Safe Excavation and Trenching

Loss Control TIPS

Introduction

Implementing an effective excavation/trenching program is a key ingredient to ensure a successful construction project. Although hazards associated with excavation and trench work are recognized and preventable, and OSHA regulations mandate appropriate controls be established, accidents and fatalities resulting from cave-ins continue to occur at an alarming rate.

Excavation is defined as any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal. A trench is a narrow excavation (in relation to its length) made below the surface of the ground. Generally the depth of a trench is greater than the width and the width is not greater than 15 feet.

According to the NIOSH Fatality Assessment and Control Evaluation (FACE) Program, trenching and excavation hazards resulted in at least 542 construction fatalities from 1992–2001, or an average of over 54 deaths annually. Although cave-ins account for the majority of the fatalities (76% of the total according to the FACE Program), other causes include falls, struck-by, caught in, electrocution, drowning, and asphyxiation incidents. In addition, excavation and trenching hazards are prevalent causes of nonfatal lost time injuries in construction. Fatalities and severe injuries to construction workers are not the only concerns during excavation and trenching projects. A poorly planned excavation or trench can also result in significant property damage if an underground utility line is struck. Damage to an underground utility (i.e. electricity, water, sewage, natural gas, oil, telecommunications, cable, etc.) can cause significant damage, disrupt service, and may adversely affect the environment or the safety of the public.

According to *Dig Safely*, (http://www.digsafely.com/about.htm) a national campaign to address damage prevention to underground utilities administered by DOT's (Department of Transportation) Office of Pipeline Safety, utility strikes during excavation and trenching operations are the leading cause of service disruption to the nation's underground facilities. Excavation and trenching projects also may create a public safety and/or "attractive nuisance" exposure, which must be addressed. An unattended open trench or excavation is an invitation for disaster. Many states have public safety statutes that are designed to protect non-workers from trenching and excavation hazards.

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Develop an Excavation/Trenching Program

Construction employers should:

- Preplan all excavation or trenching work
- Provide appropriate protective systems
- Ensure sufficient means of egress
- Include provisions for pre-inspection and continuous monitoring
- Control mobile equipment and vehicular traffic
- Provide employee training

With certain exceptions, OSHA Standard 1926.652 requires that employees be protected from cave-ins by an adequate protective system (refer to http://www.osha.gov/ for more information).

Preplanning

Preplanning an excavation or trenching project is necessary to ensure that workers are protected, utility lines are not struck, and the general public is protected. Planning should begin during the bidding process and should specifically identify the route of excavation, depths of cuts, protective system(s) to be used, means of egress, equipment use, location of underground utilities, traffic control, communication, and rescue provisions. Responsibilities for safety and health should be clearly identified before any project begins. Management should designate who will act as the "competent person" at each construction site. A competent person is one who is capable of identifying hazards in the workplace and who has the authority to take prompt corrective measures to eliminate them.

Notify Utility Companies

OSHA Standard 1926.651 and state laws require the notification of utility companies prior to digging. The National One-Call Directory provides the utility locators in each state; thedirectory can be found at http://www.digsafely.com. The excavator requests the location of underground utilities at a given site by notifying the appropriate utility company through the one-call system. The excavator receives and maintains a reference number from the one-call center that documents the request. The excavator is then notified by the appropriate utility company that a "no conflict" situation exists (negative response) or the tolerance zone of the underground utility is marked or flagged (positive response). Many states require the excavator to mark the route of excavation (commonly referred to as "white-lining") with white paint, flags, or stakes before the locator arrives at the site and/or participate in a preexcavation meeting with the locator. Utility companies, or contracted locators, utilize standard color-coding to identify the type of underground line as listed in figure 1. A proactive approach for excavators is to document utility markings using dated pictures, videos, or sketches with distance from markings to fixed objects recorded. If locate markings are adequately documented before excavation work begins, the excavator will be more successful resolving disputes if an underground line is damaged due to improper marking, failure to mark, or markings that have been moved, removed, or covered. This simple added step of documenting utility markings may help avoid unnecessary litigation and expensive legal fees for the excavator.

Another method to document or verify underground utilities is the use of portable mapping or locating equipment such as GPS (global positioning system), metal detectors, MF (magnetic field) detectors, acoustic detectors, and GPR (ground penetrating radar) detectors. Each of these devices has advantages and disadvantages associated with their use dependent upon the type of utility line (i.e. metallic vs. plastic pipe), depth of utility, and soil conditions. Always follow the manufacturer's recommendations regarding calibration, set-up, use, and results interpretations of any mapping or locating device.

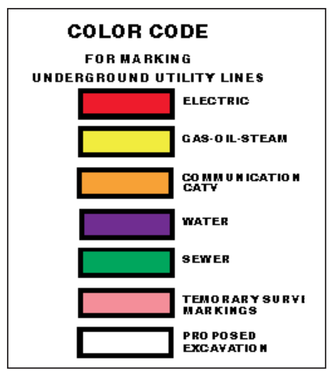

Figure 1: Color Code of Underground Utilities

- Red – Electric
- Yellow – Gas, Oil, Steam
- Orange – Communication: Telephone, Fiber Optics, CATV, etc.
- Blue – Water
- Green – Sewer
- Pink – Temporary Survey Markings
- White – Proposed Excavation

Excavation Failure

When an excavation is cut, the system is disturbed and no longer stable. The combination of tension in the ground surface and shear stress causes cracks to form beyond the edge of the excavation. When cracks develop, the weight of the soil in the excavation wall causes great stress to the lower portion of the excavation wall. Since there is no lateral stress to prevent the failure, the bottom of the excavation fails, or "kicks", into the excavation and the failure begins. An excavation may fail from the top, in the middle (referred to as bulging), and/or at the bottom. Other external factors, besides the excavation itself, often contribute to the cavein. External factors include water flow (precipitation, flooding, surface runoff), wind, freezing and thawing, vibrations from construction equipment and/or vehicular traffic, loads from spoilbanks along the excavation edge, and excavating in previously disturbed soils.

Soil is a mixture of rock, water, air and trace amounts of other substances (i.e. organic material such as peat, roots, and other plant matter). Soil can be composed of various sizedparticles such as clay, silt, sand, gravel, and stone. The amount of water filling the air spaces in soil determines its percent of saturation. Engineering properties of soil vary based on particle size, shape, texture, and composition. In addition, soil properties will vary along the length and depth of an excavation. Undisturbed soil is usually made up of many layers of various compositions and is considered to be in equilibrium and is perfectly stable.

The average untrained laborer does not understand the danger of an excavation failure. Saturated soil weighs approximately 114 lbs per cubic foot, which equates to approximately 3,078 pounds per cubic yard, or a little over 11/2 tons; roughly the weight of a small pick-up truck! An excavation failure will usually occur with no warning and will cause many yards of soil to fall in a matter of seconds. Statistics indicate that the majority of victims who are killed from excavation collapse will suffocate or be crushed by the soil around them.

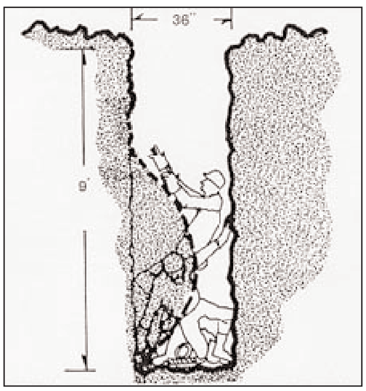

Figure 2: Diagram provided by the OSHA Office of Training & Education, Fatal Facts Summaries

Soil Classification
Soil classification of an excavation is one of the duties of the competent person. OSHA requires soil classification and testing in accordance with 1926 Subpart P, Appendix A. The classification of soil deposits must be made based on the results of at least one visual and at least one manual analysis. In a layered system, the system must be classified in accordance with its weakest layer. However, layers may be classified individually where a more stable layer lies under a less stable layer. Reclassification is required whenever conditions affecting its classification change in any way. OSHA 1926 Subpart P categorizes soil and rock as:

- ***Stable Rock*** – natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed. Examples include granite and sandstone.
- ***Type A Soils*** – cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (tsf) or greater. Examples include clay, silty clay, and clay loam.
- ***Type B Soils*** – cohesive soils with an unconfined compressive strength greater than 0.5 tsf but less than 1.5 tsf. Examples include angular gravel, silt, silt loam, and sandy loam.
- ***Type C Soils*** – cohesive soils with an unconfined compressive strength of 0.5 tsf or less. Examples include granular soils such as gravel, sand, and loamy sand, submerged soil, soil from which water is freely seeping, and submerged rock that is not stable.

Inspections
OSHA Standard 1926.651(k) requires inspection of excavations, the adjacent areas, and protective systems used. Inspections should be performed:

- Daily and before the start of each shift;
- As needed by the work being done;
- Following rainstorms;
- After other events that could increase hazards (i.e. snowstorm, windstorm, thaw, vehicle or equipment approaching the edge of an excavation);
- When fissures, tension cracks, sloughing, undercutting, water seepage, bulging at the bottom, or other similar conditions occur;
- When there is a change in the size, location, or placement of the spoil pile; and

When there is any indication of change or movement in adjacent structures. Inspections must be conducted by a competent person who:

- Has training in soil analysis;
- Has training in the use and limitations of protective systems;
- Is knowledgeable of the OSHA requirements; and
- Has authority to immediately eliminate hazards.

In order to properly document all inspections, records should be maintained. A sample excavation inspection guide, developed by OSHA, can be found at the following web-link.

http://www.osha.gov/SLTC/etools/construction/trenching/excavchec.html

Whenever an inspection reveals a condition that may lead to a possible cave-in, potential failure of a protective system, hazardous atmosphere, or any other hazardous condition, the competent person must immediately instruct the removal of all exposed employees from the excavation.

Egress
Inadequate access and egress to and from an excavation is the cause of many severe injuries from slips or falls and is one of the most commonly cited OSHA violations found at excavation projects. Proper access and egress is needed for normal entry and exit from the excavation as well as to facilitate a quick evacuation in the event of an emergency. Access/ egress, in the form of stairways, ladders, or ramps, are required for all trenches or other excavations that are 4 feet or more in depth. Means of egress must be positioned within 25 feet of lateral travel for workers, thus two means of egress must not be positioned greater than 50 feet apart; see figure 3. All ladders must extend at least 36″ above the landing. Metal ladders should be avoided, especially when electric utilities are present. Structural ramps used for access or egress from excavations must be designed by a competent person. Earthen ramps as a means of egress must be designed so a worker can walk them in an upright position. To protect employees from loose rock or soil falling or rolling from an excavation face, spoil and other equipment or materials must be kept at least 2 feet from the edge of excavations; see figure 4.

Surface Hazards
If surface hazards are not adequately controlled in the vicinity of an excavation, it may result in excavation failure. Mobile equipment must be kept away from an excavation edge by providing warning systems, erecting barricades, using equipment stop logs, and/or utilizing hand and mechanical signals. The vibration alone from mobile equipment can create an excavation failure. Soil should be graded away from an excavation to assist in vehicle control as well as help channel run-off water. Employees are not allowed to work under raised loads and must be instructed to stand away from equipment that is being loaded or unloaded. If vehicular traffic is nearby, employees must be provided with and required to wear reflective vests or other suitable garments marked with or made of reflectorized or high-visibility materials. In addition, trained flag persons, signs, signals, and barricades should be provided.

Surface crossing of trenches should be avoided unless absolutely necessary (i.e. no alternative access). However, if necessary, such crossings are permitted under the following conditions:

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

Protective Systems

OSHA Standard 1926.652 requires protective systems be used when an excavation is 5 feet or greater in depth (or less than 5 feet deep when conditions indicate a potential for cave-in); the exception being excavations made entirely in stable rock. Protective systems used in excavations with a depth of 20 feet or greater must be approved by a licensed professional engineer. Designing and/or selecting the appropriate protective system(s) for a project are one of the roles of the competent person. Factors that must be considered in choosing an appropriate system include soil classification, depth of cut, water content of soil, changes due to weather and climate, space limitations, and other operations in the vicinity. Protective systems are commonly categorized as:

- Sloping and Benching
- Shoring
- Shielding
- Engineered Design

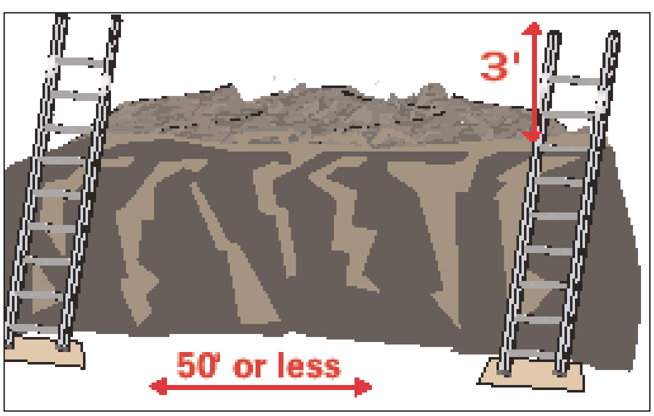

Figure 3

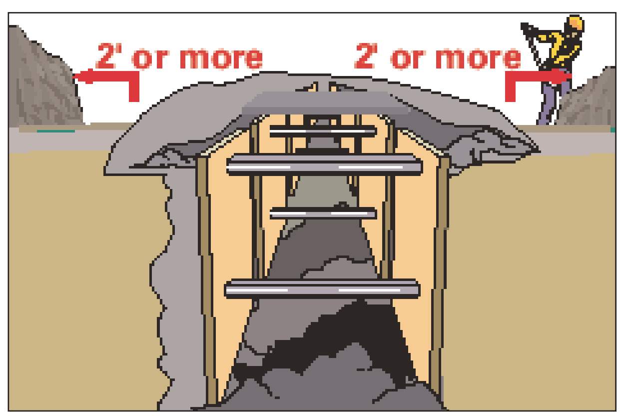

Figure 4

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Sloping and Benching

Sloping removes soil to an extent to maintain its stability, keeping forces in equilibrium, thus preventing it from caving under its own weight. Benching is similar to sloping except the sides of the excavation form a stair-stepping design. Both sloping and benching require a significant amount of space since the face of the excavation is cut back to an acceptable slope angle. Table 1 outlines the maximum slopes for each soil type when sloping or benching is used.

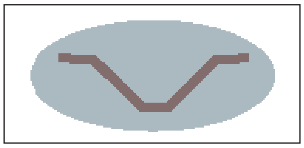

Figure 5: Sloping

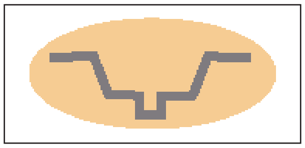

Figure 6: Benching

Table 1: Maximum Allowable Slopes

SOIL OR ROCK TYPE	MAXIMUM ALLOWABLE SLOPES (H: V) FOR EXCAVATIONS LESS THAN 20′ DEEP
Stable Rock	Vertical (90º)
Type A Soil	0.75: 1 (53º)
Type B Soil	1: 1 (45º)
Type C Soil	1.5: 1 (34º)

When soil classification is not conducted the excavation walls should be sloped for type C soil (34º angle or less) unless written tabulated sloping/benching data is used or the system was designed by a registered professional engineer.

Shoring

Shoring excavated walls provides support to prevent soil movement. This type of protective system is used when the location or depth of cut makes sloping back to the maximum allowable slope impractical. Shoring systems consist of posts, wales, struts, and sheeting. They may run vertically or horizontally as in a waler system. Traditional timber shoring has generally been replaced with the lighter, easier to handle, aluminum hydraulic or pneumatic shoring. Pneumatic shoring works in a manner similar to hydraulic shoring but it uses air pressure instead of hydraulic pressure; thus an air compressor must be available on-site to use pneumatic shoring. The advantages of aluminum shoring include:

- Ease of use (light enough to be installed by one worker)
- Provides an even distribution of pressure along the excavation wall
- Can be adapted easily to various trench depths and widths
- Protective system of choice when obstructions (i.e. existing utility lines) traverse the trench

All types of shoring should be installed from the top down and removed from the bottom up. 1926 Subpart P Appendix C offers tabular data that can be used for installing timber shoring and Appendix D provides information for selection and installation of aluminum shoring.

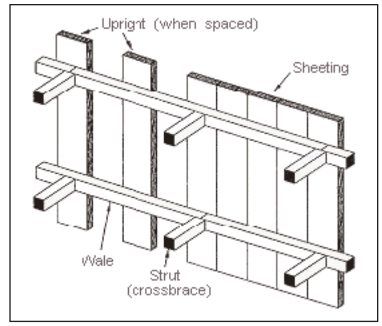

Figure 7: Timber Shoring

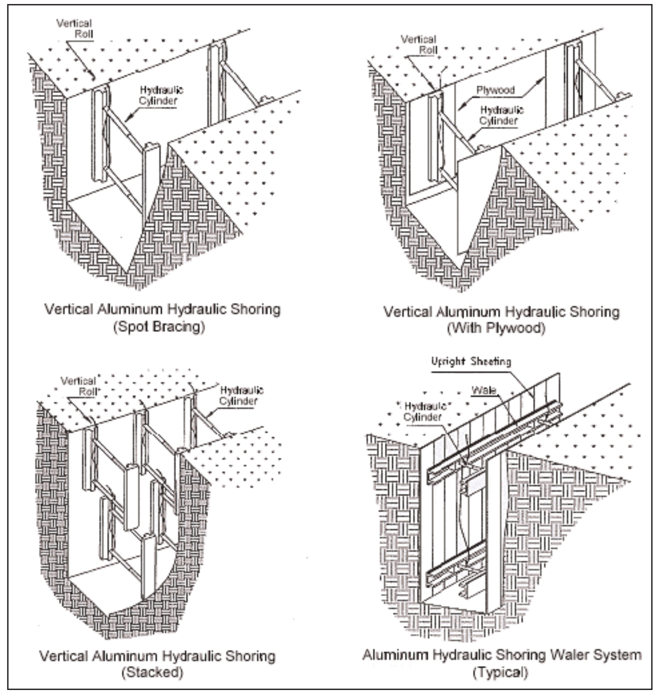

Figure 8: Aluminum Hydraulic Shoring

Shielding

Shielding provides a safe work area within an excavation, even if the soil fails. Trench shields, commonly called trench boxes, do not prevent soil movement but are designed by manufacturers to be strong enough to withstand the lateral earth pressure from a failure. The excavated area between the outside of the trench box and the excavation face should be as small as possible. The competent person must ensure the trench box used is rated for the type of soil and depth of cut. Instruct employees to stand away from a trench box being set or removed, provide proper access/egress to and from the trench box, and prohibit employees from staying in the trench box when it is being moved vertically. Any structural modifications to the trench box must be approved by a licensed professional engineer. Trench boxes can be used alone, in series,

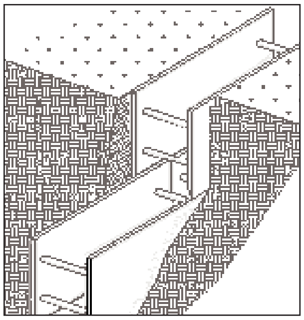

Figure 9: Trench Shield

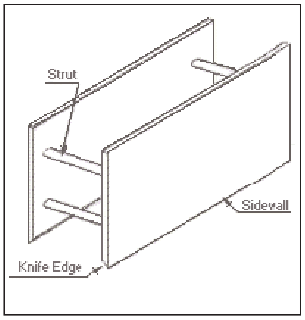

Figure 10: Trench Shields Stacked

stacked, or in combination with sloping and benching. The trench box must extend at least 18 inches above the surrounding area if there is sloping toward the excavation. Since OSHA 1926 Subpart P does not address trench shield design, contractors must rely upon data from the supplier or manufacturer.

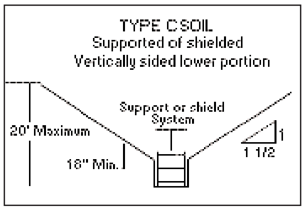

Figure 11: Trench Shield Used with Sloping

Engineered Design System
Other protective systems not addressed in OSHA 1926 Subpart P are categorized as a sitespecific engineered design system. Examples include steel sheet piling systems, soldier pile systems, screw jack systems, tie back systems, and rock bolting systems. The installation of a soldier pile system is illustrated in figure 12.

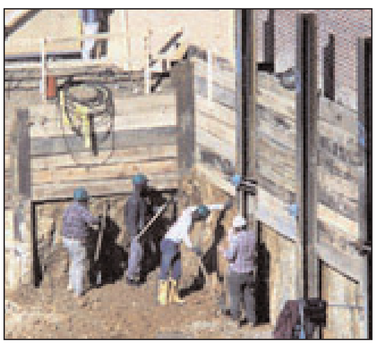

Figure 12: Installation of Soldier Pile System

As previously mentioned, the competent person must choose the appropriate protective system(s) for a project. Although the protective system most often used is the trench shield, it should not be the only system considered. In the event a trench box is not practical (i.e. trench box is too large for the excavation, will not fit around existing utilities, the surface area doesn't allow enough space to set the trench box, etc.) a secondary system should be readily available to all excavation work crews. Aluminum hydraulic shoring is a very good selection for a secondary system since it is lightweight, portable, easy to install, and works well in confining spaces.

Water Accumulation

Surface water should always be diverted away from a trench and employees should not be allowed to work in excavations during a rainstorm or when there is accumulated water. Excavations must be carefully inspected by a competent person after each rainstorm before employees are permitted to re-enter. Whenever water removal equipment is needed, it must be monitored by a competent person.

Water is almost always damaging to an excavation and is the cause of many excavation failures. Water can alter the soil's weight, density, and lateral pressure by entering the air voids of the soil. Water also reduces soil's shear strength by decreasing its internal friction, disrupting the particle-to-particle attraction (cohesion) between clay particles, and may cause soil to expand. The dipolar nature of water allows it to travel upward against gravity by means of surface tension and capillary action to disrupt the cohesion of sand and silt particles. Surface water run-off quickly fills tension cracks exerting downward and lateral pressure that forces the cracks to become deeper and wider. Frozen soil will quickly lose its cohesion and shear strength when it starts to thaw. Since rain and other storm events can cause such devastating effects to an excavation, supervisors of an excavation project should stay updated on local weather forecasts.

Hazardous Atmospheres

Employees should not be permitted to work in hazardous and/or toxic atmospheres. Such atmospheres include those with:

- Less than 19.5% or more than 23.5% oxygen;
- A combustible gas concentration greater than 20% of the lower flammable limit; and
- Concentrations of hazardous substances that exceed those specified in the Threshold Limit Values for airborne contaminants established by the ACGIH® (American Conference of Governmental Industrial Hygienists).

Where oxygen deficiency or a hazardous atmosphere exists or could reasonably be expected to exist, OSHA requires the competent person to test the excavation before allowing employees to enter and to retest thereafter to ensure that the excavation remains safe. Conditions that may warrant atmospheric testing would be excavations made in a landfill area or if the excavation crossed, was adjacent to, or contained pipelines with a hazardous material (i.e. natural gas). Atmospheric testing may also be warranted if welding, cutting, burning, or painting is performed within the excavation or if equipment used within the excavation may produce byproduct emissions (i.e. carbon monoxide). Some trenches qualify as confined spaces. When this occurs, the OSHA Permit-Required Confined Space Standard would apply.

Rescue

Preplanning for rescue should be performed for all excavation projects even if the risk of excavation failure is minimized with the use of an appropriate protective system. Work related injuries such as a fall, struck-by, caught in, and electrocution, as well as non-occupational injuries (i.e. heart attack, seizure, etc.) may necessitate emergency rescue from an excavation. In addition, emergency rescue provisions are required for deep trenches or excavations in which a hazardous atmosphere may exist.

Rescue procedures to safely evacuate personnel from an excavation site should be included in the company's emergency action plan and should specify means of communication, emergency notification, rescue equipment, personnel training, and coordinating off-site emergency medical services. The competent person should ensure that each excavation site is readily accessible for rescue vehicles or preplan other means to transport injured personnel in the event of an emergency incident.

If an excavation failure partially buries a worker, never attempt to pull the person out using a rope, belt, sling, or chocker. Rescue attempts are typically performed by hand to avoid causing additional damage. Emergency rescue personnel must also be protected from excavation failure (i.e. with the use of aluminum shoring) since removing a partially buried victim often loosens surrounding soil creating another collapse. The competent person is responsible for ensuring that all emergency equipment and supplies are on-site and in good condition.

Training

The designated competent person on an excavation site must be trained, and have experience in soil analysis, use of appropriate protective systems, and OSHA 1926 Subpart P. In addition, the competent person must be able to detect:

- Conditions that could result in cave-ins;
- Failures, defects, and limitations of protective systems;
- Hazardous atmospheres; and
- Other hazards including those associated with confined spaces.

Remember, the competent person must also have the authority to take prompt corrective measures to eliminate existing and predictable hazards and to stop work when required.

Involving all employees associated with an excavation project is a critical component in keeping the jobsite safe. Emphasize specific rules and job responsibilities during regulartraining sessions. These rules may include requirements that workers:

- Remove or minimize all surface obstacles;
- Wear warning vests or other reflective or high-visibility clothing;
- Wear or use prescribed protective gear and equipment correctly;
- Operate equipment only after being properly trained;
- Stay alert for potential excavation failure and other worksite hazards; and
- Follow safe work practices.

Enforcement

A contractor's excavation/trenching program is only as good as its enforcement program. A program that mandates the use of protective systems is worthless without the means to enforce it. Many excavation fatalities occurred with contractors that had an established excavation/trenching program but a single shortcut or error in judgment resulted in a catastrophic event. If all employees and supervisors are not held accountable for safe excavation, then excavation failures will inevitably occur. Excuses such as "the trench box didn't fit", "we only had to access the trench for a very short time", or "it never collapsed before" should never be tolerated. A written disciplinary/enforcement policy specific for the use of excavation protective systems should be developed and implemented. The policy should be introduced to new employees during orientation training, clearly communicated to all employees on a regular basis, and enforced fairly amongst all employees and supervisors. Allowing exceptions to the enforcement policy will eventually lead to an ineffective program.

For More Information

For additional information specific to your need, please contact your Hartford loss control consultant, or visit us at http://www.thehartford.com/corporate/losscontrol/

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