SOIL MECHANICS AND CLASSIFICATION

OBJECTIVES:
Upon completion of this section, the participant should be able to:

1. Understand the forces that hold the soil together and tear it apart.
2. Explain how environmental factors can affect soil stability.
3. Describe the characteristics of each of the soil texture types.
4. Perform soil classification test and correctly categorize a soil sample.
DEVELOPMENT OF SOIL

Soil is the byproduct of thousands of years of wearing rock down by water, wind, and weather. Other organic and chemical components to the soil were supplied by animal and plant life. Chemical and waste additions to the soil have been made by man.

The base materials that a particular soil is composed of and the processes which have given rise to that soil account for the strength and classification of the soil, and will be the focus of this section.

FACTORS WHICH HOLD SOIL TOGETHER

There are two primary forces within the soil, which tend to hold it together: cohesion and internal friction.

COHESION is the tendency for two particles to "stick" together.

When two surfaces are glued together, the glue has the ability to stick to the surface to which it was applied. Likewise, the molecules that make up the glue have the ability to stick to or link up with other glue molecules. So, an "adhesive chain" is established between the two surfaces. This chain holds the surfaces together.

In soil, thin films of water act as "glue". To explain this, we need to look at a few chemistry principles. First, water is made up of one oxygen and two hydrogen atoms, and they are chemically linked to form a water molecule. This water molecule is slightly charged due to placement of electrons within the molecule. Because the bonding electrons spend more time around oxygen than hydrogen, the area around the oxygen atom possesses a slight negative electrical charge. It follows then that the hydrogen atoms have a slight positive charge. With these positive and negative charges, a water molecule is just like a small magnet.

Like the water molecule, the molecules on the surface of soil particles are charged as well. Some areas are positively charged and some areas are...
negatively charged. Since unlike charges attract (like north and south poles of a magnet), the water is attracted to the surface of these particles. Water molecules too are attracted to other water molecules. Now, we have water (the "glue") sticking to the surface of the soil particles and forming a cohesive bond within itself.

This type of particle cohesion, which is based on capillary action and surface tension of water, is dependent on a couple of things. Since it works only on the surface of a soil particle, the more surface area there is (the more finely divided the particles are), the more effective this type of cohesion will be. As we will learn a little later, clay is made up of many very small particles (and therefore a large amount of surface area) and is well suited to this type of bonding. A mass of pea-sized gravel, however, is composed of larger particles (and relatively less surface area) and is not effectively held together by this type of process.

Particle cohesion is also dependent upon the amount of water present between the particles. The greatest cohesion is seen when a very thin film of water is present between the two surfaces. This thin film allows for maximum "orderliness" of the water molecules. If you think of the water molecule as a magnet, this is analogous having all of the magnets laying side-by-side and parallel to each other. All of the magnets are pulling in the same direction.

When the amount of water between the particles increases, the effective strength of the "glue" decreases. Remember that when you glue two boards together, the strength of the resulting board is in the wood, not the glue. If you had three inches of glue between the boards, the glue would fail before the
Further, when a particle is surrounded by relatively large amounts of water, it can become mobile and slip. In some soil types, this cohesive nature allows the soil to exhibit plasticity.

**Plasticity:** a property of a soil to be deformed or molded without cracking, or appreciable volume change.

Soil in the plastic mass condition is putty-like and is easily deformed and re-shaped. The degree of plasticity is dependent upon the amount of moisture within the mass, the particle size and type, and the amount of impurity within the mass.

Some mineral deposits also act as a cohesive medium. These primarily calcium-containing deposits were left behind following water evaporation. The deposit hardened and incorporated the soil particles in a rigid matrix. Caliche is an example of a cemented soil.

**Cemented soil:** a soil in which the particles are held together by a chemical agent, such as calcium carbonate, such that a hand-size sample cannot be crushed into powder or individual soil particles by finger pressure.

**INTERNAL FRICTION**

The other main factor, which holds soil together, is internal friction between the particles within the soil. Geometric shape of the soil particles is of great importance in determining whether soil can support itself. To illustrate, take a bucket of cubic building blocks and a bucket of marbles. Quickly invert the bucket. The piles of blocks and marbles are maintained as long as there is a structure around it. Now, lift the buckets up. The cubic blocks will spill, but many of them will still be left in a pile. The marble pile, however, will flatten out and almost all of the marbles will end up on the same level.

Why? The geometric shape of the cubic blocks provided a flat surface for the block on top of it to rest upon. This allowed more of them to remain piled up. The marbles, however, had no such surface, and very little of a pile was established.

It is quite apparent then that those soils whose particles form geometric shapes with flat edges and sharp corners will be those soils whose structures are
interlocking and which are able to support themselves on the side of an excavation. Those soils whose particles have rounded corners and surfaces will be less able to support their own weight.

The weight resting upon the soil also influences how effective internal friction is. Angular interlocking soil particles which have weight pressing down on them are less likely to move than if the weight is removed. To see this, allow the abrasive surfaces of two pieces of coarse sandpaper to contact each other. It is easy to move the pieces back and forth as long as no pressure (weight) is applied. After pressure is applied, the pieces are much more resistant to movement.

**FACTORS WHICH CAUSE SOIL TO FAIL**

Operating in natural balance with those forces which hold soil together are those forces which tend to cause the soil to fail. The determination of whether the trench wall will stand or fall depends on the outcome of this struggle.

**GRAVITY AND SHEAR FORCES**

Gravity is the natural force that pulls everything toward the center of the earth. It is also the force which gives everything weight. Soil weighs approximately 100 pounds per cubic foot. Imagine the earth surface as an infinite number of adjacent columns of cohesive soil. Stacking one-foot cubes of soil atop one another makes each column. For every foot in height added, the weight on the base of this column increases by approximately 100 pounds. So, at a depth of 15 feet, the pressure on the bottom cube would be about 1500 pounds per square foot. This is surely enough pressure to compress the bottom cube and cause some soil types to fail. Why doesn't it? The bottom cube is being supported on all sides by the adjacent columns. The compressed soil has no where to go, the base holds, and the column stands.
Now, dig a 15-foot deep trench and expose one side of this column. The weight of the soil is not buttressed on the exposed side. The lateral soil pressure on the exposed side can be as much as 1/2 of the weight of the column at that depth, and the only thing which will keep it from compressing and "squishing" out the base of the column is the internal strength of the soil. But at a depth of 15 feet, the lateral pressure could be 750 pounds per square foot, quite enough pressure to overcome the cohesive and internal friction strengths for some soil types. We are setting the stage for a trench collapse.

A couple of things will happen to the soil, which illustrates the tension that it is under. First, the soil is being stretched at the surface of the ground. This stretches causes gaps called tension cracks to appear in the soil back from the trench face. These fissures run parallel with the trench and may be as far from the trench as the trench is deep. Also, the soil near the edge of the trench subsides as the lower part of the wall sags.
These cracks isolate columns of soil from their supporting neighbors. Finally, the weight is too much for the soil at the bottom of the trench, and a portion of the lower trench face fails. (The point at which the soil fails is called it Unconfined Compression Strength or UCS.)

**UNCONFINED COMPRESSIVE STRENGTH**: the load per unit area at which soil wall fall in compression. It can be determined by laboratory testing, or estimated in the field using a pocket penetrometer, by thumb penetration tests, and other methods.

Those forces that cause a mass of soil to slide on a slope are called shear forces. Now that the base of the column has lost its strength, the only thing holding the hanging column is the shear strength of the soil. This too will fail, and the column falls into the trench. This further isolates the columns formed by the stress cracks, and they too fall.
TRENCH DEPTH

As the depth of the trench increases, the ability of the soil to support itself decreases. The amount of soil, which could potentially cave into the trench, is also affected by depth. A rule of thumb says that if the depth of a trench is doubled, the amount of material, which will enter the trench during a cave-in, is increased by four times.

![Diagram of Trench Depth]

4 TIMES THE AMOUNT OF SOIL AVAILABLE TO CAVE IN

LAYERED SYSTEMS

Layered system: 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 systems that consist of layers of different strengths of soil or rock can lead to two types of trench collapse. If a stronger soil is under a weaker soil, the weaker soil may have a tendency to flow in. If the weaker soil is on the bottom, the lower part of the trench wall fails and large sections of the stronger topsoil enter the trench.

![Diagram of Layered Systems]
Layered systems are made much more dangerous when they are sloped into the trench. Analogous to a fault in a rock formation, a weakened plane below the soil surface, such as a vein of shale, mica (Micaceous seam), or weaker soil, can serve as a cleavage or shear plane where a large section of soil or rock can slide into the trench. Whenever layered systems are present, protective measures must be taken. (See illustration below)
WATER

Water is the trencher's enemy. As we saw, water can weaken the cohesive force that glues soil particles together. Water can fill void spaces and add to the soil's weight. Seeping or flowing water can make the soil particles mobile and therefore unable to support any weight. Seepage also has a drag effect, which tends to pull soil particles out of the main body of the soil. This drag effect is proportional to the velocity of the seepage flow. Water can undermine the base of trench walls and cause them to fail. Finally, mud makes working in the trench difficult and disagreeable. Whether the water comes from the surface or from within the soil itself, the presence of water must be considered when classifying the soil.

FROST

Alternate freezing and thawing will cause expansion and contraction of the soil and possibly lead to wall failure. Also, frozen walls may become less stable if the soil turns to mud. In many cases, the soil under a frost line will be soft and weak as well. Occasionally, soil is made more stable by freezing it with carbon dioxide or some other cryogenic material.

VIBRATION

Vibration of the soil is disruptive to the cohesive bonding process. It mobilizes soil particles and allows movement to overcome the cohesive bonding forces. This effect can be seen when a cement vibrator is inserted into a pile of wet cement.

Significant vibration can come from heavy equipment, tamping devices, or vehicle traffic. The protective measures needed will have to address the vibration issue if the vibration source cannot be suppressed.
SOIL COMPACTION

Undisturbed soil has had thousands of years to settle and naturally compact. Soil that has been previously excavated and back filled is not as compact as before, even if tamping or rolling devices have been used. It has been estimated that it takes centuries for a disturbed soil to regain its natural, pre-disturbance compaction state.

SURCHARGE

Any additional weight close to the trench can increase the lateral soil pressure on the exposed trench face. Spoil piles, vehicles, equipment, rocks, or other heavy objects need to be placed at least 2 feet back from the trench opening. Further, if sloping is used as the protective system, the surcharge weight must be placed so that it does not encroach past the angle prescribed.

CAVE-IN WARNING SIGNS

- Bulging at the bottom of the trench
- Bulging in the center of the wall or toe of the slope
- Spalling (large chunks of soil falling off of the trench face)
- Tension cracks
- Subsistence of the soil near the trench
- Water running from the soil
- Appearance of water from the bottom of the trench
- Sagging walls
- Raveling (small "crumbs" of soil falling from the face)
SOIL CLASSIFICATION

SOIL TYPES

Soil has been divided into four main texture categories: gravel, sand, silt, and clay with the latter three being the most important to us. The texture of the soil is usually an accurate reflection of particle size and shape.

<table>
<thead>
<tr>
<th>PARTICLE SIZE</th>
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<tbody>
<tr>
<td>GRAVEL</td>
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<td>2.0 mm</td>
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It should be noted that in the following discussion, the physical characteristics of each category are based on a pure, non-mixed sample. Characteristics of mixed soils will be discussed later.

GRAVEL

Any soil where 1/2 of the constituent particles is greater than 3/16" in size is considered to be gravel. In cases such as pea gravel, the particle size is much larger. Gravel exhibits essentially no cohesiveness or plasticity. It has little ability to hold water. The shape of the particles can either be angular or rounded, and this shape will determine its internal friction and particle inter-locking characteristics (how well this material will pile up).

Granular Soil means gravel, sand, or silt (coarse-grained soil) with little or no clay content. Granular soil has no cohesive strength. Some moist granular soils exhibit apparent cohesion. Granular soil cannot be molded when moist and crumbles easily when dry.

SAND

Sand is composed of individual mineral or rock fragments, which are in the area of 0.05mm - 2.0mm in size. At this size, the particles will be retained by a #200 sieve. These fragments are usually made of silica and can have either rounded (water borne) or angular (glacier borne) geometry. It too has little plasticity and cannot be molded to any great extent. Because of the large void spaces between particles, its ability to hold water is very limited, thereby making it useful for drainage fill. Most of the individual sand particles can be seen with the naked eye.
Unlike gravel, moist sand does exhibit apparent cohesion. This allows damp sand to stand vertically unsupported for short periods of time. As would be expected, the apparent cohesion is strongest when the sand is damp. If the sand is dried out, the "glue" is removed and the vertical face will collapse. The remaining pile will assume a slope angle similar to its natural angle of repose (about 35 - 40 degrees to the horizontal). Then, if too much water is introduced, the capillary action bonding becomes disrupted, the particles become mobile, and the vertical face falls.

**SILT**

The classification of a soil as "silt" can be quite confusing since most people associate that word with a thin, weak, fine soil found in a delta or quiet lake. In the soil engineering sense however, the term "silt" refers only to the particle size. With a particle size of 0.005mm - 0.05mm, silt is still able to respond fairly quickly to changes in wetting or drying conditions. In some instances, however, particle size and compaction can restrict the flow of water through the soil and make it very difficult to drain. Depending upon moisture conditions, it has very limited plasticity and is somewhat cohesive. Most individual silt particles cannot be discerned with the naked eye. Silt particles usually have angular, irregular, and sometimes rod-like shapes. Because of this, certain types of silt exhibit fairly strong shear strength under the right moisture and compaction conditions.

Trenching in silt soil has always been considered risky because its strength characteristics vary greatly with minimal changes in moisture content. Further, the more mixed the soil is, the less strength it has. Then too, silt may offer few visual clues prior to failure.

**CLAY**

Clay is the finest soil recognized with a particle size range less than 0.005mm. Significant plasticity and cohesion characteristics are found in clay because the clay particles are so small and so numerous. This provides maximum surface area for cohesive bonding activity to take place.

Cohesive soil means clay (fine grain soil), or soil with a high clay content, which has cohesive strength. Cohesive soil does not crumble, can be excavated with vertical sideslopes, and is plastic when moist. Cohesive soil is hard to break up when dry, and exhibits significant cohesion when submerged. Cohesive solid include clayey silt, sandy clay, silty clay, clay and organic clay.

Like "silt", most people have a mental idea of what "clay" is. They envision the high degree cohesiveness and plasticity of the material, which is an accurate portrayal of this substance under specific moisture conditions. Clay, however, can manifest itself in other ways too.
Varying from liquid-like slurry to a rock-hard mass, clay has the most versatile texture range of any of the classes. The appearance variability of clay is based upon the amount of moisture it contains. In its arid state, a mass of clay is rock hard and is very difficult to break. Even though it looks absolutely dry, the bonding power in the hard mass still comes from a thin film of water between the clay particles. (When clay objects are baked in a kiln however, all moisture is driven out. During this process though, the cohesive medium changes when silica within the clay melt to form a glass-like matrix, which holds the individual clay particles.) As moisture is added, the form of the mass is moldable when the plastic limit has been reached. As moisture continues to be increased, the caramel candies like mass transforms into a mass similar to drywall compound. Swelling of the mass may also be seen. Further addition of water causes the “liquid point” to be reached as the clay reaches a semi-liquid slurry. Here, the clay particles are mobile in the water. At this point, the clay exhibits neither cohesiveness nor plasticity.

OTHER CLASSIFICATIONS OF SOIL

LOAM

Loam is a term used for soil composed of varying amounts of clay, sand, and silt. It is soil similar to that found in farm fields and yards. The shear strength, cohesiveness, and plasticity are all functions of the amount of clay in the sample, its drainage qualities rely mainly upon its sand content, and its ability to support plant life is a function of the amount of silt and organic matter within the sample.

HARDBAN AND CALICHE

Hardpan and Caliche are examples of cemented soils that are impervious to water. They generally lie at or below the surface of the ground, are impervious to drainage, and cannot be crushed into powder with hand pressure. Hardpan can either be a vein of clay or cemented soil bonded with compounds of calcium or iron. Caliche is a cemented soil usually found on the surface of rocky soil. The bonding agent is usually calcium carbonate, which was dissolved in water and was left behind during evaporation.

Man-made cemented soils an also be produced by injecting cement grout, clay slurry, or other chemicals into the ground. This process stabilizes the soil and is commonly used to seal the bottom of sheet pile walls.

ORGANIC MIX SOILS

Most soil contains a varying amount of organic material. Generally, the presence of this material weakens the soil since it cannot be significantly compressed and serves as a barrier to particle cohesion. "Black dirt" or peats are examples of soil, which contain high amounts of organic material.
MIXED SOILS

As the name suggests, this type of soil contains more than one soil classification. Most natural occurring, non-sifted soil is a mixture of sand, silt, and clay. The behavior of the soil will depend upon the relative quantities of the three constituent groups. For example, we say that clean gravel has no cohesion. If you mix it with clay and silt however, you end up with a concoction, which is very difficult to get off of your boots.

Of a more serious nature are mixtures in the soil making up a trench wall. These "contaminations" can drastically affect a soil's cohesiveness and shear strength. The presence of or very small silt and clay particles can greatly affect the stability of gravel and sand beds.

Various schemes to classify mixed soil have been developed. Perhaps the clearest is the use of the triangular classification chart. The percent by volume of sand, silt, and clay is calculated after removal of the gravel. Plotting the respective percentages yields a qualitative description of the soil type.

![Triangular Classification Chart]

SOIL MOISTURE STATE

OSHA describes the five following moisture states for soil (this is taken directly from Appendix A):

**Dry** Soil that does not exhibit any visible signs of moisture content.

**Moist** Soil looks and feels damp. Moist cohesive soil can be shaped and rolled moist granular soil shows some cohesion.
Wet Soil 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. Granular material that would exhibit cohesive properties when moist will loose those cohesive properties when wet.

Saturated Soil in which the voids are filled with water. Saturation does not require flow. Saturation or near saturation is necessary for the proper use of instruments such as a pocket penetrometer or shear vane.

Submerged Soil which is under water or freely seeping water

We have seen that the presence of water in varying amounts have either increased or decreased the strength and cohesion of the soil. Depending upon the soil type(s), the moisture conditions for the soil near the ground surface may be vastly different from the soil at the bottom of the trench. How the Competent person deals with moisture conditions will in large part determine how safe the trenching operation will be.

SOIL TESTING

One of the most important jobs of the competent person is to classify the soil type. All of the protective measures and systems decisions will hinge on this classification.

As we have seen before, the lines between the textural classifications of soil are by no means distinct. For example, the difference between "sandy loam" and "loam" may be very subtle. For this reason, OSHA bases its soil classification on the basis of visual and manual tests that are comparatively straightforward. Further, they divide soils into only four classes: Stable rock, TYPE A, TYPE B, and TYPE C.

STABLE ROCK

Rock is considered to be the "mother" of all soil. Accordingly, OSHA has included Stable Rock into the soil classification scheme even though it is a very distant relative to the other three groups. It is the most infrequently used classification as well.

As the name implies, this material is made of solid mineral material, which is not fissured or loose. It has the ability to be excavated leaving vertical walls that will remain stable and vertical until backfilling. No protective systems are required for trenches in stable rock.
Most rock formations do have seams, fissures or cracks that probably tell of distinct layers within the formation. The stable rock classification cannot be used for those formations where a layered system slopes toward a trench wall. Seams of mica, shale, soil, or fissures between two rock surfaces may provide a cleavage plane, and the stable rock classification cannot be used.

**TYPE A SOIL**

TYPE A soil is a soil which has an unconfined compressive strength of 1.5 tons per square foot (ft.) or greater. Many of the cemented, hardpan and clay-containing cohesive soils can be classified as TYPE A soil.

Containing high amounts of clay, the soil will be highly cohesive. In some cases, the soil may be plastic when moist but very hard when dry.

Soils, which CANNOT be classified as TYPE A soil, are:

- Soil which is fissured;
- Soil subject to vibration;
- Soil in a layered system where the system slopes toward a trench wall;
- Soil which is seeping water or is submerged;
- Soil which has been previously disturbed;
- Soil which has been judged by a competent person as being less stable for some other reason.
**TYPE B SOIL**

TYPE B soil has an unconfined compressive strength which is less than 1.5 ft. but greater than 0.5 ft. Soil mixtures, which have less clay (less cohesion), and more sand and/or loam fall into this category. Angular gravel can also be considered TYPE B soil.

Sometimes, the TYPE B classification is used for flawed soils, which meet unconfined compressive strength standards for TYPE A soils. Examples include:

- Previously disturbed compacted soils (unless TYPE C);
- Fissured or layered soils (unless TYPE C);
- Rock which is not stable (fractured rock);
- Layered systems where the slope toward the trench is less than 1V:4H;
- Subject to vibration (unless TYPE C).

**TYPE C SOIL**

TYPE C soil has an unconfined compressive strength less than 0.5 ft. This type of soil is the least stable and most prone to collapse. Therefore, trenches dug in TYPE C soil requires the highest degree of protective measures.

TYPE C soil usually has a minimum of cohesion and clay content is usually low. Soils are often granular and particle shapes are rounded rather than angular. Often, this type of soil is saturated or submerged. Examples of TYPE C soil conditions include:

- Sand, granular soils, and round gravel;
- Submerged soil;
- Soil freely seeping water;
- Disturbed soil not classified as TYPE B;
- Submerged unstable rock;
- Layered systems sloping toward the trench at a greater than 1V: 4H slope.
SOIL TESTING

OSHA says that the competent person is responsible for visually and manually testing the soil. Soil testing is optional only when TYPE C soil is assumed and the maximum level of protection is to be taken anyway. In all other cases, the testing of at least one sample is required. Further, it is prudent to take numerous samples from the excavation site especially when different soil textures are visible. The tests used are either prescribed by OSHA in Appendix A or are those adopted by the American Society for Testing Materials or the U.S. Department of Agriculture.

The Competent person can test the soil in the trench face itself or can test larger fresh clumps in the spoil pile. THE COMPETENT PERSON MUST NOT ENTER THE TRENCH TO CONDUCT SAMPLING AND TESTING UNTIL THE PROPER SAFETY PROCEDURES AND DEVICES ARE IN PLACE. If the soil sample is dry, it may have to be re-hydrated prior to testing.

If layered systems are present, the classification shall be based upon the weakest layer if the weaker layer is under the stronger.

If the weaker layer is the top layer, then each layer can be classified individually. This differential classification may allow for a trench wall with multiple slopes.
It is the responsibility of the competent person to test the soil at the beginning of each workday and also after each event which might change the classification of the soil. If the soil must be re-classified, the protective measures must reflect that change. It is also a good idea for the competent person to keep a log of the soil tests that they have performed. See the Supplementary Materials section for a sample soil testing log form.

**Reclassification**

If, after classifying a deposit, the properties, factors, or conditions affecting its classification change in any way, the changes shall be evaluated by a competent person. The deposit shall be reclassified as necessary to reflect the changed circumstances.

**MANUAL TESTS FOR COMPRESSION STRENGTH**

The manual tests are used to determine the soil texture, plasticity, and/or unconfined compressive strength of the soil. In most cases, the use of a **pocket penetrometer** will yield the strength information that is needed for classification. This instrument uses a graduated spring-loaded piston to compress the soil. The tip of the piston is pushed into the soil sample until the tip has been buried to a calibration mark. As the soil is compressed, a ring on the graduated cylinder moves and stops at a point corresponding to the unconfined compressive strength. For a more detailed operation description, please consult the operating instructions.
Shear vane device uses torque to test the soil. A disk with vanes protruding from it is imbedded in the soil. The other end of the device is a round handle with a graduated dial. As the device is turned, torque pressure is applied to the soil sample. An indicator moves around the dial until the soil fails. The corresponding number is then multiplied by 2 to get the approximate unconfined compressive strength of the soil in tons per square foot. Again, for a more detailed description of the shear vane operation, please consult the operator's manual.

The approximate strength of the soil can also be determined without the use of an instrument. OSHA recognizes the thumb penetration test as an acceptable way of approximating soil strength.

Thumb penetration test is used to estimate the unconfined compressive strength of cohesive soils.

The soil must be cohesive in nature. TYPE A soils can readily be indented by the thumb; however, they can be penetrated by the thumb only with very great effort. TYPE C soil can be easily penetrated several inches by the thumb, and can be molded by light finger pressure. This test should be conducted on an undisturbed soil sample, such as a large clump of spoil, as soon after excavation as possible to keep to a minimum the effect of drying. If the excavation is later exposed to wetting influences, then the classification must be changed accordingly.

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<thead>
<tr>
<th>SOIL TYPE</th>
<th>THUMB PENETRATION</th>
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<tbody>
<tr>
<td>A</td>
<td>Soil indented with difficulty</td>
</tr>
<tr>
<td>B</td>
<td>Soil indented up to cuticle with effort</td>
</tr>
<tr>
<td>C</td>
<td>Soil indented to knuckle easily</td>
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Other tests such as the dry strength test, plasticity test, and drying test are described below:

**Manual test**  
Manual analysis of soil samples is conducted to determine quantitative as well as qualitative properties of soil and to provide more information in order to classify soil properly.

**Plasticity test**  
Mold a moist or wet sample of soil into a ball and attempt to roll it into threads as thin as 1/8 inch in diameter. This determines whether the soil is cohesive or non-cohesive.

**Dry test**  
The basic purpose of the drying test is to differentiate between cohesive material with fissures unfissured cohesive material, and granular material.

It should be noted that "feeling" the soil with a piece of heavy equipment is not an acceptable means of soil testing. So, the fact that the backhoe is having difficulty digging through the soil does not necessarily correlate with the soil type.

**VISUAL TESTS**

Visual tests are conducted to determine qualitative information regarding the excavation site. Factors such as the soil adjacent to the excavation site, soil forming the sides of the trench, and excavated materials need to be evaluated by the competent person.

- Observations of the soil that is excavated and the sides of the excavation. Estimate the range of particle sizes. Soil that is primarily composed of fine-grained material is cohesive material. Soil composed primarily of coarse-grained sand or gravel is granular material.

- Observe the soil as it is excavated. Soil that remains in clumps when excavated is cohesive. Soil that breaks up easily and does not stay in clumps is granular.

- Observe the side of the open excavation. Crack-like openings such as tension cracks could indicate fissured material. If chunks of soil spall off a vertical side, the soil could be fissured. Small spalls are evidence of moving ground and are indications of potentially hazardous situations.

- Observe the area adjacent to the excavation and the excavation itself for evidence of existing utility and other underground structures, and to identify previously disturbed soil.

- Observe the opened side of the excavation to identify layered systems. Examine the layered systems to identify if the layers slope toward the excavation. Estimate the degree of slope of the layers. Slope of the layers may be approximately the slope of the ground around the trench site.
• Observe the area adjacent to the excavation and the sides of the opened excavation for the evidence of surface water seeping from the sides of the excavation, or the location of the level of the water table.

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

With these manual and visual tests, the competent person should be able to accurately determine the soil type. Once the type of soil is known, the protective systems can be determined and designed.