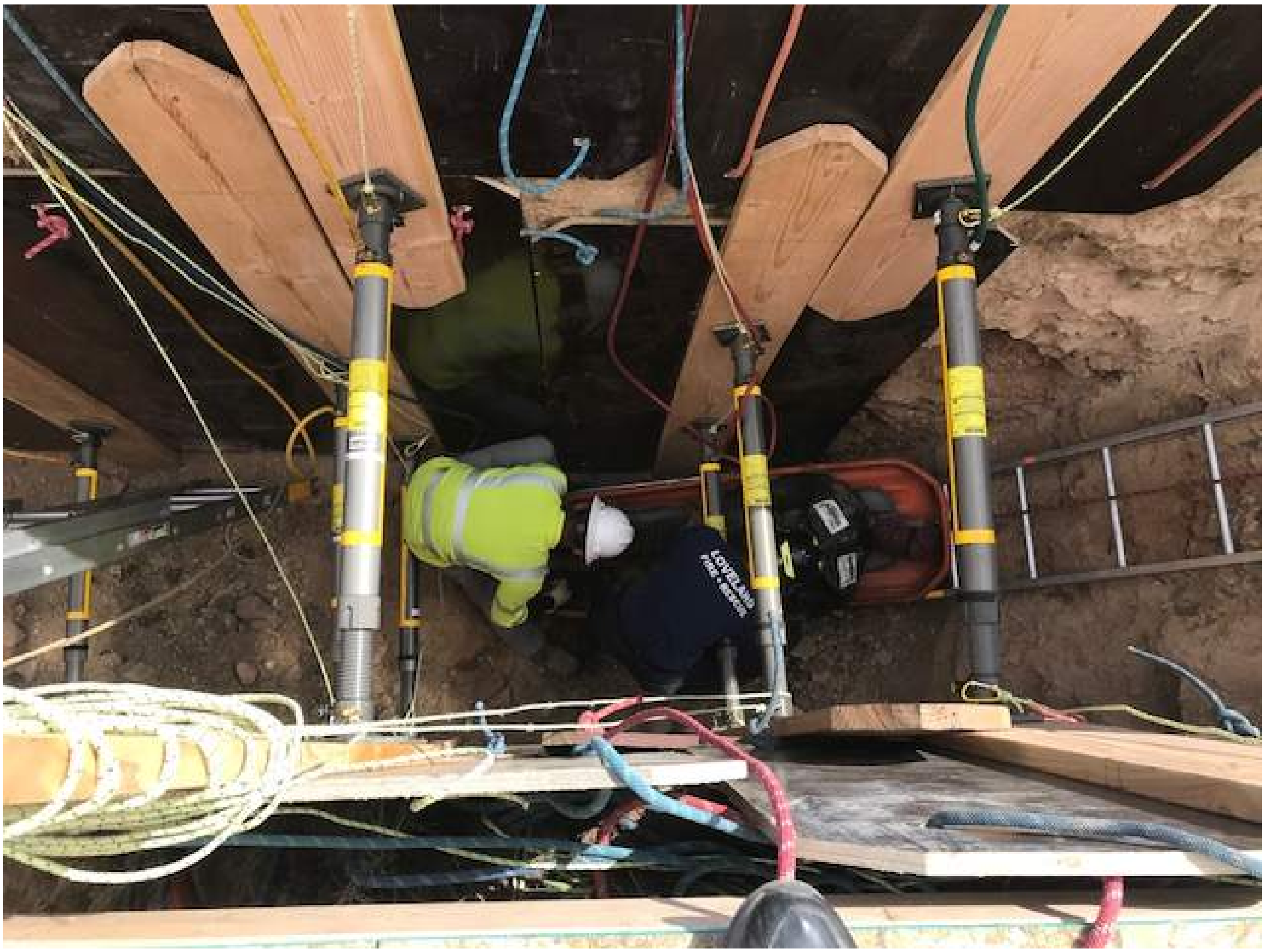
FUNDAMENTALS OF TRENCH RESCUE SHORING



MATRS (2018)

FUNDAMENTALS OF TRENCH RESCUE SHORING
Course Objectives

1. Recognize the differences between trench (construction) shoring and trench rescue shoring.
2. Identify common trench collapse patterns
3. Estimate soil forces
4. Identify “best practices” for trench rescue component use.
5. Implement a trench rescue Shoring Plan.

Section 1
Trench Rescue Shoring Synopsis

The origin of many of the sheeting and shoring techniques used by rescuers comes from the underground construction industry. The "Godfather" of trench rescue was James Gargan (R.I.P.). James Gargan's roots were in construction and his trench rescue shoring practices were loosely taken from the OSHA construction shoring charts. While construction shoring and rescue shoring share some similarities, several significant differences exist. In the only study ever published on the subject of trench rescue shoring, author Dr. Marie LaBaw concluded that "Underground construction shoring and trench rescue shoring are significantly different. Many of the theories and field observations that have been done for construction shoring may not be applicable to trench rescue shoring."

Several theories exist concerning trench shoring. The theories are based on accepted practices for planned excavations and are used by the underground construction industry. ***None of the theories are based on shoring trenches that have collapsed and trapped victims.*** Dr. LaBaw concludes *"There are significant differences in the typical braced excavation analysis using available empirical methods and the standard trench rescue shoring system that raise questions about the validity of using the same analysis methods (and practices) to examine the standard trench rescue shoring system."* Using the same practices and principles for shoring typically braced excavations (construction trenches) and rescue (collapsed) trenches is questionable at best.

Differences between Trench Construction Shoring and Trench Rescue Shoring:

Practices

- PLANNING
  - Construction- A planed excavation for construction typically includes extensive soil testing and an engineered shoring design. The shoring equipment and material are brought to the site before the excavation begins. Construction workers are provided with information about the soil type, width, depth and purpose of the trench and they install the shoring according to the design that has been engineered for that specific excavation.

  - Rescue- At a trench collapse, rescuers arrive with no prior knowledge of the trench (soil type, width, depth and purpose). The collapse has occurred because construction workers failed to have or follow an adequate shoring plan. Firefighters must design and install shoring on collapsed trench walls based on a rapid trench assessment. Pre-planned shoring designs with site specific equipment is not available for trench rescue operations.

- TIME
  - Construction-Properly installed shoring at a planned excavation site begins soon after (or during) the digging process. By beginning to shore early and adding (phasing) shoring as the excavation expands and maintaining a stable excavation bench cut depth, underground construction workers can shore trench walls that are contiguous (connect without a break**).** Highly stable soil and contiguous walls may allow for the use of skip shoring and spot shoring techniques.

  - Rescue- At a trench rescue scene (cave-in) the walls are weakened by the lack of support for hours and sometimes days and rescuers are supporting active (ongoing failing and moving) soil. At a trench cave-in the walls have at least partially collapsed and other wall areas may be moving more slowly toward failure. The walls are broken, uneven, are out of plumb, undercut and they have voids. This makes full contact between the shoring and the trench wall impossible and requires different shoring techniques.

- INSTALLATION
    - Construction- At underground construction sites shoring is often phased with the excavation. That means that shoring is added (in phases) as the excavation gets deeper and/or longer. By limiting the excavation bench cut or cut face depth, relative stability of the soils is maintained. Shoring is accomplished by starting at the top and working down. Early and phased shoring commonly results in optimal contact between the shoring and trench wall. This is usually a requirement of the designed shoring system and is often accomplished by grouting behind the shoring materials. In relatively stable soils, on most narrow and shallow trench utility projects, a rigid steel trench box is drug through the excavation to protect workers inside the trench box while it progresses along its length.

    - Rescue- At a cave-in (rescue) the entire excavation is typically open and not shored when rescuers arrive so phased shoring (lifts) is not an option. The area that needs to be shored has caved in and has a victim trapped below it. The voids left by the collapsed may not provide for the "top to bottom" sequence of strut placement required by OSHA for construction shoring. Optimal contact between shoring materials and trench walls cannot be achieved during rescue operations. Rescuers must first install shoring to protect the victim from additional collapse and second to provide a safe area that can be expanded for rescuers to treat and extricate trapped victims.

- OPTIONS
    - Construction- Sloping, benching, trench boxes, piling and sheeting and shoring are some of the options that are available to construction workers. Knowing the soil type, width, depth and purpose of the excavation (trench) allows the best option to be at the site and ready for installation before the digging begins.

    - Rescue- Trench rescue teams bring one option to the scene. That option is most often panels and struts. Firefighters currently apply a "one size fits all" approach to a variety of soil conditions, trench depths and widths.

Trench Rescue Shoring vs Trench Construction Shoring Summary

Shoring in the underground construction world (large construction projects and utility installation and repair) differs from shoring of a trench for rescue in several ways:

- CONSTRUCTION- Shoring used for construction purposes is designed to be installed before the soil becomes active. That is accomplished by installing the shoring during, soon after, or in some cases even before the excavation takes place. In those cases, the OSHA shoring charts, manufacturer's tabulated data, and construction shoring techniques are valuable guidelines. Rescuers, in contrast, are often confronted with problematic soil conditions that have already become active and have usually collapsed and may be continuing to collapse. As a result, OSHA shoring charts and procedures, strut manufacturers' tabulated data, and construction techniques, derived for the controlled conditions of the construction industry may not be the best practices for rescue shoring. In reality, OSHA shoring charts and "tab data" are often talked about but seldom used at rescue incidents. Construction shoring is intended to be installed in measured more deliberate planned steps and its design service life is more permanent in comparison.

- RESCUE- Rescue shoring at a trench collapse takes place when the soil is active (has moved and/or is moving). Rescue shoring must focus on the needs of a trapped victim. It must begin with techniques that will provide the victim with immediate protection from additional collapse. Rescue shoring is intended to be installed rapidly and its comparative short design service life is the length of the rescue operation.

- That immediate need, coupled with the active soil that has collapsed and created voids in the wall(s), often requires a departure from traditional construction shoring methods and OSHA mandated practices such as, but not limited to, always shoring from the top down.

A vast variety of methods, techniques, and equipment are used for underground construction shoring, whereas the methods, techniques, and equipment used for rescue shoring are limited. While it is common to see sloping, benching, sheet pile, soldier piling/lagging, soil nail or anchored shotcrete walls, and trench boxes or expandable modular shoring used by construction workers, these techniques require a large assortment of material and often specialized heavy equipment for installation. This equipment if used in a rescue situation could be a cause of additional collapse in some conditions. Rescuers, by comparison, are constrained to a small assortment of shoring equipment that must be manually installed.

OSHA/TAB DATA/ ENGINEERS

The evolution of trench rescue shoring has included OSHA guidelines, manufacturer's tabulated data, engineering calculations, myths and folklore. Most of the OSHA guidelines, tabulated data or engineer's calculations are applicable to construction shoring but they often lack practical application to rescue shoring operations. OSHA has developed a shoring standard for underground construction work. The OSHA Standard includes four options for the use of sheeting and shoring.

OSHA (Standards-29-CFR)
Selection of Protective Systems-1926 Subpart P App. F

***Protective systems for use in* excavations (trenches) more than 20 feet in depth, must be designed by a registered professional engineer…**
For trenches and excavations less than 20 feet in depth…Soil classification is required when shoring or shielding is used. The excavation must comply with one of the following options:

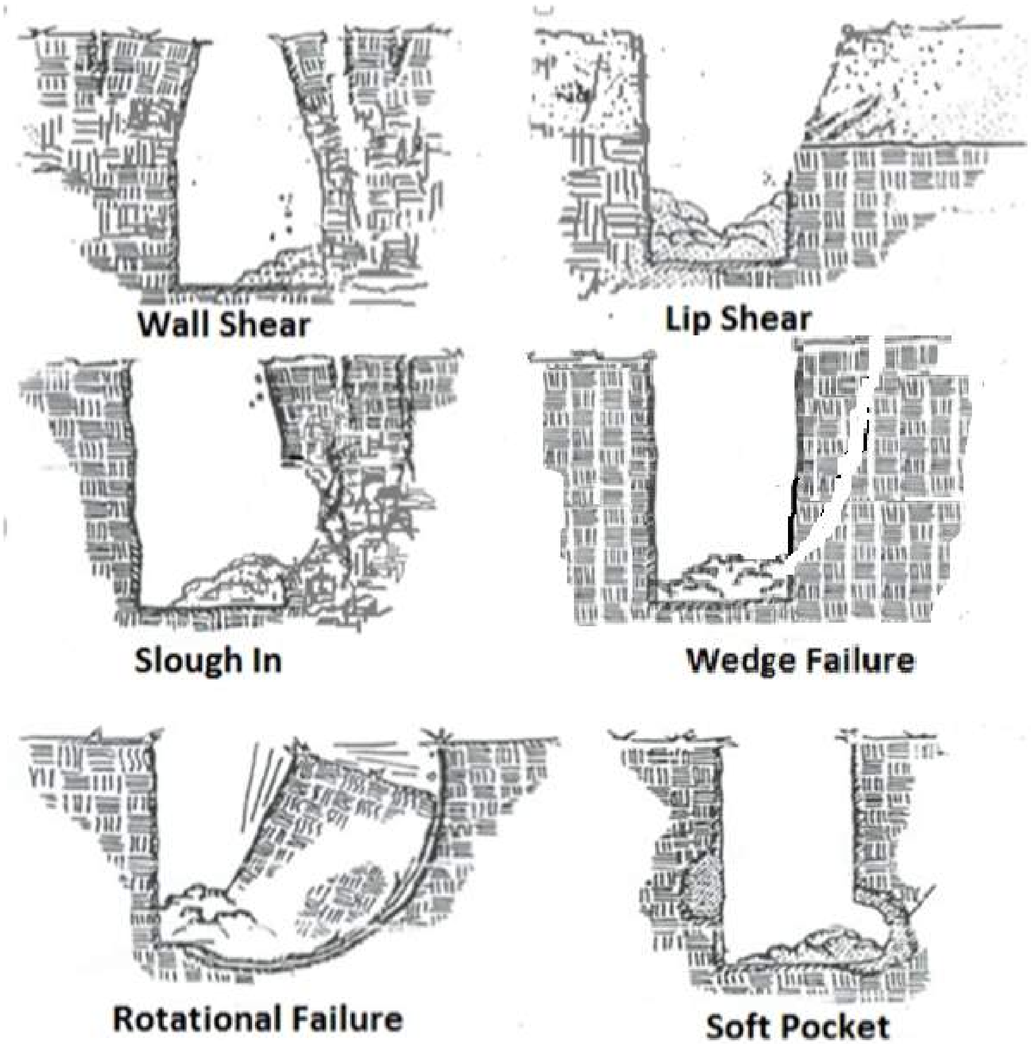
- **Option 1- Timber Shoring**
    - Spec 1926.652 (c) (1)
    - RESCUE REALITY: Accurately measuring, cutting and installing timber shores is a time-consuming venture. The sequence for timber shore installation is top to bottom. This method does not provide the options needed to protect the victim from impending collapse. Trench rescue teams do not carry the timber sizes (cross braces, uprights and wales) required by OSHA to shore unstable (up to and including C-60) soil conditions.

- **Option 2- Hydraulic, air shores, jacks and shields**
    - Spec 1926.652 (c) (2) requires manufactures data to be followed
    - RESCUE REALITY: Manufacturer's tabulated data is designed for use by construction workers. It does not match up with the equipment and strut spacing used by rescuers to shore collapsed trench walls. Deviation from the specifications recommendations, and limitations issued or made by the manufacturer shall only be allowed after the manufacturer issues specific written approval.

- **Option 3- Any system as per other tabulated data**
    - Spec. 1926.652 (c) (3) requires tabulated data to be used
    - RESCUE REALITY: Engineers can use or create tabulated data other than what is provided by the manufacturers. The tabulated data shall be in written form and must explain the use and limitations of the data and information that will aid the user in selecting the proper protective system. This option is not commonly used by rescue teams.

- **Option 4- Professional engineer design**
    - Spec. 1926.652 © (4) requires the excavation shoring system to be designed by a Registered Professional Engineer
    - RESCUE REALITY: Engineers may design a shoring system that is independent of manufacturer and other tab data. Designs shall be in written form and shall include a plan indicating the sizes, types, and configurations of the materials to be used in the protective system. At least one copy of the design shall be present at the job site. The reality is that very few professional engineers have enough field experience with trench rescue soil conditions and rescue shoring methods to allow them to design shoring systems that be installed by rescuers in a manner timely enough to save a victim's life.

Section 2
Common Types of Trench Collapse



NOTE: See Section 4-Best Practices for void back-fill options

Section 3
SOIL BASICS

SOIL TYPES

Soil is made up of rock based material (grains), minerals, water (moisture), organic material and air. Since soil is made up of such diverse materials it is often divided into three basic types based on the size of the particles it contains. The basic types are **sand**, **silt** and **clay**. Most soils have a combination of clay, silt and sand. Sand has the largest particles and clay has the smallest. Sand particles can be seen by the naked eye. Clay and silt particles may only be seen with a microscope. Clay has the most internal strength (resistance) while sand has the least.

CLAY

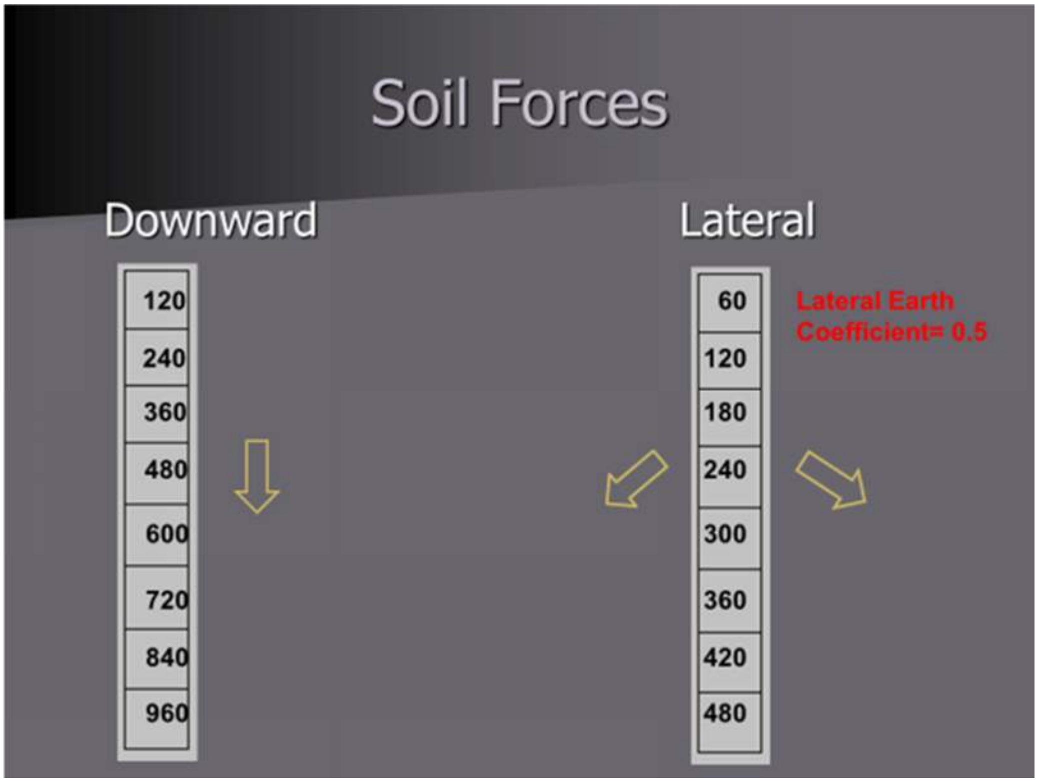
SILT

SAND

FORCES ASSOCIATED WITH SOILS

- **Downward (Gravitational) Force of Soil**
  Soil will typically weigh between 80 and 130 pounds per cubic foot (pcf).
  On average soil weighs about 100 psf. Soil that weighs 100 pcf will exert a downward force of 100 pounds for each cubic foot. There is a direct relation between gravitational potential energy and the mass of an object. More massive objects have greater gravitational potential energy.
- **Lateral Forces**
  The typical force that each square foot of weak soil will exert laterally or diagonally is approximately 50 percent of its weight per cubic foot. For example, a cubic foot of soil that weighs 120 pounds can exert a lateral force of 50% of its mass or 60 pounds of lateral force. Weak soil that has little cohesion (shear strength) can create lateral forces of more than 50% of its mass.

Factors that determine the lateral force of a given trench wall:
* Weight of the soil in pounds per cubic foot (pcf).
* Internal Friction angle in degrees
* Cohesion in pound per square foot (psf)
* Water content
* Surcharged loads

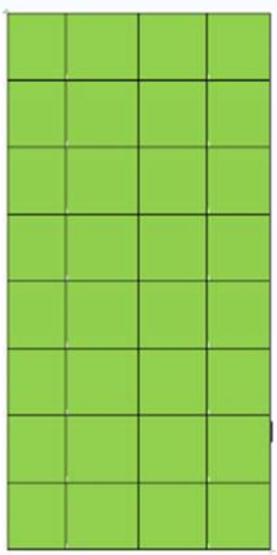


Calculating Lateral Forces for "At Rest" Soils

TRIBUTARY AREA

The tributary area is the square footage of the exposed wall (or section of wall) to be supported.

The area covered by one panel is 32 square feet (4' x 8'=32 square feet)



LATERAL FORCE

The tributary area (square footage) times the force times the depth of the strut.

32 x 60 x 4= 7,680

60	60	60	60
120	120	120	120
180	180	180	180
240	240	240	240
300	300	300	300
360	360	360	360
420	420	420	420
480	480	480	480

If we divide the 32 square foot tributary area in half (2 struts) we will see that the potential force at the bottom (strut) is much higher than the force at the top (strut).

60	60	60	60
120	120	120	120
.180	180	180	180
240	240	240	240
300	300	300	300
360	360	360	360
420	420	420	420
480	480	480	480

Upper Half #1- 16 x 60 x 2= 1,920
Lower Half #2- 16 x 60 x 6= 5,760

Resistant Forces

Pushing and pulling forces may be opposed by resistant forces such as friction, normal forces and in the case of soil "cohesive" and adhesive forces. Gravity and the resistant forces create a direction and magnitude called a vector (resultant) or a lateral force on the trench wall. Passive soil may turn active as changes (moisture content, surcharged loads etc.) occur. If the resistant force(s) of the soil are greater than the lateral force, rapid acceleration will not occur and the trench wall will remain standing for a while. When the lateral force overcomes the resistant forces the soil will become "active" (rapid acceleration) and the wall will collapse.

- **Soil Friction**
  Friction angle is a measurement of the particle shape. Perfectly round ball bearings will not stand in a pile. Ball bearings have a zero Internal Angle of Friction. Dry sand will form a cone when poured on a table. That is because the angular shape of the grains does not allow the particles to roll freely past each other. Sands and gravels typically have a friction angle of 30 to 35 degrees. The friction angle is also the natural angle of repose of the soil with zero cohesion. When processed gravel is stacked off a conveyor at a mine the pile forms a uniform cone that maintains a constant slope between 1.5 and 2 to 1.
- **Normal Force**
  Soil has a resistant force created by the soil surrounding it. It is an equal and opposing force. A cubic foot of soil six feet below grade (for example) is at rest because of the normal force (resistance) above, below and around it. When we dig a trench one side (of the six sides around, above and below) of that cubic foot of soil loses its normal resistance. It loses an opposing force from a lateral direction. That creates a path (vector force) of least resistance.
- **Cohesion**
  Cohesion is an attractive force between like molecules. The shape and structure of its molecules which makes the distribution of orbiting electrons irregular when molecules get close to one another, creating electrical attraction that can maintain a macroscopic structure. Cohesion contributes to the shear strength of soil, the glue that binds the grains together. Clay is the only soil type capable of electrical attraction (cohesion).
- **Moisture**
  If water is added to sand, it can be molded in intricate shapes such as sand castles often seen at the beach. The surface tension of the moisture (water) provides a bond between the sand grains. This adhesion presents a cohesive quality to the soil. The moisture present in most soils provides a cohesive quality. Often a gravel bank will safely stand on a 1 to 1 cut bank for a short duration. As the bank surface dries it will slide (move) to a 1.5 to 1 slope.

Passive Soil (Potential)

An object can store energy as the result of its position. The stored energy is called potential. A trench wall always has stored energy (potential force). The amount of potential energy is based on weight (mass) and depth of the wall (position). ***When the resistant force of soil (friction and cohesion) is enough to prevent the soil from moving we consider the conditions to be "passive soil".***

Active Soil (Kinetic Force)

In physics, kinetic force is anything that can cause a massive body to accelerate. It may be experienced as a push or a pull. Kinetic force (a pull or push that has overcome the resistant forces) has an active effect on the object. The continuous kinetic force that is pulling on a trench wall is gravity. Other forces that can cause soil to become active include vibrations and surcharged loads. Both of these can result from rescuers and equipment on the trench lip. ***When soil is moving it is unstable and we call it "active soil".***

Signs of active soil include fissures (cracks opening up),
soil falling or sliding off the wall (sloughing or raveling) and bulging walls.

SOIL CONDITIONS AT A TRENCH RECUE

Soil conditions at a trench rescue are usually much different than those present when the trench is first dug and when construction shoring should begin. During and shortly after the initial dig the soil is often at rest (passive). The internal strength of the soil allows the walls to remain intact and they can be shored before the soil begins to move and before cave-ins create void spaces in the walls. When the walls are intact, and the soil has not become visibly active empirically based theories such as “soil arching”, “elliptical strut pressure zones” and “zero movement” have merit. When the walls are moving (sloughing, raveling, cracking and caving) these theories become questionable at best. Clearly no quantitative value can be assigned to these theories when soil is active or has caved in. Because of the many differences between rescue shoring and construction shoring, trench rescue shoring systems must be designed and tested to resist “collapse” soil conditions which include:

- Soil which has not been shored (or not been properly shored) prior to it becoming visibly active.
- Soil which has caved in leaving voids in the wall(s). The walls are no longer intact or "monolithic" in appearance. Soil walls will act more like damaged URM than reinforced concrete walls.
- Continuous visible signs (sloughing, raveling, bulging, expanding fissures etc.) may or may not be apparent but the soil is unstable.
- Portions of vertical or "near vertical" walls exist.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Soil that has “caved in” has demonstrated the fact that it is “active”. Shoring methods used to shore passive soil should not be used. Despite our best efforts to prevent movement active soil will find the paths of least resistance. Shoring components and systems must be strong enough to support the potential forces of unstable soil.

RESCUE SOIL ASSESSMENT

A rescue soil assessment is a quick evaluation used to identify soil conditions, predict probable areas of collapse and to assign a level of risk to those conditions.
A rescue soil assessment is not the soil analysis and soil classification method required by OSHA for construction work. We must recognize the inherent differences of the soil conditions and the time available for analysis.

Performing Rescue Soil Assessment

1. **FAILURE POINTS:** Identification of failure points, either past or ongoing, will help predict the next collapse. The area of immediate concern is 6' to 8' on both trench faces at the trapped victim's location. Visual indicators of collapse (failure) include but are not limited to: (a) fissures or tension cracks on the surface (b) bulging of the walls (c) leaning of the walls (d) sloughing/raveling of the walls (e) seeping water from the walls or trench floor and (f) heaving or boiling soil from the trench floor.

2. **DIRECTION**: Once you have identified the failure point(s) in the victim area you will want to predict the initial movement (direction) of the collapse. Some soil types (cohesive) are more likely to topple (initial movement from the top tipping in- see TOPPLE image). Other types (granular) are more likely to slide (initial movement toward the bottom of the failure-see SLIDE image). Yet some of either type (when highly saturated or under water pressure) may flow. Very quick/basic visual and manual assessments can determine if the soil is more cohesive or granular and relative degree of wetting or presence of free moisture.

   <u>Visual Assessment</u>

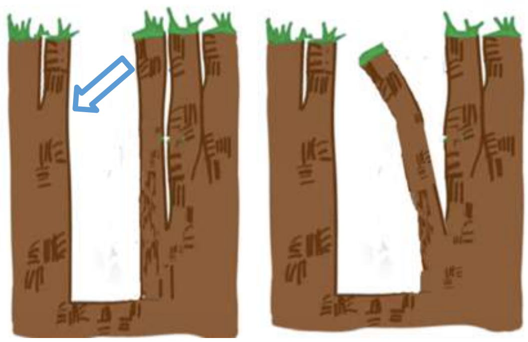
   a. **Spoil Pile:** Look at the spoil pile itself and the angle at which the standing soil is resting under its own weight. If you remember earlier, we defined this angle as the "angle of repose." If the excavated material is lying at a somewhat steep angle, it is most likely cohesive. If the angle at which it is resting is flat the soil is likely granular with little or no cohesion. Of course, do not forget the effects moisture can have on the spoil pile's angle. The free-standing time and the overall effects of drying can take what was once a fairly cohesive soil and over time turn it into a dangerously active soil potential
   b. **Soil Sample:** Look closely at a soil sample from the spoil pile. If you can easily see the individual grains, it is sand or gravel base. This means that it is not very cohesive and, therefore, has potential to become active, or fail. Likewise, if you look at the sample and it is difficult to make out the individual grains, it is most likely cohesive.

Manual Assessment

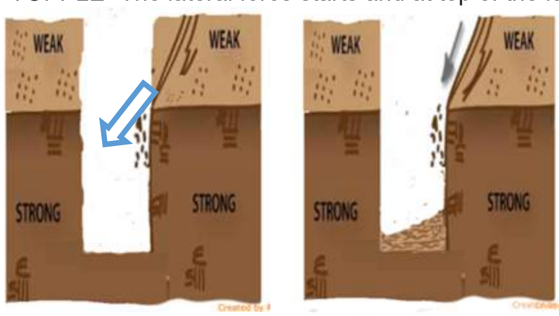
a. **Moldability:** Grab a sample of soil from the pile and slowly add water. As the water is added, try to mold the sample into a ball. If it will mold and stick together it contains clay. If you cannot mold the sample, it is sand or silt.

b**. Breakability:** Find a dirt clod and stomp on it with your foot. If the clod breaks, it is mostly silt—if your foot breaks, it is mostly clay. If there are no clods it is sand/gravel.

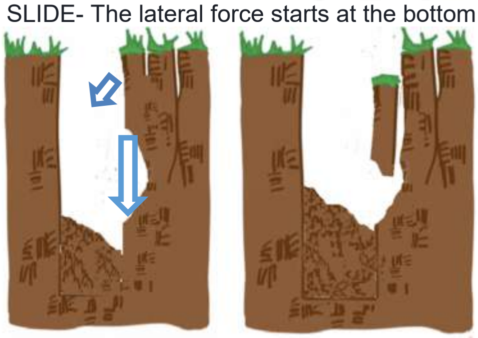
Still, other configurations (slough-in with an overhanging lip) are more likely to drop (see-DROP image). The initial "direction" of the movement of the failure will determine the selection and installation sequence of shoring equipment that will most likely stop the progression of an impending collapse.



TOPPLE- The lateral force starts and at top of the failure.



SLIDE- The lateral force starts at the bottom of the failure



DOWNWARD- Overhangs create a downward force

3. FORCE: The force that we are concerned about at a collapse scene is different than the “potential force” at a construction (OSHA A-25 psf, B-45 psf and C-80 psf) site. Soil at a collapse is unstable and moving. Rescue shoring must be designed to support moving rather than “at rest” soil forces. The lateral pressure from a moving section of trench wall can be safely calculated by using the weight of the soil and the soils lateral earth coefficient. For rescue situations (trench collapse) with trench walls that can be shored with panels and struts a lateral force of 66 pounds per cubic foot should be used. The lateral force can be calculated by using the number of cubic feet multiplied by the area (cubic feet) of the failure across the shoring system. For each 4’x4’ section of shoring 66 pcf creates just over 1,000 pounds of force. The downward force is the weight of the mass of soil that will be supported by the shoring system. Rescuers can use 130 pcf for that calculation

Section 4
“BEST PRACTICE” SHORING

At a trench rescue (cave-in) incident the soil is active and the walls are no longer intact. These facts require more than simply supporting passive soil to prevent cave-ins. Trench rescue shoring methods must include the support of active soil with damaged walls with large voids. Shoring methods which compensate for these voids and allow the shores to collect the load, transmit the load and distribute the load are required. Theories and shoring charts used for construction shoring have questionable application in this environment.

The strength of a trench rescue shoring system must exceed the soil force (pressure) of the section of the wall the system is installed in. The entire system as well as each component should be tested in a position of function (in a trench or excavation). Rescuers must understand the ultimate strength and “best practice” use of each component of a trench rescue shoring system

The following recommended (best) practices are the result of experimental testing, engineering analysis and shoring experience.

I.SHORING COMPONENTS

STRUTS- (used to transmit the load)

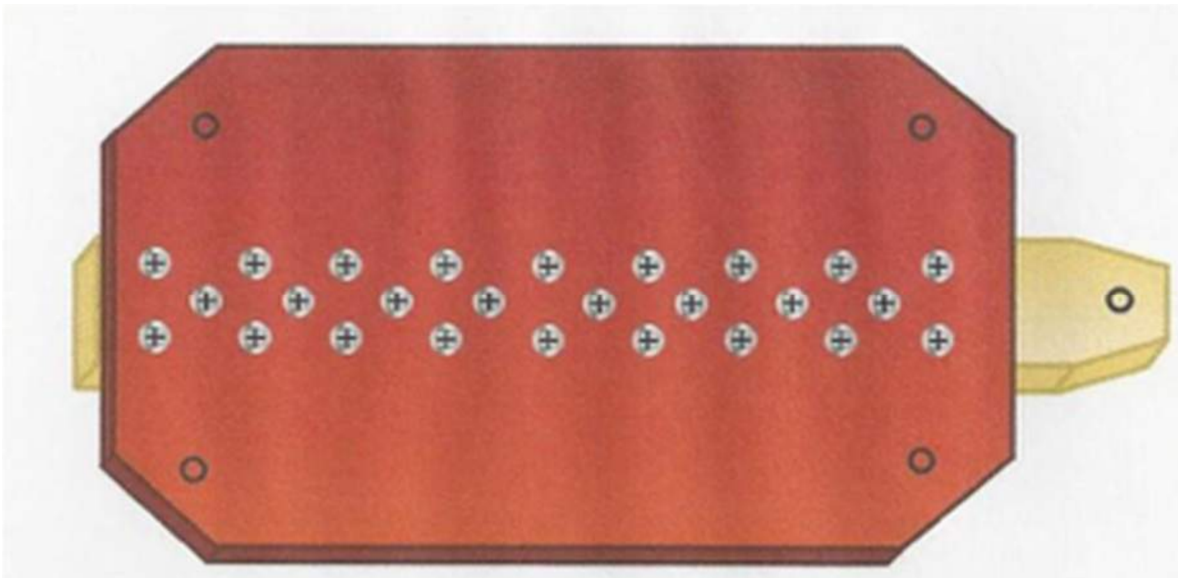
"Best practice" is the use of struts that can be installed and removed without entering the trench. Struts should have with adjustable lengths and activation pressures. Full compression strength can be achieved at activation forces of 1,000-1,250 pounds. (Paratech Gray @200-250 psi) (Paratech Golds@ 150-175 psi)

Non-entry strut installation and removal

Strut Summary

- Timber, pneumatic and hydraulic struts are commonly used for "cross braces" in trench rescue shoring. Tabulated data for the compression strength of struts is available. This data provides results which were obtained in laboratory testing environments (hydraulic press) where forces are perpendicular to the struts and where bearing points are uncompromised. Tabulated data for strut compressive strength should not be confused with the "ultimate strength" of a trench rescue shoring system when installed in a position of function (i.e. against distressed soil walls).
- The effect of pressure (pneumatic, hydraulic or mechanical) used to install struts is a subject of debate in the trench shoring industry. Most of the theories concerning this topic are based on conjecture and field observations from the underground construction industry. None have come from testing done in the types of trenches common to rescue incidents. The only actual study done on the effect that strut activation forces have on soil stability was done by Dr. Marie LaBaw in 2009.
- MUSAR Training Foundation tests have shown that strut pressure significantly increases the strength of the beam (strong-back or waler).

PANELS (used to collect the load and distribute the load)
"Best Practice" are panels constructed of ¾" Finnform with 1.75"x12" LVL" (Laminated Veneer Lumber) lumber glued and screwed to ¾" Finnform.
Shoring manufacturers recommend the use of panels and tight shoring whenever soil is active (sloughing, raveling, caving etc.). Panels should be used in shoring systems designed to protect rescuers whenever possible.

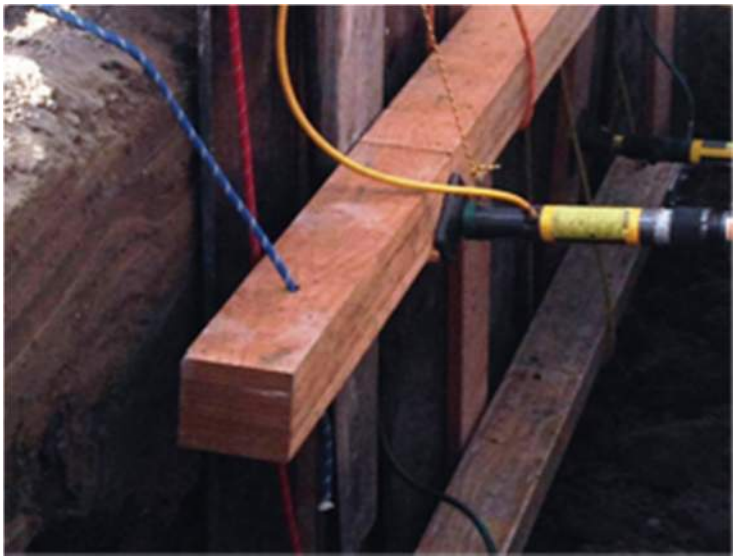


Screw layout for panel/strong-back attachment

Panel Summary

- Panels used in trench rescue are typically built from plywood attached to nominal 2"x12" or 2"x10" lumber (strong-backs).
- Because of its superior strength and ductility the use of Finnform (Choudoform) is considered a best practice. Tests conducted by the MUSAR Training Foundation have shown the ultimate failure strength of ¾" Finnform to exceed 30,000 pounds of force (distributed) between struts spaced at 4 feet on center)
- Strong-backs used by rescue teams are usually built from nominal 2"x12" or 2"x10" lumber. Their capacity varies greatly from sample to sample
- LVLs have a much more consistent capacity
- By themselves neither 2" thick nominal lumber nor 1.75" LVLs are capable of resisting the lateral force of Type C soil
- Strong-backs are commonly attached to panels but sometimes used by rescuers without panels

WALERS (used to span larger areas of trench walls and to replace missing sections of soil walls)
Best Practice is 7"x7" LVL beams with maximum surface contact on panels. Walers must not be bent during installation.



LVL Beam used as a waler

Waler Summary

- 6"x6" timbers are commonly used by rescue teams
- Typical spans of 8 feet (3 panels) are used
- 6"x6" timbers with a 8' span average breaking point is 14, 500 pounds of force
- 8"x8" timbers with a 8' span average breaking point is just under 40,000 pounds of force
- 7"x7" LVL with a 8' span average breaking point is over 45,000 pounds of force
- Aluminum Walers- MUSAR conducted a single test on an 8' Paratech aluminum waler. The waler failed (permanently deflected at just less than 17,000 pounds of force). Paratech comparisons to timber walers do not reflect the results of our test.

II.BACK-FILL

Back-fill is a generic term used for material and equipment that helps collect the load, distribute the load and minimizes soil movement. Commonly used back-fill methods include: Air bags,Backshores, Wood, Soil and Buttress.

AIR BAGS

"Best Practice" is the use of airbags for voids 18" to 40" with air pressure set at 0.5 (1/2) pound per square inch for every foot below the lip as measured at the center of the bag.

Low pressure air bag used to back-fill a void behind a primary panel

Air Bag Summary

- Low pressure (7.25 psi) and Medium pressure (14.5 psi) air bags are commonly used as back-fill.
- The force created by the bag (pressure x surface area) should match the soil pressure at the depth of bag installation.
- Air bags can be installed in voids with overhangs as well as in open lip area voids. They must be contained to prevent movement during and after inflation.

BACKSHORES

"Best Practice" is the use of backshores for voids accessible from the lip and greater than 48"

Backshores used to back-fill an inside corner collapse

Backshore Summary

- Backshores are struts placed on the back side of panels or walers. They must have a near vertical surface behind them.

WOOD

"Best Practice" is the use of wood for voids accessible from the lip between 2"-8"

Wood Backfill Summary

- Sections of timber, lumber and wood shims may be used to fill void in trench walls.
- Use of wood for back fill is only practical when a void exists at the lip. Wood should not be placed into the void until at least one strut has pressurized the panel set.
- It is very important to create full contact with the panel and the existing wall directly behind the strut.

SOIL

"Best Practice" is the use soil back-fill for voids accessible from the lip up to 18".

Rescuer compacting soil used for back-fill

Soil Backfill Summary

- Soil from the spoil pile may be shoveled into voids from the lip after the panels and at least one strut are in place.
- Soil should be compacted behind the panels after the struts are in place.
- Use of soil for back fill is only practical when a void opening exists at the lip.

BUTTRESS

"Best Practice" is the use of a buttress for large lip shear voids accessible from the lip which have left angled walls

Buttress used to shore a wall opposite a large lip shear

Buttress Summary

- A buttress can be constructed using timber or aluminum (pneumatic) struts.
- A buttress supports the back of a panel at the level of the lip. It can be used to resist the movement of the opposite wall but should only be counted on to resist the force transferred from the strut positioned two feet below the lip.
- A buttress does nothing to prevent soil movement from the wall that it is built on.

III.ARTIFICIAL RESISTANCE

PICKETS (used to resist vector forces created by angled struts)

Best Practice is the use 1" dia. picket driven 36" into compact soil

Pickets Summary

- *Angled struts are part of both excavation raker and intersecting trench shoring designs.
- *Anchor s commonly include 1" diameter cold rolled steel pickets
- *Pickets may be driven into trench floor and/or trench walls. In compact soil a 1" diameter picket driven 36" into the soil will fail at about 1,500 pounds of force.

CORNER BRACKETS (used to resist shear forces created at inside corner walls)

Best Practice is the use of 3/8" T6 6160 aluminum with quality welds

Corner Brackets used in a L-Trench with an inside corner collapse

Corner Bracket Summary

- *Brackets should be attached to panels with high shear strength ½" bolts

RATCHET STRAPS (used to resist shear forces created at inside corner walls)
Best Practice is the use of 4" ratchet straps with 10,000 breaking strengths

*Rat*chet s with the Paratech Thrust Block system

Ratchet Strap Summary

- *Ratchet straps are installed and tightened prior to full strut activation force on diagonal struts

IV. LIP PROTECTION

LIP BRIDGE (used to remove rescuer load from the trench lip)

Best Practice" is the use of lip bridges whenever the walls are unstable or have collapsed resulting in significant voids in the walls

Lip Bridge used to work over a slough in collapse

Lip Bridge Summary

- Built with girders (timbers), beams (ladders or timbers) and decking (plywood or lumber) and supports (sections of timbers placed away from the compromised wall) and used to elevate the bridge above the lip.

GROUND PADS (used to distribute rescuer load)

"Best Practice" is the use of ground pads when the trench walls are stable

Ground Pad Summary

- Ground Pads- 4'x8" sheets of ¾" plywood are used to distribute the weight of rescuers working on the lip.
- 2"x12"- 12' lumber is used as a ground pad on the spoil pile side of a trench.
- Ground pads help distribute the weight of rescuers but do not eliminate the load above weakened walls.

Warning: *Ground pads may hide the formation and expansion of fissures*

Section 5
TRENCH RESCUE SHORING PLAN

STEP 1: (TRENCH SHORING SIZE UP)

Purpose: Evaluate the trench for shoring needs.
Scope: The trench walls and lips surrounding the victim(s) area.
Procedure:

- **Soil Assessment**- Soil that has the ability to maintain nearly vertical walls (even after a partial collapse) can be shored with typical rescue shoring methods. Soil that cannot maintain nearly vertical wall long enough to be shored may have an at rest soil force of 80 psf or more and require a professional engineer's design and construction based shoring methods.
- **Trench Depth/Width**- Measure the depth and width of the trench from a safe position on the lip protection. Utilize shoring charts to determine shoring requirements based on trench depth and width. Trenches deeper than 20 feet and/or wider than 15 feet are beyond the scope of rescue shoring and shall require a professional engineer's design and construction based shoring methods.
- **Lip Protection**-Determine appropriate lip protection for shoring and panel team work. Ground pads are appropriate for stable soil conditions. Lip bridges are needed for working over unstable trench walls and trench walls with voids in them.
- **Collapse Potential**- Make an assessment of the location and mechanism of the next collapse. You will need to evaluate the soil conditions to determine if it is likely to topple, slide or drop. You will need to look for fissures, bulging, sloughing and raveling as well as the existing collapse and the void conditions in order to predict the area that is most likely to collapse next.
- **Void/Failures**- Measure or estimate void size and failure points. Determine the most appropriate back-fill method based on void size, location and wall angle.
- **Victim Condition**- Determine the condition of the victim(s). Calculated risks are appropriate for live victims. Higher shoring safety factors and/or construction based shoring methods which greatly reduce the risks for rescuers are appropriate for clearly deceased victims.

STEP 2: (PRIMARY SHORING)

Purpose: Rapidly protect the victim from the next most likely collapse
Scope: A shored area around the victim's head and chest. The shored area covers the exposed trench walls that are adjacent to the victim(s). The shored area is 4' wide and extends from the top to bottom of the trench walls.
Procedure:

- Position rescue panels on the walls adjacent to the victim(s)
- As soon as possible, install a strut that will support the largest section of the wall that is most likely to collapse next
- Install back-fill to cover a minimum of 80% of the void(s)
- Install a minimum of two struts per panel set. Primary panel sets usually have three struts. (Consult your shoring chart for strut spacing)

STEP 3: (SECONDARY SHORING)

Purpose: To create a safe area large enough for 2-3 rescuers to treat and extricate the patient
Scope: A shored area that is a minimum of 12 feet long (horizontal) and as high (vertical) as the trench wall.
Procedure:

- Position a panel set on each side of the primary shores
- Install a minimum of two struts per panel set (consult shoring chart for strut spacing)
- Back-fill behind secondary panels as needed to achieve 80% coverage of all voids

STEP 4: (COMPLETE SHORING)

Purpose: Enhance rescuer safety and provide supplemental shoring during soil removal for patient extrication.
Scope: A shored area around the victim(s) which has a minimum horizontal distance that is equal to or greater than the vertical distance (depth) of the trench wall.
Procedure:

- Install panels on one or both sides of the secondary panel sets
- Place minimum of two struts are in place on every set of panels
- Install back-fill to cover a minimum of 80% of all void(s)
- Install supplemental shoring each time 2 feet of trench wall is exposed during the digging (soil debris) removal process
- Activate all struts to the recommended force (strut pressure x surface area) in order to achieve a uniform force across the shored area
- Secure all struts (bases) to panels and wales with 16d nails

STEP 5: (SHORING ASSESSMENT)

Purpose: Evaluate and adjust shoring to maintain safety.
Scope: All shored areas and trench walls adjacent to the shored area
Procedure:

- Physically inspect all shores twice during the first hour and then once an hour:
  - Struts loosening- use the strut activation mechanism (pneumatic pressure, screw jack, wedges etc.) to adjust strut activation forces.
  - Increased soil force- Panels/wales bending. Having wood in your shoring system provides warning signs (creaking, groaning, popping noises)
  - When signs of loading are present add struts half way between existing struts to reduce the unsupported surface area on the bending wood members
- Visually check the walls (on both sides of the trench) that are next to the shoring for:
  - Signs of moving soil- Widening fissures, bulging, leaning, sloughing and raveling
  - Expand the shoring to support adjacent trench walls that are showing signs of movement.

MUSAR TRENCH RESCUE SHORING-POCKET GUIDE

IMPORTANT NOTICE:

The visible failures at a trench collapse provide valuable information about the soil forces that can be expected during short term, rescue shoring. This shoring chart uses an estimated soil load based on visible failures (cave ins or collapses) or signs of failure (fissures or soil cracking), known as “Failure Based Loading”. It is critically important to understand and notice the signs of soil failure and how it impacts the safety of the shoring system.

Shoring Size Up

- Assess the Trench for Default Shoring (soil, depth width)
- Assess the work area *(lip conditions, voids present, hazards)*
- Assess cave-in potential (*fissures, bulging, overhangs, layers, water, vibrations*)
- Assess voids/failures in wall(s) *(determine appropriate backfill)*
- Assess patient(s) condition *(rescue/recovery)*

Shoring Benchmarks

- Hazard Control (zoning, utilities, atmospheric conditions)
- Lip Safety *(ground pads, bridges)*
- Primary Shoring *(protect the patient)*
- Secondary Shoring *(create a safe zone for rescuers)*
- Complete Shoring *(expand safe zone/ supplemental shores)*

Component Spacing

PARATECH GRAY STRUT SPACING

MINIMUM SAFETY FACTOR of 2:1

Trench Width	Trench Depth	Horizontal Strut Spacing	Vertical Strut Spacing
8’	20’	4’	4’
8’-10’	8’	4’	4’
8’-10’	8’-14’	4’	3’
8’-10’	14’-20’	4’	2’

7”x7” LVL WALER SPACING

MINIMUM SAFETY FACTOR of 2:1

Trench Width	Trench Depth	Horizontal Strut Spacing	Vertical Waler Spacing
8’	10’	8’	4’
8’	10’-15’	8’	3’
8’	15’-20’	8’	2’

TRENCH RESCUE SHORING & STRUT SPACING
2:1 RESCUE-STRUT SPACING

CHART NOTES:

- This shoring chart is valid for most soil conditions found at trench rescue incidents
- This shoring chart provides a minimum factor of safety of 2 to 1
- This rescue shoring chart is conditional upon the following soil and shoring system conditions:

1. Shoring will be in use for less than 12 hours
2. Water level that is below the bottom of the trench
3. The bottom of the excavation is not "boiling"
4. The soil is not oversaturated and/or flowing
5. Spoil piles are set back at least 2 feet from the lip
6. Heavy equipment is set back from the lip a distance at least equal to the depth of the trench
7. Tight sheeting with composite panels (¾" 14 ply arctic birch panels with 12"x1.75" LVL strong backs screwed and glued together)
8. Struts must be placed within 10 degrees of level and 10 degrees of perpendicular (horizontal) to the trench walls
9. Use swivel bases on both ends of Paratech struts secured with (2) 16d nails in each foot
10. Do not use for trench widths greater than indicated in the chart
11. 80% of panel in contact with earth and voids behind panels are backfilled
12. Do not place any vertical loads on struts or wales (don't hang items from them, stand on them, climb them or cross shore to them)
13. Horizontal shoring distances should exceed the depth of the trench
14. This shoring chart is not designed for soil that will not stand up long enough to install shoring
15. After placement, warning signs to be aware of:
    a. Cracking and popping of the wood panels after installation is a sign of increasing loads
    b. If the panel deflection exceeds 1" between struts evacuate the trench and add an intermediate strut. Monitor panels to assure the deflection has stopped before reentering the trench.
    c. The strong back will generally break before the panel breaks
    d. If a strong back begins to break, evacuate the trench. From outside of the trench add a strut at the break location and monitor the panels closely for signs of increasing load (increasing deflection) or instability
    e. The interface between the strut feet and strong back most be monitored for excessive crushing of the wood
    f. Any movement of the in place shoring system indicates possible instability
    g. Continually monitor the lip of the trench for widening or growing cracks and fissures
16. For all trenches a strut must be within 2' (below) the lip and within 2' feet (above) the trench floor. Maximum vertical spacing is 4 feet.