Safety in Construction
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Module No # 03
Lecture No # 12
Trench Cave-ins

So, in the last week we started with intruding the fatal 4 hazards so we start from falls, Cave-ins, caught in between or struck by, electrocution and so on. So, I also said we will be discussing each one of the hazards along with where generally it is seen along with the operation also, we will be discussing. So last week we have seen on falls and concreting work and demolition primarily in the scaffold and farm work where the falls is predominantly seen.

So, this week we will see on Cave-ins and excavation is one of the major operations where Cave-ins are real killer. So, if you talk about excavation then Cave-ins are the major hazard, we will also be discussing what are the other hazards available also. So, excavation as such I will be covering in this particular class.

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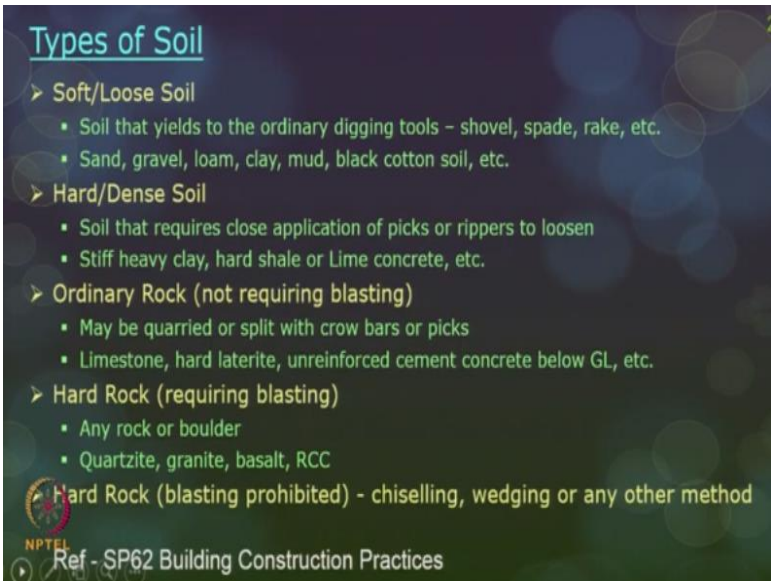

Now why should you go for excavation so the top soil as such is not suitable for construction and it comprises of mineral matter or organic matter and so on. So, water, air etc., so that is why it is not really suitable for construction and hence the soil as to be removed. I am talking about

surface excavation and deep excavation also generally happens to support a structure and its foundations.

So even the top soil has to be fully leveled and cleared and also the separate you know holes or openings has to be made earth has to be cut to support this structure and its foundation. So, when you say earth work it is not just one single operation. There are so many steps in the earth work operation itself. So as such if you start looking, there are some preparatory issues which implies before you did and then you have think of how do you did for the choice of equipment and combination and so on.

Then digging out how exactly you have to dig along with protection of sides and the shores until the foundation is completed preventing from side collapse. Then whenever you encounter with a water table dewatering or bailing out the water from the pit or the trench then back filing of this trench pit one side excavation of foundation is completed. And then you dump this surplus earth into some specified marked locations.

So, these are all the different steps you have in earth work operations and now we are going to see different hazards available in all these steps. Now let us start with before you dig what are the major precautions you have to take. And before understanding that let us discuss about something on IS code and what they talk about types of excavation. So as given in SP 62 there are several types of soil.

Soft soil or loose soil so what happens here is examples sand, gravel, loam, clay, mud, black cotton soil and so on. So, you can use ordinary digging tools like for examples shovels, spade or rakes for actually you know cutting of the earth. The next type of soil is hard or dense soil examples stiff heavy clay hard shale or lime concrete. So, you may have to be close in applying your energy and force.

So, you may have to accordingly use repose or something because you may have to closely work on and loosen the soil so that you are digging of the earth. The next category is ordinary rock again in rock you have several categories one is rock which does not require blasting and the other one blasting is prohibited. So, in ordinary rock, lime stone hard laterite and reinforced cement concrete etc.

So, all these are examples and maybe you have split with crowbars or picks hard rock which requires blasting. So, any rock or boulders are the examples and you can go with quartzite, granite, basalt, RCC are the examples of hard rock you have to blast the ground in order to do the cutting of the earth. The next is hard rock where in blasting is prohibited due to some reason or the other. You can use chiseling, edging or any other agreed method by the engineering in charge.

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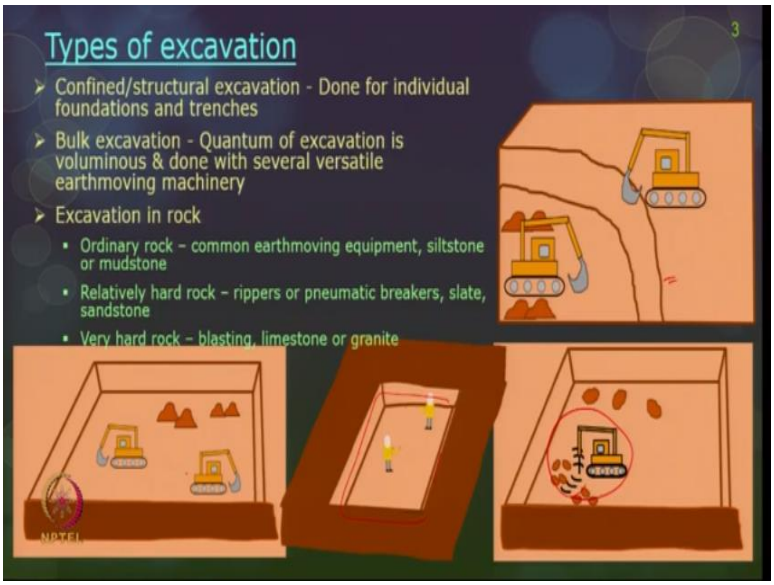

So, what are the types of excavation now again there are several words which comes in research in industry practice starting from structural excavation, bulk excavation, confined excavation, sloped excavation and then stepped excavation and so on. Like these there are, lot of terms coming in but let us think about based on protective measures which we have to follow in the construction site.

So accordingly, the first category is confined or structural excavation so once your drawings are all completed you give a good for construction point and based on that drawing you actually know cut the earth only to that portion. So, it can be trench excavation or only for individual footings or foundations you cut the earth as the walling. So, you may use close cutting of earth only in specified locations then that is primarily called confined or structural excavation.

The next type is bulk excavation wherein your quantum of excavation is voluminous and you have to use several equipment like as shown in the figure here. Several equipment and which may be moving on in the site for cutting of the earth. Excavation in rock for relatively a hard rock you can use rippers or pneumatic breakers for very hard rocks you know you can go for blasting operations.

For example, this is a confined excavation so this is like a trench excavation shown here and this is actually a bulk excavation. So here you can see it is a very large site and the bulk excavation lot of equipment's will be available in the site as seen here for the work. And these are the excavation work in rocks primarily you have to use rippers or breakers or even drilling machines for cutting of and loosening the earth.

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Now before you dig you have to post warning messages to the public and you have to prevent the public from the entering into the construction. So, what you should do is first provide sufficient number of notice boards and other danger signals and warning signals to prevent the accidents. So, the next one is barriers, barriers are primarily you know obstacles or obtrusions so that the public is not intervening in the excavation work.

And this should be provided for any excavation shaft or pit or opening having a vertical distance of more than 2 meters. Then this is primarily a picture of fencing so fencing is actually erected for deep excavation and then there is lot of likely hood of public you know frequenting that area.

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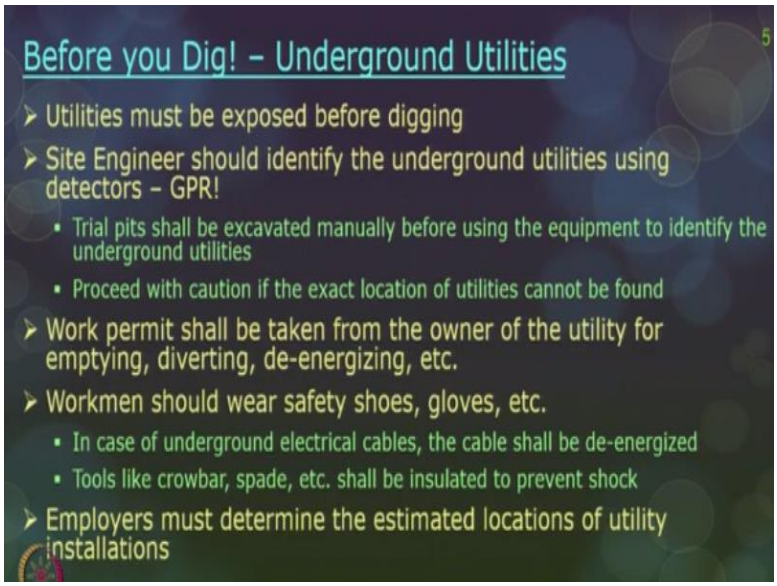

So, the next precaution so first is you have posted a message you have allowanced to the public you have given enough warning signals on excavation is going on. The second precautions, that you have to do is identify all the buried underground utilities. There are so many underground utilities which are buried inside the ground and you may have to identify all of them so that do not mess up with those utilities when you are actually putting your know excavator equipment there.

So, all the utilities which are all you know passing through the site has to be identified before you start the digging and so and there are, lot of means of identifying also. So, utilities much be exposed before digging the site engineer should identify the underground utilities using detectors you can also use ground penetrating radar and there are other devices also available. So, you may have to use an appropriate device and an appropriate choice of GPR based on what you wanted to scan.

You are actually scanning the ground and you should know what exactly you have to scan? And what is the depth of scan? What is the intensity or the accuracy with which you want to scan? Based on that you may have to choose equipment sometimes even your scanning measurement may go wrong. You may not be able to know get a right data or sometimes there may be some mystery or obstruction present inside the soil.

And you would not know what exactly it is? So, you should not be leading that it is a doubtful so you can also do trial pits. So, trial pits can be done manually at several locations in order to identify those underground utilities. So, you can do at trial pit at very close to those utility and watch for what is the utility? And once you have you know confirmed as what is the utility? Then you can identify all the others and then go.

So always even if the utilities are all found or even if you think and confident and all utilities are identified still you have to proceed with proper cautions when you are doing the digging operation. And the work permit has to be obtained for either emptying the utility provided it is a sewerage line or a waterline or something. Or diverting the route or maybe de-energizing if it is an electric cable or something.

So, you have to take adequate measures from the concerned authority and you have to know divert or safe guard the site first of all the buried utilities and then you may have to work. And all the workmen who are working in the site wear and proper shoes, gloves and other PPEs as recommended. Suppose if you have identified or you have a suspicion on some underground electrical cables then the cables should be de-energized.

Otherwise also the equipment which you are using for example tools like crowbar or spades etc., they should be well insulated. So that you do not the workers do not get an electric shock while they are digging those places. And the employees also should determine all the estimated locations of these installations so that it is easy for them to divert and turn. Once you identified all the utilities then the next step is you have to mark those utilities on to the ground.

There are some color codes and color symbols for the marking all those utilities on the ground you can use a flag as shown in the figure here.

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You can either you know put color flags and then say that these are the lines where utilities are available or you can also apply spray paints to show that utilities are available. And American public works association APWA has recommended uniform color codes which is followed in several countries. White color is generally recommended for the proposed excavation pink color for temporary survey markings.

Yellow color for gas, oils, steam petroleum or gaseous materials red generally is used to show electric power lines cables, conduits and lighting cables. Blue for portable water orange for communications, alarms, signals, cables or other issues. Purple for reclined water, irrigation and slurry lines and green for sewers and drain lines. So according to these color codes you can mark and show the presence of the utilities which you have identified before you start with the excavation work.

And now the first step I told before you dig is first you have to post adequate warning messages, signs and then you may have to proper barriers, fencing and so on. Second is identifying all the undergoing utilities, the next step is there maybe adjacent structures close to your site. Your site may not be like too spacious that you do not have any neighboring structure close by will have so many neighboring structures close by.

So, you have to analyze what are the neighboring structures close by; and you have to see whether those foundation. The foundation of those neighboring structures, are interfering with

your excavation or not. And sometimes what happens your site maybe you may be excavating some portion it may be closed to one foundation of other existing building. And suppose if you are taking out soil from a close base structure.

That structure may start weakening and it may lose its strength. So, there are some ways of preventing that then only you have to start with our excavation work.

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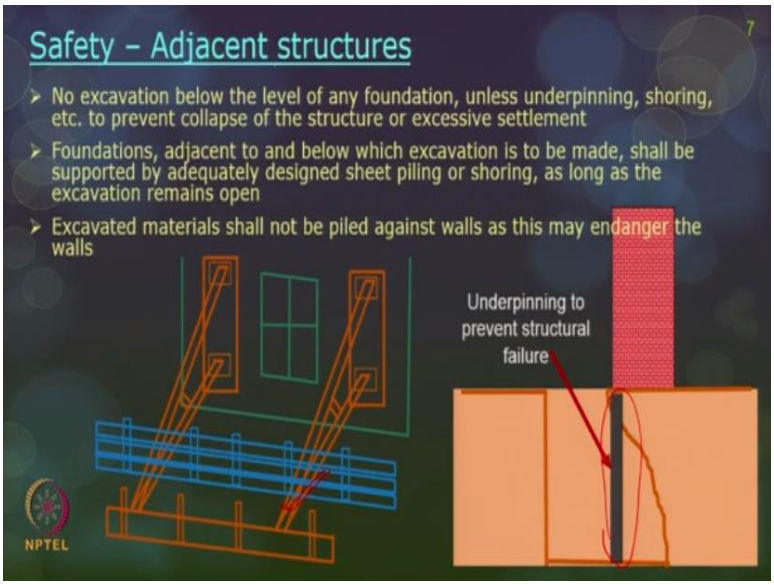

So, no excavation works shall happen below the level of any foundation unless underpinning. So underpinning is actually providing an additional support like this below the structures so that the structure is not falling off. Or these are the pictures of shoring or shoring etc., to prevent collapse of this structure or excessive settlement. So, the foundations adjacent to or below which the excavation is to be made shall be supported by either adequately designed sheet pilling, shoring or any other agreed method.

And till the excavation of this particular site is open and these excavated materials also should not be piled against the walls of all these neighboring structures because it can collapse. Those buildings can also collapse so that you have to take care of.

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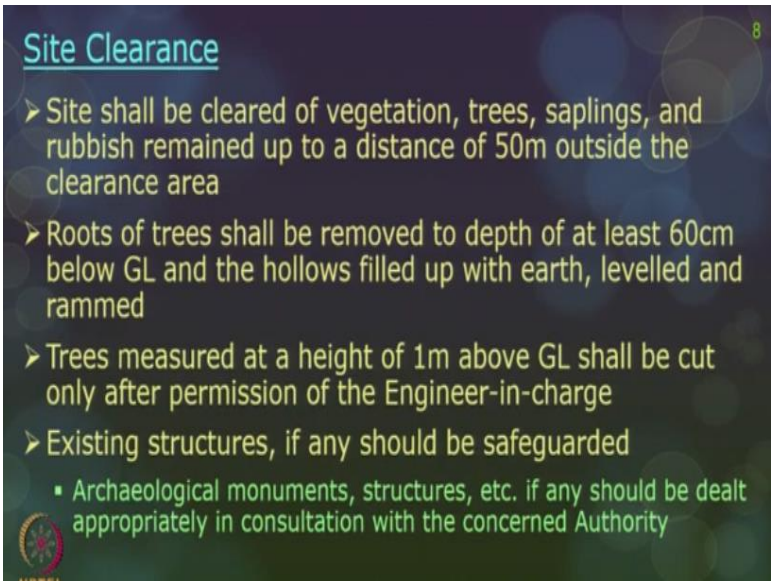

Then the next step is site clearance. So, as I told you may have to follow clear and level the ground before you start with your excavation. So, site clearance what all you should think of so before site clearance itself, you should have some usable structure or some existing structures, some trees you want to safeguard some archeology monuments, structures etc., If they are there then you should proper permission for safeguarding that so that your excavator or your excavation work is not bombarding that.

So, the site should be cleared of vegetation, trees, saplings any rubbish which is remind up to a distance of 50 meters outside the clearance area. And roots and the trees shall be removed to the depth of least 60 centimeters below the ground level. So that should happen and the, hallows of the, you know removed roots and so on. Should be filled up earth leveled ramped and you should must ensure it has attained the normal compaction level.

And the trees measured at a height of 1 meter above the ground level should be cut only after you get a proper permission from the engineer in charge.

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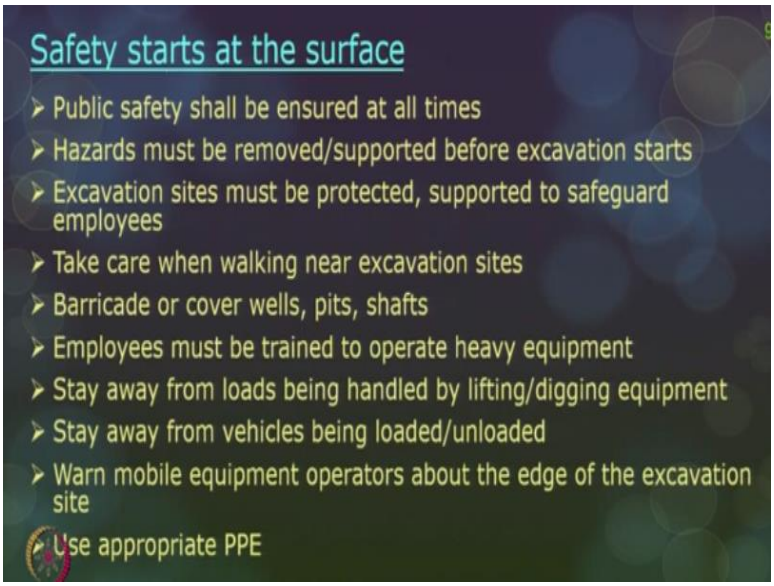

In the existing structures if they are all available it should be safeguarded properly and then only you should start with your excavation. So, all many of the safety precautions starts from you know from even before you start your excavation, number 1 public safety should ensure that you have seen earlier. The hazard should be removed or supported before the excavation starts. Excavation sites should be protected or supported and to safeguard the employees and take care when you are walking neat excavation sites.

Because with the movement of vehicle, maybe with the flow of water or maybe with a dump of soil flows by. The land maybe slippery and you may be tending to slip or trip and fall. So better you should be very careful when you are walking near excavation sites and always try to barricade or cover any well pits or shafts. And the employees must be trained to operate any equipment and so general precaution is when any lifting or digging equipment is happening.

So do not go near that, so stay away from the loads and stay away from the vehicles which are loading and unloading. When mobile equipments are operated close to the edge of the excavation site you should be you know stopping those processes. Because vibration of that equipment can naturally disturb the soil which you have cut and use appropriate PPE. These are the steps which are like generic steps which you keep in your mind before you start with your excavation.

Now let us talk about the actual excavation and there Cave-ins are more. So, Cave-ins are generally happening, one is trenches and other one is excavation but generally trenches

excavation trenches are considered to be number 1 killer in Cave-ins. So, let us now discuss what is a trench? What is an excavation?

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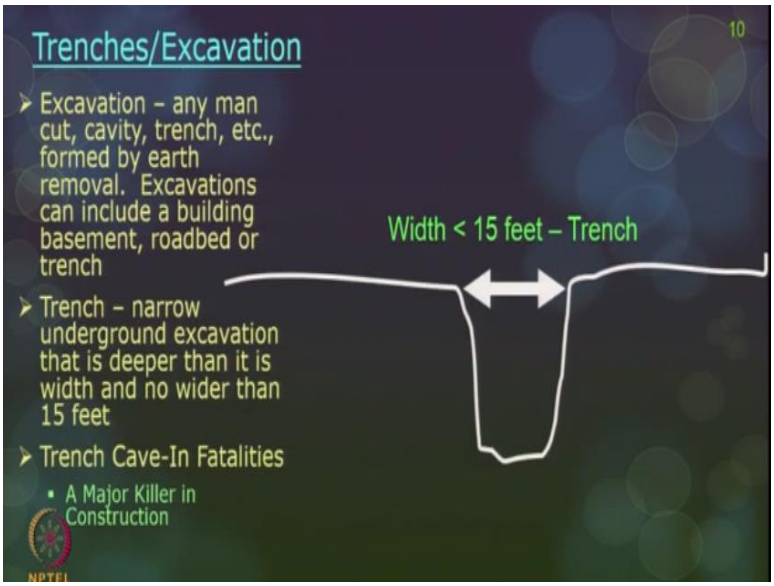

So, when any width of your cut earth is less than 15 feet then it is primary called as trench. And if it is more than 15 feet it is generally called as an excavation whether it is a trench or an excavation, they are all man made cut it is not a natural hole on the earth. So primarily, it is a man-made cut formed by removing some portion of the earth and this excavation can be done may be for a building basement or for a road bed and so on.

So, what is a trench? It is a narrow underground excavation so primarily your depth of the trench is more compared to your width. As I told the width is generally less than 15 feet and depth is really you know steeper and steeper. That is primarily called as a trench, so possibilities of Cave-ins are more inner trench compared to your regular excavation. So that is deeper than it is not wider than 15 feet. So, trench Cave-in's fatalities are major killer in construction. So, let us see what is this cave-ins fatality?

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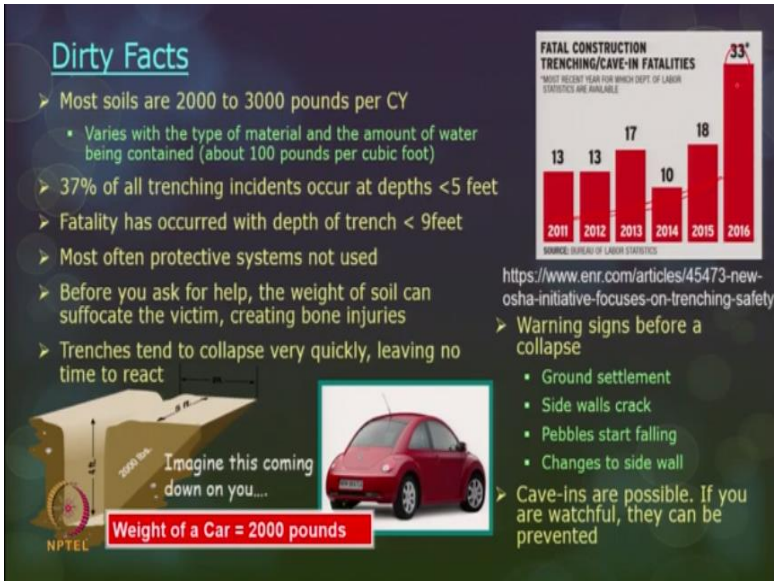

And some statistics on what is this cave-in all about? So, some dirt facts soil is considered to be dirty let us talk about some dirt facts. Most of the soil; are at least like very heavy soil is not light weight. So, statistics says so one cubic yard of soil weighs around 2000 to 3000 pounds on any phase so 1 cubic feet of soil weighs almost more than 100 pounds. So, again the weight of soil depends on type of material amount of water and air contained in it.

And all the compassion levels and so with which it has been disturbed earlier so all these are inclusive of weight of the soil. How is this soil or falling on worker is linked with this? 1 cubic foot of soil is equal to a weight of a car. So, imagine a car a normal medium sized car and just falling on you so that is the weight of the soil which will fall on the workers. And what happens is it takes very less second for the worker to react on to the soil which falls on to the worker.

And if you see the statistics on death or fatality with regard to trenching or cave-ins incidents 37% of most of these incidents have occurred at death trench death less than 5 feet. It is not too steeper and depth but still many fatalities have happened. So ironically if you see the more, deeper you go there are not too many fatalities or adequate safety precautions are already in place.

Only for shallow depths of trenches where in people take it very easily their lots of fatalities have happened. So, fatality many of the fatality has happened only when the depth of the trench is less than 9 feet itself not more than that. And most often in during these fatalities protective systems

where; not in place that also you should understand. So, what happens is when this weight of the soil is on you it can actually suffocate the victim and it can also create bone injuries.

So, compared to the death there are many permanent fatalities permanent disability also has happened to the workers. So, the trenches trend to collapse very quickly leaving no time to react. But there are some warning signals which are given before a collapse happens; ground settlement can be seen. Side walls, you can see lot of cracks and minute movement or dislocation of some pieces of the earth.

Pebbles or small pieces of soil can start falling that it shows a warning sign that this soil may collapse at any point of time. There can be changes on to the side walls from where you have cut so the cave-ins are possible when you are doing the cut of the earth why because? See when a soil is undisturbed you have actually the pressure coming on the top. And also, the capillary action and other pressures coming on the bottom and also the soil pressure which; comes on all the sides.

So, all these pressures tenses to be equalized and soil is actually very stable the minute you start cutting the earth what happens is some forces on these equal movement is disturbed. And as a result, it starts collapsing and lot of accidents starts happening. But if you are very watchful in the construction site for all these small signs of warning then you can easily prevent accidents in the construction site.

So cave-ins can happen but accidents can be prevented provided you keep proper safety precautions. Now what is the statistics on fatality in trenching accidents this is primarily from Bureau of Labor statistics which says 2011 to 2016 if you see this is the trend of the accident, you can see here. So, there are quite of few, fatality which has happened and for almost these 2-digit number at least 3-digit number of permanent disabilities also is reported in several documents.

So, there are quite a few fatalities and quite a few major injuries or permanent disabilities have also happened as a result of collapse of soil. Now what can be reasons for soil in stability? One reason as I said is primarily you are disturbing the mass and wherein whereas you have all the

forces intact. And some forces are getting disturbed because you are just cutting the earth and taking it away that is other scientific reason.

But there are other reasons also which can be manmade which can create a soil instable and it can start collapsing.

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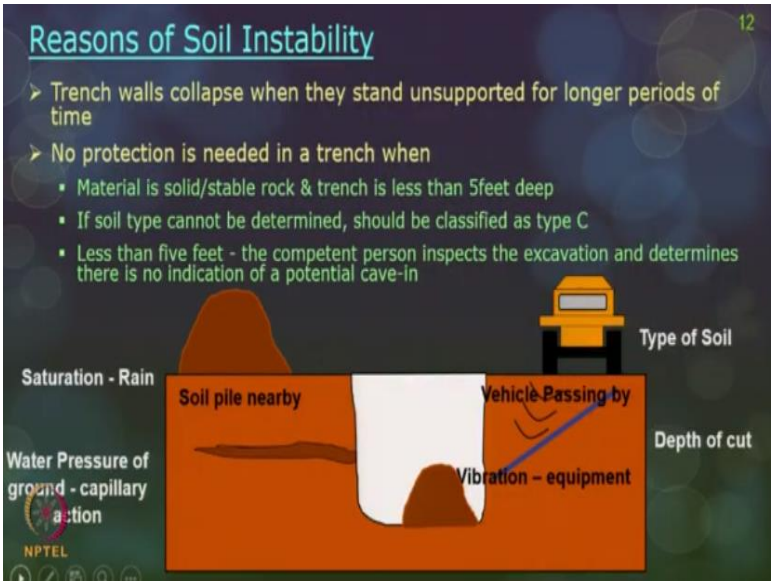

The trench wall collapse when they stand unsupported for a long period of time. You are cutting the earth and the side portions are standing firmly it would not be standing firmly for you know longer hours of duration maybe for some time it can stand and before that you should put proper safety you know precautions so that it is all standing firm. If you leave the earth as such you know without putting a safety barrier or barricade in terms of shoring or shielding.

Then automatically it starts collapsing and it closes the trench opening which you have done. And before we discuss on what are the reasons for instability we will also discuss when you are not you need to be bothered about side wall protection. No protection is required in a trench when the material is solid or stable rock and trench is also less than 5 feet deep. So, the trench can go till 5 feet deep you need not have a protection.

If the soil is investigated as a solid rock or a stable rock then you need not worry about stable or any safety protection. It can stand on its own suppose for everywhere you should know what can happen if something goes inside anything can go wrong especially the soil anything is possible.

If the soil type is not determined or it is difficult to identify what type of soil then better to classify it has type C soil.

We will discuss about type A, B, C soil after few slides and when you have less than 5 feet when you gone know when you are just below 5 feet and so on. A competent person should actually start inspecting the excavation and determine whether there is no indication of a potential cave-ins. Then you start putting in all your safety shield and barriers and then you can go in ahead in continuing with your excavation.

Now let us come back to factors which actually you know which are primarily behind the instability of a soil. Number 1 is your soil which is excavated from the cut portion which you are dumping in very close by. Suppose you use an equipment or excavator and start cutting the earth. You actually no turn the boom and put the dump the soil in a little close by location. So, there are some guidelines as to where how much distance away from the cut the earth you can dump those soils.

So always follow that, guidelines so otherwise if the soil pile is very close by to the cut earth. So that can be imbalance load which can happen and easily cave-ins, are possible. The next is vehicle which are passing by it can be suppose if you are close to a busy street or something. There may be movement of vehicle and your excavation can be a disturbed with the movement of that vehicle which can create vibrations and that can let you to cave-ins accidents.

Other one is vibration because you wanted to know use some vibrators just to loosen the soil that can also know, create lot of vibrations and the soil is loosened and obviously there may be a cav-in accidents. The next is your types of soil suppose if you have not identified a proper soil type and you have chosen a wrong protective measure for safeguarding the side collapse. The obviously it is not going to be a preventive measure at all.

You identify the type as C, I identify soil type as A. And you have chosen a measure as different one then, what happens is? It is not going to safeguard so obviously you are going to be you are having an accident then there. Depths of the cut, there are guidelines as to when then depth, which you have to go you have to bring in adequate measures also. And after some level down in also have to think of falling accidents.

So, from the edge of the ground level of the pit or opening person or vehicle anything can fall down that also you may have to anticipate. The next is saturation it is through rain sometimes raining can happen and it may also start collapsing soil. And as a result, there can be a cave-in accident other one is natural capillary action as a result of which the order table can be seen when you are starting to begin that is one of the reason for cave-ins accidents to happen. In the last one is buried utilities which are available.

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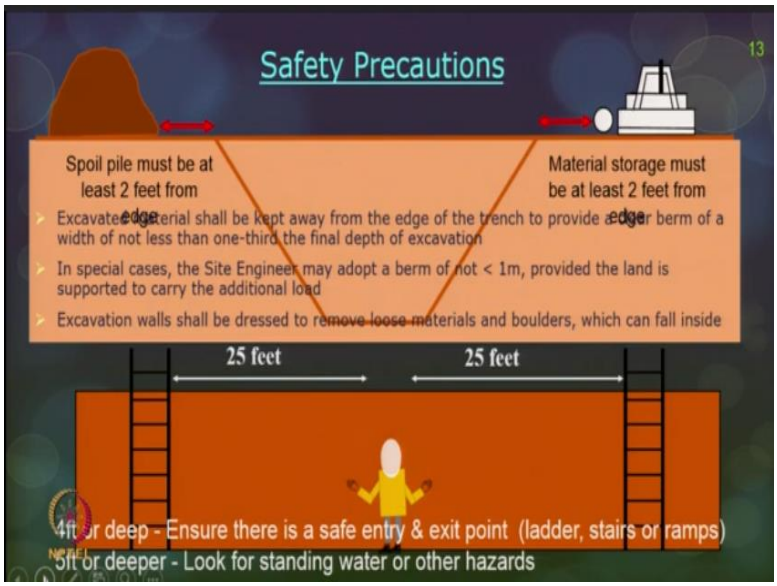

Safety precautions so as I told you the soil, spoil safety should be you know at least kept 2 feet away from the edge. And on either, sides and the material storage should be also at least 2 feet away from your edge. And there is something on 1 foot, 2 feet rule and so on let us talk about that this safety precautions it is easy for you to remember in terms of numbers. So excavated materials should be kept away from the edge always maintain that 2 feet distance on either side of the cut edges.

And in special cases if you are not able to dump it away from 2 feet because you do not have a proper place to dumb in. Then you can have little closer one but it should be not less than 1 meter and you should also be checking whether that particular land is able to support all your additional load just because of the cut earth. Now the next is when a person or when a worker is inside the excavated pit, he should be able to reach to a nearby access for evacuation.

And the nearby access should be not more than 25 feet so whatever direction he is not more than 25 feet he should be able to see an access. The access can be in terms of ladder, ramp or steps or stairs. And beyond 4 feet or deep then the worker should not be entering unless there is a safe entry and exit point. And if your trench pits are more than 5 feet or deeper you should be looking for water accumulation hazards also.

The next is types of soil collapse let us talk about you know the pattern of side wall collapse that is what we have seen has one of the major dangers. When you start cutting out the earth the side walls you know tend to collapse in due to several reasons.

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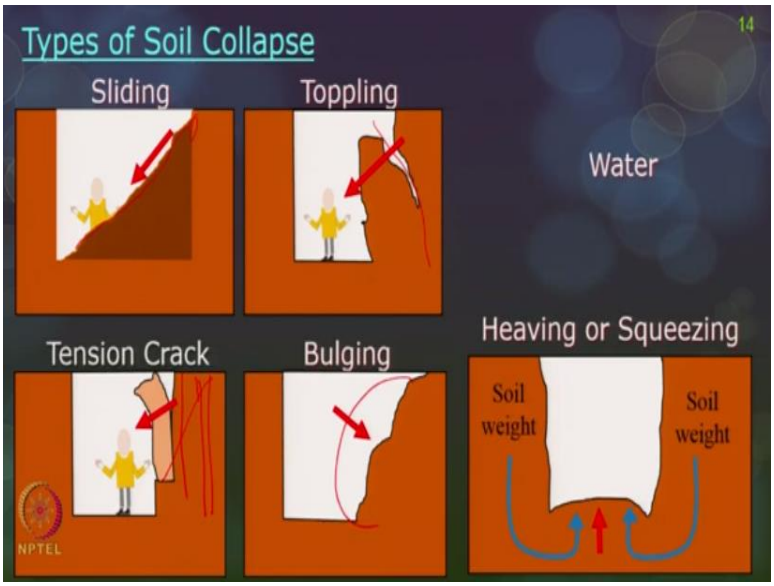

Number 1 is sliding, slowly the soil particle can start coming down sliding and it can bury the worker or toppling there can be a cut along the sides. And one portion of the earth can actually topple on to the worker and there can be accident. Tension cracks, there can be lot or lot of cracks which can happen all along the excavated sides and as a result it can start falling off on to the worker. The next one is bulging, bulging is primarily you know bulging of the bottom portion of the soil.

And the top portion of the soil is more bulged than the bottom portion and as a result you have the earth to be fallen off. The next is heaving or squeezing it is nothing but with the weight of the soil on the other ends it starts coming down and actually you know you actually find not a proper

pit which is excavated but actually you know a little bounded one. So that is primarily a called as heaving or squeezing.

Now what are the different measures of protective systems so whenever you are cutting out the earth. Then you should be having lot of protection systems are available.

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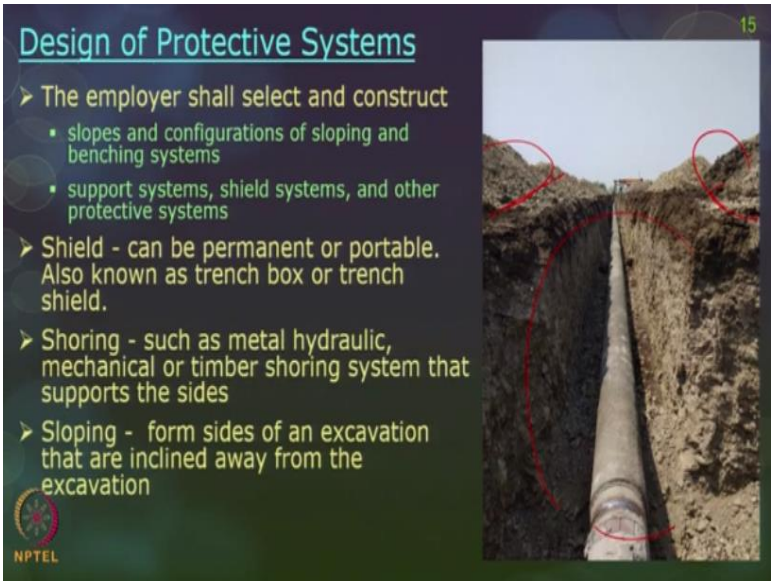

And number 1 is shielding, then shoring and sloping. So, shielding, shoring and sloping are the 3 methods of protecting any open pits or trenches and so on. So, this picture is primarily to show that you know actually the excavator material is lying too much away from your cut portion. And you can see this pipe laying operation and the excavated earth is you know it is not piled up all along the walls and little away from the walls.

So, the employer shall select and construct the slopes and configurations for sloping and benching systems we will discuss about what is the sloping benching system for which you should know what are; the type of soil? And accordingly, the sloping and benching system we have to understand. And sloping and benching are supposed to be called natural ways of safeguarding the earth.

And the artificial way of safeguarding the earth is either through shores or through shields. Shores are nothing but some panels are support you keep on the sides all along the cut earth to prevent the collapse. Shieldings are like trench boxes they are primarily called trench boxes and

they are like boxes they are just fixed all along their and inside the box the workers can start working in.

So even if the collapse of the side walls, happen since you are inside the trench box there is no fatality or accidents happening are really minimized. Now let us talk about types of soil and also the sloping or as a precaution for the collapse or prevent the collapse of soil.

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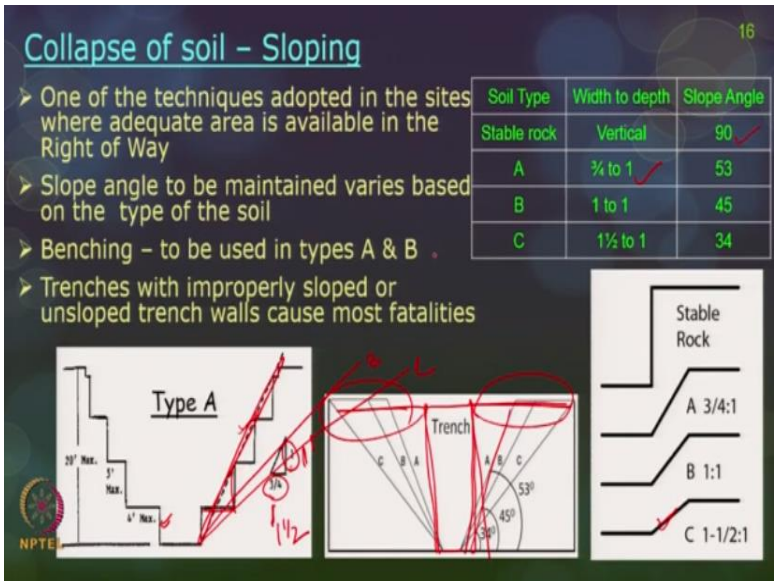

So, type of soil so A, B, C are the 3 types of the cohesive soil. We are only going to talk about the cohesive soil. For any stable rock you need not think of a sloping, sloping is only to give a slanting nature of the soil cut by nature itself what happens is the soil cave-in will not happen. So instead of cutting the earth like this your actually know having a slope so that your cut earth naturally will not yield and cave-in is not happening.

Now there are for stable rock which can stand on its vertical line itself you need not think of a protective pressure at all you need to think of an angle also. So, for a stable rock vertical is what is allowed so it is 90 degrees for type A soil, B soil and C soil then the width to depth ratio under slope angle all varies. For example, slope angle is what is given here? So, this is primarily a trench and if you see here this is the portion for which you have to excavate.

Instead of cutting out like this you are actually maintaining a slope so for A, B, C you have 3 different slopes 34 degrees, 45 degrees and 53 degrees. Now what do you mean by this so

primarily if you maintain your horizontal width that is three fourth and your vertical as one forth this is for type A soil. For B this will be 1 and this is also 1 and for type C soil this is one and half and this is 1. So, type C soil generally happens like this and this is actually your type B soil which is what is shown here.

So, you will have a very low slopes for type C; and you will have little steeper slope for type A soil. One of the techniques adopted in many of the sites where adequate area is available in the right of A to have a natural slope like this and then to have a natural means of excavation protection. You should have so much of space you should have so much of ways this is actually your cut portion.

So, you should have all this width available all along your sites so that you can actually do this sloping. The slope angle has also to be maintained based on the type of soil you have identified suppose if you wrongly have chosen the soil then you would not be able to have a proper protection. Benching so this is primarily called benching and this is the sloping so this is sloping and this is called benching.

So benching is used only for types of A and B and trenching with improperly sloped or un-sloped trench walls can cause most of the fatalities.

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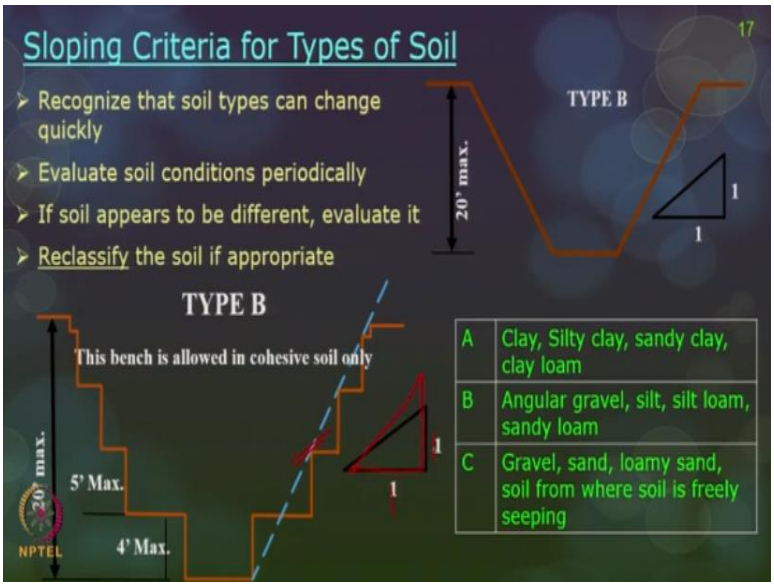

Now let us see what are the A, B, C types? A is primarily clay soil, silty clay, sandy clay and so on. B is angular gravel, silt or silt loam and sandy loam and C is primarily gravel, sand loamy sand, soil or soil with which where water is you know is freely is you know seeping away. Now if you see here this is also an, other picture to show on benching. For type B soil you have to maintain 1 is to 1 so this is 1 and this is 1. So, this is how the benching looks like.

Now some precautions recognized the soil types can change quickly in the sense when you start digging out from the top level to next little lower level and so on. The type of soil can be really varied. So, evaluate the soil conditions periodically whenever you start cutting out the earth. And if the soil starts looking out different then you have, to really evaluate it and then you may have to identify.

So, reclassify the soil if appropriate and as I told earlier if you are not able to identify what is the type of the soil better classify it has type C soil. The next artificial systems number 1 shoring and the other one is shielding system.

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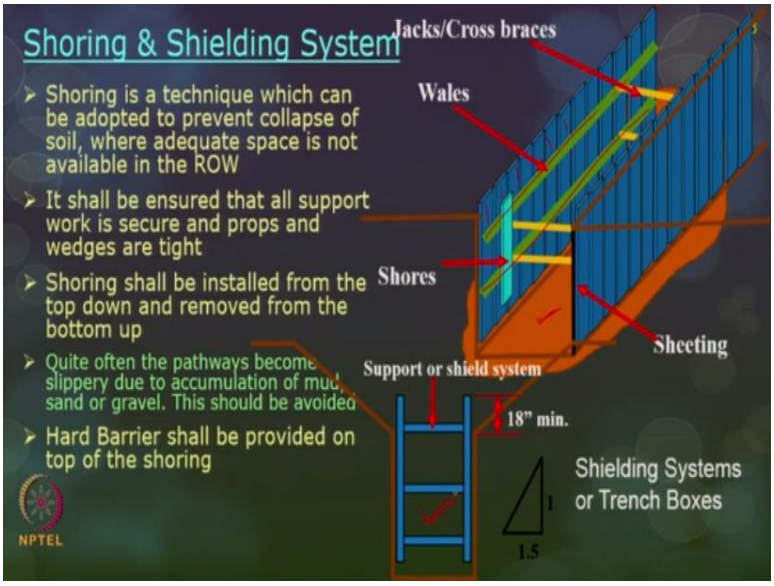

So, shoring is a system which can be adopted to prevent collapse of soil. When there is no proper right of way available for doing your natural sloping process. So, it shall be ensured all the support work is secured props and edges are tied. And the shoring can be installed from the top down and it should be removed from the bottom to top. Actually, you have all vertical panels like this and you have all horizontal panels here.

This vertical panels are called sheeting, horizontal one are called wales and there are lot of cross braces are also to prevent maintain the 2 vertical distance of the sheeting. And there are lot of shores which are actually protecting your which are through which the braces are handled this is primarily called shoring system. And this is a picture to show on the trench boxes or the trench shields.

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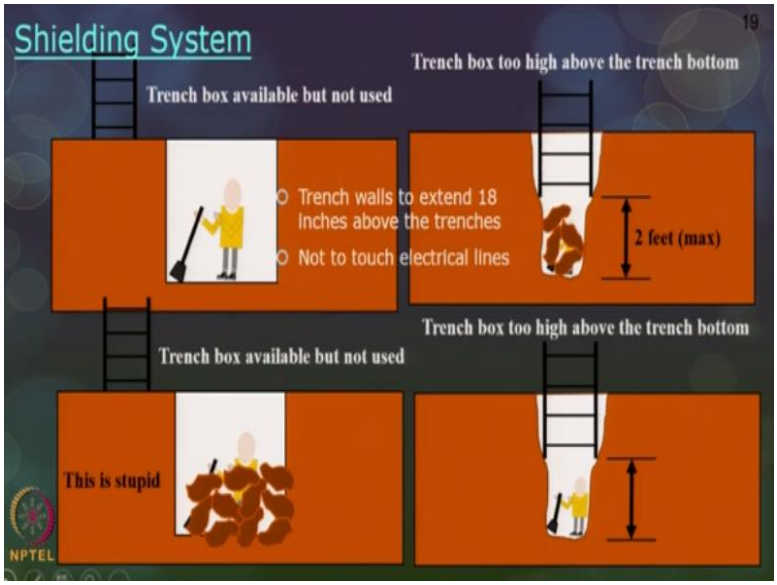

Now let us see more on the trench shields or trench boxes, some so these trench shields are like boxes they come as boxes and with which you have to put in to the excavator portion. As you start, cutting out the earth you have to put these boxes inside and the workers can actually start working inside these boxes. Now the next hazard which is seen in the construction site is water accumulations.

So, water what happens is? Naturally the soil is full of water up to the water table and soil above the water table also has some water because of capillary action and so on. Water as such is very hazardous because it makes the soil slippery and hence it is very unstable to be working on in this site.

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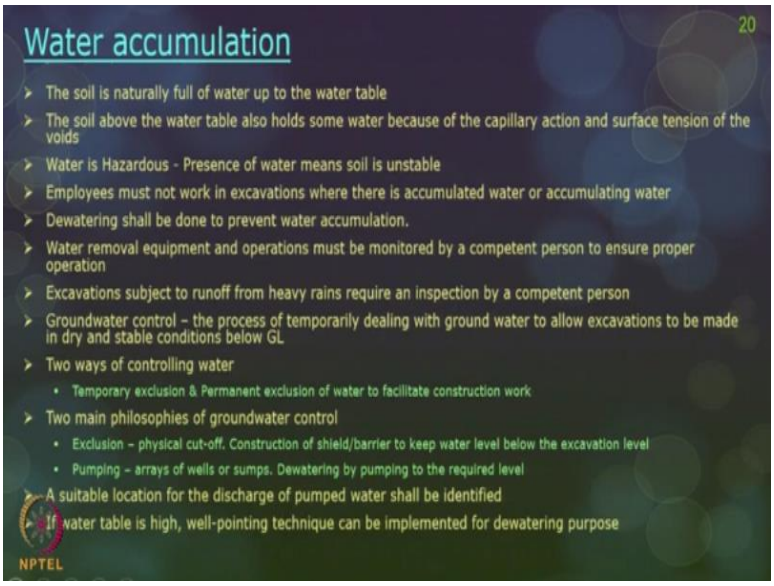

And employers must not work in excavation where there is accumulated water or where there is water which is accumulating. So, dewatering has to be done before you start working on excavation you may have to have adequate dewatering equipment along your site so that you have to using it immediately to drain out or pump out all the water. And the excavation, which are subject to heavy rainfall should be inspected before you start putting in the equipments and continuing with your excavation work.

That also you should take care off now the ground water control the process of temporarily dealing with the ground water to allow the excavations to be made in dry and stable. So that you can continue with your excavation now there are 2 ways of controlling water. Number 1 is temporary exclusion and other one is permanent exclusion. So, what is temporary exclusion? So temporary exclusion will help you to prevent water or water seepage into the construction site till the foundation is over.

And then you know the protective measures are all remote in permanent exclusion of water. The water is permanently sealed off into the building or structure even after the construction is completely over. For example, metro construction so it is not only during the construction there should be you know you should be safeguarding water ingress into the site even after the metro station is opened and it is operational and maintenance period also.

You should be seeing to that you know water is entered into the structure it is like permanent sealing off water entering into the site into the site premises. In temporary exclusion of water what happens is? Maybe for a pipe laying or canal till the construction or laying of pipes is done who is actually you know prevent water from coming in and once your structure is maybe a foundation work is done then you do not bother about water entering into the construction site.

In the sense once your foundation is very strong and stable and it can support the load then you are not worried about that. So, it is primarily removal of all those temporary precautions. Two main philosophies of non-water control one is like exclusion and the other one is called pumping in the sense. Exclusion is permanently you keep a barrier and remove and otherwise you use pumps or other sucking measures of taking out water from the site periodically.

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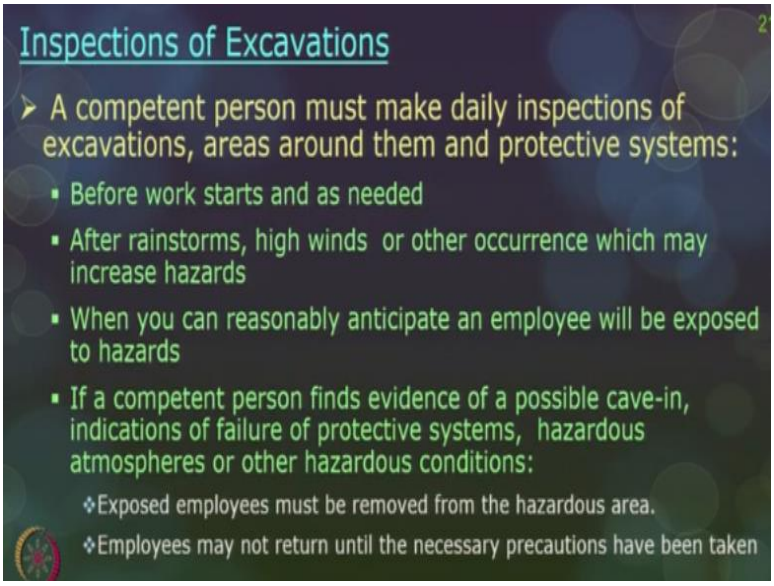

Examples for all these dewatering techniques for temporary and permanent one. So temporary you can think of easily or sump pumps and so on for permanent measures you can think of you know what is that called? Diaphragm walls or maybe you can think of well point systems. Well point system is very for temporary means of removing water from the construction site. Now you have to do inspection of excavations as the excavation work is going on.

Say competent person or a site engineer of site supervisor has to make daily inspections or periodic inspections on the work under certain circumstances also he as to be doing this inspection regularly. Before the excavation starts and as and when; it is needed maybe after a

heavy rainfall. Or maybe after an incident or an accident you have to be really checking on the site conditions. After rain, storms, high winds or other occurrence so there you may have to do the inspections.

When you can reasonably anticipate, an employee will be exposed to hazards then also you should be thinking of inspections. If a competent person finds evidence of a possible cave-ins, then you have to be doing the inspection. And those under such scenario the exposed employees must be removed from the hazardous area. And until precautions are put in place they should not be allowed to return back.

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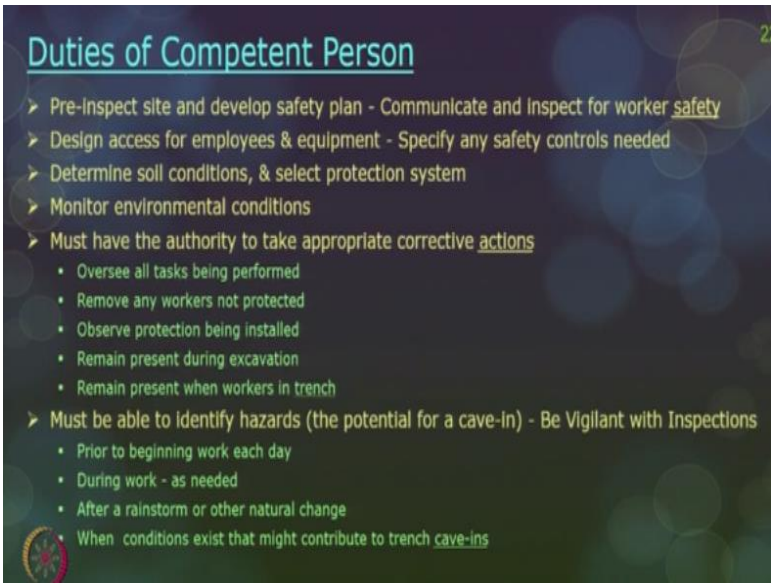

Now, duties of a competent person, so pre-inspect the site and develop a safety plan. Communicate and inspect for worker safety and design proper access for employees and for the equipment. Determine the soil condition and select a protection system whether it is sloping shielding or shoring systems. Monitor the environmental conditions for any you know rain or something happening then you should not be taking up series or severe activities.

Must have the authority to take appropriate corrective measures when something goes wrong and oversee all tasks being performed. So, this competent person or a site engineer you should be available at all times when the excavation work is going on. And they have to also remove any workers who are not protected properly or who do not have a proper PPE or not in a proper safe place inside the excavator pit.

Observe the protection when it is installed also and remain present during the complete excavation. And remain present when workers are in the inside the trench. And these people also should be able to identify hazards, which implies the potential for possible cave-in and they have to be vigilant with all inspections also. So, prior to beginning the work each day during the work as needed and after a rain storm or any other natural calamity which has happened.

And any condition exist which might lead to a cave-in happening. Now so far, we have talked about the before you dig primarily the preparatory processes. Then you talked about the different types of soil different types of excavation also. And we also have discussed about the different protective measures for preventing the collapse in the trenches. So, it is primarily the sloping or benching then shoring and also shielding.

And we also have talked about what is trenching and excavations? That also we have discussed and some statistics on the accident possibilities and so on. And some tips or safety tips when you are actually doing your excavation work and last, we have talked about what are the hazards with regard to water and now we will move on into equipments related to excavation work. So, whenever you talk about excavation work manual method of digging the earth is no longer valid still small construction site it is still a practice.

But in very large construction sites and especially for bulk excavation work generally you know excavating equipments are often used. And these excavating equipments are too many in number starting from backhoe, shovels, drag lines, clamp shells and so on.

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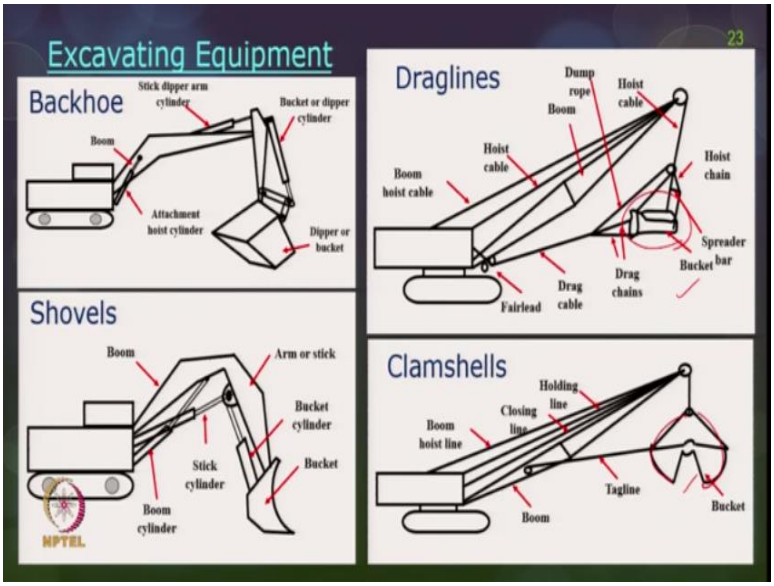

Backhoe is nothing but which has an arm the bucket or the grab it is actually you know towards the equipment in shovels. It will have a bucket or grab which is like away from the equipment. And draglines are like you can see it is like actually like a tray or some sort of a set up through which it takes out the soil and do lot of the dredging operations. Clamp shells and draglines are generally used in places where there is water table seen.

Where primarily you know water logged areas and clamp shells generally has a bucket type of an approach through which it can start you know it is like 2 arms which are fitted like an inch. With which it starts digging out the soil and it starts dumping away like this. And drag lines are something like which actually drags through lot of ropes and other supports and bulldozer and so on.

Like this you have so many equipments. So, now let us talk about safety precautions with the earth moving machinery primarily with the earth cutting machinery. So, number 1 is power shovel and number 2 will be bulldozer. So these 2 safety precautions we will discuss.

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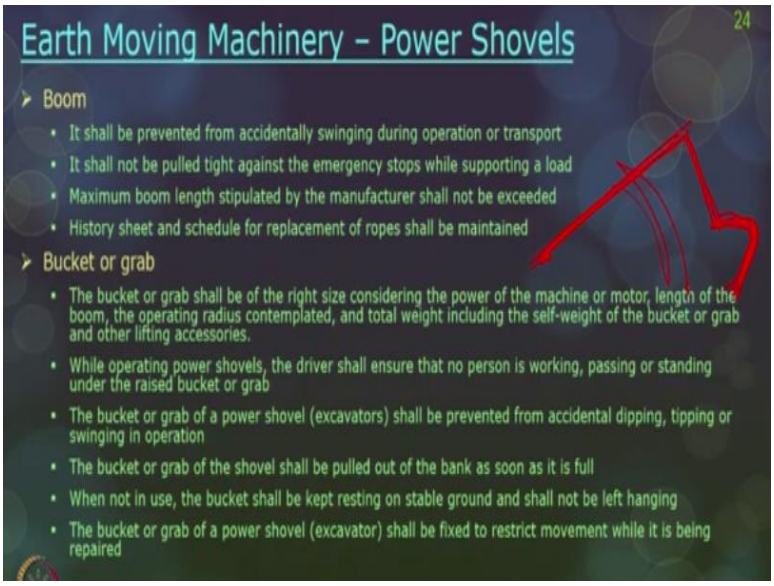

So, in power shovel so there are 2 parts one is nothing but this boom, this is primarily called as a boom. And this is the bucket or the grab so we will be talking only about these 2 issues. The boom shall be prevented from accidentally swinging during the operation or transport. And it should not be pulled out very tight when the emergency stops are happening. Again, it should not be you know swinging or moving ahead and hitting on something.

So, the boom should be intact every point of time and the maximum boom length and the maintenance issues of the boom of the equipment all should be as per the manufacturer guidelines. Now what about the bucket or the grabs so primarily the bucket or the grab load as planned earlier should not be overloaded at any point of time. And while operating at power shovel the driver shall ensure that no person is working, walking or passerby under the raised bucket of grab.

And the bucket or grab of a power shovel can be prevented from accidental dipping, tripping or swinging operation. And the bucket or the grab of the shovel shall be pulled out of the back as soon as it is full. And when it is not in use the equipment should be on level stable around and should not be left hanging. And the bucket or the grab shall be fixed to restrict the movement even when it is during repairing position.

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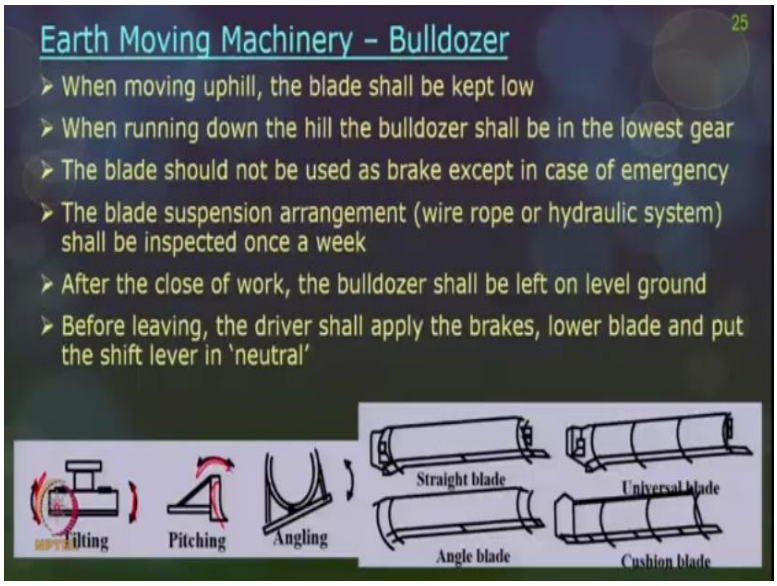

Now next is bulldozer so there are, bulldozer actually as several types of blades. It consists of several types of blades like for example straight blade, angle blade, universal blade, cushion seat blade like this in a lot of blades available. So, you have tilting, pitching and angling movement tilting is and the blade can move along these 2 directions. And pitching is this is the blade and it can move in along the curve maybe when you are having a curved part of an excavation.

Then the equipment, the blade can be pitched so that it is actually going in a curved path. So, it can tilt and angle of your blade cutting, angling is actually the curves for angle with which the blade with the cutter blade is actually cutting the earth. And pitching is the movement too far or too close to the equipment. Now when the equipment is moving uphill the blade as to be kept is low and when the equipment is running down the hill the bulldozer has to be in the lowest gear.

And the blade shall not be used as like a brake in terms of emergency, like putting the break into the blade into the ground it should not be left as like an emergency stop or something. And when the work is closed out, the bulldozer has to be kept on level ground.

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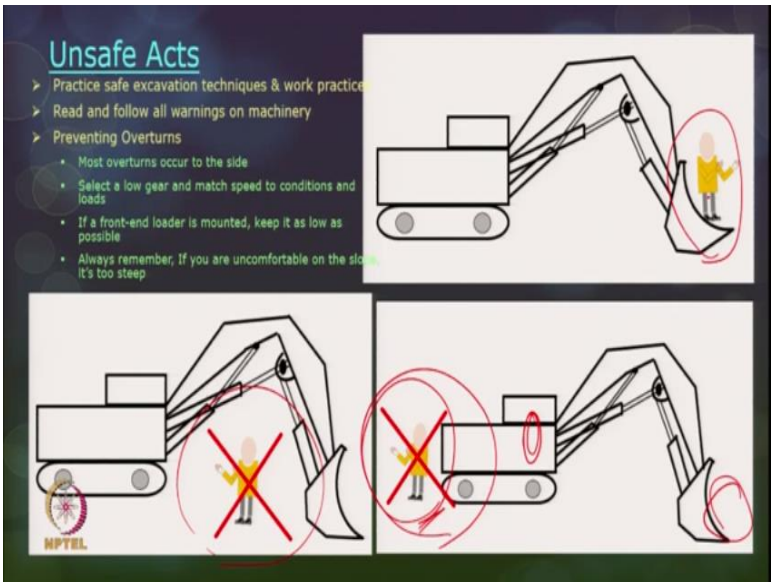

And before leaving, the driver has to put the brakes and check whether the equipment is in a stable position and so on. And then only, he as to leave the place there are some unsafe facts which you can notice in the sites for example, a worker standing between the loads. As seen here or a worker standing in a blinds part so actually the driver maybe sitting here and the excavating work may be happening in the front so his concentration maybe only in the front portion.

And there are workers who are actually standing behind the equipment or primarily like blind spots. Blind spots are not that visible in heavy equipment so these blind spots work should be avoided and these buckets are nothing but like a you know transporting and place. So, the workers are not supposed to you know stand or move anything by standing on to the bucket or the grab.

So, practice safe excavation techniques and work practices and read and follow all warnings on the machinery whatever is given? And to prevent over turns most overturns occur on to one side. And also, if a front-end load is mounted then keep it as low as possible always remember if you are not comfortable. Especially when you are on a slope when a slope is too steep or something so it is not safe at all. Next, we will talk about overhead lines electrical lines when you are operating all these excavating equipments.

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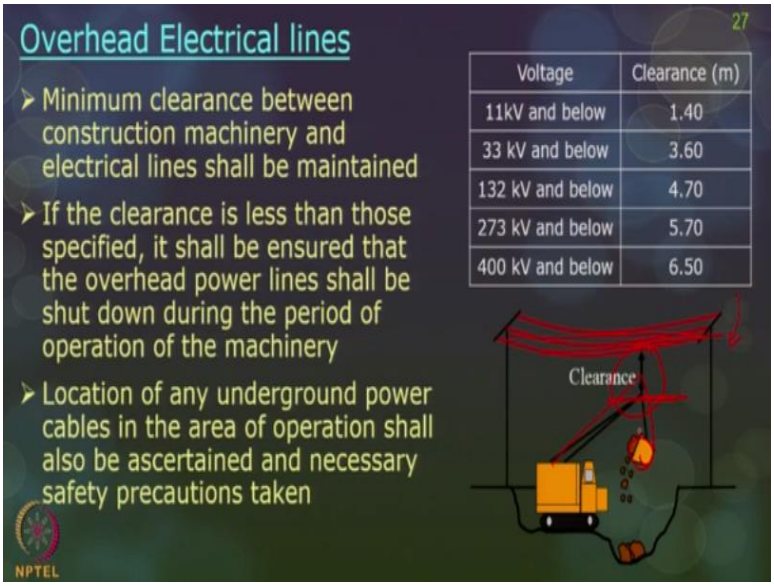

Most of them have a boom under bucket grab. So, when the movement happens. It actually you know touches on it is actually swinging and moving in the air. So, the accidentally may get interfering with some of the electrical lines which are passing by the area. And there is something called clearance which implies a minimal distance of this equipment or the grab with actually all these electrical lines.

And as per the IS code the guidelines for 11 kilo watts and below, 1.4 meters, 33 kilo watts and below 3.6 meters, 132 kilo watts and below 4.7 meters, 273 kilowatts and below 5.7 meters, 400 kilo watts and less 6.5 meters clearance is supposed to be maintained. If you do not have an adequate place for clearance and it is less than specified, then it should be ensured the power coming on to the power line is shut off or de-energized and then only you should go for operating the machinery.

While you are working with slide, wherein there are undergo electrical cables also adequate precautions should be taken for while you are digging out the earth with those power cables beneath. The next is there are other hazards primarily when you are cutting the earth, last week we have talked about fall hazards. So, fall hazards there we have discussed fall from a several floor above on to the ground level.

Here also fall happens from the ground level into a depth which is below the ground level it can be fall of person it can be fall of material it can be fall of equipment also. So, IS Codes have given some guidelines as to some safety precautions to prevent this fall of person and materials.

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So hard barriers are earthen bund warnings signs, warning lights shall not be provided to prevent fall of persons or vehicles inside. Cross over bridge with guard rails shall be provided across that trench for the local people and animals. So, you should prevent the entry of someone falling into the pit like how it is given here. Ladder should be used this I will show it in the next slide. Use to enter or leave the excavation.

And the ladder shall extend one meter above the ground level the sides of the excavation shall be provided with benching or maybe benching to prevent the rollover of materials. And the materials shall not be stored or moved so closely to the edge of the excavation that they may fall down.

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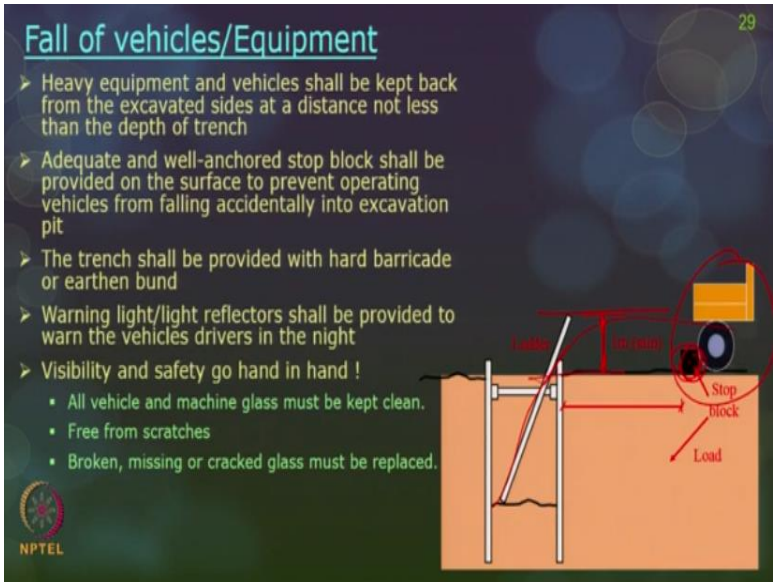

For fall of vehicles or equipment before that so this is ladder which I talked to you in the last slide. So at least 1 meter above the ladder has to extend this is primarily for workers to climb or escape in terms of an emergency. The heavy equipment and vehicles shall be kept back from their excavator sites at a distance of not less than the left of the trench. So, they should be really away from the excavated site and adequate and well anchored chop block.

Should be provided on this surface to prevent should be provided on the surface to prevent these equipments accidentally running in and falling into these pits. In the trench shall be provided with hard barricades and visibility and safety should also go hand in hand. So primarily these vehicles should be properly cleaned free from scratches or if, the broken or missing or cracked glass, are there.

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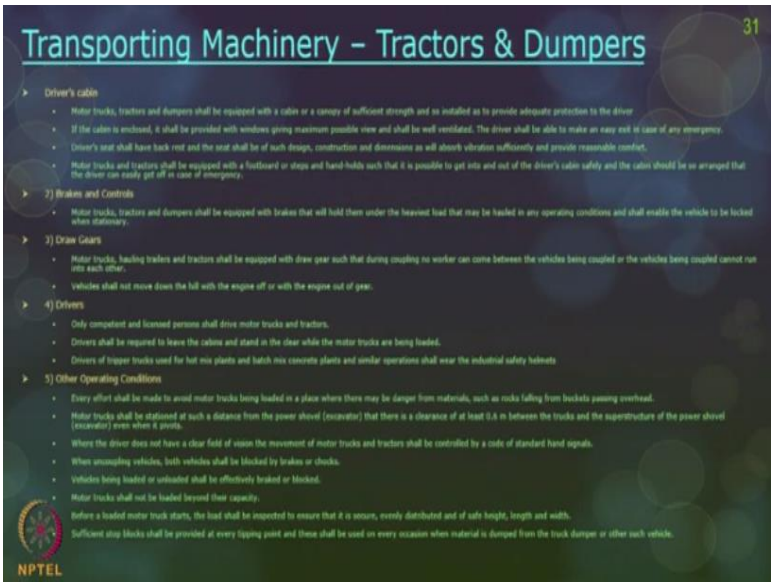

So, it should be replaced and repaired so that visibility of the operator is clear at all times. And there is no compromise on visibility now general precautions on earth cutting machinery and general precautions on transporting machinery primary on tractors and dumpers. Are all not covering here but they are all given in the IS code. For example, let me talk to you on what are these, equipment's? So, when you see any construction site especially with terms of earth cutting operation. You have an equipment for earth cutting.

So, there is equipment only for cutting the earth and there is another equipment for loading this cut earth on to dump truck. And there are lot of dump trucks and other trucks for pushing all the earth into your specified location and dumping it somewhere. So, you will have 3 types of equipments whenever you are doing an earthwork operation one is for cutting, other one is for loading it into another equipment. And the third one is for transporting into the site.

So as such you will have different combinations of equipment and some equipment can do all the cut load and hauling operation. That is how it is termed in a construction site near the cutting earth loading and earth moving operations. Accordingly, we will have so many machinery combinations available. And based on whether it is surface excavation or confined excavation or bulk excavation the choice of machinery also various and accordingly the safety precautions have to be maintained.

Now, with this the major part of the lecture is over now a small recap on what we have discussed.

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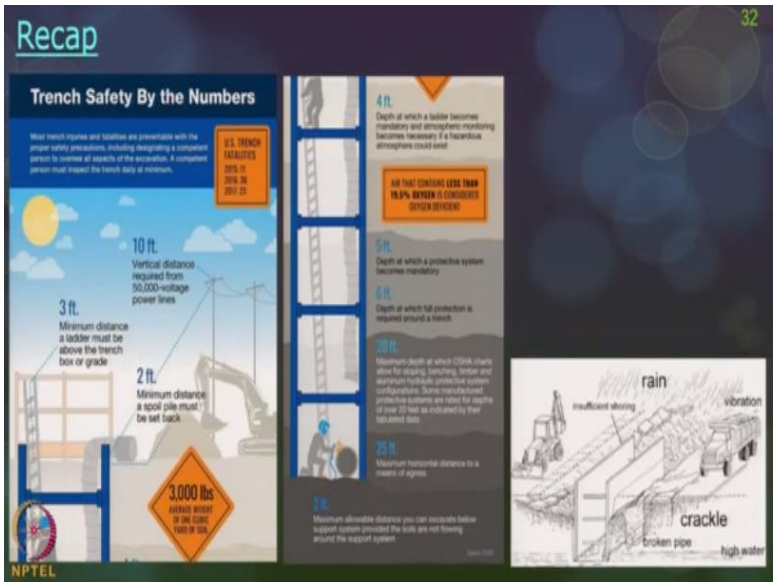

So, trench safety by numbers this is one of the pictures which I liked on info-graphics. So, 3 feet minimum distance a ladder must be above the trench box are great. 2 feet the minimum distance of soil spoil must; be set back then 10 feet vertical distance from 50000 voltage power lines. 4 feet depth beyond which a ladder is very compulsory, and beyond which air also is maybe toxic you have to look for the contamination in the air.

And also, the air quality checks as to be below you go for 4 feet down and 5 feet onwards protective systems becomes mandatory you have to think of showing or shielding systems. And the next is 6 feet and down you have to really look for fall protections. So, the workers have to have all the fall protection means and also you may have to have guard rails above your pits. So let us assume this is your ground level you are starting to go in depth.

So, when you cross below 4 feet then what happens? Ladders becomes compulsory the minute you start going 5 feet down you have to have all the productive measures. Like for example shoring or shielding. When you go below 6 feet or fall protection as to be providers workers has to have lanyards and other systems and this also should have a guard rail. And 20 feet is a maximum depth wherein you can think of shoring, sloping, benching and so on.

And 25 feet you may have to have horizontal distance for means of figures. This is the chart on different numbers so that you will be easily, understanding what is there?

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If you want to prevent accidents and there are also lot of OSHA facts sheet and quick cards on working safely in trenches and doing the excavation works safely. For example, never enter a trench unless it has been properly inspected by competent person cave-ins protection measures or in place and there is a safe way to enter and exit. Equipment the materials or should be always away from the edge and the trenches free of standing, water and atmospheric hazards.

Prevent trench collapses so trenches 5 feet or deep require a protective system and trenches 20 feet or greater will require a protective system which is primarily designed by a professional engineer. Protective systems slope or bench shoring and shielding are the 3 protective systems which are available in place. Then based on the type of soil you may have to choose your slope angles or your bench angles. And when you are going for benching only type A and type B soil you can do you cannot think of type C soil.

So, this is primarily a shoring (1:01:47) system which comes with timber, aluminum and lot of hydraulic jacks and this is a shielding which is nothing a trench box. The trench box picture; is shown here and always follow a 2-feet cleared distance on the edges. And do not deposit any sort of excavated material or your equipment nothing should be seen there. And a safe way of exist

must be provided within 25 feet of workers in a trench. So, these are all like a recap is to what I have covered so far.

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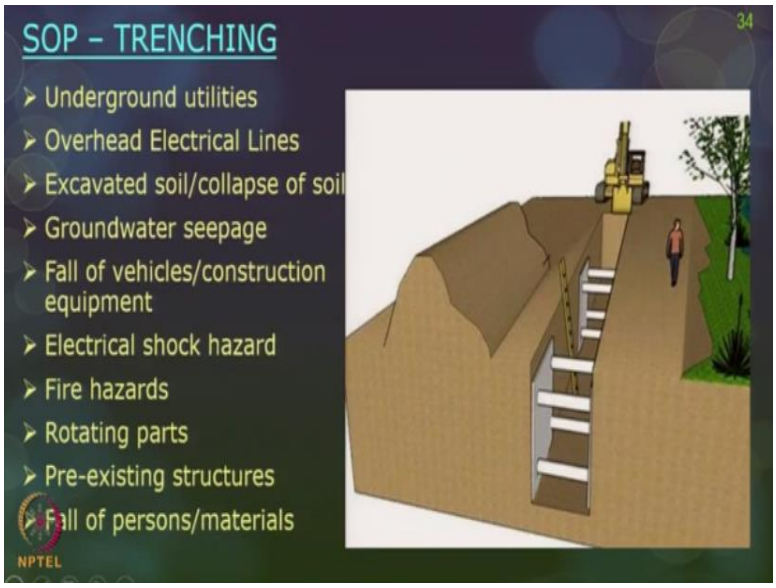

So again, what are all the different hazards available underground utilizes overhead power lines then excavated soil or collapse of soil. Ground water seepage, fall of vehicles fall of equipment fall of person. Electrical shock hazards fire hazards rotating parts of these moving machinery preexisting structures. So, these are the different hazards available.

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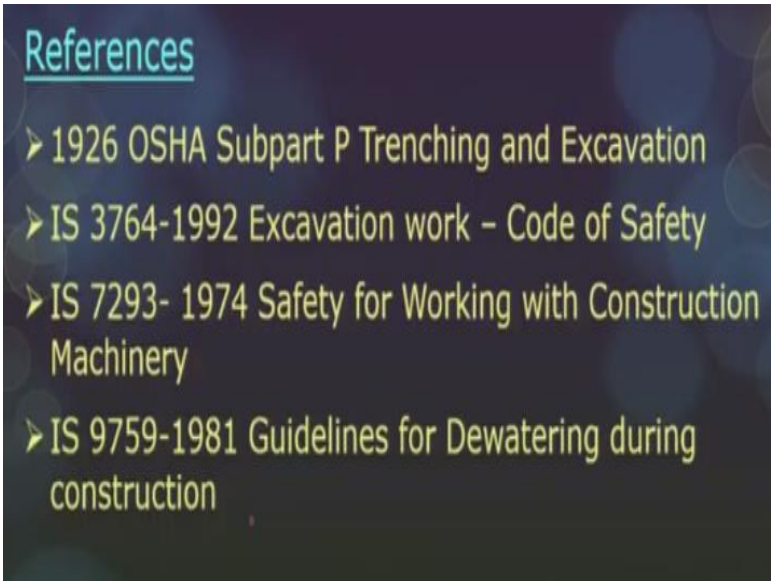

References, I have picked up these materials from OSHA Subpart P and also from IS 3764 excavation work code on safety. And also, safety for working with construction machinery and guidelines for dewatering within construction. Thank you.