Engineering Geology
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LECTURE – 16
Introduction to Subsurface Exploration and
Intensive Method for Subsurface Exploration

Hello everyone and well come back. In the first part of today's lesson, we are going to finish the unfinished business from the last lesson and that was on introduction to subsurface exploration and the second part, we are going to talk about some of the most commonly used intrusive methods for some subsurface exploration.

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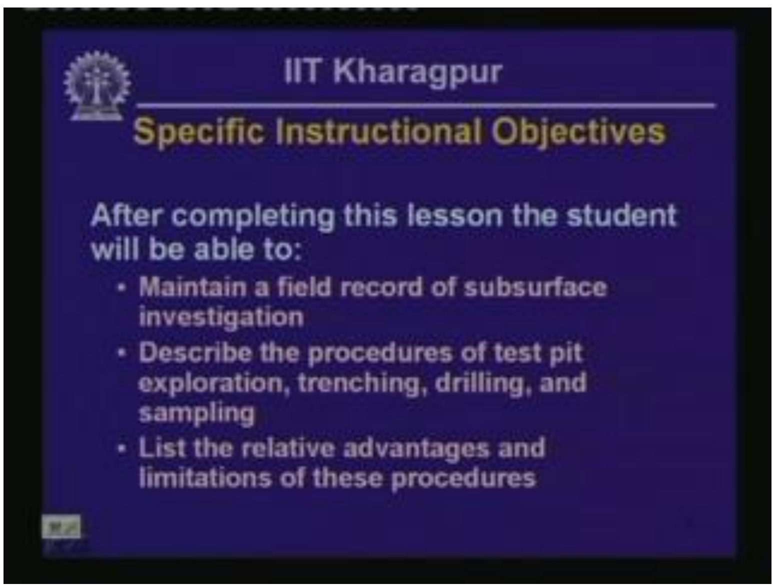

So, let us begin with the subject matter of the lesson; what are the objectives? So, we are going to look at the procedures for description of rock material during a subsurface exploration process obtained during a subsurface exploration process, we are going to see how to maintain an appropriate field record documenting all the proceedings of subsurface investigation process and then we are going to describe the procedures for test pits exploration, trenching, drilling and sampling, list some of the relative advantages and limitation of the procedures.

We begin with the unfinished part of the last lesson; so we finished the description process for soil samples, field description of soil samples and now we are going to get in to the field description of rock samples. Now, field description of rock samples should include the state of weathering; how weathered is a sample is and we are going to give a systematic categories of all these aspects.

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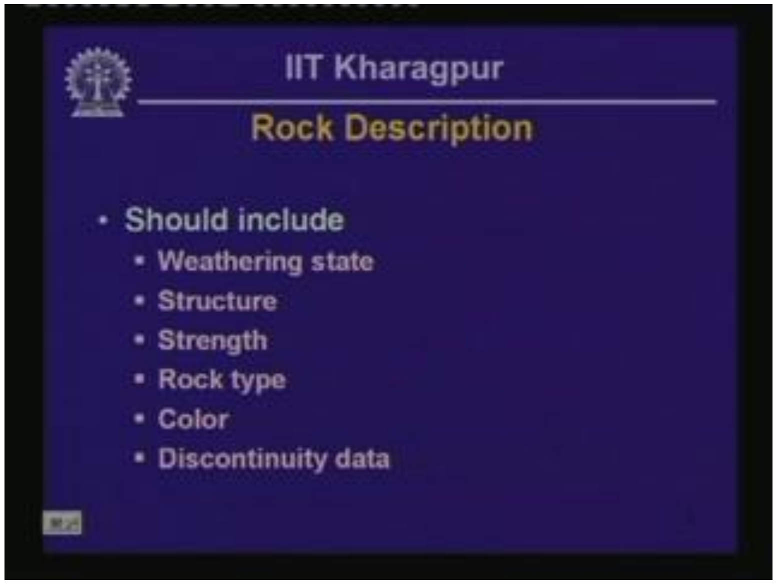

Then we are going to describe the structure of a rock sample, we are going to describe in very crude manner what is the expected strength of the sample, what would be the expected strength of the sample, whether it is going to be relatively strong or weak, then we are going to name the rock type, we have to talk about the color of the rock sample and we have to provide the discontinuities that are there within the rock mass in the form of joints or silicon sides or partings or that kind of stuff.

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So, we begin with the description of weathering state. Now, a rock could be fresh if it is free from any aspect of weathering, relatively free from all signs of weathering. Then it could progressively be more and more weathered and it could end up with a state which is designated as extremely weathered state in which the entire rock sample is composed of decomposed material, decomposed preexisting rock material.

So, there are three intermediate states; the first one - in the order of increasing weathering - the first one is slightly weathered where there is no discoloration; discoloration is only visible on the main discontinuities, main joint sets and not in other minor discontinue locations.

Then the rock could be moderately weathered. If the rock is less than 50% decomposed and this is composed mainly of interconnected frame work of fresh rock, so unweathered rock, it composes the majority of the entire volume of the rock and they are going to be interconnected. So, the unweathered part of the rock mass will not be present in general as isolated islands or isolated patches within the entire volume.

Then the rock volume could be highly weathered. In this case, you are going to look at a rock mass composed of more than 50% decomposed material but here the decomposed material are in a continuous connection to each other and the undecomposed material, they exist as relatively discontinuous isolated pockets within the volume of the rock. And then finally, you have got extremely weathered state in which the entire rock mass is composed of decomposed or weathered rock as we have already seen.

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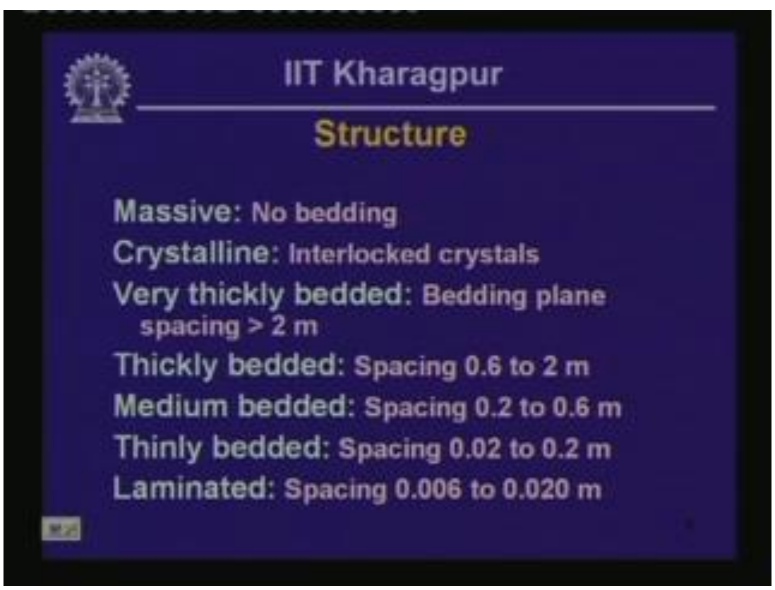

Then the second thing is the structure. Now, some these terms are already know to you when we trying to classify different types of, different categories of rock, different categories of volcanic sedimentary and metamorphic rocks. So, the first type of structure which was also there and we have got it here as well is massive where the rock mass is composed of relatively homogenous body and basically no bedding, no bedding planes or such type features are there within the mass of the, within the volume of the rock.

Then the second type of structure is crystalline structure and we have seen this term earlier as well and this type of structure represents rocks that are comprised of interlocked crystals.

Then we get into bedded structures, we begin from in the order of decreasing thickness of the bedding. Very thickly bedded; here, the bedding planes are spaced at spacing of greater than 2 meters from each other. Then thickly bedded - here the spacing could be anywhere between 0.6 of a meter to 2 meters, then the rock could be medium bedded - here the spacing is between 0.2 meter to 0.6 meter or it could be thinly bedded spacing between 0.02 meter to 0.2 meter and finally, we get into laminated rocks such as fine lights where we have got spacing in between 6 mm and 20 mm thickness.

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Then we have to describe roughly the strength of the rock specimen that is obtained during the investigation process. If the rock, again in the scale of increasing strength; we begin from the least strong specimen which is designated technically as extremely weak and this type of rock sample can be indented or can be marked with the thumbnail.

Then we have got very weak rock which crumbles under the firm blow of the point of geologic hammer. Then we could have weak rock; in this case, the firm blow of geologic hammer or the point of the geologic hammer could only cause a shallow indentation, shallow marking on the surface of the rock.

And then, we have got strong specimen, this type of rock can be fractured by one or more blows of the point of geologic hammer and then the rock is extremely strong and this is at the highest end of the strength scale. Here, we can only chip the rock specimen under several blows of the point of geologic hammer. So, that is how you describe the strength of a hand sample or a sample of a rock specimen that is obtained during the drilling process or the subsurface investigation process.

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Then, we move on to rock type; color and discontinuity. So, we have to mention the geologic name of a given type of hand sample. Say for example, micaschist quartzite and this type of classification we have already discussed in detail when we were talking about different types of rocks.

And then, you have to describe the color of the rock and as it was indicated for the description of soil hand samples, rock samples also changed their coloration with the exposure to the weather. So, colors will have to be described as soon as the rock sample is available during the subsurface investigation process and here also we have to describe the primary color and any secondary staining which might be due to the action of ground water or other agents.

And finally, we have to describe the discontinuity within the rock mass and as I indicated earlier, discontinuity of rock is indicated by other types of happenings that are recorded during the investigation process such as dropping of drill rods during the drilling process or no sample recovery over a certain depth of drilling, then RQD - RQD is rock quality designation; we are going to look at the details of what is the technical meaning of this term in one of the later lessons.

And then, we have to talk about the joint sets that cress cross a given mass of rock and the orientation of these joint sets in terms of their Azimuth and depth basically. So, we have to describe all these discontinuities in a very clear and systematic manner because these discontinuities can be affecting the overall stability of the structure that might be constructed on this type of bedrock.

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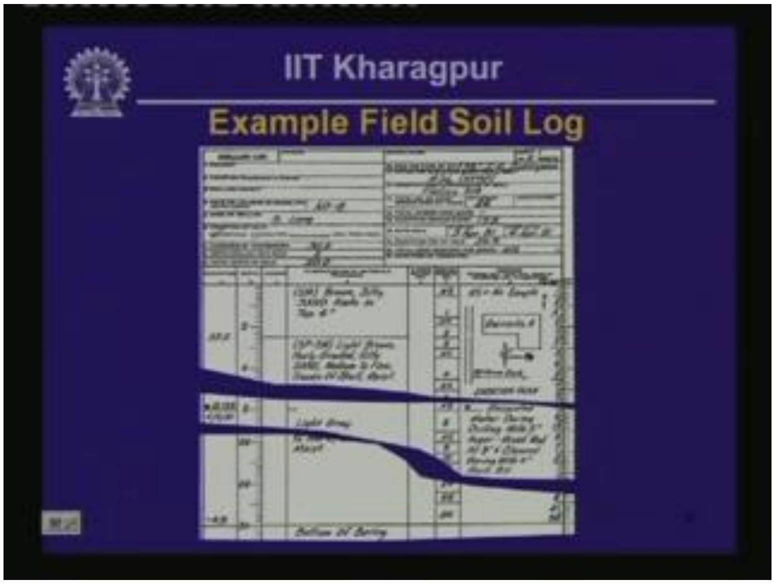

Now, this one here is an example of a soil log that is obtained during a drilling and here you can see that the top portion of this soil log, near the top portion of the soil log, we give the information regarding the location of the bore hole who is supervising the drilling, who is performing the drilling; then what kind of weather was there drilling work, when the drilling was done, what is the top elevation of the drilling and what was the procedure used in the drilling process.

So, all these things are mentioned in the header portion of this particular format of hand log and there are several other types of hand logs available but they are very similar qualitatively. So, this is the header portion that we talked about and the content of the header portion is also mentioned.

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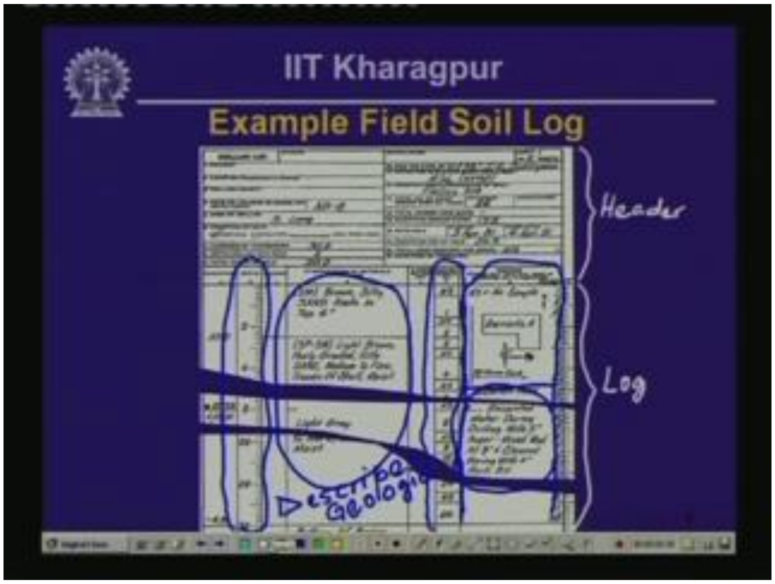

Now, this is the main log, this is the main portion of the log and here what you see is there is a column near the middle portion and this column describes the geologic units - the geology, describes the geologic units. So, we will look into it in greater detail.

Then there is another column here towards the left of this particular log. Now, this column is a scale, is the depth scale that means a given geologic unit or given a layer of soil or rock at what depth this type of soil or rock is according and what is the thickness of that particular layer, in order to understand that, we have mention the depth scale on this particular log.

Then there is another column out here in which the sampling activity during the drilling process is described. So, you can see terms like ns here; ns means no sample and then where sample was obtained, soil sample was obtained, there the sample number is indicated on the log itself and then there is a column of remarks further right and here you are going to mention all those things that you think is going to be having some bearing on the design process of the facility that is being proposed.

So, for instance here, the drilling supervisor has recorded the location of the bore hole with Reference to a nearby building at the top portion of the remark column, at the top portion of the remark column. So, that is the location plan. And then, at elevation of about 8 feet, this particular depth scale is in feet. So at the depth of 8 feet during the drilling process, water was encountered and that is indicated near the bottom portion of this remark column.

And also, you should notice that further down near the bottom of this particular drilling log, it clearly indicates the depth at which the drilling was terminated. So, that is very essential and below that often times also it is required to indicate how the drilling was abandoned whether there was any instrument installed within the boring or whether it was backfilled after the logging process by some special material or by the drill cuttings itself. So, those things are mentioned near the bottom of a field soil log.

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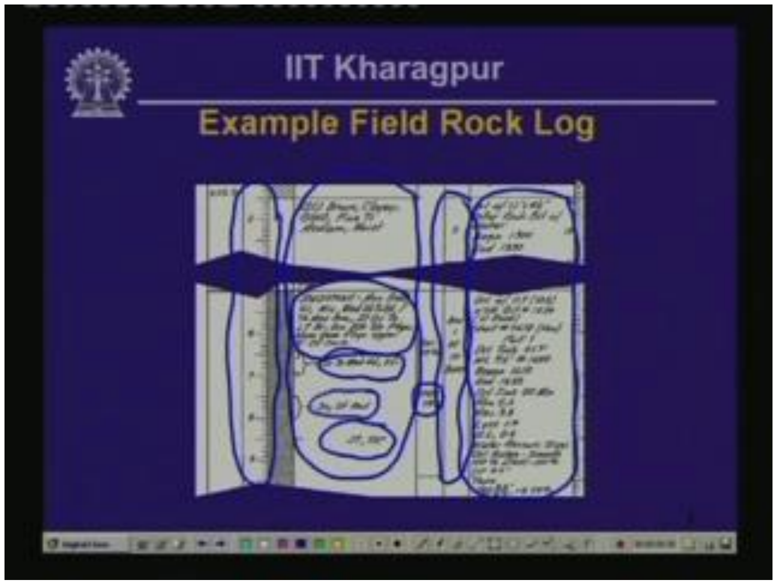

Then we move on to a similar rock log and here also you see near the left portion of the log, you have got a description of the bedrock. For instance, at this site, a massive sandstone was encountered as indicated here and then, this out here, the joints and tip of the joints are also mentioned and there are some thin layers, thin inter beds of different coloration within the massive sandstone and those things are also mentioned within this column that describes the units of bedrock.

And as earlier, further left, you have got a depth scale which actually tells us what is the thickness of a soil or bedrock layer or at what depth, they are going to be encountered and then like earlier, we have got column which actually tells us the depths from which core samples were obtained and all these core samples, how much recovery or how much RQD are there for these core samples or these hand specimens, they are also indicated on the column, next to the column that numbers the box number for retaining the core samples.

And finally, further right you have got the remarks column and here what is typically indicated is what kind of drill bit is used during the boring and from what depth to what depth, a particular coolant actually continues. So, all these things will make sense, will make more sense after we look at the details of the post procedures, procedural details used in rock drilling which will come in the second part of this particular presentation.

So, that finalizes or that actually brings us to the end of the unfinished business from the last presentation and now we get into the description of intrusive methods that are used in subsurface exploration.

What is meant by intrusive methods? In intrusive methods, what we do is actually we try to insert something into the underground formation and we try to recover some samples also in the process and we try to identify these samples right in the field or we take the samples to the laboratory for further testing and identification of the different geologic units.

So, basic thing that is done here is to get into the soil volume or rock volume by using some probes or using some drilling tools in order to gain an entry into the characteristics or get some insides into the characteristics of the subsurface layers. Now, there are several different types of intrusive testing we discussed earlier and we talked about test pit and trenches and we talked about different types of drilling processes and we are going to look at the details of these processes in the following half of this particular presentation.

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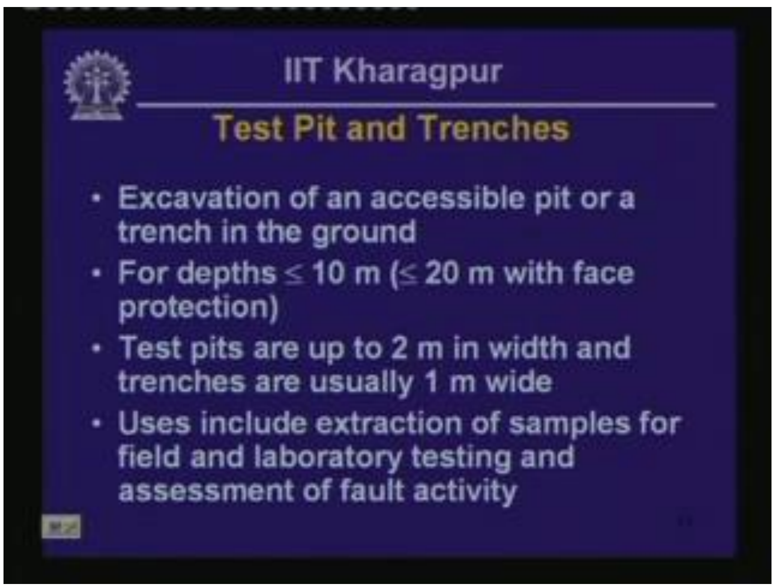

We first begin with test pits and trenches. So, what is the test pit and trenches? So, test pit and trenches are really, they are holes dug in the ground, holes or trenches dug in the ground, excavations in the ground and the depths of these test pits or trenches, they can extend typically upto about 10 meters. So, this particular type of procedure is used for investigation of shallow soil and rock layers really. Or in some cases, the depth of investigation can go upto about 20 meters; but in this case, the sides of the excavation cannot be left unsupported and some temporary support has to be installed in order to take care of the stability of the sides of the investigation, of the sides of the excavation.

Now, test pits are typically about 2 meter in width and trenches are usually 1 meter wide. Now, what are these process used for? These process are used for, the excavation of test pit and trenches is done basically to identify the subsurface formation, in order to identify the stratigraphy of a given location or a given location within a site. It is also done to obtain samples of soil and rock in order to do field and laboratory testing. In some cases, actually trenches particularly, they are used for assessment of fault activity. Now, what is or let us try to understand the details of these things.

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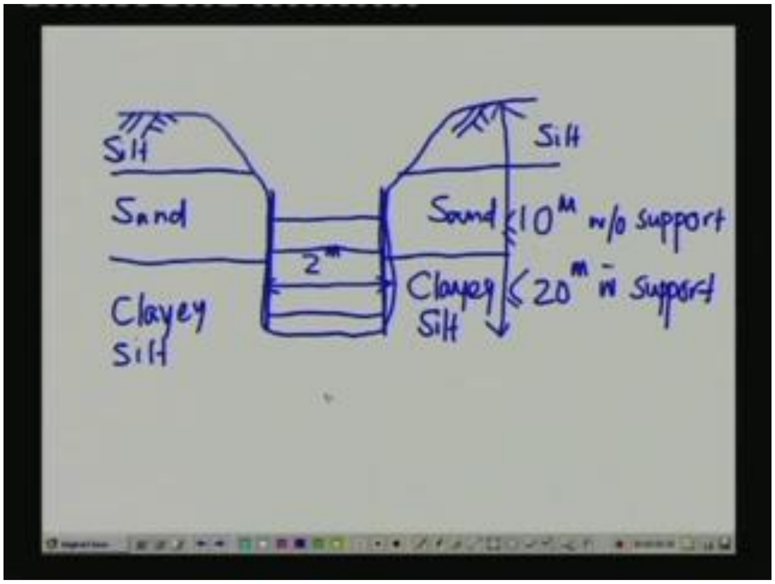

So, what is a test pit? Say essentially, it is an excavation in the ground is carried typically like this and this width could be 2 meters or it could be in some cases more or some cases less and this depth is typically we said is about or is less than or equal to 10 meters but if you provide a support, a support or if you provide an appropriate structural support to ensure the stability of the face of the excavation, then the excavation can actually proceed upto 20 meter depth and this is actually as I mentioned is less than or equal to 20 meter width support. So, what is meant by the phrase support; I tried to schematically show it there.

So, this one here is a vertical section of a soil or rock that we are trying to investigate. Now here, what we might see is that there might be a layer of slit near the surface, underlained by a layer of sand and say that is again underlained by clayey silt. This is just an example of a hypothetical stratigraphy that might have been encountered at a given site. So here again, we have got slit; on the other side, sand and clayey silt.

Now, as the excavation progresses down, you could take disturbed samples from the excavator bucket itself or you could try to recover some undisturbed samples. Now, how do you do that? Let us try to understand how it is done in case of a clayey deposit because that is where you might actually get a very high quality undisturbed sample during the excavation of the test pits itself.

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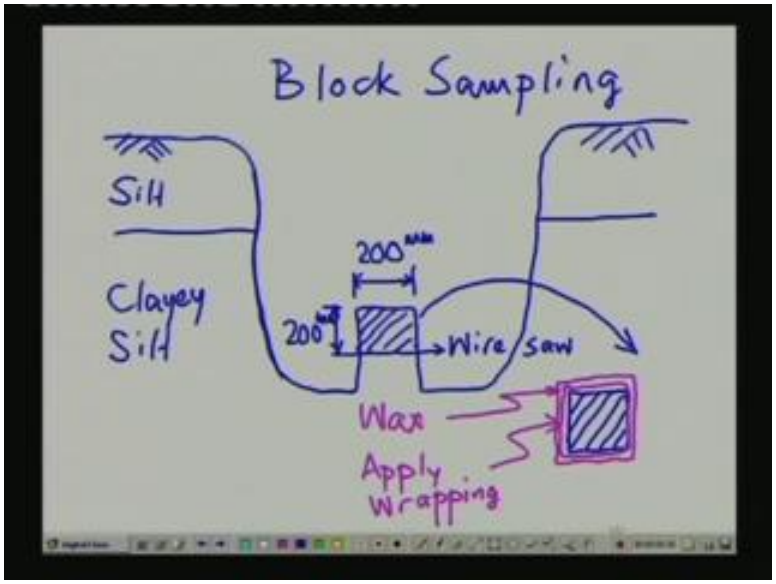

So, this is our pits and here, say we have got a shallow layer of slit near the surface underlained by a thick deposit of clayey slit. And, how the stratigraphy appears, that also becomes apparent from the description of the excavation process and identification of the samples from the site of the excavation like along these surfaces.

So here, we are trying to get some undisturbed samples of a clayey silt soil. So, for doing that what is done is a column of soil is left within the test pit and then this particular soil, this particular block is cut using a wire saw and then what you are left with is a cube typically of size of say about 200 millimeter, 200 millimeter, roughly 200 millimeter cube and then this particular block is taken out and it is typically wrapped in order to preclude drying up and that wrapping is done by a plastic sheet.

So, apply some wrapping and then the entire thing is encased in wax and then, after encasing the whole thing in wax, then that particular block can be transported carefully to the laboratory without inflicting any damage on the wrapping or causing any disturbance to the soil and this particular process gives you a very high quality on the disturbed sample of clayey soils and this type of sampling activity is also called block sampling which is performed often as a part of testing pit investigation. So, that is how you get samples of disturbed and undisturbed samples from within the test pit.

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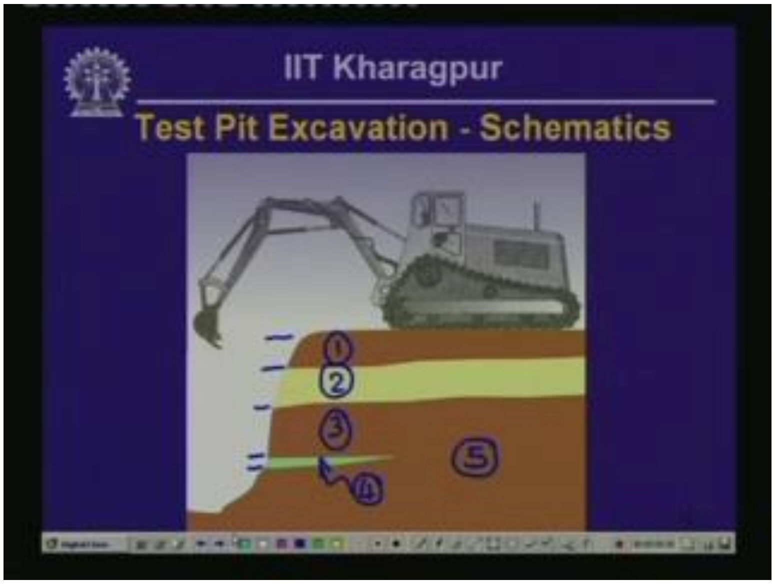

So, this one, this cartoon here shows a schematic of a test bit excavation process. Now here, what we see is that the test pit is actually proceeding from say soil number 1 near the surface, then it penetrated the soil number 2, all these things could be different types of soils like slit or sand or clay slit or any organic material whatever, then it enters soil 3 and then we have also got a lens really of another type of soil called the soil number 4 and we also have soil number 5 in this case.

So, during the excavation process itself, you can see from what depth to what depth each type of soil is present and you have to describe, you have to take hand samples of each one of these different types and you have to describe systematically all this different types of soils using the procedure that was given in the previous lesson. So, that is the details about how a test pit excavation is done and what are the informations available from test pit excavation.

Now, advantages of test pit is really is that the holes that are dug in the ground, they are accessible for general inspection and the drilling supervisor or the supervisor who is actually logging the test pit excavation activity has got an access to a very close access really to the different soil formation and of course, you can imagine that as the depth of excavation goes down, the access becomes more and more limited.

Now, the second thing, the second type of investigation process that we are look at is drilling or boring. So, what is involved here is drilling a vertical shaft into the soil or rock and this shaft is typically a circular hole in the ground really and the procedures that were used for drilling the hole, the common procedures that were used in the drilling process, they include wash boring or auger boring, percussion drilling and rotary drilling. So, we are going to look at the details of all these individual drilling processes as we continue with particular lesson.

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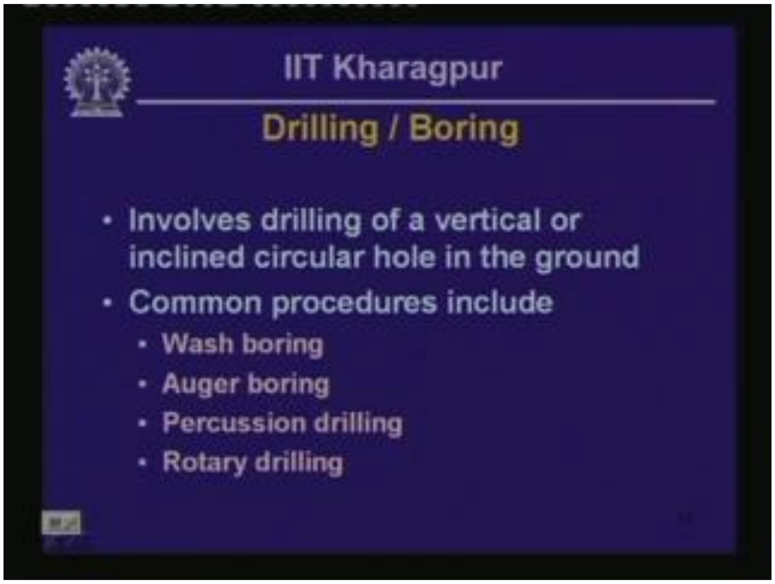

Now, first of all, we have to understand here is that the drilling process actually, the advantage, the relative advantage of drilling process as supposed to test pit excavation or trench excavation is that the drilling process can investigate a relatively thicker layer of soil and as it can extend to great depths; as we are going to see a little while later.

Now, this also actually can be done to drill a large diameter hole which can be accessible to the drilling supervisor for taking a closer look to the sides of the bore hole and get a feel about what kind of different layers different soil and rock layers one is encountering and also another aspect in this case is important is during the drilling process itself one could take reasonably high quality samples from depths which would otherwise not be accessible by the process of simple test pit excavation.

Now, when the depth of drilling increases quite substantially, then access becomes a problem and the drilling supervisor cannot go into the drill hole because the diameter of the drill hole progressively becomes smaller and smaller as depth increases typically. So, in those situations, an indirect access can be obtained to observe the different types of geologic materials that are encountered, that are being encountered during the drilling process by the means of a bore hole camera which can be lowered within the bore hole to take pictures of the sides of the bore holes.

So, although the access in this case is relatively limited when you are talking about drilling or boring of bore hole; but in general, the sides of the bore hole can actually be observed for different characteristics of geologic materials. First we begin with wash boring that is one of the simpler techniques for drilling a bore hole in the ground.

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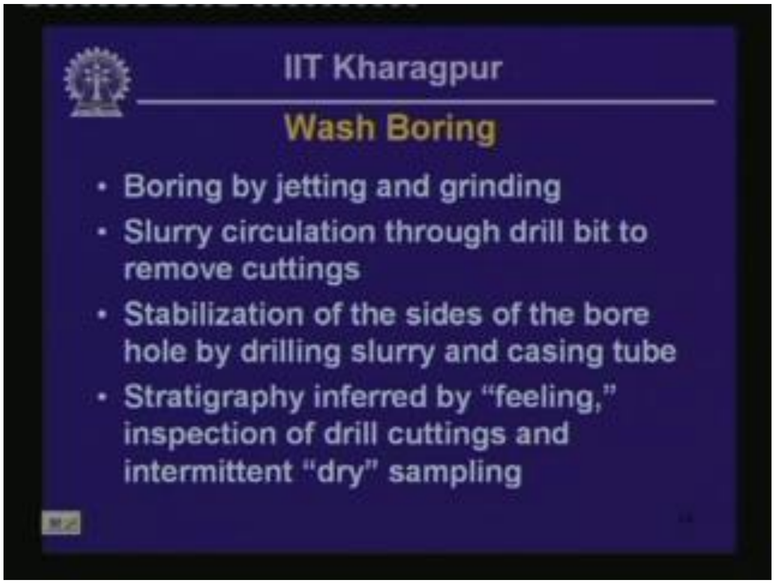

So, what is done here is a heavy chopping bit actually is lowered within the soil layers and this particular chopping bit is pounded upon, it is pounded upon the formation near the bottom of the bore hole and it is also actually, while pounding it is also rooted a little bit; not a continuous circular rotary motion but it is rotated back and forth over a few tons of degrees really in the horizontal plane and that causes additional rock grinding. It actually leads to an abrasive action because of the friction between the drill bit and the rock or soil layer which is underneath the drill bit and also at the same time, a water jet or a jet of drilling slurry, a slurry of water mixed with some stabilization fluid typically such as bentonite that is pumped through the tip of the drill bit and that imparts as a scouring action.

So, because of all these simultaneously actions like scouring and grinding, the rock samples or soil samples or soil particles, they are broken down to smaller pieces and they get carried up the hole by the drilling slurry itself and the bottom of the bore hole, bottom of the drilling actually proceeds to deeper depths. I am going to try to sketch these activities in the next little bit and we are going to try understand the details of these procedures.

So here, what is done is slurry circulation is done through the drill bit as I indicated earlier that allows us to remove the drill cuttings and also it stabilizes the uncased portion of the bore hole. We will see what is meant by all this different terms in the next little bit.

Now, stratigraphy of different soil layering that are present along the depth of the bore hole that is inferred by the driller or by the tiller really by how he or she feels during the drilling activity. But that is going to give you a very rough idea, very approximate idea about what kind of different soil layers are there within the bore hole in order to confirm what is there really, what is done typically the entire drill steam is withdrawn and a dry sample, so called dry sample is taken from the bottom of the bore hole. Let us try to understand all these activities in a little bit greater detail.

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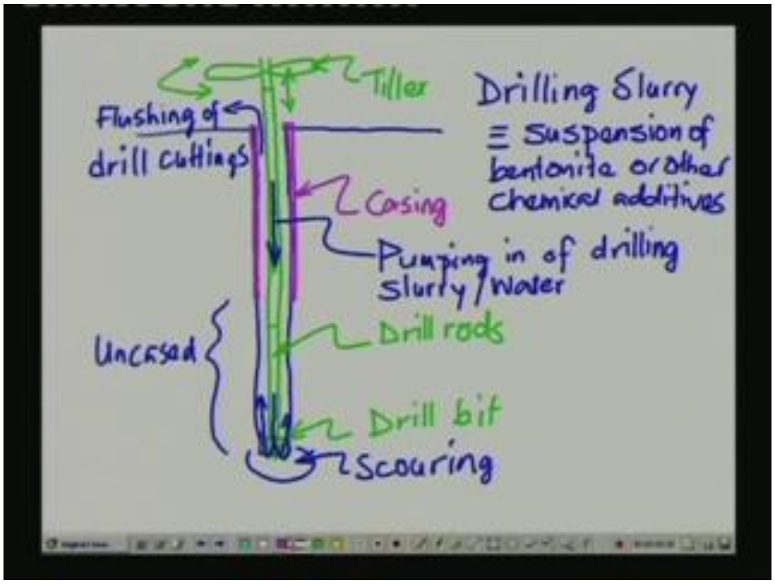

So, what is done here is to extend a relatively small diameter bore hole into the ground and the top portion of this bore hole is often supported using a metal pipe so that the soil after the bore hole is drilled, it does not collapse into the bore hole. So, this particular metal pipe is called the casing and then what you have got is a drill bit typically mounted at the bottom of a string of drill rods. So, these are drill rods and this one here is the drill bit.

So, this entire combination goes down in an irregular manner, it is not done in a very regular manner and then there is a handle near the top of this particular drill stem and this is called the tiller and this tiller actually is rotated back and forth in the horizontal plane as I mentioned earlier and these rods are in a sense hollow near the centre and through the centre of these rods, a drilling slurry is circulated.

This one is pumping in of drilling slurry or it could be plain water, drilling slurry or water, drilling slurry is typically or a typical composition of drilling slurry is essentially a solution, a suspension really, suspension of bentonite or other chemical additives. So, these drilling slurry actually, they flush through the tip of the drill bit and that jetting action actually scours the soil in this area and the scouring action together with the action of tiller and the up and down motion of the drill stem that actually dislodges the particles from near the bottom of the bore hole and it gets mobilized and come to the surface, it gets flushed to the surface along with the drilling mud. So, flushing of drill cuttings, it occurs like this.

Now, drilling mud also has got another function. You can see that the bottom portion of the hole typically left uncased; so drilling mud, it actually stabilizes the uncased portion of the bore hole by preventing the soil within the uncased portion from collapsing into the bore hole once the support is removed by the drilling process. So, that in a sense is the technique of wash boring.

Now, we want to also look at what are the advantages and disadvantages of this particular procedure. What we are looking at in this case is the boring within a relatively shallow layer, wash boring typically extends to not more than say 50 feet or say 15 or 20 meters. So, typically it cannot go to deeper depths, it cannot be used for highly cemented or hard layers or hard layers of geologic units or even soft rocks, they cannot be penetrated by this type of boring technique.

Another problem in case of wash boring is that it imparts a great disturbance by the jetting action or by the scouring action near the bottom of the bore hole. So, any sample that is recovered by inserting a sampler near the bottom of the bore hole can be disturbed to substantial depth from near the bottom of the bore hole. So, these are the different problems that are there for wash borings. But wash boring is quite popular particularly in India, in many parts of India especially in the rural areas because they do not require any mechanical power and the assembly is quite simple and light so that the transportation of these instruments is relatively simpler in areas which are having limited access to mechanized drilling vehicles. So, these are the advantages and disadvantages of the wash boring technique.

Now, we move on to the next drilling procedure involving the use of an auger. So, here also a hole is dug in the ground, a hole is actually, a hole is dug in the ground, it is a circular hole and in the digging process, what we use is the string of solid or hollow stem augers which are essentially drill rods with helical flutings so that they look like a screw; we will look at the picture of this one in the next little bit.

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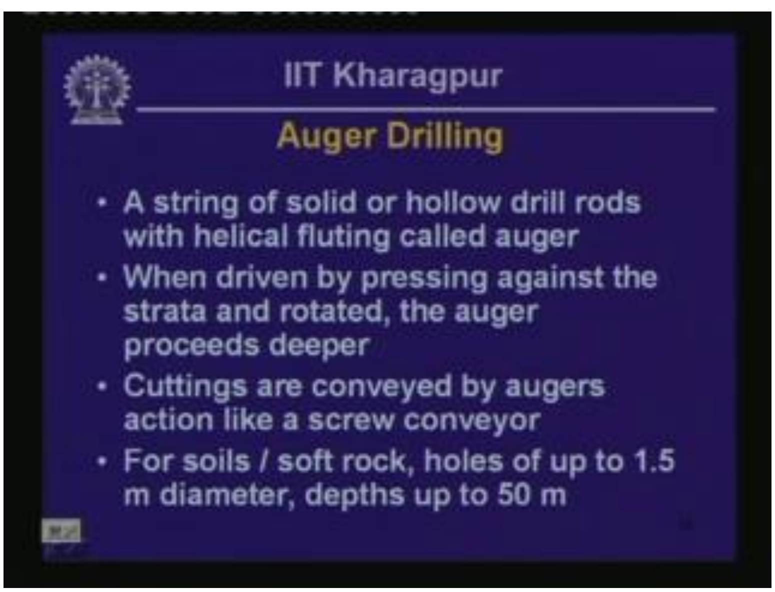

And, what is done is these augers they are kept pressed against the bottom of the stratum and they are rotated by mechanical means such as by using a hydraulic motor and as a result, the auger proceeds deeper and the soil cuttings that actually collect on the flutings of the screw like augers, they actually are conveyed to the surface, they get carried to the surface because augers also act as a screw conveyer.

Now, from time to time, what is done is these auger flights, they are withdrawn from within the bore hole and that also helps us to remove the soil samples, remove the soil cuttings within the flutings and it also allows us to take disturbed samples from within the auger flights.

Now, what is it used for? This type of drilling can be used for soils and soft rocks only; like in the previous case, we cannot penetrate hard and highly cemented geologic units and here a hole of upto 1.5 meter diameter can be drilled within the formation and the depths in this case can also be upto 50 meter below the ground surface and actually as the depth increases, then the auger equipment becomes quite heavy and unwieldy and the power requirement increases quite substantially. As a result, auger drilling process becomes quite uneconomical; as the depth increases, it starts to become uneconomical as the depth increases to beyond 30 meters.

So, this one here is a picture of a hollow stem auger.

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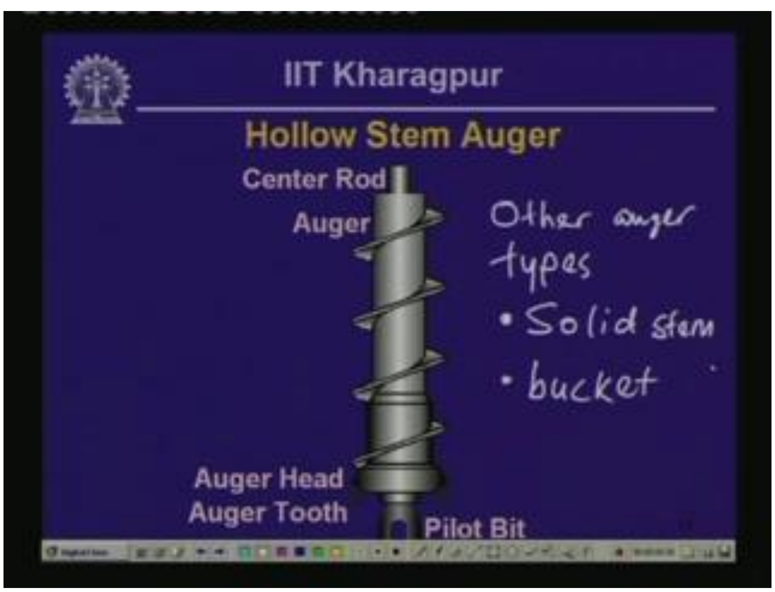

What you have got here is really, the hollow stem auger is the pipe that you see, this outer pipe is really the hollow stem auger and it has got auger head with the properly machined hard faced teeth that choose into the soils underneath and through the center of the hollow stem auger is another tube that runs through the center and this tube itself has got a pilot bit at the top of it and the chewing action is because of the rotation of the auger head, of the auger teeth as well as the pilot bit and the abrasion that it causes to the soil and rock underneath the bottom portion of the auger.

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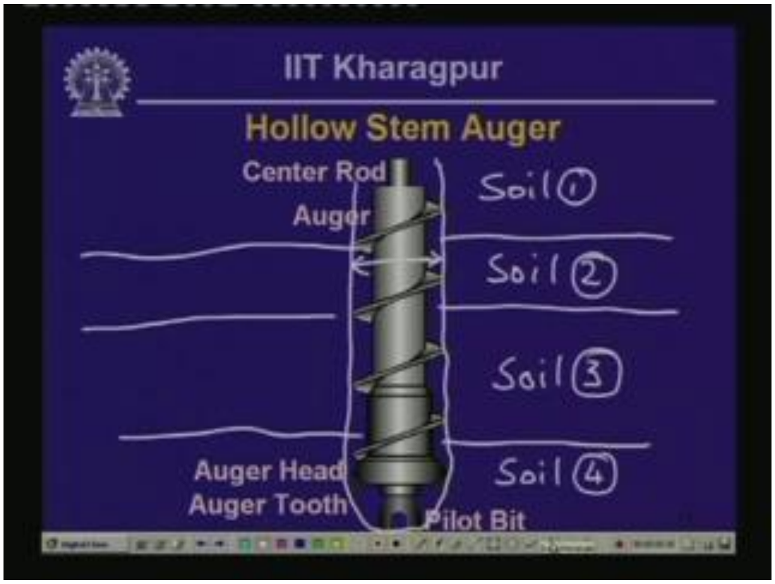

So here, what is done? If we look at actually or if I want to draw on top of this particular picture itself, the hole actually proceeds like this. So, that is how the hole is going to proceed and this much of diameter of hole will be excavated by this auger. So here, again we are going to look at the stratigraphy details of different types of soil and rock that are encountered. So, this one here could be soil 1, this could be soil 2, then we could have soil 3 and then we could have soil 4 in this case.

So, one advantage of hollow stem auger is very obvious from the discussion here is that the hollow stem auger itself acts as casing and that actually keeps the soil from collapsing into the bore hole and the hole can be kept opened and you can do some dry sampling near the bottom of the bore hole by withdrawing the central rod and lowering a tubular sampler thick wall or thin wall tube sampler at the bottom of the bore hole.

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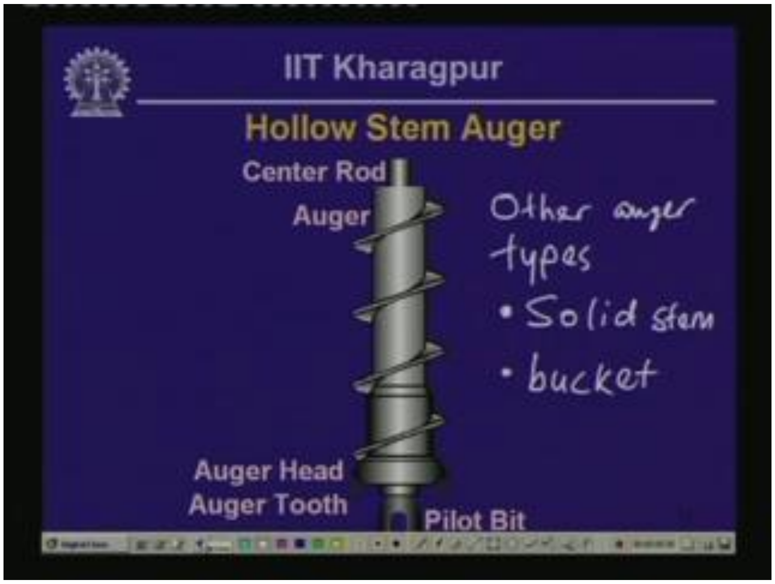

There are other types of augers also, other auger types as well which could be solid stem auger or a bucket auger. Bucket augers are of larger diameter typically, they can be upto 60 inches in diameter.

Now, we get into percussion drilling. Percussion drilling essentially pulverizes the formation by bouncing a heavy drill bit against the soil and rock at the bottom and the cuttings are removed with a bailer or a clean-out auger. So, this is a simple percussion drilling activity and this is useful when a high pressured drilling mud circulation is not acceptable because that might lead to the high refracturing of the layers. So, in that case, percussion drilling is an option.

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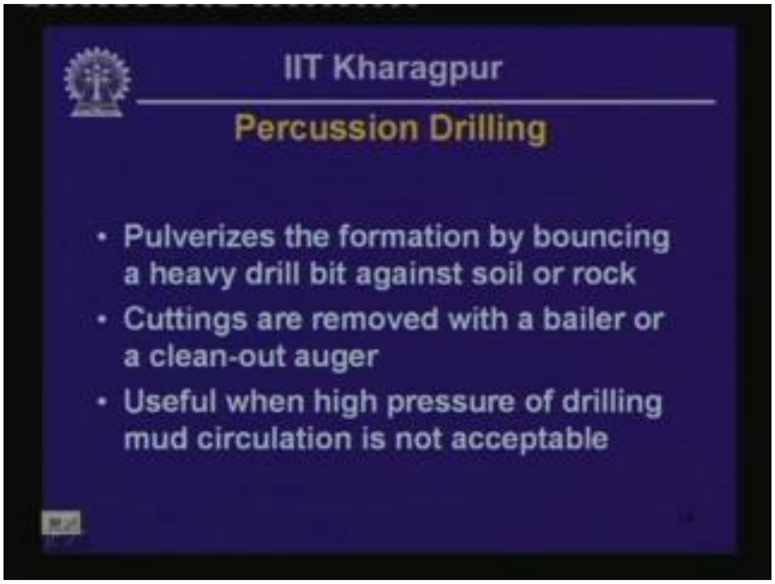

Percussion drilling typically also is a shallow drilling process, cannot proceed beyond say about 30 meters depth and this has got some of the advantages of the wash boring and the disadvantages that are associated with wash boring as well alright.

Now, we get into the mechanized drilling process - rotary drilling process. The first one that we are going to describe here is the air rotary drilling.

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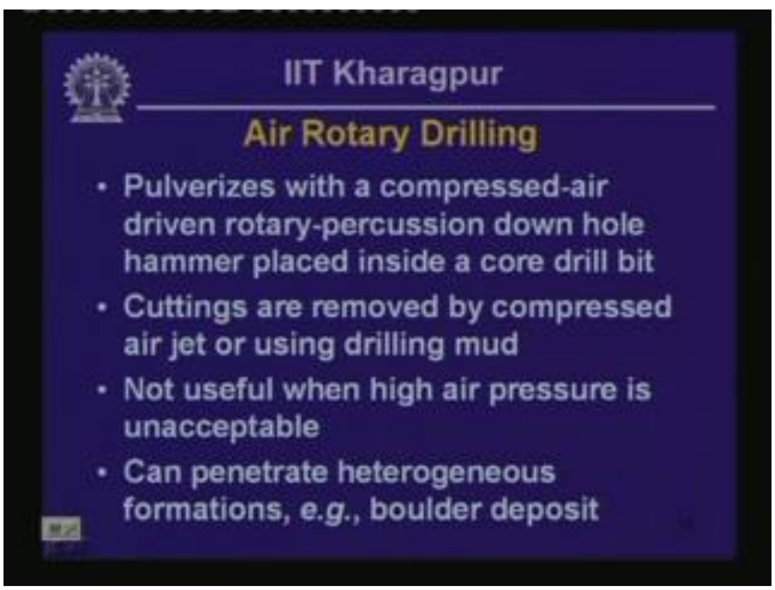

So here, we again pulverize the rock at the bottom of the bore hole and in this case, we use a compressed air driven rotary-percussion down hammer that is placed inside a core drill bit and here cuttings are removed by compressed air jet or by using drilling mud and this is not useful, this particular cannot be used in situations where high air pressure becomes unacceptable such as drilling through a water retaining dam or an embankment. This type of drilling process can penetrate to great depths, it can go up to about say, it could easily go to 1000 meter depth say and it is very effective in penetrating heterogeneous deposits such as those composed of clays and boulders.

Finally get into mud rotary drilling. This is perhaps the most commonly used drilling process and most versatile. This particular process actually drills into the soil or rock by having a special type of drill bit, we are going to see some of the examples of drill bits, they cut through the rock by abrasion and the particles that are generated because of the drilling process, they are floated by circulated a slurry of drilling fluid and flushed to the surface. Drilling fluid circulation also allows the bit, the drill bit to cool down and as we have seen earlier, it allows us to stabilize the sides of the bore hole to which the casing cannot be installed.

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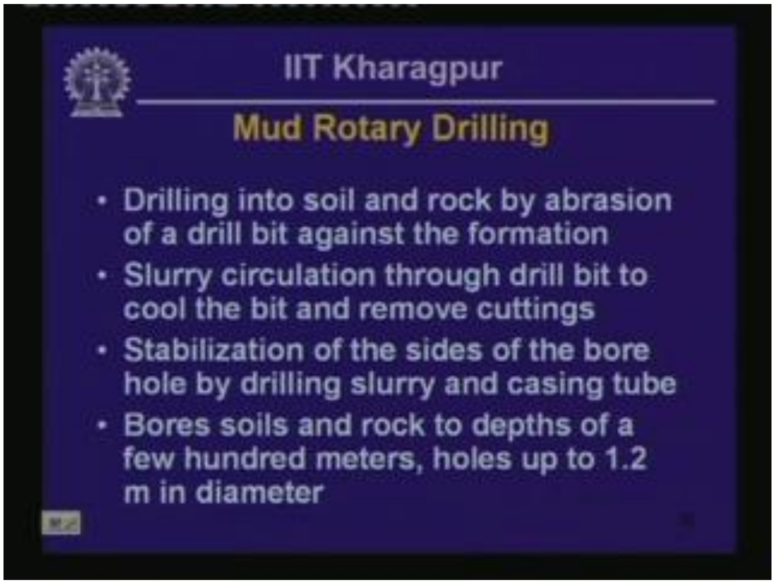

And here, we can actually drill upto say about 300 meter depth and bore holes are upto 1.2 meter diameter can be constructed. See, I remember, when I was describing the air rotary process, I was saying that it can be used to drill upto 1000 meter depth and that is really a mistake - the drilling depth of air rotary drilling can be upto about 1000 feet not 1000 meter and you should note this particular problem and the drilling can go upto a depth which is very similar as in case of mud rotary - a few hundred meters really. So, air rotary and mud rotary both can go upto a few hundred meter depths.

Now, what are the advantages and disadvantages of mud rotary drilling? This particular process cannot be used again in case of air rotary drilling if the pressure of the drilling fluid cannot be tolerated or in pulverize formation such as open work gravels where the drilling fluid pressure cannot be sustained because the drilling mud can actually flow through the formation without much resistance.

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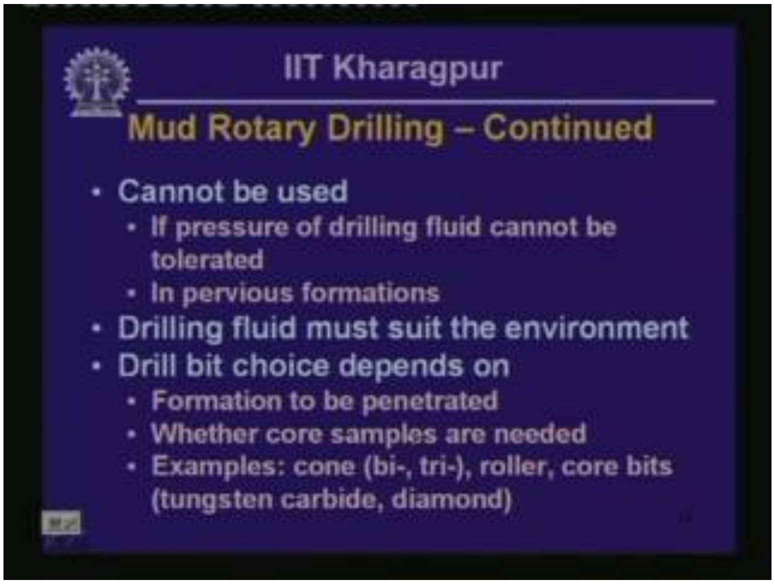

You also have to make sure that you use a drilling fluid which suits the environment which does not cause any damage to the environment and drill bit that varies quite a bit depending on the formation to be penetrated and whether core samples are to be obtained or not. Some of the examples are going to be seen in the next little bit, in the next sketch.

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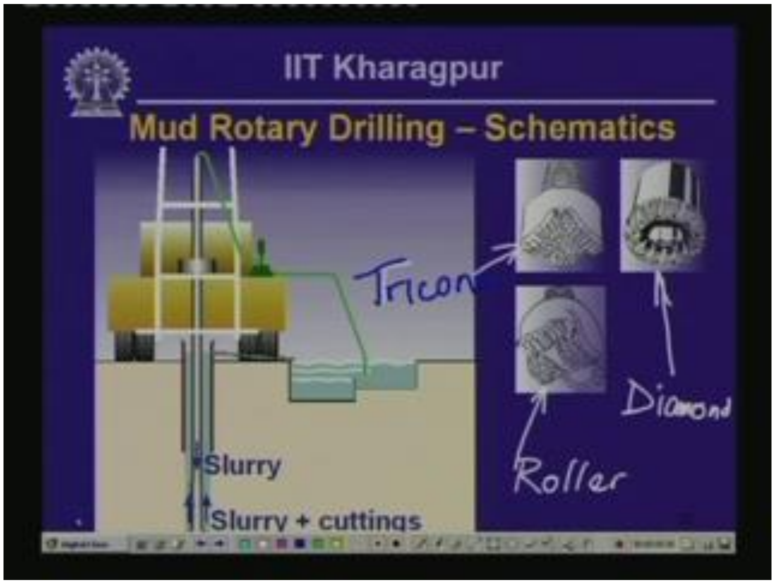

This sketch, the sketch on the left actually shows the process which are already described. So, what we have got here is the essentially a drill stem through which your circulating the slurry and the slurry and cuttings are getting back flushed up the hole and they get collected and this particular slurry is typically recycled again. Some of the drill bits, typical drill bits used in the drilling process is shown on the right. The drill bit on the top left, this one here is actually is called a tricon bit, this drill bit is a roller bit, so this one is a roller bit and this here is tricon bit and the one on the right is a diamond bit which can used in drilling core samples.

Now, we try to summarize this lesson.

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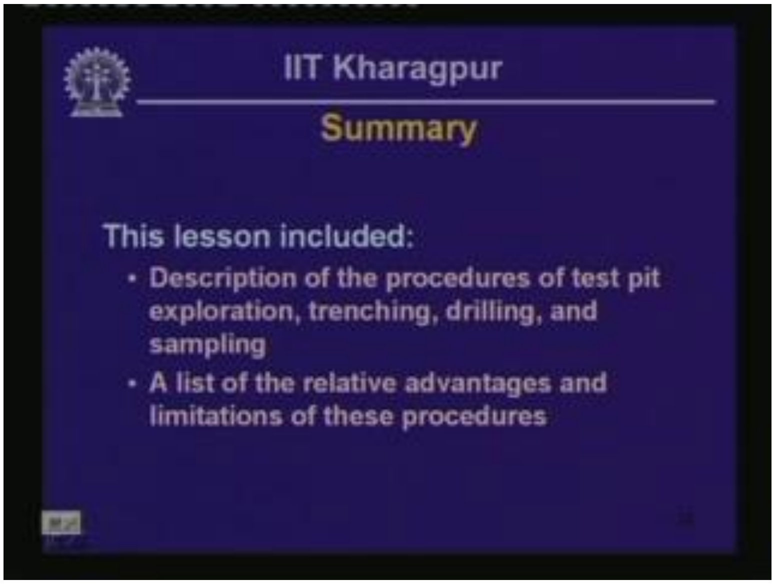

What we learned here is a description of the procedures used for intrusive testing, then we looked at a list of relative advantages and disadvantages of the different procedures used in intrusive testing; in addition to it, as a part of the previous lessons unfinished business, we looked at the procedure for systematic description of a rock hand sample and how a field record can be systematically kept detailing all the necessary description of the activities that are there during the drilling process, during the subsurface investigation process.

Finally, we wrap the presentation up with the question set. Try to answer these questions at your leisure.

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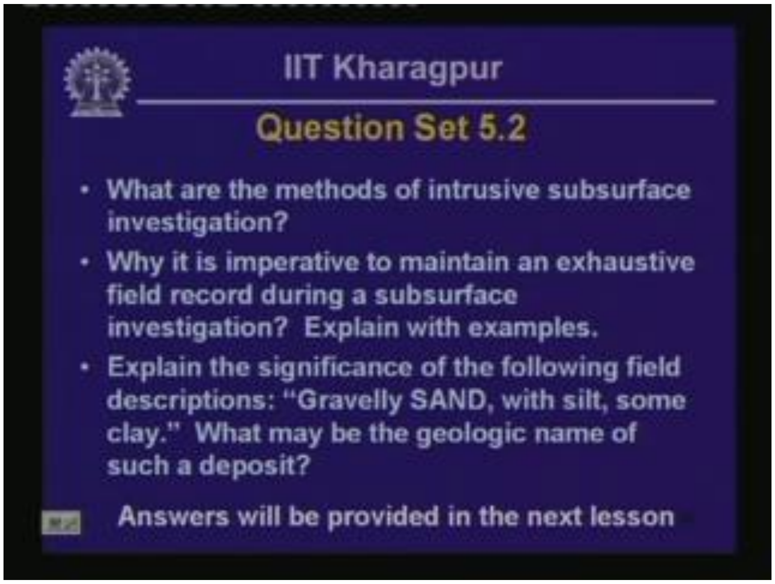

The first question is what are the methods of intrusive subsurface investigation? Then the second that I ask is why it is imperative to maintain an exhaustive field record during a subsurface investigation; give some examples and explain. Third one is explain the significance of the following field descriptions of hand samples of soil really - gravelly sand, with silt, some clay; what may be the geologic name of such deposit. Try to answer these questions; I will try to give you my answers when we meet again. Until then, bye for now, thank you very much.