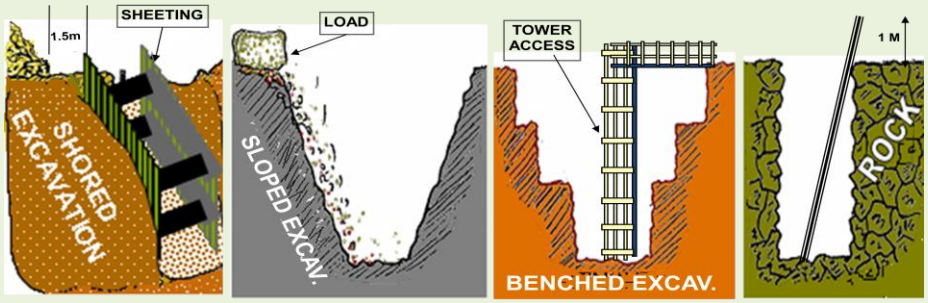
Excavation Safety

Construction work is dangerous; and work involving trenching and excavating activities tends to be the most hazardous in the industry. Yet, we see trenching and excavating work going on all around us. Excavations are needed for the installation and repair of utility lines, replacement of water and sewer lines, pipelines, general construction activities, swimming pool construction, even grave digging. Excavation projects vary considerably, each with its own set of unique problems. Every year, people involved in this type of work are killed or seriously injured. These deaths and injuries are caused mainly by the collapse of the side walls of the excavation, the tipping of machinery over into the trench or people being struck by the bucket of the excavator.

To ensure the safety of those involved, excavation work has to be properly planned, managed, supervised and executed in order to prevent accidents. Persons involved at all stages should be aware of the hazards involved and the procedures in place to control the risks associated with this type of work.

Excavation is any man-made cut, cavity, trench, or depression in the earth's surface formed by earth removal.

Trench is defined as a narrow underground excavation that is deeper than it is wide, and is no wider than 15 feet (4.5 meters).



As excavation activities can involve significant hazards, a high degree of management commitment is required. Anyone in an excavation deeper than 1.25 meters be protected from dislodgement of the sides of the excavation. This protection could be in the form of shoring (support for the excavation), battering (sloping the excavation) or other suitable means. Notwithstanding this, all excavations (including those shallower than 1.25metres) and the area in the vicinity of an excavation must, when people have access to them, be as far as is reasonably practicable safe and without risk to health.

Excavations and trenches need not be deep or large to create a life threatening hazard. Soil is heavy, and failures take place with little or no notice. A person can be trapped before there is time to react. So it is important that every excavation be prepared correctly, allowing to complete job safely and efficiently. Remember that every trench is different. Soil type, moisture content, depth, configuration, proximity to existing structures, and location of spoil piles all work together to make every excavation unique. Keep these points in mind when working:

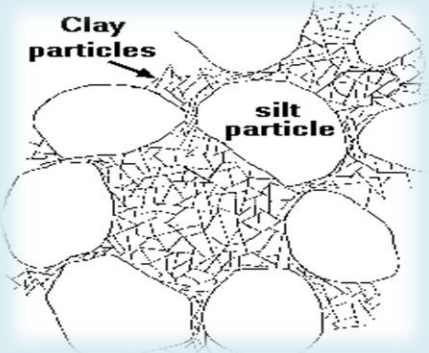
THE HIERARCHY OF CONTROL MEASURES

Some control measures are more effective than others. Control measures can be ranked from the highest level of protection and reliability to the lowest. This ranking is known as the hierarchy of control. It management must always work to eliminate a hazard with the most effective control. If this is not reasonably practicable, it must minimize the risk by one or a combination of the following:

- Substitution – for example, using an excavator with a rock breaker rather than manual method
- Isolation – for example, using concrete barriers to separate pedestrians and powered mobile plant to reduce the risk of collision
- Engineering Controls – for example benching, battering or shoring the sides of the excavation to reduce the risk of ground collapse.

Weight of Soils

The weight of soil varies with type and moisture content. One cubic foot of soil can weigh from 50kg to 65 kg or more, and one cubic meter (35.3 cubic feet) of soil can weigh more than 1360kg.



Common Soil Problems

The terms *soil* and *earth* are commonly referred to in the excavation process to describe the naturally occurring materials uncovered on a during excavation. Soil conditions vary from one site to the next. Soil may be loose or partially cemented, organic or inorganic. However, most soils can be referred to as a mixture or an accumulation of mineral grains that are not cemented together. An exception is hard rock, which remains firm after exposure to the elements.

Soil failure is defined as the collapse of part or all of an excavation wall. The most common soil failure is typically described as an unexpected settlement, or cave-in, of an excavation. Soil sliding is the most common factor leading to soil failure. Proper planning and supervision can avoid the unsafe working conditions caused by soil sliding. Unless such safety precautions have been implemented, sliding soil failure can occur in all types of excavations (including sloped trenches and excavations with braced trench boxes).

A safe slope can be defined as the maximum angle of the edge wall or bank of an excavation at which sliding will not occur. The unique mixtures of the different types of soil (sand, clay, silt and rock) necessitate different safe slopes from one excavation site to the next. There are other complicating factors that can result in sliding soil failures. During an excavation, visibly different layers of soil maybe uncovered. Each of those layers may call for different safe slopes. It is essential to plan your excavation around the most gradual (rather than steepest) safe slope for all of the different soil types and layers encountered during the excavation. During an excavation, as the soil composition changes, the safe slope for trench wall excavation also changes.. Sliding and other modes of failure can also occur in soils that are not densely compacted. Soil failure can occur for any number of reasons. Factors that increase the chances of soil failure are:

1. excessive vibration
2. surface encumbrances
3. weather conditions

Soil Classification

One cubic meter of soil weighs an average of 1365 kg, and a cave-in is like dropping a small car from one foot above your head. To excavate and trench safely, knowledge about soil mechanics and how to slope and shore. Horizontal and vertical forces within the earth keep undisturbed soil in place. An excavation disturbs or eliminates these forces. Soil naturally moves downward and inward. A number of factors govern how fast this occurs, such as soil type, moisture, vibration and surface loading. The type of soil governs the stability of the excavation. It is required that soil classification be made by a competent person and installation of adequate protective equipment be made before workers enter the excavation. Soil types include:

Type A soil - This is the most stable soil and is composed of clay, silty clay, clay loam and sandy clay. It has an unconfined compressive strength of 1.5 tons per square foot (t/sf) or greater. Type A soil is very cohesive. Unfortunately, people wrongly assume it is stable and will not collapse if not shored.

No soil, no matter the composition or apparent stability, can be classified as Type A soil if the soil is fissured or subject to vibration from traffic, equipment, or other excavation activities.

Soil cannot be classed as Type A soil if layers dip into the excavation on a slope of four feet horizontal to one foot vertical or there are other factors, such as seeping water, that would make the soil less than stable.

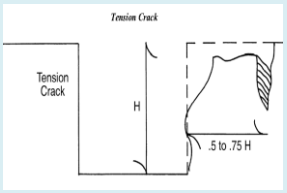
Type B soil - This cohesive soil is composed of silt, silty loam, sandy loam, and granular cohesive solids including angular gravel (crushed rock). It has an unconfined strength greater than 0.5 tons per square foot but less than 1.5 tons per square foot.

Type C soil - Type C soil – This is the least stable soil. It is a non- cohesive soil composed of granular soils, including sand, gravel, loamy sand, submerged soil or soil from which water is draining, submerged rock, or soil in a sloped layered system where the layers dip into

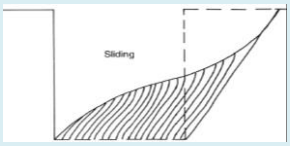
Soil Mechanics

A number of stresses and deformations can occur in an open cut or trench. For example, increases or decreases in moisture content can adversely affect the stability of a trench or excavation.

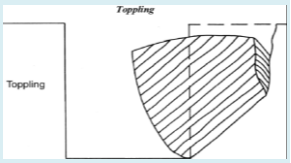
Tension cracks Tension cracks usually form at a horizontal distance of one-half to three-quarters times the depth of the trench, measured from the top of the vertical face of the trench



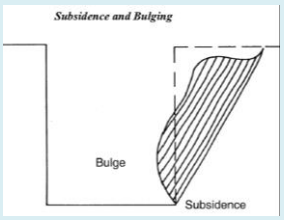
Sliding or sluffing may occur as a result of tension cracks,



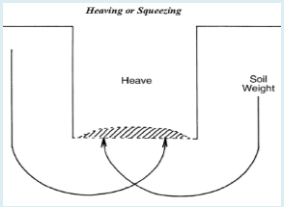
Toppling In addition to sliding, tension cracks can cause toppling. Toppling occurs when the trench's vertical face shears along the tension crack line and topples into the excavation.



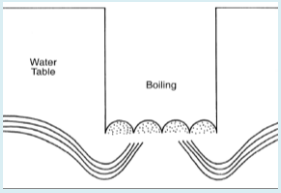
Subsidence and Bulging An unsupported excavation can create an unbalanced stress in the soil, which, in turn, causes subsidence at the surface and bulging of the vertical face of the trench. If uncorrected, this condition can cause face failure and entrapment of workers in the trench.



Heaving or Squeezing Bottom heaving or squeezing is caused by the downward pressure created by the weight of adjoining soil. This pressure causes a bulge in the bottom of the cut



Boiling is evidenced by an upward water flow into the bottom of the cut. A high water table is one of the causes of boiling. Boiling produces a "quick" condition in the bottom of the cut and can occur even when shoring or trench boxes are used.



If cracks are observed in rocky types of soil, sliding has already occurred. These cracks should signal that a more gradual slope for excavation is needed because the rocky soil is very susceptible to slides and other types of failure.

the excavation at a slope of four feet horizontal to one foot vertical or greater. It has an unconfined compressive strength of 0.5 tons per square foot or less.

Stable rock - This natural solid mineral material can be excavated with vertical sides and remains intact while exposed.

Testing :

When making a site soil classification, the competent person conducts both visual and manual tests. Factors to examine are:

Soil particle size - Usually there is a mixture of sizes. The percentage of sand to silt and clay determines the soil type.

Grain size - If a grain of soil is larger than a pencil lead, it is classified as gravel. If it is smaller, but can be seen by the unaided eye, it is classified as sand. Clay and silt particles cannot be seen without the use of a microscope. A general statement is the larger the grain size the less stable the soil.

- Soil that clumps and holds together when dug out is most likely to be clay or silt.
- Cracks in walls of the excavation, with material spilling off (slabs of soil falling off the sides) indicates Type B or C soil.
- Standing water or water seeping out of the bottom or trench walls automatically classifies the soil as Type C.
- Layered soil adjacent to roadways or buildings, disturbed soil, or soil exposed to a source of vibration, requires a soil classification to be made by a registered professional engineer.

Protective Systems

Except in stable rock, workers should be protected against the danger of cave-ins in trenches and/or excavations that are five feet or deeper. There are four recognized methods of protection: sloping, benching, shoring and shielding (trench box). The use of any of these methods or combinations of these methods are governed by factors such as space, soil types, depth, speed, and expense.

Requirements : "Each employee in an excavation shall be protected from cave-ins by an adequate protective system."

There are only two exceptions when a protective system is not required: (1) excavation made entirely in stable rock; or (2) excavation less than five feet deep which has been examined by a competent person who determined there is no indication for a potential cave-in.

Sloping is a protective measure that cuts the walls of the excavation back at an angle from the floor to produce a stable slope. The slope angle is based on soil type. The flatter the angle of the slope, the greater the protection factor for the employee (see Figure 1).

- Type A Soil: The ratio is 3/4 ft. horizontal for every foot vertical (53° from the horizontal)
- Type B Soil: The ratio is 1 ft. horizontal for every foot vertical (45° from the horizontal)
- Type C Soil: The ratio is 11/2 ft. horizontal for every one foot vertical (34° from the horizontal)

Benching is the process of cutting benches or steps into the excavation *(see* Figure). The angle used for benching is based on a ratio of horizontal to vertical cuts. It should be noted that benching is reserved only for cohesive soils.

It is *not* permissible to bench Type C soil because of its inability to support a vertical wall. Type C soils always require the use of sloping, shielding, or shoring.

Factors like these make soil less stable:

- Vibration from machinery or traffic;
- Exposure to rain or flooding;
- Periods of low humidity (drying); and
- Soil loading from overburden or equipment.

When these factors are present the excavation, whether benched or sloped, must be re-inspected for signs of distress. Distress signs include:

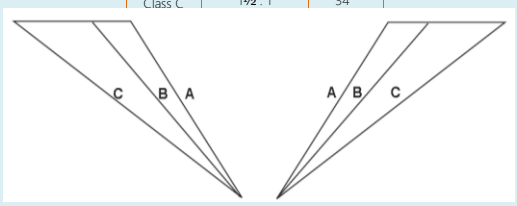
- Cracking excavation walls;
- Cracks in the surface soil 1/2 to 3/4 the distance back from the excavation as the excavation is deep;
- Bulging of the trench wall; and
- Sloughing off of clods or small sections from the trench wall.

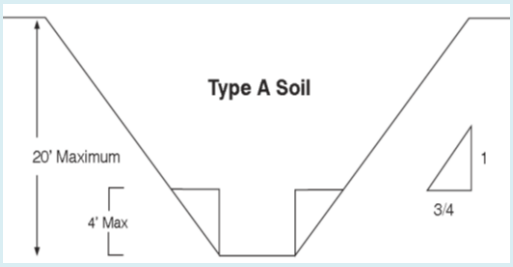
All of these indicate an imminent danger of cave-in. If any of these signs are observed, employees shall be directed to evacuate the excavation and the slope shall be cut back further or a mechanical protective system installed.

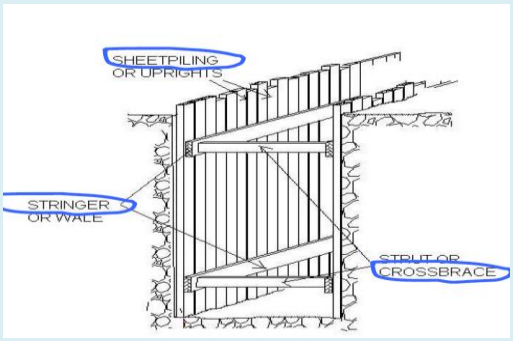
Shoring and Shield Systems

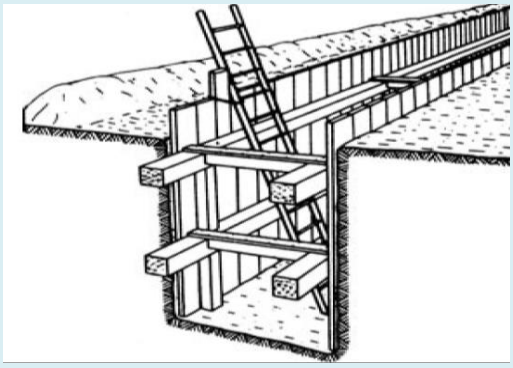
Shoring and shield systems are protective measures that add support to an excavation. The safest system is one that can be installed and removed without personnel entering the excavation.

Simple Slope Excavation		
Class	Measurement	Degree
Class A	3/4 : 1	53°
Class B	1 : 1	45°
Class C	1½ : 1	34°









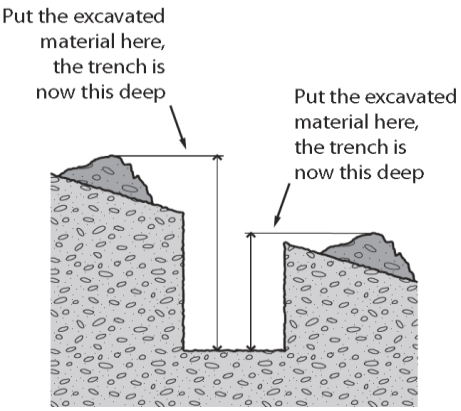
Shoring

This system is designed to prevent excavation failure (cave-ins) by supporting trench walls with a system of vertical uprights and/or sheeting and Cross braces (shores). Shores are structures that cross the trench and put pressure on the vertical uprights and sheeting .

Some safety requirements for using aluminium hydraulic shoring are as follows:

- Installation and removal of the shoring is done from outside of the excavation.
- Individual shores (elements) are pressurized and depressurized slowly to prevent failure of the remaining shores or collapse of the excavation walls.
- Any modification must be made by competent authority.

Excavated material impact on effective excavation depth



Shielding

A trench shield is an engineered metal box that is placed in the excavation. It does not provide structural strength to the excavation, but provides workers a safe worksite that protects them from collapsing material. A registered professional engineer must design the trench shield or trench box system which can be pre-manufactured or built on site as necessary. Regardless of where they are built, they must be constructed to exact engineering specifications. There are several safety requirements when using a trench box:

- Shields must be installed in a manner that restricts side-to-side movement or any other hazardous movement in the event of sudden lateral movement, i.e., trench failure.
- The shield system shall not be exposed to loads exceeding the design standard.
- Workers shall be protected from the hazards of cave-ins when entering or leaving the area protected by the shield.
- Workers shall not be allowed inside the shield or to ride on the shield, when the shield is being installed, removed or moved vertically.
- Shield structure shall extend a minimum of 18 inches above the lip of the excavation when used in conjunction with a sloped or benched excavation.
- Excavation may be permitted up to a depth of 2 feet below the bottom of the shield *provided* the shield is designed to resist the forces calculated for the full depth of the trench and there is no indication while the trench is open of a possible collapse of soil from behind or below the bottom of the shield.

Final Safety Requirement : All excavations must be backfilled as soon as possible after removal of the support system. No worker is permitted in an unshored or unprotected excavation or trench no matter how compelling the reason.

Specific Safety Requirements

A basic rule for excavation is, "plan your dig, then dig your plan." If you encounter something unplanned for, then stop and re-plan. Before excavation, know everything possible about the excavation route.

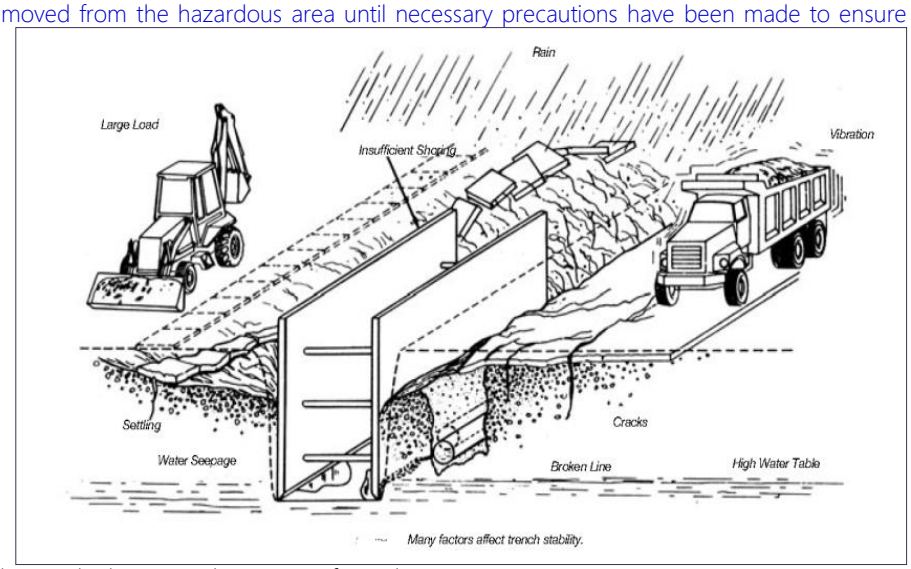
Hazard Identification and Risk Assessment : Anyone require that anyone in an excavation deeper than 1.25 meters be protected from dislodgement of the sides of the excavation. This protection could be in the form of shoring (support for the excavation), battering (sloping the excavation) or other suitable means. Notwithstanding this, all excavations (including those shallower than 1.25 metres) and the area in the vicinity of an excavation must, when people have access to them, be as far as is reasonably practicable safe and without risk to health. A Risk Assessment should be carried out in relation to activities being undertaken and a safe system of work be prepared and implemented.

Safe System of Work Plan- Once identified what the risks are, put in place, a plan to effectively manage those risks.

The main Hazards related to excavations are :

- Surface encumbrances - includes trees, signs, sidewalks, power poles, parking lots, and walls which must be removed, braced, shored, or otherwise supported to prevent a hazard.
- Underground utilities - such as sewer, water, gas lines, communications, and electric lines must be identified, and physically located. Once the utility is uncovered, protect or have the utility removed as necessary.
- Access and egress - Any trench or excavation four feet or deeper must have a means of exit. Ladders and/or ramps must be located no more than 25 feet from any employee while he or she is in the excavation. Ensure that ladders extend three feet above the surface of the excavation and be tied off if possible.
- Exposure to vehicular traffic - Workers exposed to vehicular traffic must wear "high visibility" vests or clothing.
- Exposure to falling loads - Under no condition should workers be permitted under loads handled by lifting or digging equipment. Workers must stand away from vehicles being loaded or unloaded.
- Warning systems - All mobile equipment (front-end loaders, bulldozers and dump trucks) must be equipped with a warning device such as a backup alarm if the operator does not have a clear and direct view of the edge of the excavation. Some other good safety practices are use of hand signals from a flag person, stop logs, barricades or other mechanical signals. An attentive operator and a flag person who knows and uses proper hand signals provide the safest method.

- Hazardous atmospheres - In excavations deeper than four feet with the potential for a hazardous atmosphere or oxygen deficiency, conduct air testing before workers enter the excavation and as often as necessary to ensure the atmosphere remains safe. Ventilation or respiratory protection may be needed to protect workers from harmful atmospheres.
- Water accumulation hazards - Workers must not work in excavations where water is accumulating unless adequate precautions are taken to protect these workers from these hazards. This protection involves specific shoring, water removal (to control the level of accumulating water), use of lifelines, harnesses, and careful monitoring by a competent person.
- Stability of adjacent structures - Excavation below the base or footing of a foundation, wall, sidewalk, pavement, or other structure is not permitted unless
  - shoring or bracing is provided to prevent cave-in
  - excavation is in stable rock
  - a registered professional engineer determines the structure is far enough away that the excavation is not affected or that the excavation will not pose a threat to the workers
- Loose rock and soil protection - Excavated earth (spoil), materials, tools, and equipment shall be placed no closer than two feet from the edge of the excavation. Rock and soil should be scaled off the face of the excavation or retained by shoring or other acceptable methods to prevent the material from falling and striking workers.
  Good work practice should dictate that no person will work on the sides of the slope or benched excavation above other workers unless the lower workers are protected from falling materials. If possible and practical, grade the slope away from the excavation. This serves a dual purpose of keeping equipment and vehicles from accidentally rolling into the excavation and directing rain water away from the excavation
  - Inspections - A competent person must inspect the excavation and its support system for evidence of a situation that could result in possible cave-ins, indications of failure of the protective system, hazardous atmospheres, or other hazardous conditions. The inspections shall be done prior to start of work and as often as needed throughout the shift. Inspections shall be made after every rainstorm or other hazard-increasing occurrence. When an inspection finds evidence of a situation that could result in a hazard to the worker, exposed workers will be removed from the hazardous area until necessary precautions have been made to ensure their safety.
  - Fall protection - Where personnel and/or equipment must cross an excavation, a walkway or bridge shall be engineered to withstand the maximum expected load. All excavations in a remote location or unattended should have adequate barriers or physical protection to prevent people from falling into the excavation.

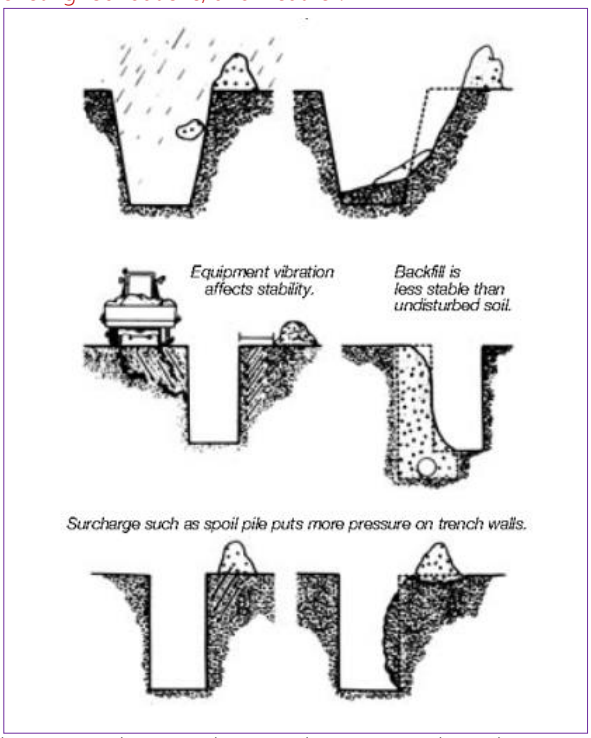


- Excavation Collapse:
  - The following is a summary of some of the steps than can be taken to prevent a person becoming engulfed or injured in an excavation.
  - Prevent the sides and the ends from collapsing by battering them to a safe angle
  - No vehicle or item of plant is allowed near an edge of an excavation, which is likely to cause collapse Where it is not possible to batter, support the walls with timber, sheeting or proprietary support systems.
  - Do not go into unsupported excavations that have not been battered to a suitable slope.
  - Never work ahead of the support.
  - Even work in rock cut excavations may result in boulders falling in on persons at work. Secure them with adequate means.
- Materials Falling into Excavations
  - Do not store spoil or other materials close to the sides of excavations. The spoil may fall into the excavation and the extra loading will make the sides more prone to collapse. Any excavated spoil must be kept at least 1meter away from excavated edge.
  - Make sure the edges of the excavation are protected against falling materials. Provide toe boards where necessary.
  - Wear a hard hat when working in excavations.
  - In rock cut excavations where the rock is friable netting should be used.
- People and Vehicles Falling into Excavations
  - Steps to prevent people falling into excavations should be inplace. Provide substantial barriers, for example guard rails and toe boards.
  - Keep vehicles away from excavations wherever possible. Use brightly painted stop blocks or barriers where necessary.
  - Where vehicles have to tip materials into excavations, use stop blocks to prevent them from over-running. Remember that the sides of the excavation may need extra support.
  - Never have a person in an excavation while machinery is working over it. The extra surcharge from the weight of the machine may induce a collapse

- People Being Struck by Plant or Heavy Items
  - Keep workers away from moving plant such as excavators. Workers should work outside the reach of the excavator bucket. Where this is not possible, use safe systems of work to prevent people being struck.
  - Plant operators should be competent and
  - Mobile work equipment such as articulated dump trucks that have reduced visibility in their direction of travel must be fitted with auxiliary visibility aids.
  - The work should be carried out under the control of competent slinger or signaller
- Protecting the public
  - Fence off all excavations in public places to prevent pedestrians and vehicles falling into them.
  - Where children might get onto a site out of hours, take precautions (for example back-filling or securely covering excavations) to reduce the chance of them being injured. If possible, excavations in public roads or streets should be back-filled or covered over at night to minimize the risk of accidents to the public.
  - Provide adequate guarding, signage and lighting on all footpaths, cycle tracks or roads.
  - Do not leave materials lying beside an area of work. Materials should be stored in a secure compound and removed and used only as required.
- Supervision
  - A competent person must supervise the installation, alteration or removal of excavation support.
  - Excavation works on a road, footpath or cycle track must be supervised by a competent person who is competent and experienced in road safety .
  - People working in excavations should be given clear instructions, through training, on how to work safely.
- Inspection and Examination of Excavations
  - All excavations must be inspected by a competent person at least once in every day during which persons are at work in the excavations.
  - Every excavation more than 2 metres deep must be inspected for safety requirements by a competent person at the commencement of every shift.
  - A thorough examination of the excavation must be carried out at least every 7 days by competent engineer for safety requirements and a record should be maintained.

Causes of Cave-Ins

Soil properties often vary widely from the top to the bottom and along the length of a trench. Many factors such as cracks, water, vibration, weather, and previous excavation can affect trench stability. Time is also a critical factor. Some trenches will remain open for a long period, then suddenly collapse for no apparent reason. Figure 3 shows the typical causes of cave-ins. The main factors affecting trench stability are soil type, moisture, vibration, surcharge, previous excavation, existing foundations, and weather.



- Moisture content : The amount of moisture in the soil has a great effect on soil strength. Once a trench is dug, the sides of the open excavation are exposed to the air. Moisture content of the soil begins to change almost immediately and the strength of the walls may be affected. The longer an excavation is open to the air, the greater the risk of a cave-in.
- Vibration: Vibration from various sources can affect trench stability. Often trench walls are subject to vibration from vehicular traffic or from construction operations such as earth moving, compaction, pile driving, and blasting. These can all contribute to the collapse of trench walls.
- Surcharge: A surcharge is an excessive load or weight that can affect trench stability. For instance, excavated soil piled next to the trench can exert pressure on the walls. Placement of spoil piles is therefore important. Spoil should be kept as far as is practical from the edge of the trench. Mobile equipment and other material stored close to the trench also add a surcharge that will affect trench stability. One metre from the edge to the toe of the spoil pile is the minimum distance requirement. The distance should be greater for deeper trenches.
- Previous excavation :Old utility trenches either crossing or running parallel to the new trench can affect the strength and stability . Soil around and between these old excavations can be very unstable. At best it is considered Type 3 soil — loose, soft, and low in internal strength
- Existing foundations: Around most trenches and excavations there is a failure zone where surcharges, changes in soil condition, or other disruptions can cause collapse.
- Weather : Rain, melting snow, thawing earth, and overflow from adjacent streams, storm drains, and sewers all produce changes in soil conditions. In fact, water from any source can reduce soil cohesion

Reference

The following websites and books have been referred in compiling this topic. They are also suggested for further readings to increase and enhancement of knowledge in health and safety.

WEBSITES

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