Introduction

Excavating and trenching are recognized as one of the most hazardous and dangerous of all construction operations. OSHA revised “Subpart P—Excavations” of 29 CFR 1926.650, .651, and .652 to make the standard easier to understand, permit the use of performance criteria where possible, and provide employers with options when classifying soil and when selecting employee protection methods.

This overview on Trenching and Shoring is intended to assist employers, superintendents, foreman, field staff, and others in the recognition of the hazard of trenching and preventing collapses.

Trench/Excavation Definitions

Accepted Engineering Practices – Those requirements which are compatible with standards of practice required of a registered professional engineer.

Adjacent Structure Stability – Concern for the foundation(s) of adjacent structures whose location may create surcharges, changes in soil conditions or other disruptions which extend into the “failure zone” of the excavation or trench.

Competent Person – One who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

Confined Space – A space which by design and/or configuration has limited openings for entry and exit, unfavorable natural ventilation, which could contain or produce hazardous substances, and not intended for continuous employee occupancy.

Excavation/Trenching – Excavation means any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal. Trench means a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 meters). If forms or other structures are installed or constructed in an excavation so as to reduce the dimension measured from the forms or structure to the side of the excavation to 15 feet (4.6 meters) or less (measured at the bottom of the excavation), the excavation is also considered to be a trench.

Failure Zone – The area between the vertical face of the excavation and the maximum allowable slope per Table B-1 in Appendix of the Excavation Standard.

Hazardous Atmosphere – An atmosphere which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, may cause death, illness, or injury.

Ingress/Egress – The providing for safe employee entry and/or exit from the excavation or trench.

Protective Systems – A method of protecting employees from cave-ins; from material that could fall or roll from an excavation face or into an excavation; or from the collapse of adjacent structures. Protective systems include support systems, sloping and benching systems, shield systems, and other systems that provide the necessary protection.

Registered Professional Engineer – A person who is registered as a professional engineer in the state where the work is to be performed. However, a professional engineer, registered in any state, is deemed to be a “registered professional engineer” within the meaning of this standard when approving designs for “manufactured protective systems” or “tabulated data” to be used in interstate commerce.

Support System – A structure such as underpinning, bracing, and/or shoring, which provides support to an adjacent structure, underground installation, or the sides of an excavation or trench.

Subsurface Encumbrances – Consist of underground utilities, foundations, underground streams, high water tables, transformer vaults as well as geological anomalies.

Surcharge – An excessive vertical load or weight caused by spoil, overburden, vehicles, equipment and/or other activities which may affect trench stability.

Tabulated Data – Tables and charts approved by a registered professional engineer and used to design and construct a protective system.

Underground Installations – These include, but are not limited to, utilities (sewer, telephone, fuel, electric, water, as well as other product lines), tunnels, shafts, vaults, foundations, or other underground fixtures or equipment that reasonably may be encountered during excavation and/or trenching work.

NOTE: For a variety of reasons, several terms commonly used in the past, are no longer used in the standard. These include:

- Angle of Repose – conflicting and inconsistent definitions have led to confusion as to the meaning and intent of the old standard. This term has been replaced by Maximum Allowable Slope.
- Bank, Sheet Pile, Slope and Walls – previous definitions were unclear and/or their use in the standard was inconsistent.
- Hard Compact Soil and Unstable Soil – the soil classification system uses new terms.

Continued on reverse...
Soil Mechanics

There are a number of stresses and deformations that can occur in an open cut or trench. Increase or decrease of Moisture Content for example can adversely affect the stability of a trench or excavation. The following are some of the more frequently identified causes of trench failures. A CRITICAL WORD OF CAUTION: “Boiling” and “Heaving” can occur even with shoring and/or shielding properly installed.

Heaving or Squeezing – Bottom heaving or squeezing is caused by the downward pressure created by the weight of adjoining soil. This pressure has a tendency to cause a bulge in the bottom side of the cut.

Boiling – This condition is evidenced by an upward water flow in the bottom of the cut. A high water table is one of the causes of boiling. Boiling causes a “quick” condition in the bottom of the cut and can occur even when shoring or trench boxes are used.

Tension Cracks – The formation of tension cracks usually occur at a horizontal distance of 0.5 to 0.75 times the depth of the trench measured from the top of the vertical face of the trench.

Sliding – Sliding or “sluffing” is a condition that may be encountered as a result of “tension cracks”.

Toppling – The other result of “tension cracks” is that of toppling. This is where the trench’s vertical face shears along the tension crack line and topplies into the excavation.

Subsidence and Bulging – An unsupported excavation can create an unbalanced stress in the soil which in turn causes subsidence at the surface and bulging of the vertical face of the trench. Uncorrected this condition can cause face failure and entrapment of the workers in the trench.

Unconfined Compressive Strength – Is the load per unit area at which a soil will fail in compression. It can be determined by laboratory testing, or estimated in the field using a pocket penetrometer, by thumb penetration tests, and other methods.

Unit Weight of Soils – The weight of soil varies with type and moisture content. One cubic foot of soil can weigh from 110 to 140 plus pounds. One cubic meter (35.3 cubic feet) of soil can weigh as much as a pickup truck, in excess of 3000 pounds.

Determination of Soil Type

OSHA recognizes four types of soil and rock deposits which are identified as follows:

Stable Rock – Natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed. This type of deposit may be difficult to determine if it is unknown whether cracks exist and whether or not the cracks run into or away from the excavation.

“Type A” Soil – Cohesive soils with an unconfined compressive strength of 1.5 tons per square foot, tsf, (144 kPa) or greater. Examples of “Type A” cohesive soils are: clay, silty clay, sandy clay, clay loam and, in some cases, silty clay loam and sandy clay loam.

No soil is “Type A” if it is fissured, subject to vibration of any type, been previously disturbed, or is part of a sloped, layered system where the layers dip into the excavation on a slope of 4 horizontal to 1 vertical (4H:1V) or greater and has seeping water.

“Type B” Soil – Cohesive soils with an unconfined compressive strength greater than 0.5 tsf (48 kPa) but less than 1.5 tsf (144 kPa). Examples of “Type B” soils are: angular gravel; silt; silt loam; previously disturbed soils unless otherwise classified as “Type C”; soil that meets the unconfined compressive strength or cementation requirements for “Type A”, but is fissured or subject to vibration; dry unstable rock; and, sloped layered systems sloping into the trench at a slope less than 4H:1V but only if the material would be classified “Type B”.

“Type C” Soil – Cohesive soils with an unconfined compressive strength of 0.5 tsf (48 kPa) or less and include granular soils including gravel, sand and loamy sand, submerged soil, soil from which water is freely seeping, submerged rock that is not stable. Also included is material in a sloped, layered system where the layers dip into the excavation or has a slope of four horizontal to one vertical (4H:1V) or greater.

Layered Geological Strata – Where there is a layered geologic structure the soil classification shall be based on the weaker layer. Each layer may be classified individually where a more stable layer lies below a less stable layer, i.e. A “Type C” soil resting on top of “Stable Rock”.

Testing and Test Equipment

Pocket Penetrometer – Is a direct reading spring-operated instrument that is used to determine unconfined compressive strength of saturated cohesive soils. Once pushed into the soil an indicator sleeve holds the reading until it is read. The instrument is calibrated in either tons per square foot (tsf) or kilograms per square centimeter (kPa).

Shearvane (Torvane) – This instrument requires the use of a conversion factor of 2 which must be used to multiply the device’s reading in order to obtain the unconfined compressive strength. To obtain a reading the blades of the vane are pressed into a level section of undisturbed soil, the torsional knob is slowly turned until soil failure occurs. The direct instrument reading times 2 will then provide results in tons per square foot (tsf) or kilograms per square centimeter (kPa).

Thumb Penetration Test – The procedure is to attempt to firmly press the thumb into the soil. If the thumb makes an indentation in the soil with great difficulty, it is probably a “Type A” soil. If the thumb penetrates no further than the length of the thumb nail, it is probably “Type B” soil, and if the thumb penetrates the full length of the thumb, it is “Type C” soil. The thumb test is subjective and the least accurate of the three methods.

Dry Strength Test – Dry soil that crumbles on its own or with moderate pressure into individual grains is granular. Dry soil that falls into clumps which break into smaller clumps, but the smaller clumps can only be broken with difficulty, is probably clay in combination with gravel, sand or silt. If the soil breaks into clumps which do not break up into small clumps and which can only be broken with difficulty, and there is no visual indication the soil is fissured, the soil may be considered to be unfissured.
Plasticity or Wet Thread Test – Mold a moist sample of the soil into a ball and attempt to roll it into a thin thread approximately 1/8 inch (3 mm) in diameter (thick) by two inches (50 mm) in length. Hold the soil sample by one end. If the sample does not break or tear it is cohesive.

Visual Test – This is a qualitative evaluation of the conditions around the site. Observe the excavation site in general, soil adjacent to the site, indications of vibration, and type of soil being excavated. If it remains in clumps, it is cohesive; if it appears to be coarse grained sand or gravel, it is granular.

Check for crack-like openings along the failure zone which would indicate tension cracks. Look for existing utilities which would serve to identify previously disturbed soil. Observe the open side of the excavation for indications of layered geologic structuring.

Look for signs of bulging, boiling, sluffing, as well as for signs of surface water seeping from the sides or the location of the water table. If there is standing water in the cut, check for “quick” condition.

Check the area adjacent to the excavation for signs of foundations or other intrusions into the failure zone. Check for surcharging and the spoil distance from the edge of the excavation.

Shoring Types - Uses and Applications

Shoring – There are primarily two basic types of shoring, timber and aluminum hydraulic. Shoring is a support system for trench faces used to prevent movement of soil, underground utilities, roadways and foundations. Shoring and/or shielding is used when the location and/or depth of the cut make sloping back to the maximum allowable slope impractical.

Shoring consists of posts, wales, struts, and sheeting. The trend today is toward the use of hydraulic shoring, a prefabricated strut and/or wale system manufactured of aluminum or steel. Hydraulic shoring provides a critical safety advantage over timber shoring in that workers do not have to enter the trench in order to install or remove the shoring. Most hydraulic systems provide the following advantages:

- Light enough to be installed by one worker.
- Gauge-regulated to ensure even distribution of pressure along the trench line.
- Able to “pre-load” trench faces, thereby using the soil’s natural cohesion to prevent movement.
- Easily adapted to suit various trench depths and widths.

All shoring should be installed from the top down and removed from the bottom up. Hydraulic shoring should be checked at least once per shift for leaking hoses and/or cylinders, broken connections, cracked nipples, bent bases, and any other damaged or defective parts.

Pneumatic Shoring – Pneumatic shoring works in a manner similar to hydraulic. The primary difference is that pneumatic shoring uses air pressure in place of hydraulic pressure. A disadvantage to the use of pneumatic shoring would be the need for the presence of an air compressor.

Screw Jacks – Screw jack systems vary from hydraulic and pneumatic systems in that the struts of a screw jack system are manually adjusted. This creates a hazardous condition as the worker is required to be in the trench in order to adjust the strut. Uniform “pre-loading” is not able to be achieved with screw jacks and their physical weight creates handling difficulties.

Single-Cylinder Hydraulic Shores – Are generally used in a water system, as an assist to timber shoring systems and in shallow trenches where face stability is required.

Underpinning – Is the process of stabilizing adjacent structures, foundations and other intrusions which impact the excavation. As the term indicates it is a procedure where the foundation or exposure is physically reinforced. Underpinning should be conducted only under the direction and approval of a registered professional engineer.

Shielding Types - Use and Application

Trench boxes are different from shoring as they are not usually intended to shore up or otherwise support the trench faces. Trench boxes serve the purpose of protecting workers from cave-ins and other similar incidents.

The excavated area between the outside of the trench box and the face of the trench should be as small as possible. Trench boxes can serve as a support system for trench faces if the area between the trench box and the trench face is back filled. Shields shall not be subjected to loads exceeding those which the system was designed to withstand.

Trench boxes are generally used in open areas but may be used in combination with sloping and benching. The box should extend at least 18 inches (0.45 m) above the surrounding area. This can be accomplished by providing a benched area adjacent to the box.

Earth excavation to a depth of 2 feet (0.61m) below the shield is permitted, but only if the shield is designed to resist the forces calculated for the full depth of the trench and there are no indications while the trench is open of possible loss of soil from behind or below the bottom of the support system. Conditions of this type require documented calculations and recommendations from a registered professional engineer.

Calculations should be also include considerations for bulging, heaving and boiling. Careful consideration shall be given to the effect surcharging, vibration, adjacent structures, and similar type situations would have on excavating below the bottom of a shield.

Careful visual inspection of the above referenced condition offers the primary and most prudent approach to hazard identification and control.

Sloping

Sloping – Maximum allowable slopes for excavations less than 20 feet (6.09 m) based on soil type and angle to the horizontal are as follows:

<table>
<thead>
<tr>
<th>Type</th>
<th>Slope</th>
<th>Maximum Allowable Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable Rock</td>
<td>vertical</td>
<td>(900)</td>
</tr>
<tr>
<td>Type A</td>
<td>3/4:1</td>
<td>(530)</td>
</tr>
<tr>
<td>Type B</td>
<td>1:1</td>
<td>(450)</td>
</tr>
<tr>
<td>Type C</td>
<td>1 1/2:1</td>
<td>(340)</td>
</tr>
</tbody>
</table>

Benching – There are two basic types of benching: simple and multiple. The type of soil determines the horizontal to vertical ratio of the benched side. In layered soil there can be a combination of benching and sloping configurations.
As a general rule, the bottom vertical height of the trench should not exceed 4 feet (1.2 m) for the first bench. Subsequent benches may be up to a maximum of 5 feet (1.5 m) vertical to a total trench depth of 20 feet (6.0 m). All subsequent benches shall be below the maximum allowable slope per soil type.

**Spoil**

**Temporary Spoil** – Should be placed no closer than 2 feet (0.61 m) to the surface edge of the excavation. This measurement is from the nearest base of the spoil to the cut. It should not be measured from the crown of the soil deposit. The weight of the spoil creates surcharging which can affect the stability of the trench.

Spoil should be placed so that it channels rain water and other run-off water away from the excavation. Spoil should be placed so that it cannot accidently run, slide or fall back into the excavation.

**Permanent Spoil** – Permanent spoil should be placed in a predetermined location which should be some distance from the working excavation. This condition exists at locations where underpasses are to be constructed and utilities have to be lowered.

Improper placement of permanent spoil can cause a complying excavation to fall out of compliance with horizontal to vertical ratio requirements. This can be easily determined through visual observation. Permanent spoil can also change an undisturbed soil condition to a disturbed soil condition. This could dramatically change the slope requirements.

**Special Health and Safety Considerations**

**Competent Person** – The designated competent person should be able to demonstrate the following:

- Training/experience and knowledge of:
  - Soils analysis.
  - Use of protective systems.
  - Requirements of 29 CFR, Part 1926, Subpart P.
  - Capability of detecting:
  - Conditions that could result in cave-ins.
  - Failures in protective systems.
  - Hazardous atmospheres.
  - Other hazardous conditions including confined spaces.
  - Authority to take prompt corrective measures:
  - To eliminate existing and predictable hazards.
  - To stop work when required.

**Surface Crossing of Trenches** – Surface crossing of trenches should be discouraged, however, if trenches must be crossed, such crossings may be permitted only under the following conditions:

- Vehicle crossings must be designed by and installed under the supervision of a registered professional engineer.
- Walkways or bridges shall be provided for foot traffic. These structures shall:
  - Have a safety factor of 4.
  - Have a minimum clear width of 20 inches (0.51 m).
  - Be fitted with standard rails.
  - Extend a minimum of 24 inches (0.61 m) past the surface edge of the trench.

**Ingress/Egress** – Access to and exit from the trench:

- Trenches 4 feet or more in depth should be provided with a fixed means of egress.
- Spacing between ladders or other means of egress should be so placed that a worker will not have to travel more than 25 feet laterally to the nearest means of egress.
- Ladders must be secured and extend a minimum of 36 inches (0.9 m) above the landing.
- Caution should be used in the use of metal ladders particularly when electric utilities are present.

**Exposure to Vehicular Traffic** – To prevent employees from being injured or killed by vehicular traffic:

- Employees must be provided with and shall wear warning vests or other suitable garments marked with or made of reflectorized or high-visibility materials.
- A designated and trained flagperson or additional law enforcement as needed, along with signs, signals, and barricades may be required for traffic control.

**Exposure to Falling Loads** – Employees must be protected from loads or objects that might fall from lifting or digging equipment.

- Employees shall never be permitted to work under raised loads.
- Employees shall be required to stand away from equipment that is being loaded or unloaded.
- Equipment operators or truck drivers may stay in their equipment if it is properly equipped with a cab shield or adequate canopy.

**Warning Systems for Mobile Equipment** – Steps should be taken to prevent vehicles from accidently falling into the trench.

- Barricades should be installed where necessary.
- Hand or mechanical signals should be used as required.
- Stop logs should be installed if there is danger of vehicles falling into the trench.
- Grade away from the excavation, this will assist in vehicle control as well as the channeling of run-off water.

Continued on reverse...
**Hazardous Atmospheres** – Employees shall not be permitted to work in hazardous and/or toxic atmospheres. Appropriate action may include either engineering controls such as mechanical ventilation or the use of respirators. Hazardous atmosphere conditions include:

- Atmospheres having less than 19.5% or more than 23.5% oxygen.
- Combustible gas concentration greater than 20% of the lower flammable limit.
- Exposure to materials or substances at a concentration above those specified in the “Threshold Limit Values of Airborne Contaminants” of the American Conference of Governmental Industrial Hygienists.

**Testing for Atmospheric Contaminants:**

- Testing should be conducted before employees enter the trench and should be done on a recurring basis to assure that the trench remains safe. The frequency of the testing should be increased if equipment is operating in the trench.
- Testing frequency should also be increased if there is welding, cutting or burning taking place in the trench.

Employees required to wear respiratory protection must be trained, fit-tested and placed in a respiratory protection program.

Trenches may satisfy the elements defining a confined space. When this occurs, compliance with the Confined Space Standard shall be required.

**Emergency Rescue Equipment** – Is required when a hazardous atmosphere exists or can reasonably be expected to exist.

- Respirators must be of the type suitable for the exposure. Employees must be trained in their use and a respirator program must be instituted.
- Attended (at all times) lifelines must be provided when employees enter bell-bottom pier holes, deep confined spaces or other similar type hazards.
- Employees who enter confined spaces must be trained.

**Standing Water - Water Accumulation** – Methods for controlling standing water or water accumulation must be provided and should consist of the following if employees are permitted to work in the excavation:

- The use of special support or shield systems approved by a Registered Professional Engineer.
- Water removal equipment, ie: well pointing, is used and monitored by a competent person.
- Safety harnesses and lifelines are used in conformance with 29 CFR 1926.104. Surface water is diverted away from the trench.
- Employees are removed from the trench during a rain storm.
- Trenches are carefully inspected by a competent person after each rain storm and before employees are permitted to re-enter the trench.

**Inspections** – Inspections shall be made by a competent person and should be documented. The following is a guide on when to conduct inspections:

- Daily and before the start of each shift.
- As dictated by the activity taking place in the trench.
- After each and every rain storm.
- After other phenomena that would increase the hazard: snowstorm, windstorm, thaw, earthquake, etc.
- When fissures, tension cracks, sloughing, undercutting water seepage, bulging at the bottom or other similar circumstances occur.
- When there is any change in the size, location or placement of the spoil pile. When there is any indication of change or movement in adjacent structures.

**Site Assessment**

1. Is the cut, cavity or depression a ...
   ___Trench  ___Excavation
2. Is the cut, cavity or depression more than 4 feet in depth?
   ___Yes  ___No
3. Is there water in the cut, cavity or depression?
   ___Yes  ___No
4. Are there adequate means of access and egress?
   ___Yes  ___No
5. Are there any surface encumbrances?
   ___Yes  ___No
6. Is there an exposure to vehicular traffic?
   ___Yes  ___No
7. Are there adjacent structures that require stabilizing?
   ___Yes  ___No
8. Is there a warning system for mobile equipment?
   ___Yes  ___No
9. Is there a competent person in charge of the operation?
   ___Yes  ___No
10. Is equipment operating in or around the cut, cavity or depression?
    ___Yes  ___No
11. Are procedures required to monitor, test and control hazardous atmospheres?
    ___Yes  ___No
12. Has the soil type been determined by the competent person?
    ___Yes  ___No
13. Was a soil testing device used to make the determination?
    ___Yes  ___No
14. Is the spoil placed 2 feet or more from the edge of the cut, cavity, or depression?
    ___Yes  ___No

Continued on reverse...
15. Is the depth of the cut, cavity, or depression over 20 feet?
   ___Yes   ___No

16. Has the procedure, if the depth is over 20 feet, been approved by a registered professional engineer?
   ___Yes   ___No

17. Does the procedure require benching/multiple benching?
   ___Yes   ___No

18. Does the procedure require shoring?
   ___Yes   ___No

19. Does the procedure require shielding?
   ___Yes   ___No

20. Do the shields, if provided, extend at least 18 inches above the surrounding area?
    ___Yes   ___No

21. Does the depth of the cut extend more than 2 feet below the bottom most part of the shield?
    ___Yes   ___No

22. Are surface crossings, if required, the proper width and fitted with standard hand rails?
    ___Yes   ___No

23. Are means of egress provided to ensure that no more than 25 feet of lateral travel are required to exit the cut?
    ___Yes   ___No

24. Is emergency rescue equipment required?
    ___Yes   ___No

25. Is the minimum daily excavation inspection documented?
    ___Yes   ___No