Introduction to Soils Safety

- Module Description
  - Training in soil analysis and classification for safety during construction involving excavation and earth-moving activities. Topics will include competent person, soil properties and soil stressors, soil classification and soil testing.
  - Estimated Length: 45 minutes
  - Audience: Supervisors / Managers/Competent Person candidates
Course Objective

• Upon completion, the student should understand:
  – Fed-OSHA Excavation Standard and the application of the standard with respect to soil safety, soil mechanics, soil classification.
  – The role of the competent person regarding soil analysis and excavation safety.
  – And be able to use several visual tests and manual tests in the analysis and classification of soil and be able to identify soil stressors and their effects.
Overview

References

• Fed-OSHA Excavation Standard:
  – 29 CFR. 1926 Appendix A of Subpart P describing:
    • Tests to identify soils and soil conditions
    • Work requirements
  – This standard applies to:
    • Sloping or benching systems
    • Timber shoring
    • Aluminum hydraulic shoring
    • And other protective systems

Overview

Get Site-Specific Training!

– This training session:
  • Provides basic occupational safety and health information.
  • Is not a substitute for knowledge of OSHA or other standards.
  • Is not a substitute for site-specific, hands-on training and information.
Overview

• Your Competence is Critical
  – Trenching & Excavation is Hazardous Work:
  – Excavation allows forces previously held in equilibrium to act upon the exposed cut, and may result in the collapse of extremely heavy loads due to the lack of support.
  – Appendix A to subpart P describes a method of classifying soil and rock deposits based on site and environmental conditions, and on the structure and composition of the earth deposits.
Overview

- Case Study
  - Fatal Fact No. 31
- Which of the following was a contributing factor to the cave-in?
  - Proper shoring - wrong
  - Vibration of nearby equipment – correct
  - Good soils testing - wrong
  - Which of these did OSHA recommend?
  - Keep excavated material 2 feet from excavation - correct
  - Hire an expert soils tester - wrong
  - Protect walls to prevent cave-ins - correct
  - Employers must instruct employees on hazard recognition and regulations - correct
  - Provide ladder if trench 4 feet or more in depth - correct
Competent Person

• Competent Person

  – OSHA defines a Competent Person as:

  • “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 the authority to take prompt corrective measures to eliminate them.”
Competent Person

- The competent person must know:
  - General protection requirements
  - Soil classification
  - Protective systems
- Only the employer can give an employee the competent person authority to correct a hazard.
- Special Note: Competent Person does not have to be a Superintendent, Foreman, or Project Manager.
Competent Person

- Competent Person
  - When competent person identifies:
    - Possible cave-in.
    - Failure of protective system.
    - Hazardous atmosphere or other conditions.
  - Competent Person removes employees until precautions have been taken to ensure their safety.
Competent Person

• Why Classify Soil?
  – Competent Person Must:
    • Know soil types, properties, and OSHA soil classifications.
    • Accurately recognize existing and potential hazards.
    • Select appropriate protective system.
    • Use at least one visual qualitative test, and one manual quantitative test.
    • Have ability to “Read” Soil and Environmental conditions for the safety of you and your co-workers!
Competent Person

- Soil
  - What is Soil?
    - “soil is made up of gravel, organic matter, clay, silt, and sand.”
    - Gravel: Generally the largest particles in soil. Larger than 2 millimeters in size.
    - Silt: Particles smaller than 0.075 millimeters. But larger than 0.002 millimeters
    - Sand: Smaller than Gravel. Smaller than 2 millimeters but larger than 0.075 millimeters.
    - Clay: Particles smaller than 0.002 millimeters.
Competent Person

• Soil Classification System
  – OSHA Excavation Standard:
  – Basis for selecting protective systems.
  – Not the only classification system, but most common.
  – Most engineered systems are designed to meet this requirement.
  – Competent Person needs to accurately recognize existing and potential hazards.
Competent Person

– Authority
– The competent person must:
  • Know general protection requirements
  • Know soil classification
  • Know protective systems
  • Have authority to correct a hazard
  • Who may give the competent person the authority to correct hazards?
    • His trainer or employer - wrong
    • Only his trainer - wrong
    • OSHA or his employer - wrong
    • Only his employer - correct
Soil Properties

• Cemented soils
  – Characteristics:
    • Different soil components result in different soil properties. For example,
    • Cemented soil means a soil in which the particles are held together by a chemical agent, such as calcium carbonate. A hand size sample cannot be crushed into powder, or individual soil particles, by finger pressure.
Soil Properties

• Cohesive soil
  – Characteristics:
    • Clay (fine grained soil), or soil with high clay content.
    • Does not crumble.
    • Can be excavated with vertical side slopes.
    • Plastic when moist.
    • Hard to break up when dry.
    • Hangs together even while underwater.
    • Includes “clay-ey” silt, sandy clay, silty clay, clay and organic clay.
Soil Properties

• Dry soil
  – Characteristics:
    • Water is one of three things that may be filling the voids in soil; the others are air and dirt.
    • Dry soil shows no visible signs of moisture.
Soil Properties

• Fissured
  – Characteristics:
    • Has tendency to break along definite planes of fracture with little resistance, or;
    • Exhibits open cracks, such as tension cracks, in an exposed surface.
Soil Properties

• Granular soil
  – Characteristics:
    – Gravel, sand, or silt (coarse grained soil).
    – Little or no clay content.
    – No cohesive strength.
    – Cannot be molded when moist and crumbles easily when dry.
    – Special Note: some moist granular soils have deceptive surface cohesion.
Soil Properties

• Layered system
  – Layered systems mean:
  – Two or more distinctly different soil or rock types arranged in layers.
  – Micaceous seams or weakened planes in rock or shale are considered layered.
Soil Properties

• Plastic
  – Characteristics:
    • Can be deformed or molded without cracking.
    • And without changing its volume.
Soil Properties

Water Affected Soils

• **Moist Soil**
  – Moist Soil Characteristics:
  – Looks and feels damp.
  – Can easily be shaped into a ball and rolled into small diameter threads before crumbling.
  – Moist granular soil contains some cohesive material and clumps together.
  – Moist granular soil like wet beach sand will exhibit signs of cohesion due to the adhesive or surface tension property of water.

• **Submerged soil**
  – Characteristics:
  – Soil which is underwater or is free seeping.

• **Wet soil**
  – Characteristics:
  – Contains significantly more moisture than moist soil.
  – Its cohesive material will slump, collapse, or begin to flow when vibrated.
  – Granular material that would exhibit cohesive properties when moist will lose those cohesive properties when wet.
  – Water content adds significantly to the weight of the material often causing collapse.
Soil Properties

• Stable Rock
  – Characteristics:
    • Natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.
Soil Stressors

• Stressors
  – Trench Stress!
    • Stresses and deformations can occur.
    • Increase/decrease in moisture can damage trench stability.
Soil Stressors

• Tension Cracks
  – Tension cracks:
    • Usually form 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.
    • Are usually an indication of a trench that will soon fail!
    • For example, 10 foot deep trench, cracks from 5 to 7.5 feet back from top of trench.
Soil Stressors

- Sliding or Sluffing
  - Sliding or sluffing may occur as a result of tension cracks, as illustrated.
Soil Stressors

• Toppling
  – Tension cracks can cause toppling:
    • Toppling occurs when the vertical face shears along the tension crack line and topples into the excavation.
Soil Stressors

• Subsidence and bulging
  – Can be caused by:
  – An unsupported excavation creating an unbalanced stress, causing:
    • Subsidence at the surface.
    • Bulging of the vertical face.
    • Possible trench face failure and entrapment of workers.
Soil Stressors  33A

- Fatal Fact No. 22
- OSHA made four recommendations in which responsibility was clearly identified. To whom were OSHA’s recommendations directed?
  - The employees - wrong
  - The employer [correct] Yes, all of the recommendations implicated the employer.
  - The owner - wrong
Soil Stressors

• Heaving or Squeezing
  – Heaving or Squeezing:
    • Caused by downward pressure from weight of adjoining soil.
    • Pressure causes a bulge in the bottom of the cut.
    • Can occur even when shoring or shielding has been properly installed.
Soil Stressors

• Boiling
  • Boiling is:
    – An upward water flow into the bottom of the cut.
    – High water table is one cause.
    – Produces a “quick” condition in the bottom of the cut.
    – Can occur when shoring or trench boxes are used.
Other Soil De-Stabilizers

• Vibration
  – Vibration Effects:
    • Can destabilize soil by interrupting the adhesion between particles.
    • Caused by equipment, pile driving, blasting.
Other Soil De-Stabilizers

• Surcharge loads
  – Surcharge Loads Include:
    • Any increase in weight in the adjacent area next to the cut. (Adjacent area = areas on either side of cut equal to its depth).
    • Many hazards in adjacent area: spoils, equipment, buildings, people.
    • Additional unsupported weight can destabilize soil.
Other Soil De-Stabilizers

• Weather
  • Precipitation and temperature affect stability:
    » Wetting/saturation due to rain.
    » Ground expansion and contraction due to freezing temperatures.
    » Moisture loss due to wind and drying due to sun.
Other Soil De-Stabilizers

• Layered Systems

• Free-Seeping Flow:
  – Ground or rainwater in a layered system will produce a spring, or flow between layers and into the excavation.
  – This water will continue to drain until pressure is relieved.
Other Soil De-Stabilizers

• Layered Systems
  • Layered systems:
  • Problematic when the layers slope or dip downward.
  • Gravity tugs on the top layer.
  • Slippery sheet between the layers.
    – Causes extreme instability
Other Soil De-Stabilizers

– Shear Planes/Fissures
  • Shear Planes:
    – Small cracks or stress in an exposed surface.
    – Fissures are small cracks caused by shear planes or stress exhibited as tension cracks in an exposed surface.
Other Soil De-Stabilizers

– Submerged Soil
  • Submerged Soil:
  • Soil that is underwater.
  • Can be seriously unstable.
Other Soil De-Stabilizers

• Time
  • Passing of time:
  • The longer something is left open, the longer it has to become unstable.
  • Competent Person to visually inspect and recognize pressure or stress.

Yes, water in an excavation nearly always spells trouble.
Key Terms

• Unconfined Compressive Strength
  – Unconfined Compressive Strength:
    • The load per unit area at which a soil will fail in compression.
    • Determined by laboratory testing, or estimated in the field using a pocket penetrometer, by thumb penetration tests, or other methods.
Key Terms

• Unit Weight of Soils
  – Unit Weight refers to:
    • Weight of one unit of particular soil.
    • Weight of soil varies with type and moisture content.
    • One cubic foot of soil can = 110 to 140 pounds (43 - 55 kilograms).
Key Terms

• Unit Weight of Soils
  – About how much does one cubic yard of soil weigh?
    • About 110 lbs - wrong
    • About 1000 lbs - wrong
    • About 3000 lbs  correct  [Yes, there are 27 cubic feet in a cubic yard X 110 lbs per cubic foot = 2970 lbs]
    • About 10,000 lbs - wrong
Soil Classification

• Four Major Types
  – In Decreasing Order of Stability:
    • Stable Rock
    • Type A
    • Type B
    • Type C
  – Each soil/rock deposit must be classified by a “Competent Person” to determine what protection to put in place.
Soil Classification

• Stable Rock
  – Stable Rock:
    • Natural solid mineral matter.
    • Can be excavated with vertical sides.
    • Remains intact while exposed. (Soil_Diagram1.doc)
    • Usually granite, sandstone, or other named rock.
    • Can be cut without cracks/fissures.
    • Allowed a vertical ninety degree angle when less than 20 feet deep.
Soil Classification

• Type A Soil
  – Properties:
    – Cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (tsf) or greater.
    – For testing, soil should:
      » Be Clay
      » Contain moisture
      » Be a fresh, lump size sample
  – Sample should be collected ASAP after excavation.
  – (soil_diagram-A.doc)
Soil Classification

• Type A Soil
  – Common Types are:
    • Clay
    • Silty clay
    • Sandy clay
    • Clay loam
    • And in some cases, silty clay loam and sandy clay loam.
    • Also: caliche, hardpan, sandstone, limestone.
Soil Classification

• Type A Soil
  – Soil is NOT Type A if:
    • Cracked or Fissured.
    • Subject to vibration from heavy equipment.
    • Layers dip into the excavation on a slope of 4H:1V or greater.
Soil Classification

• Type A
  – Also NOT Type A if:
    • Has been previously disturbed, or
    • Heavy Loads along edge of trench (surcharge load).
    • Is subject to other factors (such as weather) that would require it to be classified as less than stable.

Existing utilities tell us that the soil is previously disturbed and cannot be type A. Also, given the water in the excavation, it may be no better than type C.
Soil Classification

• Type B Soil
  – Properties:
    • Cohesive soil with an unconfined compressive strength of between .5 and 1.5 tsf.

• When should type A soil be downgraded to type B or lower?
  • When it is cracked or fissured.  correct
  • When it is subject to vibration from heavy equipment.  correct
  • When layers dip into the excavation on a slope of 4H:1V or greater.  correct
  • Never  wrong
Soil Classification

- Type B Soil
  - Also includes Granular cohesionless soils including: Crushed rock
    - Silt
    - Silty loam
    - Sandy loam
    - Silty clay loam and sandy clay loam.
Soil Classification

– Type B soil
  • Type B may also be:
    – Dry rock that is not stable.
    – Process of removing (blasting) the material may reduce the classification of soil to Type B.
Soil Classification

• Type B Soil
  – Downgrade Type A to B or lower:
  – When saturation increases weight of soil, making it less stable.
  – When drying removes moisture, reducing adhesion.
  – When soil is subject to heavy vibration.
  – These soils must be downgraded even when it meets unconfined compressive strength or cementation requirements of Type A.
Soil Classification

• Type B Soil
  – Layered system:
    • Material that is part of a layered system, dipping into the excavation on an angle less steep than 4H:1V, but only if the material would otherwise be classified as Type B.
Soil Classification

- **Type C Soil**
  - **Properties:**
    - Rated at below 0.5 tsf
      - And even if clay, hardpan, or sandstone.
    - Granular soils including some gravel, sand, loamy sand, or Submerged rock that is unstable.
Soil Classification

• Type C Soil
  – Layered system:
    • Material in a sloped layered system where the layers dip into the excavation or a slope of 4H:1V or steeper.

Soil Classification

• Case Study

• For an example of why type C soil can be so dangerous open the tab for a discussion of a fatal accident.

• An employee was in a trench installing forms for concrete footers when it caved-in, causing fatal injuries. The trench, which was 7½ feet deep, was in loose, sandy (Type C) soil, and no inspection was conducted prior to the start of the shift.
• A spoil-pile had been placed on top of a curb which formed the west face of a trench. A backhoe was spotted on top of the spoil-pile. The west face of the trench collapsed on two employees who were installing sewer pipe. One employee was killed; the other received back injuries. The trench was 8 feet deep with vertical walls. No other protection was provided.
• The superimposed loads of the spoil-pile and backhoe may have caused the collapse.
Soil Classification

• Soils Chart
  – Soils classification chart:
  – May be used as a guide to help determine whether soil is type A, type B or type C.
  – Testing is required to determine the characteristics of the soil which can then be compared to the chart to determine type.
  – The chart may be found on the osha website www.osha.gov by doing a search for soil classification chart.
Soil Testing

• Visual and Manual Tests
  – The Competent Person:
    • Classifies soil deposits based on at least one visual and one manual test.
    • This analysis allows for the understanding of soil conditions and appropriate worker protection.
Soil Testing

• Visual Tests
  – Common visual tests:
    • Incorporated into Competent Person’s inspections of the jobsite at the beginning of the shift, after change in condition or after any hazard-causing event such as a rainstorm.
    • Observe samples of soil that are excavated and soil in the sides of the excavation.
    • Estimate the range of particle sizes and relative amounts of the particle sizes.
Soil Testing

• Visual tests
  – Soil that:
    • Remains in clumps is cohesive.
    • Breaks up easily and does not stay in clumps is granular.
Soil Testing

• Visual tests
  – Cracks, fissures and spalls:
  – When observing the side of opened excavation, and the surface area adjacent:
    • Crack like openings (tension cracks) may indicate fissured material.
    • If chunks of soil spall off vertical side, the soil could be fissured.
    • Small spalls are evidence of moving ground and indications of potentially hazardous situations.
    • Look for surface encumbrances.
Soil Testing

• Visual tests
  – Observe the excavation and area adjacent to the excavation:
    • Look for evidence of existing utility and other underground structures,
    • Identify previously disturbed soil.
    • Examine crossing utilities.
    • Beware of parallel utilities.
    • Backfill material usually weaker.
Soil Testing

• Visual tests
  – Identify layered systems:
    • Examine layered systems, especially if digging deep.
    • Identify if layers slope toward the excavation.
    • Groundwater can hit stiffer layer and bleed into trench.
    • Layers can slide causing cave-in.
Soil Testing

• Visual tests
  – Examine adjacent area and sides of excavation for:
    • Evidence of surface water.
    • Water seeping from the sides.
    • Location of the level of the water table.
    • Examine bottom of ditch for water and decide whether or not a means of controlling it is necessary.
    • Examine ejected material for color changes, layer changes and water.
Soil Testing

• Visual tests
  – Examine excavation and adjacent areas for:
    • Sources of vibration that may affect the stability of excavation face.
Soil Testing

• Manual Tests
  – Manual Tests:
    • Are never done from inside the cut.
    • Samples taken from recently excavated material.
    • Include:
      – Plasticity or wet thread test
      – Dry Strength Test
      – Pocket Penetrometer
      – Shearvane (Torvane)
      – Drying test
Soil Testing

• Manual Tests

• Plasticity or wet thread test:
  – Mold a moist sample of the soil into a ball.
  – Attempt to roll it into a thin thread, approximately 1/8 inch (3 mm) in diameter (thick) by 2 inches (50 mm) in length.
  – Hold soil sample by one end.
  – If the sample does not break or tear, the soil is considered cohesive.
Soil Testing

• Manual Tests
• Dry Strength Test:
  – Granular Soil or Clay:
    • That crumbles freely or with moderate hand pressure into individual grains is granular.
    • Falls into clumps that subsequently break into smaller clumps (and the smaller clumps can be broken only with difficulty) is probably clay in combination with gravel, sand, or silt.
Soil Testing

• Manual Tests
• Dry Strength Test
  • Dry Strength Test: Unfissured Soil:
    – If soil breaks into clumps that do not break into smaller clumps (and the soil can be broken only with difficulty), the soil is considered unfissured unless there is visual indication of fissuring.
Soil Testing

• Manual Tests
  – Thumb Penetration Test:
  – Guidelines:
    • Attempt to press the thumb firmly into soil.
    • If Indentation in the soil is made only with great difficulty: probably Type A soil.
    • If Thumb penetrates no further than length of the thumb nail: probably Type B.
    • Thumb penetrates full length of the thumb: probably Type C soil.
    • Is subjective and the least accurate test.
Soil Testing

• Manual Tests

• Pocket Penetrometers are:
  • Direct-reading, spring operated.
  • Used to determine the unconfined compressive strength of saturated cohesive soils.
  • Pushed into soil, reading displayed.
  • Calibrated in tons per square foot (tsf) or kilograms per square centimeter (kPa).
  • Error rate: 20 - 40%.
Soil Testing

• Manual Tests
  – Shearvane (Torvane):
    • Used to determine the unconfined compressive strength of soil.
    • Blades of the vane are pressed into a level section of undisturbed soil.
Soil Testing

• Manual Tests
  – Shearvane (Torvane):
    • Torsion knob slowly turned until soil failure.
    • Direct reading must be multiplied by 2 to provide results in tsf or kPa.
Soil Testing

• Manual Tests
  – Drying test:
    • Used to differentiate between cohesive material:
      – with fissures
      – un-fissured cohesive material
      – and granular material
    • Procedure: dry a sample of soil, approximately one inch thick and six inches in diameter, until it is thoroughly dry.
Soil Testing

• Manual Tests
  – Drying test Indicators:
    • If sample develops cracks as it dries, significant fissures will occur in the soil type.
    • Samples that dry without cracking should be broken by hand:
      – If considerable force is necessary to break sample, soil has significant cohesive material and can be classified as unfissured cohesive material.
      – unconfined compressive strength to be determined.
Soil Testing

• Manual Tests

  – Drying test – sample breaks easily by hand:
    • Fissured cohesive material or granular material.
    • To distinguish, pulverize the dried clumps of sample by hand or by stepping on them.
      – If clumps do not pulverize easily, material is cohesive with fissures.
      – If pulverize easily into very small fragments, the material is granular.
Soil Testing

• What to do with the Test Results

Competent Person Should:

• Document all tests.
• Complete at least one visual and one manual test.
• Consider site and environmental conditions.
• Base soil type upon definitions specified in Appendix A of Subpart P.

Soil Testing

• What’s the soil type?
• Check the photo and answer the following questions.
• What kind of test is this?
  – Dry strength test - wrong
  – Plasticity or wet thread test - correct
  – Drying test - wrong

• What does this test indicate about the soil?
  – It is not cohesive  wrong
  – It is cohesive and therefore is likely type A or B  correct
  – No way to tell  wrong
Practical Exercise

Trench excavation:
- No surface encumbrances, no fissures or other indications of unusual soil. Pocket penetrometer = 1.7 tsf compressive strength.
- Wet thread test = 1/8 inch thread 4 inches long.
- Existing waterline running parallel to the proposed trench several feet from the expected bottom.

How do you think he classified the soil?
- Type A - wrong
- Type B - correct. The soil is clearly Type A based on the tests but must be downgraded due to the previously disturbed soil from placing the existing waterline. It could be type C if the waterline is very close.
- Type C – correct, Its possible due to the existing waterline but another choice is also likely.
- Not enough information to classify - wrong
Summary

• Summary
  • Basics of soil safety, mechanics, and classification.
  • Report unsafe conditions and work practices.
  • Do not take risks.
  • Anticipate, recognize, evaluate and control excavation hazards.