacturers tabulated data allows 24" from the surface
    - Never space cylinder or timber strut more than 4 ft apart vertically
    - Never place cylinder or timber strut more than 4 ft from the bottom of the excavation
    - Less than 4 ft is always allowed

2. Horizontal Spacing
    - Horizontal spacing is dictated by the soil type. Soil type must be identified first, then appropriate spacing is determined.
    - Always use spacing equal to or less than given in the tabulated data, or as outlined by OSHA 1926 Subpart P, Appendix D, Table D.
    - Never exceed 18000 lb load on a cylinder

3. Rail
    - There are two types of rail; light duty and heavy duty
    - The length of the rail will depend on the number of cylinders attached
    - The decision to use light duty or heavy-duty rails is based on durability and weight. There is no set requirement outlined by OSHA.
    - The rail serves two specific purposes
        I. To keep the cylinder from punching into the soil
        II. To hold the cylinders in place when there are more than two cylinders attached
    - Spot shores have rails that can vary in length from 12" to 24"
    - Spot shores can be placed with the rail in any direction from vertical to horizontal

4. Sheeting
    - Sheeting can take the form of 1 1/8"-thick CDX plywood, ¾"-thick plyform, or similar material. Consult manufacturer's tabulated data for specific requirements
    - Sheeting is only required when sloughing or raveling occur or in OSHA Type C Soil
    - Sheeting is not considered a structural element; the main design requirements are that it cover enough area to prevent the ravel or sloughing and have enough strength to retain the ravel or slough.

There are basic procedures regarding the use of timber and aluminum hydraulic shoring that must be remembered and followed at all times:

- **Never work outside of a shored area**
- **Set first shores from a stable ground surface**
- **Work within a shored trench shall occur between a minimum of two vertical columns of shores. Trenches more than 12 ft long require that workers work within a minimum of three vertical columns.**
- **Always enter and exit the trench from within a shored area**
- **Do not stand or climb on the cylinders**

The following drawings show a potential procedure that follows these rules. As outlined previously, the soil in this example has been identified as a Type B soil. Below, Table 1 shows an example of manufacturer's tabulated data for hydraulic trench shores. While each manufacturer may display the data slightly differently, the critical information of maximum depth, vertical spacing, and horizontal spacing, should be clearly shown for each OSHA soil classification.

Hydraulic Shores - Type "B" Soils

Depth of Excavation	Maximum Vertical Spacing of Struts	Maximum Horizontal Spacing of Struts	Excavation Width	Oversleeve Required	Sheeting Required
0 ft – 15 ft	4 ft	8 ft	0 ft – 8 ft*	No	No
			8 ft – 12 ft	No	
			12 ft – 15 ft	Yes	
15 ft – 25 ft	4 ft	6 ft	0 ft – 8 ft*	No	No
			8 ft – 12 ft	Yes	
			12 ft – 15 ft	Yes	

Table 1: Example of Tabulated Data

Note that the table for trenches up to 15'-deep max, in OSHA Type B soils, allows up to 8 ft on center spacing. However, from inside the trench it is impossible to stand between 2 shored columns and reach out and place the shore at that distance. In practice, 4 ft is the best that can be done safely. In this case it is best to figure for no more than 6 ft spacing. Shores can be set and moved again or removed if there are other shores in the vicinity that still keep the 4'x6' spacing criteria.

This initial set up is for the purpose of getting the rescuers into a safe area where they can start the rescue or recovery process. Note that here they must dig and place shores from Elevation -7 to the victim at Elevation -12.

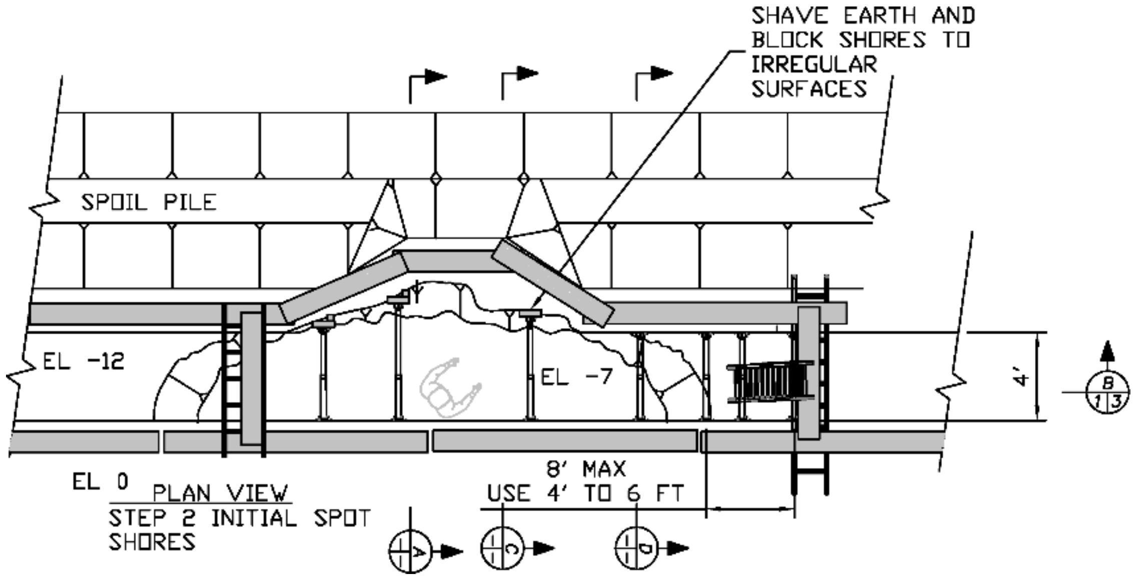
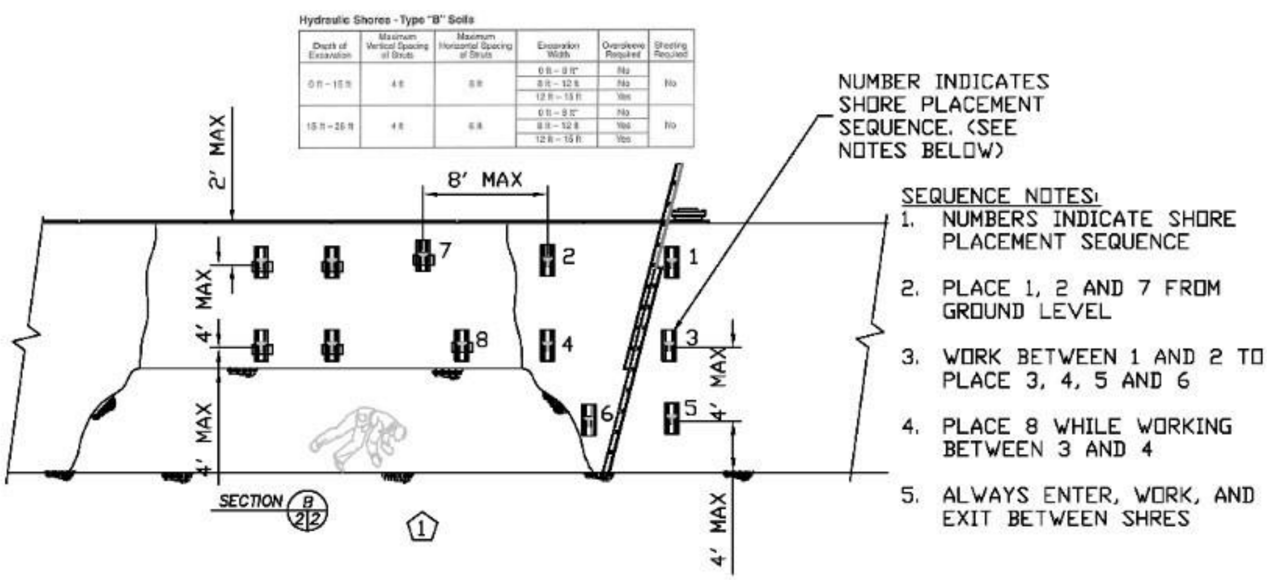
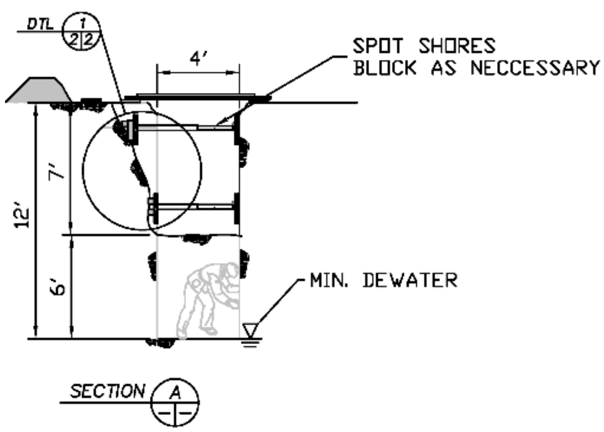
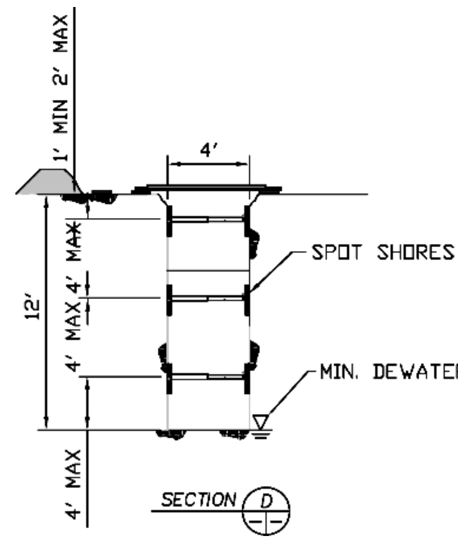
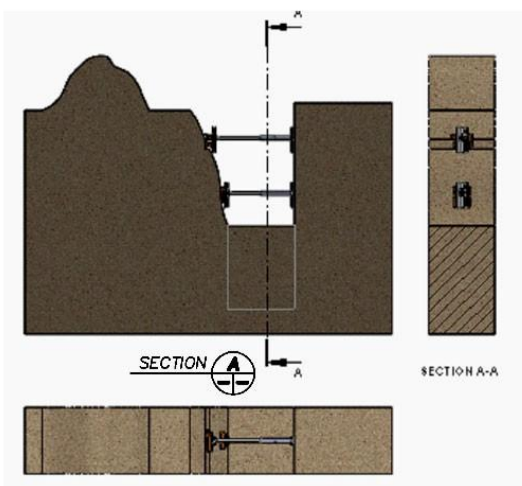


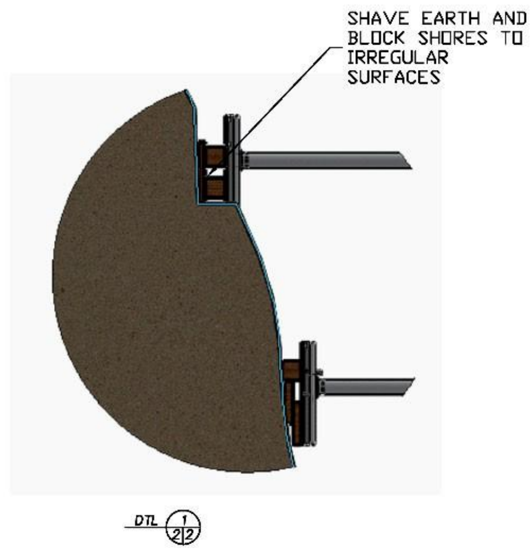
Figure 6: Shored Trench











In the area of the cave in, the trench wall will not be smooth and vertical. The cylinder of the spot shore must always have a direct connection to the trench wall. If necessary, shave the earth and install timber wedges or blocking to establish a flat and solid bearing surface. The blocking area in contact with the earth should be a minimum of 100 square inches. Such as 2- 4x4x16" long, (112 in$^{2)}$, or 2x8 x 12" long (90 in^{2}). Apply enough hydraulic pressure so that the blocking slightly indents the earth and is seated so that it will not kick out.

Conclusion

Any rescue situation a first responder may be called to will invariably be its own unique event, with its own soils, situation, and solution. It is for this reason that for the special teams tasked with responding to trench rescues, education and training should be paramount. Being able to quickly and confidently identify the soils and surcharges involved will not only aid in the correct choice of shoring system used in the rescue, it will drastically increase the safety for all involved. While it is in this NAXSA Engineering Committee's opinion that hydraulic shores have a place in trench rescue operations, it is important to note that hydraulic shores are but one tool to be utilized. Ultimately, it is up to the responders on site to determine whether they are the correct tool for that situation, and that determination can only come with training and education.