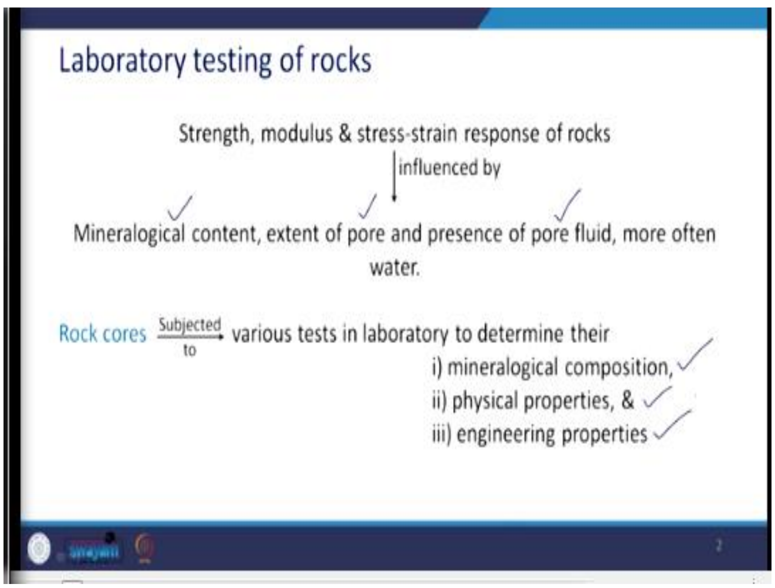
Rock Engineering
Prof. Priti Maheshwari
Department of Civil Engineering
Indian Institute of Technology-Roorkee

Lecture-10
Laboratory Testing of Rocks-Sampling

Hello everyone. So, today we will start a new chapter on the lab testing of the rocks. We will be discussing that how to get the samples from the field? How to bring it to the lab? Then how to prepare the specimens out of those samples? What are those requirements? What are the various types of specimen that are to be tested in the lab with reference to different types of tests? So, before we go to the detailed discussion on this specimen preparation, sample extraction, let us first try to see, what all are the test that we need to perform in the lab?

(Refer Slide Time: 01:47)



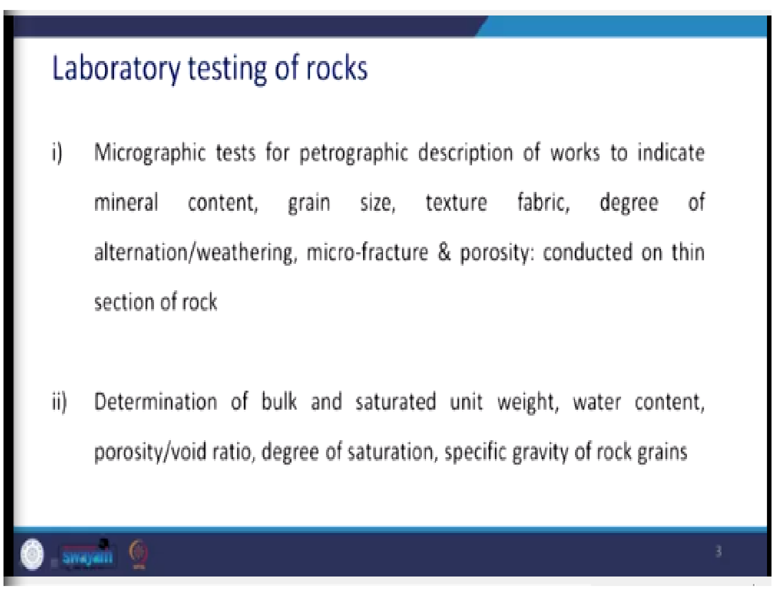
So, basically the strength modulus and stress strain response of the rocks, all these things they are significantly influenced by mineralogical content of that rock, extent of pore and the presence of pore fluid in them which is quite often water. These rock cores that we extract from the field and then to the lab, these are subjected to various tests in lab to determine three things, one is their mineralogical composition, second is their physical properties and the third one is engineering properties.

Now what exactly is the difference between these three things? We have been discussing that one rock is different from the other from the point of view of its mineralogical composition. And therefore, it is extremely important for us to know that what all those minerals with which it is comprised of. So, basically this mineralogical composition identification, it does not fall under the preview of we as civil engineers, it goes in the domain of earth sciences department.

However, because you are dealing with the material rock, we had already the detailed discussion about various minerals and rocks. And there I explained you that what is going to be the mineralogical composition in general for various types of rocks. So, we will not be discussing about the tests which are conducted to determine the mineralogical composition in this course. The second one is physical properties. We will see that what all properties are there in this category just now.

And then the last one is engineering properties. What exactly is the difference between physical properties and the engineering properties? These engineering properties, they are used in the design of underground excavations. That excavation can be for the tunnel, it can be for the dam foundation or any other application area. Whatever that we get from the physical properties, that gives me some of the overall idea like what kind of rock is this. Let us see one by one.

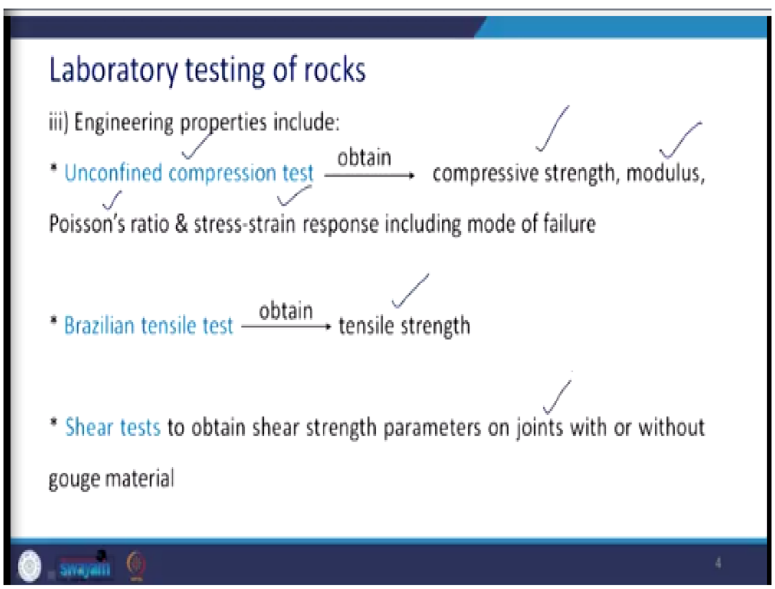
(Refer Slide Time: 05:05)



So, basically this micrographic tests for petrographic description of works to indicate the mineral content, grain size, texture, fabric, degree of alteration and weathering, micro-fracture and porosity. These are all fall under the category of the tests which are done to identify the mineralogical composition of the rock. These are conducted on a thin section of rock. As I mentioned that it is beyond the scope of this course, where we are focusing mainly on the engineering characteristics of the material called rock.

The second category, that is the physical properties of the rock. These include the determination of bulk and saturated unit weight. What is the water content? The determination of porosity or void ratio, degree of saturation and specific gravity of rock grains. Some of these tests you must have heard about with reference to soils but in case of the rocks, it is a little bit different. We will see them how these tests are to be carried out.

(Refer Slide Time: 06:36)



Now the engineering properties of the rock, these include the testing towards the determination of the engineering properties. These include, the first one is unconfined compression tests. Conducting this test, we can obtain the compressive strength, modulus, Poisson's ratio and stress strain response including the modes of failure. We will discuss all these things in detail. The name of the tests suggests unconfined compression test.

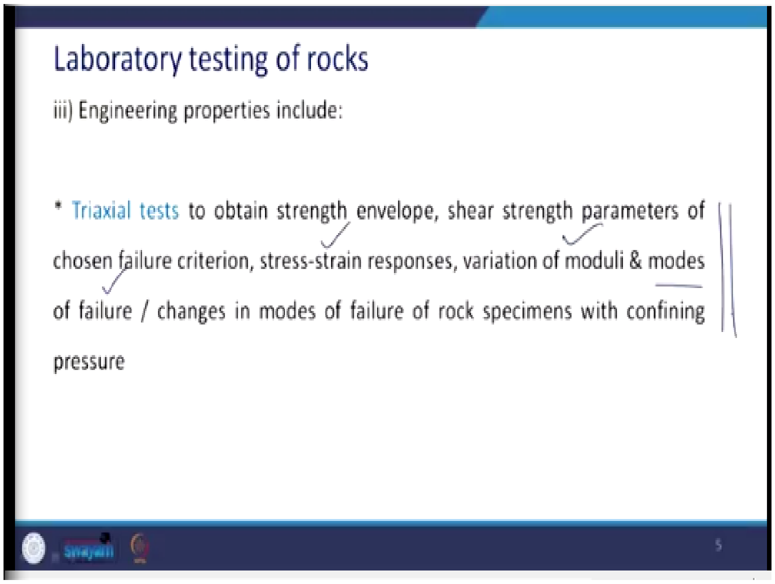
That means we have to apply the loading in one direction and then try to fail the specimen and try to get the strength in one directional compression. Then the next category of the test towards this engineering property determination is the Brazilian tensile tests. This obtains the tensile strength of the rock, as against soil where the tensile strength is almost zero. This material rock possesses some finite tensile strength, although that tensile strength is less than that of it is compressive strength, but still, it exists

Why it is important for us to know the tensile strength? Because let us say, when you go for analysis of the tunnel, at the crown of the tunnel even under the application of the compressive kind of load. At the crown of the tunnel there can be the occurrence of the tensile stresses. So, until and unless we know the tensile strength of that material, I will not be able to analyze that tunnel under that condition.

So, it is important for us to know the tensile strength of this material rock. Then the third type of tests includes various shear tests in order to obtain the shear strength parameters on joints. Those joints can be with or without gouge material. We will discuss all these things in detail in the next chapter, when we will discuss about the classification of the rocks. There I will be sharing with you that what do we mean by the joints, open joints, close joints, tight joints etc.

And what do we mean by joints with or without gouge material? But for the time being, you just note that we are going to conduct the shear test to obtain the shear strength parameters on joints with or without gouge material. Then the triaxial tests, you all are aware with reference to soil about this test.

(Refer Slide Time: 09:50)

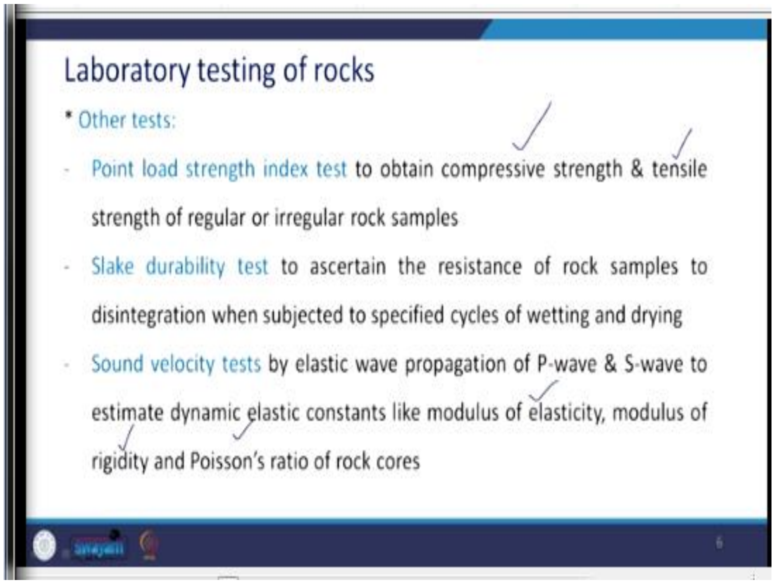


That in this test, you apply the all-around confining pressure and then you increase the pressure in the axial direction, so that the shearing can take place, so that is what we do in triaxial tests. So, similar philosophy is going to be there in case of the rocks and what it does? This test gives us the strength envelop, shear strength parameters of the chosen failure criterion. That means, it can be let us say, if we assume that it is following the Mohr coulomb failure criterion. Then, c and ϕ are the shear strength parameters.

Likewise, you have many other failure criterions, we will discuss these also in detail. So, the triaxial tests helps us in obtaining the shear strength parameters of the chosen failure criterion. Then along with the strength characteristic, it gives me the stress strain response, variation of moduli, what are the various modes of failure? Very important.

And what are the changes which happen in the modes of failure with the confining pressure? Like if we test a specimen at the low confining pressure or if we test it in at the high confining pressure, there is going to be the change in the mode of failure. So, this triaxial test gives me the idea about all these parameters.

(Refer Slide Time: 14:41)

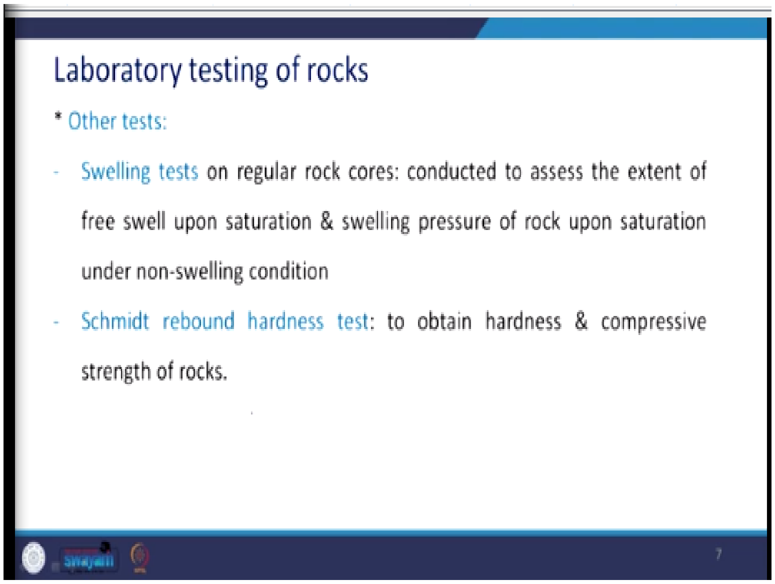


Some of the other tests which are there apart from these include, point load strength index test. So, apart from the unconfined compression test, this test also gives me the idea about the compressive strength and also the tensile strength of regular or irregular rock samples. Then the next test in this category is slake durability test, which gives me the idea about the resistance of the rock samples to disintegration, when they are subjected to some specified cycles of wetting and drying.

So, there are a standard, let us say, two cycles or one cycle of wetting and drying is there and from there. We try to obtain an index, that is an indication of the resistance of the rock sample to weathering. So, this is what we do in slake durability test. Then the next category is the sound velocity test. In this test, the elastic waves are propagated through the rock specimen, these can be type of P-waves or S-waves.

And these help in estimating the dynamic elastic constants like modulus of elasticity, modulus of rigidity and Poisson's ratio for the rock cores. So, these tests help me in obtaining the dynamic characteristic of the rock.

(Refer Slide Time: 13:27)

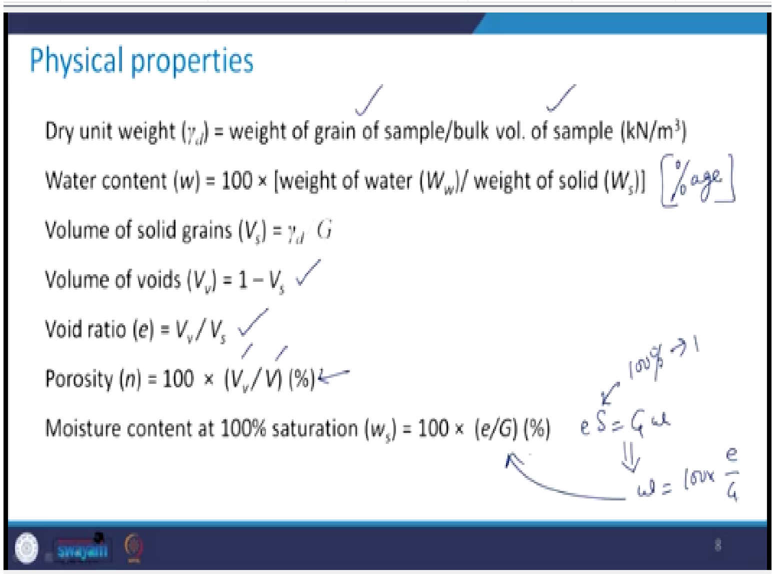


Then in this series, the next test is the swelling tests on regular rock cores. This is conducted to assess the extent of the free swell upon the saturation and swelling pressure of the rock upon the saturation, if it is under the non swelling condition. If you recall our discussion, when we were having the discussion related to mineralogical composition of the rocks, I mentioned to you that there are few minerals, when they come in contact with water, they expand in volume.

So, if the rock has any of such mineral, then this test, that is, swelling test is helpful in finding out those characteristic. Next one is, to determine the hardness and compressive strength of the rocks, we conduct Schmidt rebound hardness test, which is a very simple test where the energy is transmitted to the rock by means of a hammer, again a standard hammer. And then the value that the hammer gives that is the rebound number is correlated with the compressive strength of the rock.

So, these are the various tests that we are going to discuss in this chapter. Coming to the physical properties, the first one is how to determine the dry unit weight. So, as the name suggests, and you all know with reference to the soil mechanics, the same definition is applicable here. Weight of the grain of the sample divided by the bulk volume of the sample.

(Refer Slide Time: 15:23)



So, we need the dry weight and simply divided by the bulk volume of the sample, how to determine this volume etc? When we learn about the sample preparation, you will automatically get to know about this.

Dry unit weight (γ_d) = Weight of grain of sample/ bulk volume of sample (kN/m^3).

Water content (w) =100 x [weight of water (W_w)/weight of solid (W_s)]

Volume of solid grains (V_s) = $\gamma_d\, G$

Volume of voids (V_v) =$1 - V_S$

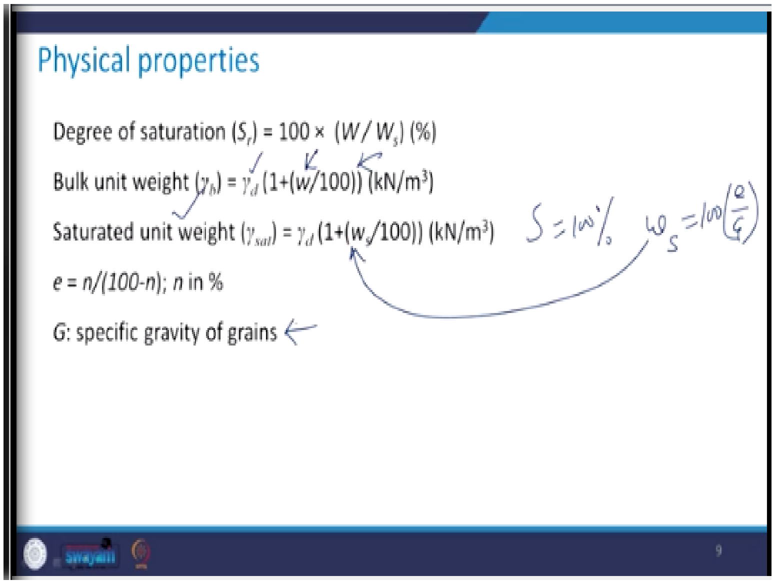
Void ratio (e) = V_v/V_s

Porosity (n) = 100 x (V_v/V) %

Moisture content at 100% saturation (w_s)= 100 x (e/G) (%)

Porosity, volume of voids by the total volume multiplied by 100. Again, this is represented in percentage. And the moisture content at 100% saturation, that is, you know that eS =Gw, now if this S is 100%, this means this is equal to 1.

(Refer Slide Time: 16:48)



Then degree of saturation, bulk unit weight, so here you see that dry unit rate that we have already obtained and the water content, and this water content should be in percentage. And you have to obtain it using the dry unit weight and the moisture content and use this expression to obtain the bulk unit weight. And then you have the saturated unit weight, that means when you have the saturation that is capital S = 100%.

Degree of saturation (S_r) = 100 x (W/W_s) *(%)*

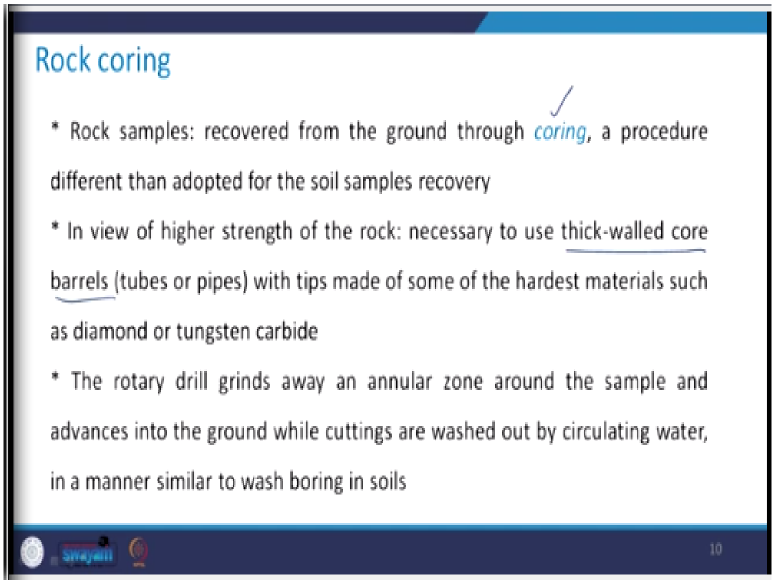
Bulk unit weight (γ_b) = γ_d (1+(w/100)) (kN/m^3)

Saturated unit weight (γ_{sat}) = γ_d (1+(w_s/100)) (kN/m^3)

$e = n/(100-n)$; n in %

Then whatever is the moisture content corresponding to that, which is 100 x e/G, just now we saw. That you substitute here and you will get this saturated unit weight, where G is given us the specific gravity of the grains.

(Refer Slide Time: 17:43)



Before we go for any kind of testing, we need to prepare the sample, we need to prepare the specimen. How to do that? So, basically exploration program as per as the rock and the rock mass is concerned, it is pretty different than that of the soil. In case of the soil, you go to the field, you have the bore log, you conduct standard penetration test, dynamic cone penetration test, plate load test, then you collect the disturbed as well as undisturbed samples. Bring it to the lab and carry out those tests, you all are aware of those tests.

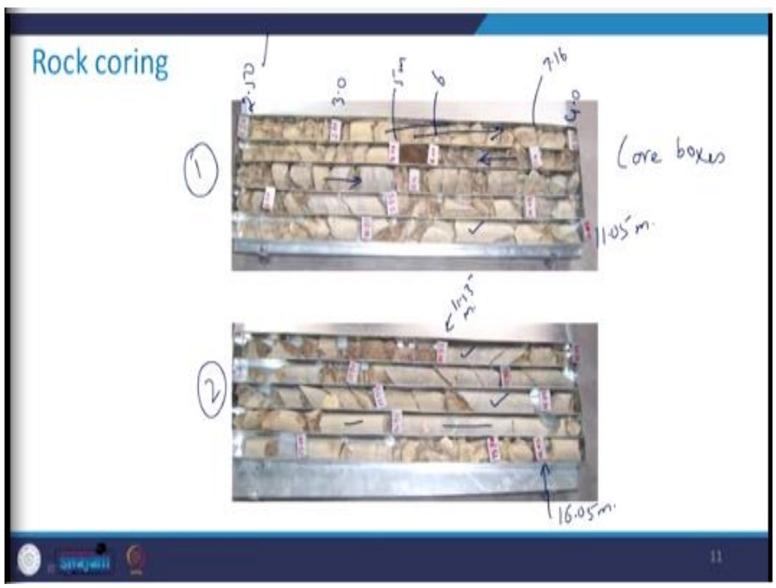
In case of rocks, that sample extraction procedure is altogether different and it is not that easy as it is there in case of the soils. So, one has to be extremely careful while taking out the samples from the rocky strata. That procedure is called as rock coring. So, the rock samples they are recovered from the ground through coring. So, in soils we call as boring. In case of the rocks, it is coring.

This is as I explained it is altogether different than soil samples recovery. How this is done? And why it is different? I do not need to tell you this, but then the strength characteristics of rock is much better as compared to that of the soil. That means that the material rock has much higher strength as compared to that of the soil. And therefore, to extract this rock sample from the ground one has to use thick-walled core barrels.

These are tubes or pipes and they have the tip which is made up of some of the hardest materials such as diamond or tungsten carbide. Can you recollect Mohs hardness scale? The hardness of diamond on the relative scale was 10. So, you see that we need to use that diamond drill bits, in order to retrieve the cores from the ground.

What is done in this case is, a rotary drill grinds away an annular zone around the sample and it advances into the ground while the cutting which is happening in this particular process, it is being washed out by circulating the water exactly on the similar lines as you do in case of the wash boring in case of soils. So, the point is, extraction process of the rock is very much different than that of the soil. In view of the high strength of the rocks, one has to go for the use of hardest material in order to extract the sample from the ground.

(Refer Slide Time: 21:31)



These are some of the pictures of the cores, which we got from a site in DarLaghat where we came across these rocky strata. So, I have just put it here, so that you get the idea that how these are retrieved, how these are arranged, and how these are transported to the lab? So, take a look here. You start from the ground surface that means at a zero level, keep on coring and what will happen? Whatever is the material that you extract depth wise, keep on arranging that material, depth wise only in these core boxes.

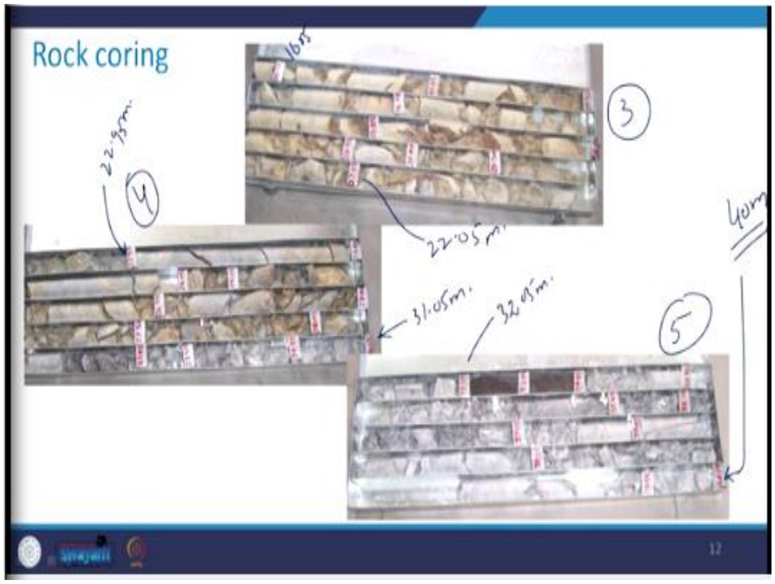
So, these are called as core boxes. We requested them to make it using the aluminum but earlier they used to use as a wooden box. But then these are safer, why? I will tell you because these cores which are extracted during the process of the extraction, during the process of the transportation to the lab from the field, there should not be any additional crack introduced in this process.

So, therefore these need to be preserved properly till we carry out the lab tests or laboratory tests on the specimen. See here, this is starting from, this is 2.50, then this is 3 meters, this is 4 meter and likewise this one is 5 meters, this is 6 meters, this is 7.16. So, likewise, they have arranged it in the increasing manner of the depth, in this direction and then from here to here and in this direction.

So, you see that here in this core box, whatever was retrieved from the ground from the depth of 2.5 meter to, this is 11.05 meter, this has been arranged exactly in the same order. Then it is the second ones here, it is 11.55 meter and so on, so this finishes here at 16.05 meter. So, this was the first core box, this is the second one. Again, like you have bore holes, so here you have the core hole. So, this is the data of one single core hole that I have put here for your reference.

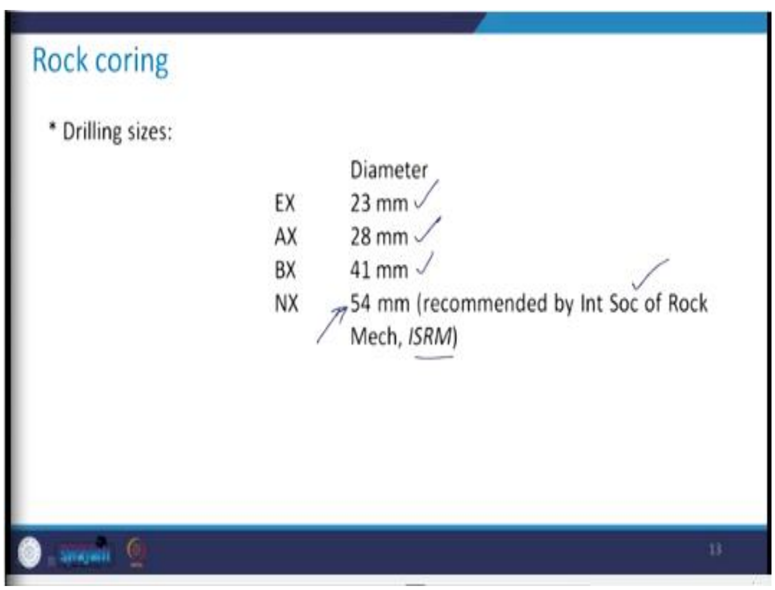
In the beginning you were getting loose pieces and then somewhere here you are getting some long cores. You can see here this is also long core, this is also long, this is. So, depending upon what is a situation in the field below the ground? what are the discontinuities etc.? Where the joints are? Everything, every information one can get from these core boxes. So, when these core boxes are brought to the lab, we need to very carefully study these.

(Refer Slide Time: 24:57)



See here, this is the third one, this is fourth one and this is the fifth one. So, you see, this is starting, this is 16.55 meter and this is ending here at 22.05 meter and this is here, this is 22.95 meter and here it is 31.05 meter and this is your 32.05 meter. And likewise, this goes up to 40 meters. That means the depth of that core hole was from the ground surface to 40 meters. So, you see, from 0 to 40 meter whatever that you have got, you have arranged it in that systematic manner depth wise in various core boxes. So, that it can be transported to the lab for the further specimen preparation and the testing.

(Refer Slide Time: 26:08)

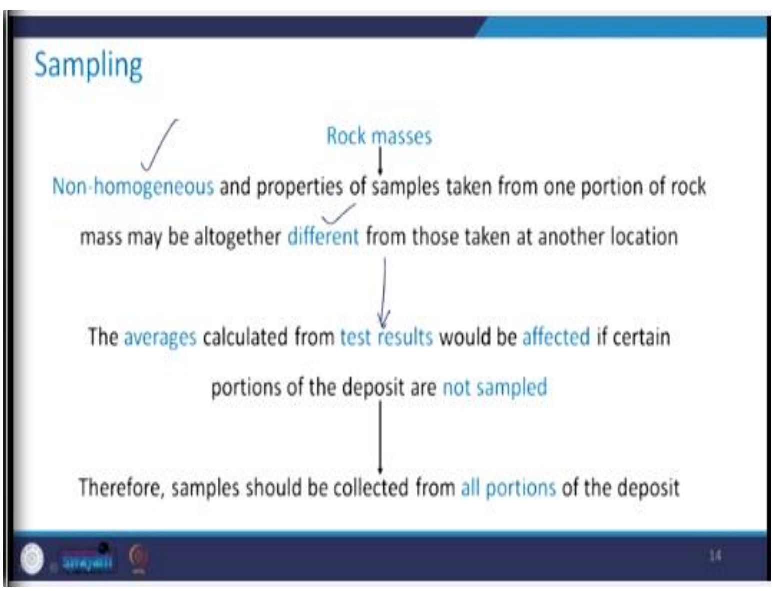


What should be the drilling size? International society of rock mechanics, so I will be using this term quite often, so in short, we call it as ISRM, has suggested that one should use NX size specimen. So, the diameter of the NX size specimen is 54 millimeters, there are other sizes as well EX, AX, BX. EX has a diameter of 23-millimeter, AX is 28, BX is 41 millimeters, NX is 54 millimeters. One needs to use 54 mm diameter specimen which is NX size.

So, from now onwards, if I say NX, immediately you should get the idea that I am talking about a specimen which is having a diameter of 54 mm. How to do the sampling? So, we go in the field, let us say, a tunnel has to come up, few kilometers. How to decide from where to do this coring? Which stretch should we choose for this coring? Because rock masses, in general they are non homogeneous and let us say, that you take the sample at a chainage of say 10 meters.

And you take the sample from the chainage of let us say, 150 meter and the characteristic of the rock at these two chainages can be altogether different. They may be same also. But then most likely they may be different, because the rock mass is highly non homogeneous. And the properties of the sample taken from one portion of the rock mass may be altogether different than those from the other location. Like I gave you the example, like you have a chainage, let us say 10 meter and 150 meters, the properties can be altogether different. So, what is the way out?

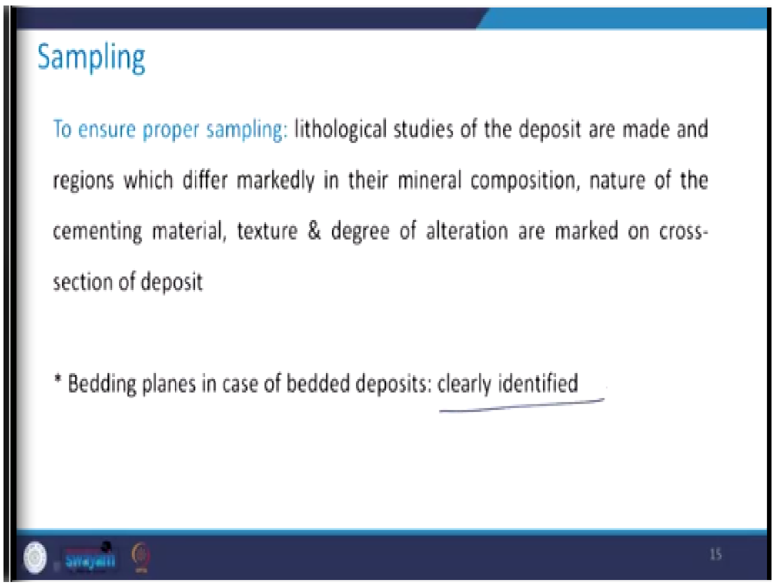
(Refer Slide Time: 28:23)



Either we take the average of those test result, but then that would be affected if the certain portion of the deposits they are not sampled, which have different characteristics and we have not sampled them in the field. Then, let us say, whatever that we have sampled, we take the average of all that, so the property that we will get from those laboratory tests, those will not be the representative properties of the rock for the entire stretch of let us say, 1 kilometer.

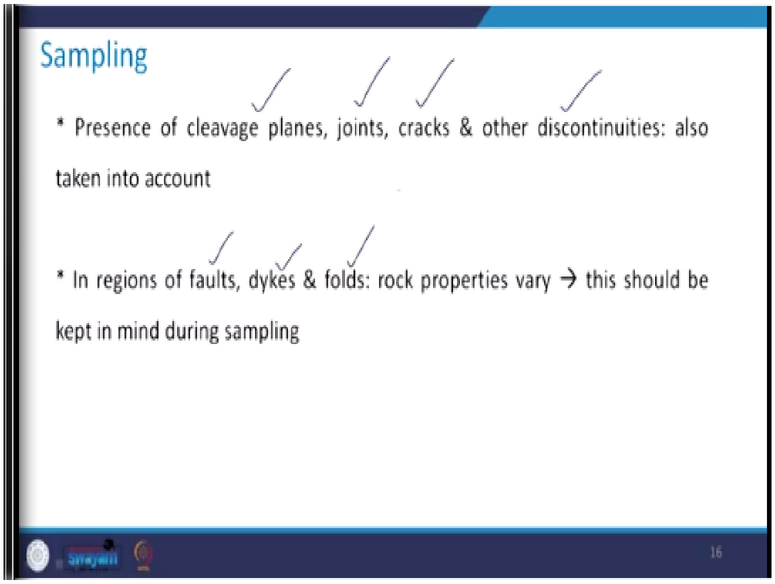
Therefore, it is extremely important that we collect the sample from all the portions of the deposit. Now again, it may not be possible like, let us say, it is, I am giving you an example that it is say only one kilometer but then it can be few kilometers. It cannot happen that we keep taking these samples very close to each other that would be highly uneconomical. Because extracting the rocks sample from the field is very expensive, in case of the rocks and rock masses. So, what is done? How to decide this? So, in order to ensure the proper sampling, we need to do proper lithological study of the deposit.

(Refer Slide Time: 29:54)



And the regions where this lithology differs from each other in their mineralogical composition, maybe the nature of the cementing material, texture and degree of alteration, wherever you see that kind of change, that is marked on the cross section of the deposit. In case of the bedded deposit where you have these bedding planes, this has to be clearly identified.

(Refer Slide Time: 30:33)



Further, the presence of the cleavage planes, joints, cracks and other discontinuities also should be taken into account. The regions of faults, dykes and folds, where the rock properties vary significantly, that also should be kept in mind during the sampling process. All these terms we have already discussed with the help of various pictures. I tried to explain various elements of these geological structures to you.

And you have seen that how the geological deposition of the material creates such type of geological structures and the rock properties can vary like anything. And one should keep in mind during the sampling all these things. Once these are sampled, what should be the next step? They should be transported carefully, so, that these are not subjected to excessive jolts which might induce fresh cracks or cause extensions of the pre-existing cracks.

Because, if this happens, you know that the introduction of these cracks, they are going to weaken the material. And if you test that weakened material what you are going to get is the lesser a strength characteristic whether it is compressive strength, whether it is tensile strength or whether it is the shear strength as what is there in the field. Actually, whatever is the strength we will get lesser value in the lab which is not desirable.

So, therefore the transportation of these samples, which we have collected in the field is equally important. So, what we have seen today that what all are the test to be conducted on the rocks, mineralogical composition, physical properties and then the engineering properties. I mentioned to you some of the physical properties, like the unit weight, void ratio etc water content. And then, I mentioned to you that we will find out the unconfined compressive strength, tensile strength, shear strength characteristic and stress strain response by analyzing the data from the laboratory tests that we conduct on these rock cores.

Then we discussed about how to choose the location at the site so that proper sampling can be made and we do not miss any significant change in the strata all along the stretch, which is required for us to explore. Then, I mentioned to you that in case if you have any special geological structure like bedding plane, fault, fold, dyke, anything, cleavage plane, we cannot afford to miss any of these.

So, wherever you see that such type of things is there, do not forget to take the sample from that location. Once you take the sample, you have to, once you have located this position from where to extract the sample, then you have to go for the rock coring, size of that which is recommended by International society of rock mechanics as NX size, where the diameter of the core is 54 millimeters.

After extraction of those cores, it is to be arranged properly in the core boxes and then transported carefully. So, see those core boxes are designed in such a manner that during this transportation process, there is the minimum disturbance to those cores which have been extracted from the field so that new cracks are not generated in the process of transporting those specimens or those samples to the lab.

So, in the next class, we will discuss about how these samples, they are prepared or how the specimens they are extracted from these samples? What are the specifications of these sample preparation, specimen preparation? All those things we will discuss in the next class, and then we will follow the discussion with the unconfined compression test. Thank you very much.