EXCAVATION
Excavations

SUMMARY OF GENERAL EXCAVATION REQUIREMENTS

a. All surface encumbrances (trees, objects, etc.) located so as to create a hazard to employees will be removed or supported.

b. The estimated locations of utility installations, such as sewer, telephone, fuel, electric, water lines, or any other underground installations that reasonably may be expected to be encountered, shall be determined before opening the excavation. Wyoming One Call at 1-800-849-2476 and the Wyoming Association of Local Utility Coordinating Councils call at 1-800-348-1030 two working days before digging for utility locations. As the excavation progresses, the exact location will be determined by safe and acceptable means.

c. While the excavation is open underground installations will be protected, supported, or removed as necessary to safeguard employees.

d. A stairway, ladder, ramp or other safe means of egress will be provided in trench excavations that are four or more feet deep so as to require no more than 25 feet of lateral travel for employees.

e. Employees exposed to public vehicular traffic will be provided and wear warning vest or other suitable garments marked/made with reflectorized or high-visibility material.

f. Employees will not be permitted underneath loads handled by lifting or digging equipment.

g. Where oxygen deficient (<19.5%) or hazardous atmosphere exists or could reasonably be expected to exist, the atmospheres in the excavations will be tested before employees enter the excavations greater than four feet deep. In addition, emergency rescue equipment, such as breathing apparatus, safety harness and line, or a basket stretcher, will be readily available and attended when in use.

h. Employees will not work in excavations in which there is accumulated water, or where water is accumulating, unless adequate precautions have been taken to protect employees against the hazards of water accumulation, such as pumps, special support or shield systems, or use of a safety harness and lifeline.

i. If the stability of adjacent buildings, walls or other structures is endangered by excavation operations, support systems such as shoring, bracing or underpinning will be provided. Sidewalks, pavements, and adjacent structures will be supported/protected if undermined.

j. Spoil piles and other material or equipment will be placed and/or kept back at least two feet from the edge of the excavation, or by the use of retaining devices.

k. Daily inspections of excavations, adjacent areas, and protective systems will be made by a competent person for evidence of a situation that could result in possible cave-in, protective system
failure, hazardous atmospheres, or other hazardous condition. The inspection will be made prior to the start of work and as needed throughout the shift, and also after every rainstorm or other hazard increasing occurrence. If hazards are identified, employees will be removed from the hazardous area.

l. If employees or equipment are required to cross or permitted to cross over excavations, walkways or bridges will be provided. If the height to the walkway/bridge surface is six feet or more, standard guardrails will also be provided on each side.

m. Employees will not be permitted to work on the faces of sloped or bench excavations at levels above other employees except when employees at the lower levels are protected from falling, rolling, or sliding material or equipment.

n. Employees will be protected from the hazard of cave-ins when entering or exiting the areas protected by shields.

o. Employees are not allowed in trench boxes/shields when they are being installed, removed or moved vertically.

COMPETENT PERSON

A competent person must be designated for the site and must have and be able to demonstrate the following.

1. Capability of detecting hazardous conditions at the worksite, which entails:

   * Training/experience and knowledge of:
     - Soils analysis
     - Use of protective systems
     - Wyoming Workers’ Safety’s excavation standard.

   * Capability of detecting:
     - Conditions that may cause cave-ins
     - Failures in protective systems
     - Hazardous atmospheres
     - Other hazardous conditions

2. Authority to take prompt corrective measures to eliminate existing and predictable hazards and to stop work when required.

PROTECTIVE SYSTEMS

Employees in an excavation will be protected from cave-ins by an adequate protective system. Exceptions are when the excavation is made entirely in stable rock, or the excavation is less than five feet deep and examination of the ground by a competent person provides no indication of a potential cave-in. Such cave-in protection will consist of one of the following protection systems.

Sloping and Benching Systems. The slopes and configurations of sloping and benching systems will be selected and constructed by the employer in accordance with the following options.

   * Option 1 – Allowable configurations and slopes: Excavation will be sloped at an angle not steeper than 1 1/2H to 1V. Under this option, soil classification is not required – just dig and slope back 1-1/2H to 1V. (OSHA’s way)

   * Option 2 - Use of Appendices A and B: Maximum allowable sloping and benching will be in accordance with the conditions and requirements of Appendix A (Soil Classification) and Appendix B (Sloping and Benching). (OSHA’s way)

   * Option 3 - Designs using other tabulated data: Designs of sloping or benching systems will be in accordance with other tabulated data, such as tables and charts. (Engineer’s way: non-site specific)

   * Option 4 - Design by a registered professional engineer: Sloping and benching systems not using Options 1, 2, or 3 will be approved by a registered professional engineer. (Engineer’s way: site specific)

Support Systems, Shield Systems, or Other Protective Systems. The designs of support systems, shield systems, and other protective systems will be selected and constructed by the employer in accordance with one of the following options.

   * Option 1 - Designs using Appendix A and Appendices C or D: Timber shoring in trenches will be in accordance with Appendix A (Soil Classification) and Appendix C (Timber
Shoring). Designs for, and use of, aluminum hydraulic shoring will be in accordance with Appendix A (Soil Classification) and the manufacturer’s tabulated data (Option 2 below), but if the manufacturer’s tabulated data cannot be used or is not available, designs and use will be in accordance with Appendix D (Aluminum Hydraulic Shoring). (OSHA’s way)

* Option 2 - Designs using manufacturer’s tabulated data: Design and use of support systems, shield systems, or other protective systems that are drawn from manufacturer’s tabulated data shall be in accordance with all specifications, recommendations, and limitations issued or made by the manufacturer. (Manufacturer’s data/engineer’s way) (Commercial aluminum hydraulic shoring or trench box/shield)

* Option 3 - Designs using other tabulated data: designs of support systems, or other protective systems will be selected from and be in accordance with tabulated data, such as tables and charts. (Engineer’s way: Non-site specific) (Shop-made trench box)

* Option 4 - Design by a registered professional engineer: Support systems, shield systems, and other protective systems not using Options 1,2, or 3 above, will be approved by a registered engineer. (Engineer’s way: site or system specific)

**SOIL CLASSIFICATION**

Wyoming Workers’ Safety classified soil and rock deposits into four types each type is briefly described below.

**Stable Rock:** Natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed. Determining whether a deposit is of this type maybe difficult unless it is known whether cracks exist and whether or not the cracks run into or away from the excavation.

**Type A Soils:** Cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (tsf) or greater. Examples of Type cohesive soils are: clay, silty clay, sandy clay, clay loam, and, in some cases, silty clay loam and sandy clay loam. No soil is Type A if it is fissured, is subject to vibration of any type, has previously been disturbed, is part of a sloped, layered system where the layers dip into the excavation on a slope of 4H to 1V or greater, or has seeping water.

**Type B Soils:** Cohesive soils with an unconfined compressive strength greater than 0.5 tsf but less than 1.5 tsf. Examples of Type B soils are: angular gravel; silt; silt loam; previously disturbed soils unless otherwise classified as Type C; soils that meet the unconfined compressive strength or cementation requirements of Type A soils but are fissured or subject to vibration; dry unstable rock; layered systems sloping into the trench at a slope less than 4H to 1V (only if the material would be classified as a Type B soil)

**Type C Soils:** Cohesive soils with an unconfined compressive strength of 0.5 tsf or less. Also includes granular soils such as gravel, sand and loamy sand, submerged soil, soil from which water is freely seeping, and submerged rock that is not stable. Also included in this classification is material in a sloped, layered system where the layers dip into the excavation or have a slope of 4H to 1V or greater.

**Layered Geological Strata:** Where soils are configured in layers, i.e., where a layered geologic structure exists, the soil must be classified on the basis of the soil classification of the weakest soil layer. Each layer may be classified individually if a more stable layer lies below a less stable layer, i.e., where a Type C soil rests on top of stable rock.

**TESTING METHODS**

Soil classification is based on the results of at least one manual and one visual analysis conducted by the competent person. The categories are determined on an analysis of the soil properties, performance characteristics of the soils, and environmental conditions. All this should answer the end questions: **How stable is the soil?** Make the following five analysis:

1. Moisture content – contain too little or too much water?

2. Cohesive properties – Inadequate amount of clays?

3. Granular properties – Too much granular gravels and sands?

4. Cementatious materials – Too little?

5. Destabilizing factors –
   - Vibrations
   - Fissures
   - Previously Disturbed Soils
   - Accumulated/free flowing water
Surcharge loading
Wind loading (poles, trees, etc.)
These destabilizing factors will make any good soil into bad soil, i.e., Type A to Type B or C.

Many kinds of equipment and methods are used to determine the type of soil prevailing in an area. Some of these are described below.

**Manual Tests.**

**Pocket Penetrometer:** Penetrometers are direct reading, spring-operated instruments that are used to determine the unconfined compressive strength of saturated cohesive soils. Once pushed into the soil, an indicator sleeve displays the reading. Take multiple readings and throw out the low and high readings. Penetrometers are error rated in the range of 20-40 percent.

**Thumb Penetration Test:** This procedure involves an attempt to press the end of the thumb firmly into the soil in question. If the thumb makes an indentation in the soil only with great difficulty, 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, and if the thumb penetrates the full length of the thumb, it is Type C soil. The thumb test is subjective and is therefore the least accurate method.

**Pencil Penetration Test:** Press the blunt end of the pencil into the soil sample. Penetration up to 1/4” indicates Type A soil. Penetration of about one inch would indicate Type B soil. If the pencil penetrates full length, then it is Type C soil.

**Plasticity or Wet Thread Test:** This test is conducted by molding a moist sample of the soil into a ball and attempting to roll it into a thin thread approximately 1/8 inch in diameter by two inches long. The thread is held by one end, and if the sample does not break or tear, the soil is considered cohesive.

**Visual Tests:** Visual tests are qualitative evaluation of conditions around the site. In visual testing, the entire excavation site is observed, not just the soil.

Include the soil conditions of the excavation walls, areas adjacent to the site and the soil being excavated. If the soil remains in clumps, it is cohesive; if it appears to be coarse-grained sand or gravel, it is considered granular.

Also check for any signs or sources of vibration.

During visual testing, check for crack-line openings along the failure zone that would indicate tension cracks. Look for previously disturbed soil indicated by existing utilities and any trench in existing roadways. Observe the open side of the excavation for indications of layered geologic structuring.

Also look for signs of bulging, boiling, or suffling in the bottom of the trench, as well as for signs of surface water seeping from the sides of the excavation or from the water table.

In addition, the area adjacent to the excavation should be checked for signs of foundations or other intrusions into the failure zone, and form surcharging. The spoil distance from the edge of the excavation must be two feet.

**INSPECTIONS**

Inspections must be made by a competent person. The following guide specifies the frequency and conditions requiring inspections to be conducted:

* Daily and before the start of each shift.
* As dictated by the activity taking place in the trench.
* After each and every rain storm.
* After other phenomena that would increase the hazard, e.g., snowstorm, windstorm, thaw, earthquake, etc.
* When fissures, tension cracks, sloughing, undercutting, water seepage, bulging at the bottom, or other similar circumstances occur.
* When there is any indication of change or movement in adjacent structures.

**DEFINITIONS**

**Competent Person:** 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 authorization to take prompt corrective measures to eliminate them.

**Excavation:** Any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal.

**Hazardous Atmosphere:** An atmosphere which, by reason of being explosive, flammable,
poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, may cause death, illness, or injury to persons exposed to the atmosphere.

**Protective Systems:** A method of protecting employees from cave-ins, from material that could fall or roll from an excavation face or into an excavation, or from the collapse of adjacent structures. Protective systems include support systems, sloping and benching systems, shield systems, and other systems that provide the necessary protection.

**Subsurface Encumbrances:** Underground utilities, foundations, underground streams, high water tables, and transformer vaults as well as geological anomalies.

**Trench:** A narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet.

**Unconfined Compressive Strength:** The load per unit area at which soil will fail in compression. This measure can be determined by laboratory testing, or it can be estimated in the field using a pocket penetrometer, by thumb penetration tests, or by other methods.

**HOUSE FOUNDATION/BASEMENT EXCAVATIONS**

Until further notice, the provisions of 1926.652 (Requirements for Protective System) are not being applied to house foundation/basement excavations when all the following conditions are present:

* The house foundation/basement excavation is less than seven and one-half feet in depth or is benched for at least two feet horizontally for every five 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 feet.

* There is no water, surface tension cracks, nor other environmental conditions present that reduce the stability of the excavations.

* 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 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.

This policy applies to all such house foundation/basement excavations including those which become trenches by definition when formwork, foundations, or walls are constructed. This policy does not apply to utility excavations (trenches) where cave-in protection (1926.652) is still required. Since the application of 1926.652 to house excavations was not specifically considered during the excavation standard rulemaking, the requirements dealing with cave-in protection are suspended until the issue can be fully evaluated.
EXCAVATIONS MADE IN TYPE A SOIL
SLOPING AND BENCHING

SIMPLE SLOPE GENERAL

SIMPLE SLOPE-SHORT TERM
LESS THAN 24 HOURS

UN SUPPORTED VERTICALLY SIGNED LOWER PORTION
MAXIMUM 8 FEET IN DEPTH

SIMPLE BENCH

UN SUPPORTED VERTICALLY SIGNED LOWER PORTION
MAXIMUM 12 FEET OF DEPTH

MULTIPLE BENCH

SUPPORTED OR SHIELDED
VERTICALLY SIGNED LOWER PORTION
EXCAVATIONS MADE IN TYPE B SOIL

SIMPLE SLOPE

This bench allowed in cohesive soil only

SINGLE BENCH

This bench allowed in cohesive soil only

MULTIPLE BENCH

SUPPORTED OR SHIELDED VERTICALLY SIZED LOWER PORTION

SUPPORTED OR SHIELDED VERTICALLY SIZED LOWER PORTION

NOTE: No stand-alone benching allowed in Type C soil.

NOTE: For sloping requirements in layered soils, please refer to the standard.
TRENCH FAILURES

- Soft Zone Failure
- Layered Soils
- Sloughing (Air Drying)
- Wedge Failure
- Rotational Failure
- Soft Pockets
- Sand Pockets
WHAT IS SOIL?

A soil is a mixture of rock, water, air and a variety of other substances. It is, however, the rock, water and air which most predominantly affect the behavior of the material in most circumstances.

A soil is made up of rock in the form of small particles and spaces called voids. The proportions of rock, water and air can vary drastically depending on the source and history of the soil. Generally speaking though, soil is composed of about ½ voids.

If the void spaces are totally filled with water, it is termed saturated. If they are completely filled with air the soil is called oven dry.

Normally, some part of the voids are filled with water. The amount of water in a soil compared with the amount it could hold is the percent of saturation.

Solid rock has a specific gravity of 2.68 and weighs about 167 lbs. per cubic foot. Specific gravity is the ratio of the weight of an object to the weight of an equal volume of water. Since water weighs 62.4 lbs. per cubic foot, a cubic foot of rock would weigh 2.68 times as much or 167 lbs. (The weight of air in soil is ignored)

Since a cubic foot of soil contains ½ cubic foot of rock, the rock will weight 1.2 of 167 or 200 lbs. When all of the voids are filled with water, the ½ cubic foot of water would weigh 1.2 of 62.4 or 31 pounds. The soil is said to be 100% saturated and weighs 191 lbs. per cubic foot.

Note that if saturated soil weighs 114 lbs. per cubic foot, a cubic yard of soil would weigh 27 times as much since there are 27 cubic feet per cubic yard. This is 3,078 pounds, or a little over 1 ½ tons. Few people realize that a cubic yard of soil can easily weigh as much as a pick-up truck!
MECHANICS OF A CAVE-IN, AN EXAMPLE

An open excavation is an unnatural situation. The average landscape shows no vertical or near vertical slopes.

Soil or dirt is a very heavy material. A cubic foot can easily weigh 114 pounds and a cubic yard can be as heavy as a pick-up truck.

Consider a column of soil which is one foot by one foot and several feet high. At one foot of depth a horizontal plane one foot by one foot is carrying the cubic foot which lies over it. The stress, or load per unit area is 100 lbs. per square foot (psf). At depth of two feet horizontal plane is carrying two cubic feet or 200 psf. At a depth of five feet the vertical stress is 500 psf, and so on.

The column described would soon collapse if not supported by similar adjacent columns. Stresses are developed which act horizontally on the column. These lateral stresses can be considered ½ as large as the vertical stresses. At a depth of five feet the vertical stress is 500 psf and the lateral, or horizontal stress is 250 psf.

Undisturbed soil may be visualized as an infinite number of columns of soil adjoining and supporting one another. The system is equilibrium and is perfectly stable.

When an excavation is cut the system is disturbed. Lateral stresses which existed on the excavation wall are removed as the excavation is done. The soil in the excavation wall immediately begins to move, however slowly, into the excavation.

At the same time the surface of the ground next to the excavation subsides, creating an unnatural situation. The surface of the ground is in tension and some of the weight of the soil in the excavation wall is transferred to the soil back away from the wall face by a phenomenon called shear.

The combination of tension in the ground surface and shear stress causes cracks to form back from the edge of the excavation. Cracks occur from the edge of the excavation. Cracks occur from about ½ to 2/3 of the depth of the excavation back from its edge. For example, if an excavation 10 feet deep is dug the cracks may be found somewhere between three to seven feet back from the excavation edge. There may be several cracks. They are usually vertical and they may be ½ the depth of the excavation.

When cracks develop, the weight of the soil in the excavation wall is no longer partly carried by the soil back from the excavation’s face.

Then the lower part of the excavation wall fails under the great stress from the weight of the soil above it. There is no lateral stress to prevent the failure.

When the bottom of the excavation fails or “kicks”, into the excavation the support for the upper part of the excavation wall is now essentially hanging only by shear and tension forces. Failure occurs.

A third cave-in quickly follows. Soil, like concrete is normally strong in compression but not at all strong in tension. Reinforced concrete makes use of the compressive strength of concrete and the tensile strength of steel. There is no steel in soil.

Cave-ins generally come in multiples. If the first one doesn’t get you, the second may and the third is always a possibility.

This example of the mechanics of a cave-in has offered a discussion of some of the forces involved in such accidents. It has by no means considered all of the forces which may be involved in such an occurrence weathering, water, vibration and superimposed loads may add to the hazardous conditions leading to cave-ins.
MECHANICS OF A CAVE-IN

1. Subsidence
   Soil Crack
   Area of Greatest Stress

2. Subsidence
   Soil in Tension
   Area of Greatest Stress

3. Subsidence
   Soil Cracks
   Second Cave-in

4. Subsidence
   Soil Cracks
   Third Cave-in

First Cave-in
SOIL CLASSIFICATION

Stable Rock:

Means natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Type A means:

Cohesive soils with an unconfined compressive strength of 1.5 ton per square foot (tsf) (144 kPa) or greater. Examples of cohesive soils are: clay, silty clay, sandy clay, clay loam and, in some cases, silty clay loam and sandy clay loam. Cemented soils such as caliche and hart pan are also considered Type A.

However, no soil is Type A if:

1) The soil is fissured; or
2) The soil is subject to vibration from heavy traffic, pile driving, or similar effects; or
3) The soil has been previously disturbed; or
4) 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; or
5) The material is subjected to other factors that would require it to be classified as a less stable material.

Type B means:

1) Cohesive soil with an unconfined compressive strength greater than 0.5 tsf (48 kPa) but less than 1.5 (144 kPa); or
2) Granular cohesionless soils including: angular gravel (similar to crushed rock), silt, silt loam, sandy loam and, in some cases, silty clay loam and sandy clay loam.
3) Previously disturbed soils except those which would otherwise be classed as Type C soil.
4) Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subjected to vibration; or
5) Dry rock that is not stable; or
6) Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than four horizontal to one classified as Type B.

Type C means:

1) Cohesive soil with an unconfined compressive strength greater than 0.5 tsf (48 kPa) or less; or
2) Granular soils including gravel, sand, and loamy sand; or
3) Submerged soil or soil from which water is freely seeping; or
4) Submerged rock that is not stable; or
5) Material in a sloped, layered system where the layers dip into the excavation or a slope or four horizontal to one vertical (4H:1V) or steeper.