Module 11: Excavations

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Module Description

Cave-ins are considered the most dangerous trench and excavation hazard. Other potentially fatal hazards also exist in excavations, such as asphyxiation due to lack of oxygen in a confined space, inhalation of toxic fumes, flammable gases, falls, and water accumulation that can cause drowning. The OSHA standards exist to protect workers in trenches and excavations.

This module gives you a basic understanding of how to work safely in excavations and what important points and requirements must be considered when working in an excavation.

Module Learning Objectives

At the conclusion of this module, you should be able to:

- Identify factors that pose a hazard to employees working in excavations
- Discover how to protect employees from cave-ins
- Describe the role of a competent person at an excavation site
- Explore other related issues associated with excavations

Lesson 1: Standards and Protection

Lesson Focus

This lesson focuses on the following topics:

- OSHA Standards
- The Dangers of Excavations
- Protection of Employees
- Choosing a Protective System
- Installation and Removal of Protective Systems
- Warning System for Mobile Equipment

OSHA Standards

OSHA Standards Application

The OSHA standards are applicable to all man-made open excavations in the earth's surface. Excavations by definition include trenches.

OSHA Standards Exemptions

House foundation/basement excavations (including those that become trenches by definition when formwork, foundations, or walls are constructed) are exempt from the OSHA requirements for protective systems if they meet the following conditions:

- *The house foundation/basement excavation is less than seven and one-half feet in depth or is benched for at least two (2) feet horizontally for every five (5) feet or less of vertical height.*
- *The minimum horizontal width (excavation face to formwork/wall) at the bottom of the excavation is as wide as practicable but not less than two (2) feet.*
- *There is no water, surface tension cracks, nor other environmental conditions present that reduce the stability of the excavation.*
- *There is no heavy equipment operating in the vicinity that causes vibration to the excavation while employees are in the excavation.*
- *All soil, equipment, and material surcharge loads are no closer in distance to the top edge of the excavation than the excavation is deep; however, when front-end loaders are used to dig the excavations, the soil surcharge load shall be placed as far back from the edge of the excavation as possible, but never closer than two (2) feet.*
- *Work crews in the excavation are the minimum number needed to perform the work.*

- *The work has been planned and is carried out in a manner to minimize the time employees are in the excavation.*

Note: While some residential construction operations may be exempt from the OSHA standards, this does not imply that no related hazards exist. Employers and employees should remain vigilant in ensuring the safety of all workers exposed to the associated dangers.

The Dangers of Excavations

Excavating is considered one of the most hazardous operations in the field of construction. An excavation is any man-made cut, cavity, trench, or depression in the earth's surface formed by earth removal.

Hazards

The dangers of excavations come from the possibility of cave-ins, in addition to the possibility of the following:

- Lack of oxygen-asphyxiation
- Fire
- Accidental break of underground utility (such as gas, electricity) lines
- Collapse due to moving machinery near the edge of the excavations
- Inhalation of toxic materials
- Water accumulation

Adjacent Structure

Any structure that is built or constructed in the surrounding area of an excavation is called an adjacent structure. The main concern when excavations are created near an adjacent structure is the structure's stability. Excavations near adjacent structures may create surcharges, changes in soil conditions, or other disruptions that could lead to an excavation accident.

Protection of Employees

OSHA's primary purpose is to protect employees from hazards present in the workplace. Employers must protect employees from accidents related to cave-ins by designing, implementing, and enforcing use of excavation protective systems.

Exceptions to the requirement for excavation protective systems include circumstances where:

- Excavations are made entirely in stable rock.

- Excavations are less than 5 feet (1.52 m) in depth, and examination of the ground by a competent person provides no indication of a potential cave-in.

Protective systems shall have the capacity to resist without failure all loads that are intended or could reasonably be expected to be applied or transmitted to the system.

Sloping

Protective systems include sloping and benching systems, shield systems, and support systems. A well designed protective system is one that works for the type of soil, depth of cut, and the type of construction being performed in the trench.

> **More Information:** Correct design of sloping, support, shield, benching, and other protective systems is crucial.

Benching

Benching refers to the formation of one or a series of horizontal levels or steps along the side walls of an excavation, often with vertical or near-vertical surfaces between levels.

Shoring or Shielding

Shoring provides support to excavation walls. It is often used where the location or depth of the cut makes sloping back to the maximum allowable slope impractical.

Trench Boxes or Shields

Both trench boxes and shoring serve to protect workers from cave-ins. Trench boxes differ from shoring, however, in that trench boxes are shields provide continuous equal protection on two sides of an excavation for the entire length of the box.

Some important factors related to the proper installation of trench boxes are:

- The excavated area between the outside of the trench box and the face of the trench should be as small as possible.
- The space between the trench box and the excavation side may be backfilled (or other means may be used) to prevent lateral movement of the box.
- Shields may not be subjected to loads exceeding those which the system was designed to withstand.

Trench boxes are usually made of aluminum or steel, and may be used in combination with sloping and benching. In addition, trench boxes must be inspected regularly, properly maintained, and used under the supervision of a competent person.

More Information: Vibrations from continuous traffic along the adjacent road can undermine the soil and cause a cave-in.

Aluminum Hydraulic Shoring

Hydraulic trench support systems can be directly dropped into an excavation. By increasing hydraulic pressure, the qualified operator can prevent the forms from moving or shifting while workers are in the trench. In addition, trench pins are installed in case of hydraulic system failure.

Choosing a Protective System

The following factors should be considered when designing an effective excavation protective system:

- Soil classification
- Depth of cut
- Water content of soil
- Changes due to weather and climate
- Other operations in the vicinity
- Availability of various protective equipment

Note: Excavations 20 feet and greater in depth must have a protective system that is planned and designed by a professional engineer. The plan must be stamped by the registered professional engineer and kept on the project site.

Installation and Removal of Protective Systems

When installing support systems, the following requirements are vital for proper employee protection:

- Securely connect members of support systems
- Safely install support systems
- Never overload members of support systems
- Install other structural members to carry loads imposed on the support system when temporary removal of individual members is necessary
- Backfilling shall progress together with the removal of support systems from excavations

Warning System for Mobile Equipment

If mobile equipment is operated adjacent to or near an excavation, or when such equipment is required to approach the edge of an excavation, and the operator does not

have a clear and direct view of the edge of the excavation, some type of warning system must be implemented.

Types of warning systems include:

- Barricades
- Hand or mechanical signals
- Stop logs

Likewise, the grade should slope away from the excavation, if possible.

Excavations

Excavations must be immediately filled back to their normal state after completing the work. Once the excavation has been cleared, workers should carefully remove the protective system, starting from the bottom up, while taking care in releasing all supporting members.

Excavations under sidewalks and pavements are prohibited unless you provide an appropriately designed support system or another effective means of support. The standard requires you to take the following steps to protect employees when installing support systems:

- Connect members of support systems securely,
- Install support systems safely,
- Avoid overloading members of support systems, and
- Install other structural members to carry loads imposed on the support system when you need to remove individual members temporarily.

> **More Information:** Construction of excavations under sidewalks and pavement are not allowed unless a properly designed support system is in place, or other effective supporting means have been implemented.

Case Study

An Excavation Collapsed

This accident occurred when earth that fell into an excavation at an agricultural channel was being removed.
The original project called for a trench to be excavated so that two drainage pipes could be installed. On the day of the accident, a water pipe that was already buried in the trench at a depth of 28 inches was broken by a landslide. This caused earth to fall into the trench.

There were three workers on this project. Soon after the project began, a worker, not working inside the trench, noticed a crack in the earth near the edge of the excavation. The worker immediately warned the workers inside the excavation. All three workers attempted to exit the trench, but all could not get out before the slope of the trench collapsed. One worker who was working at the bottom of the trench was buried by the fallen earth and later died.

Reasons

- Lack of appropriate operations plans.
- Sufficient measures were not taken to protect against collapse of the ground.
- The work was being performed without proper supervision.
- Protective systems were not in place.

Lesson Summary

Excavating is considered one of the most hazardous operations in the field of construction. Excavations must be immediately filled back to their normal state after work is completed.

Trench boxes are usually made of aluminum or steel, and may be used in combination with sloping and benching. Trench boxes must be inspected regularly, maintained properly, and used under the supervision of a competent person. Once the excavation has been cleared, workers should carefully remove the protective system, starting from the bottom up, while taking care with the releasing of supporting members.

Lesson 2: Essentials of Excavations

Lesson Focus

This lesson focuses on the following topics:

- Hazardous Conditions
- Access and Egress
- Falls and Equipment
- Planning
- Competent Person

Hazardous Conditions

Materials and Equipment

Employers are responsible for ensuring that materials and equipment are in good working condition since damaged and defective materials and equipment could cause excavation accidents.

To prevent accidents and hazards, the employer must ensure that:

- Equipment and materials are not damaged or defective.
- Manufactured equipment is stored according to the directions of the manufacturer and in such a way that will prevent employees' exposure to any related hazards.
- Any damaged equipment or defective material is removed from service and not used until it is evaluated and approved or rejected by a registered professional engineer or competent person, as appropriate.

Spoils

Employees must be protected from material or equipment that could fall or roll into excavations. Adequate retaining devices must be installed to protect exposed excavation workers. Spoils (removed soil) must be placed in such a way that water (rain, ruptured pipes, etc.) is diverted away from the excavation.

> **More Information:** Never place spoils within two feet of an excavation's edge.

Water Accumulation

OSHA standards prohibit excessive water accumulations or any water accumulation where properly monitored water removal equipment is not in place when workers are in the trench.

Employees shall not work in excavations in which there is accumulated water, or in excavations in which water is accumulating, unless adequate precautions have been taken to protect employees against the hazards posed by water accumulation.

The precautions necessary to protect employees adequately vary with each situation, but could include special support or shield systems to protect them from cave-ins, water removal to control the level of accumulating water, or the use of safety harnesses and lifelines.

A competent person must monitor any excavation project until it is completed when workers are in the trench, and water removal equipment is being used.

Surface Water

Diversion ditches, dikes, or any other suitable method can be used to prevent surface water from entering into an excavation. Furthermore, a competent person must inspect excavations after heavy rains.

More Information: Remember! Water in an excavation is potentially lethal.

Hazardous Atmospheres

Where oxygen deficiency (atmospheres containing less than 19.5 percent oxygen) or a hazardous atmosphere exists or could reasonably be expected to exist, such as in excavations in landfill areas or excavations in areas where hazardous substances are stored nearby, the atmospheres in the excavation shall be tested before employees enter excavations greater than 4 feet (1.22 m) in depth.

If a hazardous condition is present or likely to be present in an excavation, controls such as ventilation or proper respirators must be provided. Atmospheric contaminants must be tested regularly while performing work in a hazardous atmosphere/environment.

Emergency Rescue Equipment

Easily accessible emergency rescue equipment must be provided by the employer in the event that adverse atmospheric conditions exist or may reasonably be expected to develop during work in an excavation.

Types of emergency rescue equipment include:

- Safety harness and line.
- Breathing apparatus.
- Basket stretcher.

This equipment shall be attended when in use.

Do Not Work Conditions

Employees must not be allowed to work in the following hazardous or toxic atmospheres:

- Atmospheres where oxygen is less than 19.5% or higher than 23.5%.
- Atmospheres where combustible gas concentrations are greater than 20% of the lower flammable limit.
- Atmospheres where threshold limit values for airborne contaminants exceed the American Conference of Industrial Hygienists' (ACGIH) specified limit unless appropriate controls are in place, such as the use of proper respiratory protection.

Access and Egress

Access to and egress from an excavation, are two important issues that must be addressed when working in excavations. It is essential that a stairway, ladder, or ramp be provided in trench excavations 4 feet or more in depth, so as to require no more than 25 feet of lateral travel for employees.

More Information:

- Ramps and runways constructed of two or more structural members shall have the structural members connected together to prevent displacement.
- Structural members used for ramps and runways shall be of uniform thickness.

Surface Crossing

Surface crossings over trenches are not allowed unless conditions dictate such crossings are necessary.

If surface crossings are necessary, such crossings must be constructed under the supervision of a registered professional engineer.

Other crossing requirements include the following:

- Crossings must have a minimum width of 20 inches.
- Crossings must be equipped with standard rails.

- Crossings must extend a minimum of 24 inches past the surface edge of the trench.

Falls and Equipment

In addition to cave-in hazards, other hazards that may exist in excavations include falling loads, movement of mobile equipment, and worker falls.

To reduce the dangers from these hazards, employers must:

- Keep materials or equipment that might fall or roll into an excavation at a minimum distance of two feet from the edge of the excavation, and/or have retaining devices in place to keep materials or equipment out of the excavation site.
- Provide warning systems for mobile equipment such as barricades, hand or mechanical signals, or stop logs to alert the equipment operators when they are approaching the edge of an excavation. In addition to these warning systems, the grade should slope away from the excavation when possible.
- Remove loose rock or soil, or install protective barricades and equivalent protection, to protect employees against falling rock, soil, or materials.
- Prohibit employees from working on faces of sloped or benched excavations at levels above other employees, unless employees at lower levels are adequately protected from the hazard of falling, rolling, or sliding material or equipment.
- Prohibit employees from being underneath loads that are being handled by lifting or digging equipment.
- Require employees to stand away from vehicles that are being loaded or unloaded to avoid being struck by any spillage or falling materials. Operators may remain in the cabs of such vehicles if the cabs provide adequate protection from falling loads during loading and unloading operations.

Planning

Before any excavation work begins, site evaluation and planning must be completed. During the planning stage, the following must be done:

- Soil conditions must be evaluated.
- Protective systems must be designed and put in place.
- Approved safety equipment must be on site and readily accessible.
- Potentially dangerous contact points with utilities such as gas or electric services must be identified.
- Oxygen levels must be tested when conditions exist that indicate that dangerous levels could be present.
- Potentially hazardous fumes or gases must be tested for when conditions exist that indicate the potential presence of these.
- Safe entry and exit points must be determined.

Competent Person

A competent person is an individual who, through training and/or experience, is capable of identifying existing and predictable hazards and who has the necessary authority to ensure that all necessary safety precautions are in place.

Hazardous, unsanitary, or dangerous working conditions must be identified by the employer. In addition, the employer must take immediate action to eliminate or control these hazards and conditions.

A competent person must be designated by the employer and have knowledge related to soil classification, protective systems, and safety standards related to excavation.

Inspections of Excavations

A competent person must make daily inspections of excavations, adjacent areas, and protective systems for evidence of a situation that could result in possible cave-ins, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions to ensure safe operations.

Inspections must take place:

- Before work starts and as needed throughout shifts.
- After rainstorms, high winds, or other occurrences that may increase hazards.
- When employees are exposed to potential hazards.

Employees must be immediately evacuated from any excavation under the following circumstances:

- A possible cave-in is identified.
- Hazardous atmospheres are detected.
- Protective systems fail.
- When any other potentially dangerous situation arises.

Employees must not be allowed to return to the excavation until the necessary precautions have been taken to ensure their safety. For example, the hazardous condition has been corrected and the corrective system has been returned to its fully operational condition.

Lesson Summary

It is essential that a stairway, ladder, or ramp be provided in trench excavations four feet or more in depth, so as to require no more than 25 feet of lateral travel for employees.

When workers are in the trench, and water removal equipment is being used, a competent person must monitor any excavation project until it is completed.

Employees are not to work in excavations in which there is accumulated water, or in excavations in which water is accumulating, unless adequate precautions have been taken to protect employees against the hazards posed by water accumulation.

Lesson 3: Soil Classification Systems

Lesson Focus

This lesson focuses on the following topics:

- Soil Classification
- Classification of Soil and Rock Deposits

Soil Classification

A competent person must decide when to install a protective system when trenches are less than five feet deep. Soil classification is one of the factors that influences the construction of a protective system.

Cohesive Soil

Cohesive soil has high clay content and is very durable and strong. It doesn't break up or decay easily and can often be excavated using vertical side slopes. When cohesive soil is moist, it is said to be in plastic form. Cohesive soil doesn't disintegrate when dry and is solid and perseverant when submerged.

Fissured

Fissured soil is soil that tends to break up. Lines of fracture, which may further develop into open cracks, can form along the surface of fissured soil due to tension in the soil.

Granular

Granular soil is gravel, sand, or silt (coarse grained soil), with little or no clay content. These types of soils do not hold any form and are not pliable or flexible when wet. Granular soils easily disintegrate when dry.

Type A

Type A soil is a type of cohesive soil with an unconfined compression strength value of 1.5 ton per square foot (tsf) or greater.

Type A soils with an unconfined compressive strength of 1.5 tsf can be readily indented by the thumb; however, they can be penetrated by the thumb only with very great effort. This test should be conducted on an undisturbed soil sample, such as a large clump of spoil, as soon as practicable after excavation to keep to a minimum the effects of exposure to drying influences.

If the excavation is later exposed to wetting influences (rain, flooding), the classification of the soil must be changed accordingly.

Examples of Type A soil include:

- Clay.
- Silty clay.
- Sandy clay.
- Clay loam.
- Cemented soils, such as caliche and hardpan.

Note: In some cases, silty clay loam and sandy clay loam also are considered Type A soils.

Soils which have the following characteristics, however, are not considered Type A soils:

- The soil is fissured.
- The soil is subject to vibration from heavy traffic, pile driving, or similar effects.
- The soil has been previously disturbed.
- The soil is part of a sloped, layered system where the layers dip into the excavation on a slope of four horizontal to one vertical (4H:1V) or greater.
- The material is subject to other factors that would require it to be classified as a less stable material.

Type B

Cohesive soil with an indefinite strength of more than 0.5 tsf, but less than 1.5 tsf, is called Type B soil. Estimates of unconfined compressive strength of soils can also be obtained by use of a pocket penetrometer or by using a hand-operated shear vane.

Granular soils lacking cohesion, including angular gravel, silt, silt loam, sandy loam—and in some cases, silty clay loam and sandy clay loam—are all examples of Type B soil. Previously disturbed soil (except those types that fall under the category of Type C) can also be classified as Type B.

Type C

Cohesive soils with an unlimited compressive strength of 0.5 tsf or less fall under the category of Type C soils. Type C soils with an unconfined compressive strength of 0.5 tsf can be easily penetrated several inches by the thumb and can be molded by light finger pressure. Gravel, sand, and loamy sand are examples of Type C soils. Submerged soil, soil from which water is freely oozing, and submerged rock that is not stable may also be classified as Type C soils.

Classification of Soil and Rock Deposits

Classification must result from the outcome of at least one visual and at least one manual test carried out by a competent person.

In a layered soil system, the weakest layer is used to categorize the system. However, each layer may be classified individually where a more stable layer lies under a less stable layer.

Visual Tests

Visual analysis is conducted to determine qualitative information regarding the excavation site in general, the soil adjacent to the excavation, the soil forming the sides of the open excavation, and the soil taken as samples from excavated material.

Visual inspections include an examination of soil samples that have been dug up and also soil at the sides of the excavation. The inspector roughly calculates the array and approximate amounts of particle sizes. The inspector should understand that cohesive soil is chiefly composed of fine-grained material, whereas coarse-grained sand or gravel is granular material.

Soil Observation

Observe soil as it is dug up. Cohesive soil is that which stays in clumps when excavated, whereas soil that disintegrates quickly and does not form clumps is granular.

Inspecting Excavation Sites

Inspect the sides of the opened excavation and the surface area adjacent to the digging. Crack-like openings such as tension cracks could point toward fissured material. If clods of soil spall (spall is the flaking or otherwise breaking off from the main portion) off a vertical side, the soil could be fissured. Small spalls may indicate moving ground and can pose potentially dangerous situations.

Disturbed Soil

Examine the area next to the dig to identify previously disturbed soil (proof of existing utility and other underground structures).

Observe the opened side of the digging to identify layered systems. Examine layered systems to identify whether the layers slope upwards towards the dig. Estimate the degree of slope of the layers.

Water and Vibrations

Inspect the area next to the excavation and the sides of the opened excavation for traces of surface water, water seeping from the sides, or signs of the water table level.

Observe the area adjacent to the excavation and the area within the digging for sources of vibration that may affect the strength of the excavation face.

Manual Tests

Plasticity and Pat Test

Shape a moist or wet sample of soil into a ball and try to roll it into threads as thin as 1/8 inch in diameter. Cohesive soil will usually roll into threads without disintegrating. If at least a 2-inch length of 1/8-inch thread can be held by one end without tearing, the soil is cohesive.

On the palm of the hand, spread out a 1/8 or 1/4-inch-thick sample of wet soil. Wipe the surface of the sample with a finger to clear away visible water. Face the surface of the palm upwards and slap the back of the hand moderately 5 to 10 times. If water oozes out to the surface of the sample (surface will appear shiny), the soil is mostly cohesion lacking silt or sand. If no water shows up, then the soil is mostly cohesive clay.

Dry Strength

Granular soil disintegrates on its own, or with controlled pressure, into individual grains or powder when dry. Soils with clay content will break into clumps when dry, and crumble into smaller clumps that can only be broken with considerable pressure. If the dry soil breaks into clumps that cannot be further broken into smaller pieces then the soil may be classified as un-fissured.

Thumb Penetration

The thumb penetration test can be used to evaluate the compressive strength of cohesive soils. This test should be carried out on an undisturbed soil sample as soon as is practical after digging up to reduce the chance of air drying the sample. If, at a later time, the trench is flooded or exposed to rain, etcetera, the soil classification must also be changed.

Type A soils can be indented by the thumb but require greater thumb pressure to penetrate the soil.

Type C soils can be penetrated several inches by the thumb and can be shaped by applying relatively light finger pressure.

Other Strength Tests

Estimates of unconfined compressive strength of soils can also be made by using a pocket penetrometer or a hand-operated shear vane. Other tests include drying and sedimentation.

Lesson Summary

Visual analysis is conducted to determine qualitative information regarding the excavation site in general, the soil adjacent to the excavation, the soil forming the sides of the open excavation, and the soil taken as samples from excavated material. Visual inspections include an examination of soil samples that have been dug up and also soil at the sides of the excavation. The inspector roughly calculates the array and approximate amounts of particle sizes and analyzes the likelihood of a cave-in.