Pre - Test

1. Cave-ins can happen without warning?
   A. True
   B. False

2. A hazardous atmosphere can be found in a trench.
   A. True
   B. False

3. A protective system is a method of protecting employees from cave-ins.
   A. True
   B. False
4. A ladder can be used for access and egress in trenches over ____ feet in depth

A. 10
B. 25
C. 4
D. 16

5. A competent person must be aware of.

A. Access and egress
B. Water accumulating
C. Hazardous atmospheres
D. All the above

6. Soils classifications are

A. A, B, C, Stable rock
B. 1, 2, 3, 4
C. Rocky or Smooth
D. Hard or Soft

7. The testing of soil consists of a _________ and __________ test.

A. Day, night
B. Summer, winter
C. Visual, manual
D. Hot, cold
8. If water is added to soil it brings__________________.

   A. Lunch
   B. **Additional weight**
   C. Strength

9. What effects on the body can a cave-in cause?

   A. Respiratory distress
   B. Crush syndrome
   C. Total body impact
   D. **All the above**

10. Soil can weigh about ______ lbs a cubic foot

    A. **125**
    B. 400
    C. 600
    D. 50

11. Factors that influence cave-ins are ________________.

    A. Intersecting trenches
    B. Previously disturbed soil
    C. Vibration
    D. **All the above**

12. The excavation standard applies to trenches also.

    A. **True**
    B. False
   A. True
   B. False

14. A trench box should be used to protect employees.
   A. True
   B. False

15. No employee shall be permitted underneath loads handled by lifting or digging equipment.
   A. True
   B. False

### Aides

**Enabling Objectives**
Identify the laws, regulations, and standards as they apply to excavation
Describe soil classification and the testing used to determine type
Describe the protective systems used in excavations
Discuss the hazards found in trenches
Describe the role of the competent person

**Overview / Main Points**
Excavation laws, regulations, and standards
Soil classification
Soil testing
Competent person responsibilities
Hazards associated with excavations
Protective systems

- Worker in trench trapped to waist, 3 hrs to remove, crush syndrome in both legs
- Worker trapped from slide, fracture to leg
Worker buried in trench, backhoe operator tried to use bucket to free victim

Worker trapped from flowing water and mud, no lockout/tagout

**Tragic Facts**

Excavating is recognized as one of the most hazardous construction operations

541 workers were killed on excavating/trenching jobs from 1992-2001
411 (76%) were killed by cave-ins
257 (47%) worked for companies employing less than 10 people

**Tragic Facts**

60% of those killed or injured are would-be rescuers
Fire dept personnel, co-workers, by-standers
Cave-ins can happen without warning
All of the fatalities and injuries could have been prevented

**Collapse forces**

- 24 inches of soil on a person’s chest weighs 750-1000 lbs
- 18 inches of soil covering a body weighs 1800-3000 lbs

Soil weight examples

- Shear wall collapse speed
  - 45 mph

Speed of collapsing dirt

How much pressure does it take to do this?
**Effects on the body**
- Respiratory distress
- Crush syndrome
- Total body impact

**Top Five Trenching Hazards**
- Cave-ins
- Overhead electrical line contact
- Falls into excavations
- Equipment falling into trenches
- Explosion / fire / electrocution

**Unsafe attitudes**
- I know what I’m doing
- It can’t happen to me
- I’ve been doing it that way for years
- I would sleep in that hole
- Don’t worry we’ll watch the walls and tell you
- If you need to get out

**Most common causes of cave-ins**
- Poor planning
- Misjudgment of soil type
- Inadequate or incorrect installation of protective systems
- Defective protective devices
- Failure to adjust for changing conditions

**Legal aspects**
- OSHA 29 CFR 1926 (650-652)
- Excavation standard applies to all open excavations made in the earth’s surfaces including trenches, all surfaces encumbrances that would create a hazard and protective systems
What’s in the standard?
Excavation scope, application and definitions
Job site hazard listing
Requirement for protective systems
Appendixes that detail
Soil classification
Sloping and benching
Timber & aluminum hydraulic shoring
Protective system selective decision tree

Definitions
Accepted engineering practices – requirements which are compatible with practice of professional registered engineers

Aluminum hydraulic shoring – pre-engineered shoring system comprised of cross braces

Bell-bottom pier hole – excavation which bottom is made larger than cross section to form a belled shape

Benching – a method of excavating the side of an excavation to form one or a series of horizontal levels or steps

Cave-in – separation of a mass of soil or rock material from the side of an excavation

Cross braces – horizontal members of shoring systems installed perpendicular to the sides of the excavation

Excavation – any man made cut, cavity, trench, or depression in an earth surface, formed by earth removal

Faces or Sides – vertical or inclined earth surfaces formed as the result of excavation work

Failure – breakage, displacement, or permanent deformation of a structural member
Hazardous Atmosphere – atmosphere which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, may cause death, illness or injury

Kick out – accidental release or failure of a cross brace slides

Protective system – method of protecting employees from cave-ins

Ramp - inclined walking or working surface that is used to gain access to one point from another, constructed from earth materials such as steel or wood

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

Sheeting – members of a shoring system that retain the earth in position and in turn are supported by other members of the shoring system

Shield – structure that is able to withstand the forces imposed on it by a cave-in and thereby protect employees within the structure

Shoring – a structure such as a metal, hydraulic, mechanical or timber shoring system that supports the side of an excavation

Sloping – method of protecting employees from cave-ins by excavating to form sides of an excavation that is inclined away from the excavation

Stable rock – natural solid mineral material that can be excavated with vertical sides and will remain intact while exposed
Aides

**Structural ramp** – ramp built of steel or wood, usually used for vehicle access. Ramps made of soil or rock is not considered structural ramps

**Support systems** – structure such as underpinning, bracing or shoring, which provides support to an adjacent structure underground installation or the sides of an excavation

**Tabulated data** – tables and charts approved by a professional registered engineer and used to design and construct a protective

**Trench** – an excavation which is deeper than it is wide, but less than 15 feet wide

**Uprights** – vertical members of a shoring system placed in contact with the earth

**Wales** – horizontal members of a shoring system placed parallel to the excavation face whose side bears against the vertical members

**General Requirements**

Surface Encumbrances
Underground Installations
Access and Egress
Exposure to Vehicle traffic
Exposure to Falling Loads
Warning systems for Mobile Equipment
Hazardous Atmospheres
Water Accumulations
Stability of Adjunct structures
Protection from loose rock and soil
Inspections
Fall Protection

**Surface Encumbrances**

All surface encumbrances that are located so as to create a hazard to employees shall be removed or supported as necessary to safeguard employees
**Underground Installations**
Utility companies shall be contacted with in established local response times
- Advised of proposed work
- Asked to establish location of utility
- When cannot meet request employer may proceed with caution with detection equipment of an acceptable means to locate utility

**Underground Installations**
While the excavation is open, underground Installations shall be protected, supported or removed as necessary to safeguard employees

**Access & Egress**
**Structural ramps**
Used by employees shall be designed by a competent person
When used for equipment shall be designed by a competent person qualified in structural design
Stairway, ladder, ramp or other safe means of egress require no more than 25 feet of lateral travel for employees
Ladders must be secured and extend a minimum of 36 in. above the landing

**Exposure to vehicle traffic**
Employees exposed to public vehicle traffic shall be provided with and wear warning vest or other suitable garment
- Marked or made with reflector zed or highly visible material
- Requiring a designated, trained flag person along with signs, signals, and barricades when necessary

**Exposure to falling loads**
No employee shall be permitted underneath loads handled by lifting or digging equipment
Stand away from vehicle being loaded or unloaded to avoid being Struck
Operators may remain in cabs when vehicles are equipped in accordance with 1926.601
Worker was standing under load being moved

**Warning systems for mobile equipment**
When operator does not have clear view of edge of excavation
Warning system shall be utilized
- Barricades
- Hand or mechanical signals
- Stop logs

John Deere got to close to trench and sled in, operator ejected

Concrete truck falls into trench mixing the load

**Hazardous Atmospheres**
Testing and controls
To prevent harmful levels of atmospheric contaminants
- Oxygen deficient <19.5%
- Atmosphere tested before entry
Adequate precautions shall be taken
- Ventilation
- Proper respiratory protection
Testing shall be done often a necessary to ensure safe atmosphere

No ventilation from machinery and pumps
Worker using cut-off saw in trench
Atmospheric monitor with pump to read all levels
Heated propane ventilation system
Emergency Rescue Equipment
Rescue equipment
Breathing apparatus
Safety harness and line or basket stretcher
Must be readily available
Must be attended
Bell-bottom pier holes, deep and confined footing excavation
shall wear a harness with a lifeline securely attached to it

How much water is too much?

Water Accumulation
Employees shall not work in excavations where there is
accumulating water, or where water is accumulating, unless
adequate precautions have been taken, to protect employees

Water Accumulation
Must take adequate precautions to protect employees
Accumulating water
Vary with each situation
Water removal operation shall be monitored by a
competent person
Run off from heavy rains will require inspection by
a competent person

Well point system for lowering ground table

Trash pump

Stability of adjacent structures
Where stability is endangered by excavation operations
Support systems such as shoring, bracing or underpinning
shall be provided
Sidewalks, pavement and appurtenant structures shall not
be undermined unless support systems are used to
protect employees
Is the backhoe supporting the house or vise-versa
Worker buried up to his waist, beneath collapsing brick

**Protection from loose rock & soil**
That poses a hazard from falling or rolling from
Excavation face
  - Scaling to remove
  - Installation of protective barricades
  - Other means (retaining devices)
  - 2 feet from edge of excavation

Were is the protection
Who is protected/ who is not protected

**Competent Person**
One who is capable of identifying existing or predictable?
Hazards in the surroundings which are unsanitary
Hazardous or dangerous to employees & who has
authorization
To take prompt corrective measures
Has specific training an be knowledgeable about
soil analysis, use of protective systems and the
requirements of the standard

**Competent Person must be aware of**
Falling loads and/or equipment
Hazardous atmospheres
Weather conditions and forecast
Stability of adjacent structures
Surface and overhead encumbrances
Underground utilities
Access and egress
Vehicular traffic
Continuation of trade activity
Inspections

- Daily
- Star of work
- As needed throughout the shift
- Every rainstorm
- Other hazard increasing occurrence
- Employees shall be removed until precautions have been taken
- When fissures, tension cracks, sloughing undercutting water seepage, bulging at the bottom
- Change in size, location or placement of spoil pile
- Indication of movement of adjacent structure

Who inspected this trench

What makes a person competent

Fall protection

If walkway provided
- Where employees permitted to cross guard rails provided where 6 feet or more above lower levels
- Fall protection standard

Requirements of Protective Systems

1926.652
- Employee protected by adequate protective system
- Except: Entirely in stable rock
  - Less than 5 feet deep with no indication of cave-in

Is this the proper use of a protective system

How many laws were broken here

Designs using Manufacturers Data

- Deviation will only be allowed after manufacturer issues specific written approval
- Written form at the job site during construction of system
### Aides

#### Materials and Equipment
- Free of damage or defects
- Maintained in manner consistent with manufacture
- Examined by competent person and evaluated for continued use
- If damaged shall be removed from service until approved by registered professional engineer

#### Notes
- How much abuse can you do to a shield before it fails
- Make sure all cross braces and safety pins are used

### Installation and Removal
- Members securely connected
  - Prevent sliding, falling, kick outs
  - Other predictable failure
- Members not subject to loads exceeding those which were designed
- Members removed from bottom first on removal
- Backfill with removal of system
- Excavate to no greater than 2 feet below
  - Only if system is rated at full depth
- Employees not permitted to work above other employees unless adequately protected from falling, rolling, and sliding of material
- Employees not allowed in shields when installed, removed or moved vertically

#### Notes
- When an inspector is doing this something bad has happen
- Not a certified trench box, made be laborers on scene
- Safe or not safe
- Nice system for shallow trenches
- Easily placed in trench
- What’s good what’s not so good
### Shield usage and safety
Shields are used to protect workers from cave-ins, not to provide support for the trench. Manufactures data must be present at work site. Top of the shield must extend to the top of the trench. If used with sloping shield must extend 18 inches, above trench walls. Shields may be stacked, provided the bottom one is rated for the total depth. The trench may be dug 2 ft below the bottom of the shield, but the shield must be rated for that depth. Backfill around box to prevent lateral movement.

### Review
Table Top Exercise

### Soil Classification
1926 Subpart P App A

**Definitions**

- **Cemented soil**
  - Particles held together by a chemical agent
  - Can not be crushed by finger pressure

- **Cohesive soil**
  - Soil with high clay content which has cohesive strength
  - Does not crumble, excavated with vertical side slopes, and is plastic when moist

- **Dry soil**
  - Does not exhibit visible signs of moisture

- **Fissured**
  - Soil material that has tendency to break along definite planes of fracture with little resistance
Granular soil
Gravel, sand, or silt with little or no clay content
Exhibits no cohesive strength

Layered system
Two or more distinctly different soil or rock types arranged in layers

Moist soil
A condition in which a soil looks or feels damp
Can easily be shaped into a ball and rolled into small diameter threads before crumbling

Plastic
Property of a soil which allows the soil to be deformed or molded without cracking

Saturated soil
Soil in which voids are filled with water
Saturation does not require flow

Wet soil
Soil that contains significantly more moisture than moist soil, but in such a range of values that cohesive material will slump or begin to flow when vibrated

Stable rock
Natural solid mineral, excavated with vertical sides and remain intact while exposed

Submerged soil
Soil which is under water or is free seeping

Unconfined compressive strength
Means the load per unit area at which a soil will fail in compression
Can be determined by laboratory testing

Soil Category – Stable Rock
Natural solid mineral material that can be excavated with vertical sides and remain intact while exposed.
Examples include granite and sandstone
Determining whether a deposit is stable rock may be difficult unless it is known if whether cracks exist or whether or not cracks run into or away from the excavation
**Type A soil**
Soils with an unconfined compressive strength of 1.5 ton per square foot (tsf) or greater
No soil is type A if:
- Soil is fissured
- Soil is subject to vibration
- Soil has been previously disturbed
- Soil is part of a sloped or layered system of four horizontal to one vertical

How soon will it fail?
What do you have to do to make this trench safe?
How much pressure does it take to make this trench fail?

**Type B soil**
Soils with an unconfined compressive strength greater than 0.5 tsf but less than 1.5 tsf

**Type C soil**
Soils with an unconfined compressive strength of 0.5 tsf or less

**Soil strength measure**
Unconfined compressive strength (UCS)
The amount of pressure in tons per square foot (tsf) Required to cause the soil to fail
OSHA classification is based on UCS

**Basis of classification**
Deposits shall be made based on the results of at least one visual and one manual analysis Conducted by a competent person
### Aides

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<th>Notes</th>
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### Acceptable manual test

| Plasticity | |
| Ribbon and thread test | |
| Dry strength test | |
| Thumb penetration test | |
| Other strength test | |
| Pocket penetrometer | |
| Hand-operated shearvane | |

### Field sedimentation test

| Flat bottom container – at least 7 inches high (old olive jar) | |
| 1 1/2 to 2 inches of soil | |
| Place soil in glass jar | |
| 5 inches of water on top of soil | |
| After 30 seconds granular sand type material settles at the bottom | |
| After 3 minutes silt type material settles on top of the sand | |

Graph to determine soil strength
**Ribbon test**
Mix soil and water to make into Plastic mass
Roll mass into cylindrical shape
½ to ¾ inch diameter
Lay across palm of hand
Press between thumb and second joint of index finger
Pass through thumb
Squeeze until it takes the shape of a 1/8 to 1/4 inch thick strip
Allow to hang freely from hand
Clay loam will barely ribbon
And break easily
Clay = relatively long ribbon 6 to 8 inches or more
More clay = longer and stronger ribbon
Silt has tendency to produce short ribbon
With broken appearance

**Penciling**
If a 2 inch or longer thread can be held without breaking the soil is cohesive

**Shearvane/Torvane**
Select fresh clod or block of undisturbed soil from spoil pile
Cut a smooth surface on the clod
Insert vanes of device into the soil
Retract vanes to show footprint
Set indicator at zero
Hold device firmly against soil and twist in clockwise manner until soil fails in shear

**Pocket Pentrometer**
Device is designed to work on saturated clay soil
Measures unconfined compressive strength of soil
Twice the value of shear strength of same soil
Note machine ring
Aides

To begin test, remove red protective cap, push ring against body so that low side reads “0”
Slowly insert piston until engraved mark is level with soil
Read strength in tons/sq ft using low side of ring (side closest to the piston end).
Record reading and repeat step #1
For weak soils, Use 1” adaptor foot, multiply by .0625

Thumb penetration test
The thumb penetration procedure involves an attempt to press the thumb firmly into the soil in question

If the thumb makes a penetration in the soil only with great difficulty, then the soil is probably Type A

If the thumb penetrates no further than the length of the thumb nail, it is probably Type B soil

If the thumb penetrates the full length of the thumb then it is Type C soil

The thumb test is subjective and is therefore the least accurate of the test

Notes

Soil Classifications
Layered geological strata
Where soils are configured in layers
Must be classified on the basis of the weakest soil
each layer may be classified individually if a more stable layer lies below a less stable layer
Type C soil rest on top of stable rock
Look for the following conditions
Particle size
- Primarily fine grained = cohesive material
- Primarily course grained = sand or gravel
Cohesion - remains in clumps, cohesive

Soil strength is dependent upon:
- Type of soil
- Amount of moisture in the soil
- Whether the soil has been previously disturbed

If water is added
- It brings additional weight
  - Hydrostatic pressure
- It erodes the trench wall
  - Water movement typically moves soil
- It can freeze and thaw
  - Resulting in cracks and false cohesion

Soil components
- Clay
  - Composed of mineral particles less than 0.002mm in diameter
- Silt
  - Individual mineral fragments that range from 0.002 to 0.05mm in diameter
- Sand
  - Individual rock or mineral fragments that range in diameter from 0.05 to 2.0mm in diameter
- Gravel
  - Can be either angular or rounded
Cohesive soil
Soil with a high clay content which has cohesive strength
It does not crumble
It can be excavated with vertical side slopes
It is hard to break up when dry
It can be molded
It exhibits significant cohesion even when submerged

Granular soil
Soils that include gravel, sand, silt
Very low clay content
It has no cohesive strength
Some moist granular soils exhibit apparent cohesion
It cannot be molded when moist and crumbles easily when dry

Soil mechanics
Toppling
Caused by tension cracks
Occurs when the trenches vertical face shears along the tension crack line and topples into the excavation

Shear wall collapse

Subsidence and bulging
Bulging of the vertical face of the trench
Can cause loss of the trench wall

Can the weight of this crane cause a bulge or failure
Where is the crane, are the utilities supported, what shoring
What is the soil doing?
Aides

Heaving or squeezing
Caused by downward pressure created by the Weight of adjoining soil or equipment
Can occur even when shoring or shielding is in place

Forces acting on a trench

Boiling
Evidenced by an upward water flow into the bottom of the cut
Caused by a high water table
Can occur even when shoring or trench boxes are used

Trench boiling

Tension Cracks
Tension cracks usually form at a horizontal distance of 0.5 to .75 times the depth of the trench

Sliding
Sliding or sloughing may occur as a result of tension cracks

Sloping and benching
1926 Subpart P App B
Definitions
Actual slope
Slope to which an excavation face is excavated

Distress
Soil is in a condition where a cave in is imminent or likely to occur

Maximum allowable slope
Steepest incline of an excavation face that is acceptable for the most favorable site conditions as protection against cave ins
Short term exposure
   Period of time less than or equal to 24 hours that
   an excavation is open

Stable rock
   Vertical 90 degrees

Type A soil
   ¾:1 (53 degrees)

Type B soil
   1:1 (45 degrees)

Type C soil
   1 ½:1 (34 degrees)

Foot note
   Sloping and benching for excavations greater than
   20 feet deep shall be designed by a registered
   professional engineer

**Design of Sloping and Benching**
Allowable configurations and slopes
Sloped at an angle not steeper than 1 ½ to 1
   Type C soil
Designs using other tabulated data
Shall be in written form
Identify limits of use of the data
Identify registered professional engineer who approved
Maintained at the job site

**Design of Sloping and Benching**

An attempt at sloping
An attempt at benching
Allowable sloping
Examples of sloping for different soils
Benching examples
Allowable slopes

Slope configurations
Slope configurations for A soils

**Timber Shoring for Trenches**
1926 Subpart P App C

Basis and limitations of data
- Trenches do not exceed 20 feet in depth
- Each table presents the minimum sizes of timber members to use in a shoring system
- Tables are taken from National Bureau of Standards
- Each table contains data only for the particular soil type

Timber shoring examples

**Aluminum Hydraulic Shoring for Trenches**
1926 Subpart P App D

Basis and limitations of data
- Vertical shore rails and horizontal wales
- Meet equivalent strength properties
- 2 inch cylinder inside diameter minimum safe working capacity of no less than 18000 pounds compressive load at maximum extension
- 3 inch cylinder inside diameter safe working not less than 30000 pounds axial compressive load at extensions as recommended by product manufacturer
- Spacing indicated is measured center to center
- When vertical shores are used must be a minimum of 3 shores spaced equally, horizontally in a group

Aluminum Hydraulic shoring examples

Alternatives to timber shoring

Pneumatic shoring being used in rescue
**Selection of Protective Systems**

1926 Subpart P App F

A graphic summary of the requirements contained
In subpart P for excavations 20 feet or less in depth

**Factors influencing cave-ins**

Intersecting trenches
Previously disturbed
Vibration
Surcharge load
Inclined layers
Drying/saturation
Free standing time

**Collapse forces**

24 inches of soil on a person’s chest weighs
750-1000 lbs
18 inches of soil covering a body weighs
1800-3000 lbs

Soil weight examples

Shear wall collapse speed
45 mph

Speed of collapsing dirt

How much pressure does it take to do this?

**Effects on the body**

Respiratory distress
Crush syndrome
Total body impact
### Fallacies and misconceptions

**At what depth/width do most incidents occur?**
- Between 6-8ft deep and less than 6ft wide
- Most incidents occur in bad weather
- False

**Clay is the least dangerous soil type**
- False

### The typical cave-in

**Summary:**
- Excavation laws, regulations, and standards
- Soil classifications
- Soil testing
- Competent person responsibilities
- Hazards associated with excavations
- Protective systems