Underground Space Technology
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Module No # 01
Lecture No # 02
Basics of Rock Engineering: Coring, Sampling, UCS of intact Rock

Hello everyone, in the previous class, I introduced you to the material rock and rock masses, and then we discuss that what all are the tests that we conduct in the lab in order to find out the mechanical properties, engineering properties of the intact rock. So today, we are going to learn few aspects related to coring of the rock specimen from the field, then sampling, and then how we conduct the unconfined compressive strength of the intact rock in the lab. So, to start with a first, let us learn few things about rock coring.

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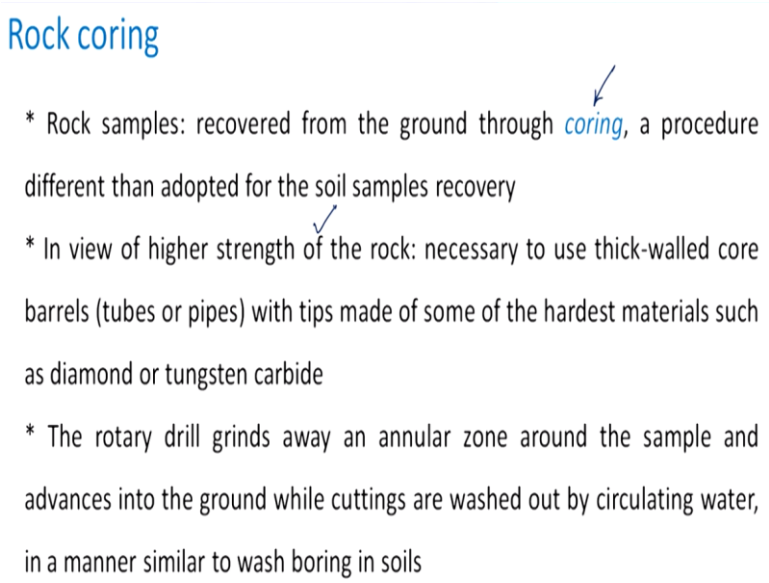

So, the rock samples these are recovered from the ground through the process called coring. This is little bit different than the soil samples that we get from boring, so in case of the soil samples, what we do is that we go ahead with the boring and the conduct the SPT test, and wherever need that we keep collecting the soil sample. And in case, if you want to have the undisturbed soil sample then we insert tube and then try to take that out.

However, it is not the same here in case of rocks, so in view of the higher strength of the rock, it becomes necessary use the thick-walled core barrels, which are kind of tubes or pipes with tips which is made up of some of the hardest material such as diamond or tungsten carbide so what happens, in this case, is that? Rotary drill grinds away and annular zone

around the sample, and it advances into the ground so what happens in that process that these cuttings are washed out by the circulating water exactly in the similar manner which is adopted for wash boring in case of soils.

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So, you see that this is how we extract the specimen of rocks from the field, and you see how, with the variation of depth, these are arranged. So, you can see here this is 2.5 meter then 3 meter and likewise, we have 5 meter, 6 meter and so on. So, these are called as core boxes in which, as you keep collecting these raw cores from the field, you just keep arranging them with reference to depth.

So, somewhere you will get the loose material which may not be even rock, it may be soil, and then somewhere, let us say here in this zone, you get a long rock core. So likewise, here these 5 boxes were code from particular site. So, of a particular borehole, so I have just placed it all with the depth here now, what can be the drilling sizes?

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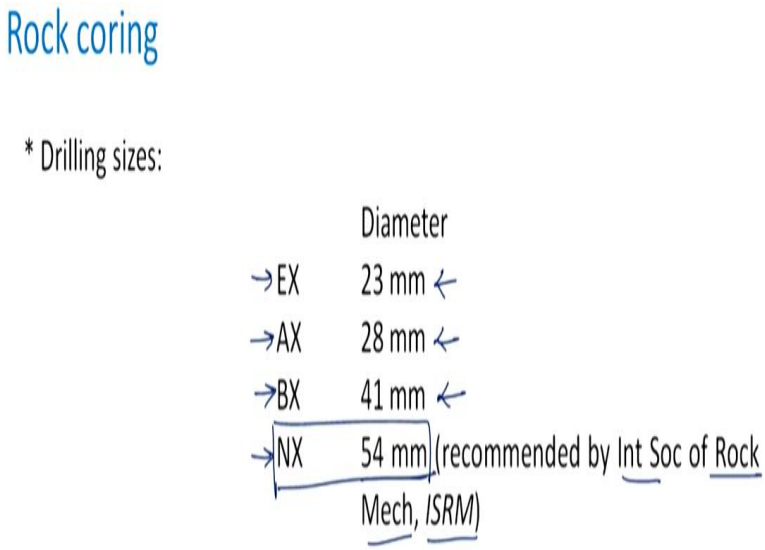

So, our international society of rock mechanics, which we in short call it as ISRM, recommends that one should go for NX size specimen which is having a diameter of 54 mm. However, we have other 3 sizes also EX, AX, and BX, having 23 millimeter, 29 millimeter, and 41 millimeter diameter, respectively. But most of the time, we go ahead with NX size specimen, which is 54mm diameter.

Please remember this when we need to get these samples from the field, so there the question comes because let us say site is there say for a tunnel. So, it will be maybe for few kilometers, so the question comes from which location should we collect the sample? So, sampling aspects becomes most important, and it should be done very carefully to have the representation of the rock mass for the complete stretch where the excavation is to be there.

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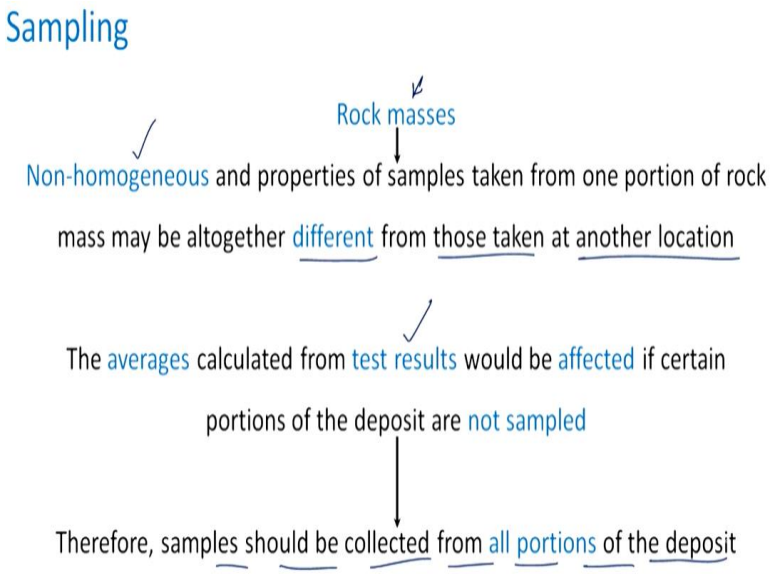

So, these rock masses basically they are non-homogeneous, and therefore the properties of the sample that you take from one portion of the rock mass. It may be altogether different than what you get from the other location, so the average which are calculated from the test result, these would be affected if you leave certain portion of the deposit and you do not sample it. So, it is very important that samples should be collected from all portion of the deposit. How to make sure this?

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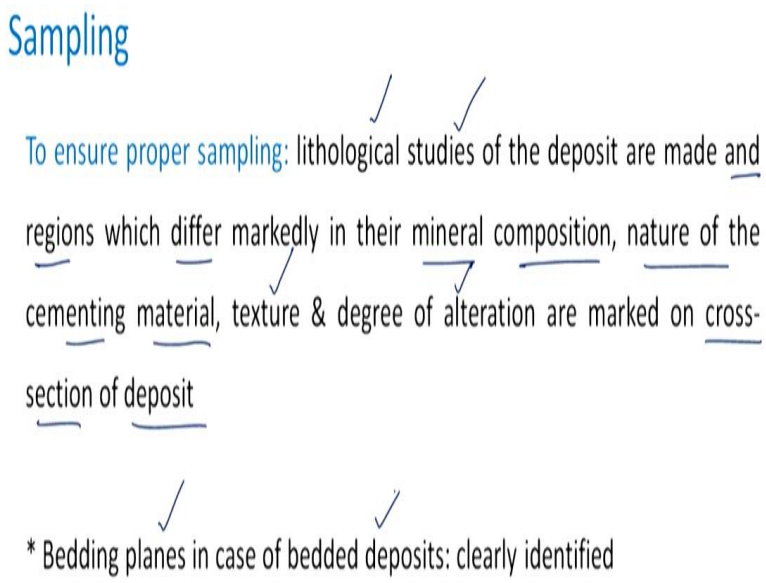

See, what we do is that we conduct the lithological study before we go for the sampling, and we mark the regions which differ from one to the other in their mineral composition, nature of cementing material, texture, degree of alteration and wherever there is a difference. We mark on the cross-section of the deposit, and then we take the sample from each of these zones. In case, if you have the bedding planes with reference to bedded deposits, these also should be clearly identified.

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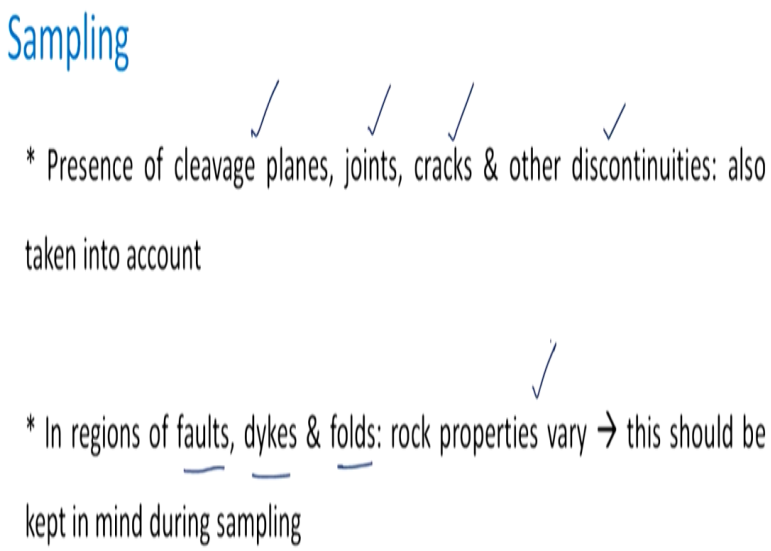

Presence of cleavage planes, joints, cracks, and other discontinuities also should be taken into account then we go for sampling in the field. Further, in case if you have the regions of faults, dykes, and folds, these rock properties vary significantly and should keep this in mind when you are going for sampling in the field. So, any geological feature, any change in mineralogy, any change in colour, texture all these should be noted throughout this stretch of the proposed structure before we go ahead for the sampling. We should not miss any of these important features.

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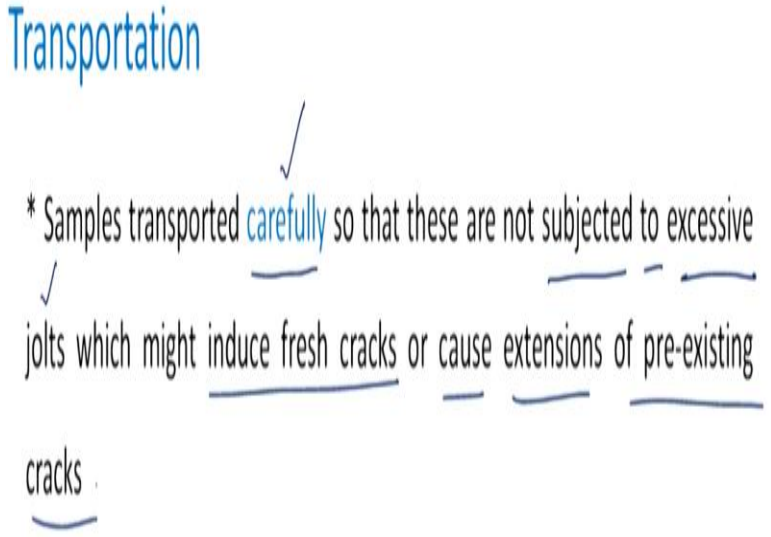

Now, when we do this sampling, and as I showed you that we arrange it in those core boxes then the next step is how to transport these to the concerned lab. We need to be very careful about it because when you take out the sample from the field, we need to carefully keep it core boxes. And then carefully transport it because it should not happen that during the

process of the transportation some additional cracks, fresh cracks, they are induced or generated.

So, we have to do this transportation carefully so that the samples which we have collected from the field they are not subjected to excessive jaws, and this might result in the induction of fresh cracks or cause extensions of pre-existing cracks. Because if this happens, the material will deteriorate, and we will not get the true representation of its engineering property. Now, let us see that I will receive these samples in the lab how to prepare the specimen?

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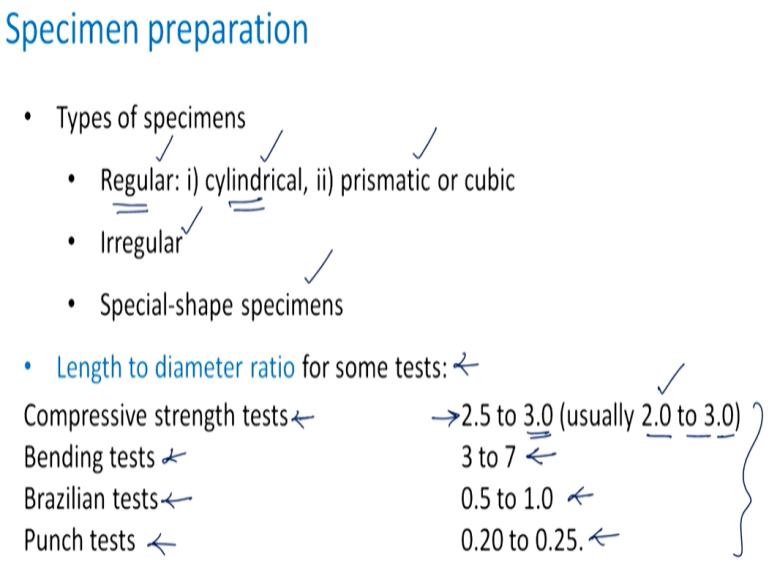

So, there can be different types of the specimen, so we can have a regular specimen which can be cylindrically in nature or may be prismatic or cubic, it can be irregular in shape, or you can have the special shape specimen. So, in case you have the regular specimen and say it is the cylindrical one, then there are some standard length to diameter ratio for some of the test which are listed here.

So, compressive strength tests usually we take 2.5 to 3, but in case if you are not able to get that long rock of core, then you can ahead with even 2. So usually, it is varying between 2 to 3. In case if you have bending type of test in that case, L by D ratio 3 to 7. For Brazilian test, it is 0.521, and for punch test, it is 0.2 to 0.25. Again, we are focusing right now on the regular specimen because these only need lots of care while their preparation.

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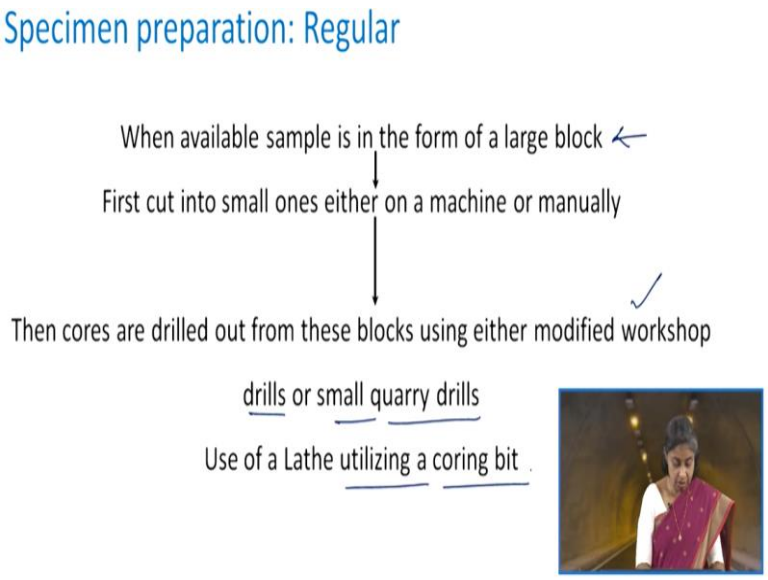

So, when the samples are available in the form of large block so what we do is first we cut them into a smaller ones on a machine or manually. And then, the cores are drilled out from these small blocks using either modified workshop drills or small quarry drills, and there comes the use of lathe machine utilizing the coring bit.

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Take a look here, on this picture these are the pictures of the machines from our lab here in IIT Roorkee. So, this is the machine that is used to exact these specimens from that small block. So, you can see here that this portion is the drill bit; we place the rock specimen rock sample here on this platform. So, you see that one is kept here, and you can see that this is having a circular hole that means one specimen that already been taken out from this sample.

So, these samples they may not necessarily be such a nice cube shape they may be of irregular shape block, and then from there, you can just extract the cylindrical specimen.

Now, as you have seen that length to diameter ratio is kind of a range is there for a particular type of test. So, in that case, when you are extracting the specimen, you may not get that exact size as far as the length of the specimen is concerned.

So usually, we take that out little bit longer, and then with the help of this cutting machine which is shown here in the other figure, we just cut the specimen. So, you can see here that this is the blade in this view; it is not very clear, but this is the blade specimen is fixed here, and then this machine is on, and this blade cuts this specimen and gives you a specific length of the specimen. So, using this extraction machine and the cutting machine, we can get this cylindrical specimen of required in the lab.

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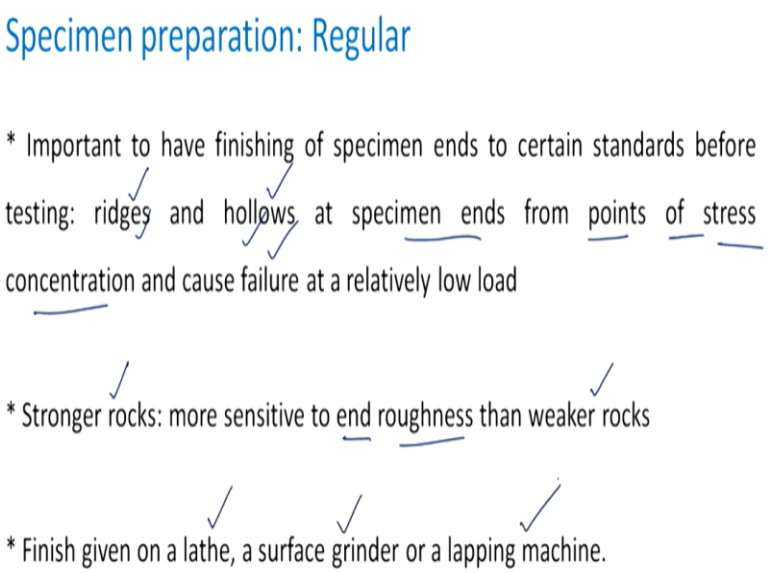

So, once we obtain this, the ends of the specimen or they may not have that particular finish. So, it is extremely important to finish these specimen ends to certain standards before we test, the reason being that ridges and hollows at these specimen ends from point of stress concentration and cause failure at relatively low loads. So basically, say it is strength is much higher, but because of the presence of these ridges and hollows, the strength may come out to be very low in the lab.

In case of the stronger rock, these are more sensitive to end roughness as compared to weaker rocks. So, finish is to be given on a lathe machine or a surface grinder, or a lapping machine. So, when we have the cylindrical specimen for compressive strength tests, the ISRM committee has suggested that there should be the tolerance as far as the finishing of the ends of the specimens is concerned.

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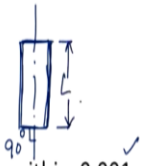
Specimen preparation: Regular

The tolerance on dimensions of cylindrical specimens for compressive strength test suggested by ISRM committee on laboratory tests:



- Ends of specimen shall be flat to 0.02 mm
- Ends of specimen shall be perpendicular to axis of specimen within 0.001 radians
- The sides of specimen shall be smooth & free of abrupt irregularities & straight to within 0.3 mm over full length of specimen

So, when we say that the finishing means, the first specification says that the ends of the specimen shall be flat to 0.02 mm. So, for example, let us say that this is the cylindrical specimen. So, when we say that the ends of the specimen means, I am referring to this surface and this surface. So, these should be flat to 0.02 mm, then ends of the specimen shall be perpendicular to this axis of the specimen within 0.001 radians.

So, you see that this is what is the axis of the specimen? So, this angle should be 90 degree within plus minus 0.001 radiant of the tolerance. So see, we have to be extremely careful when we prepare these specimens. The sides of the specimen these shall be smooth and free of abrupt irregularities and straight to within 0.3 mm over full length of the specimen. So, these are the sides of the specimen, so these should be straight to within 0.3 mm over the entire length of the specimen that is this.

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Specimen preparation: Irregular

* Blunting sharp edges by slight taps of a small hammer
* Dimensions of specimen are calculated from their weights

Number of specimens to be tested: depends on scatter, i.e., variability of results, desired accuracy & reliability of mean value

Usually: UCS: 5 and Triaxial: for each confining pressure: 3

(3) (9) 3 at each conf press

In case, if you have the sharp edges one can blunt these by slight taps of a small hammer. In case, if you have irregular specimens dimension of these specimen are calculated from their weights, in case of irregular specimens, the number of specimens which are to be tested these depends on the scatter or maybe in other words, you can say that variability of the results or the level of accuracy that you need and the reliability of the mean value.

But then, usually for the UCS test, we go ahead with 5 numbers of specimens, and for tri-axial test, we take 3 specimens for each confining pressure. So, in case of the tri-axial test, ideally you should test 9 specimens, 3 at each confining pressure. And then you know that for the tri-axial test, you need to go for minimum of 3 confining pressure, so that makes it total of the 9 specimens for 1 tri-axial test.

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So here, I have put 2 photographs of these specimen which were tested in uni-axial compressive strength condition. The UCS of the intact rock is determined the cylindrical specimen with the slenderness ratio of 2. And slenderness ratio when we say this is its diameter and this is its length, so that is length to diameter ratio as 2. So, these were tested, and you can see that the failed specimen how these look like.

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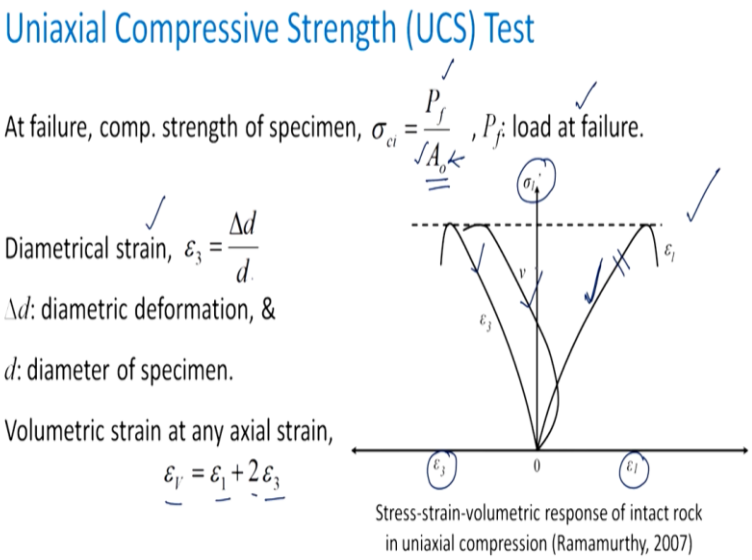

So, stress at any axial strain level is σ_1' that is given by P by A_o, where P is the axial load, and A_o be the cross-sectional area of the specimen and corresponding to this stress, the axial strain we write as ΔL upon L_o where ΔL is the deformation under the P and L_o be the original length of the specimen. Now at failure, the compressive strength of the specimen is defined as P_f/A_o here, P_f is the load at failure, and of course, A_o is the area of the cross-section of the specimen.

We can also find out the diametrical strain that is the change in the diameter divided by the total diameter of the specimen; we can find out the volumetric strain also, which is the sum of axial strain plus twice that of the diametrical strain. So, if we try to plot the stress-strain and the volumetric response of the intact rock in uni-axial compression test, this is how it looks like. So, on X axis, on one side, you have ε_1, and another side, you have ε_3, and on Y axis, you have the stress that is σ_1'.

So, this is how the axial strain varies, this is the variation of ε_1, this is the variation of the ε_3, and this is the variation for Poisson's ratio. So that is a typical stress-strain volumetric response of the intact rock that you will obtain when you go for the UCS test. Now, how we can get the various modulus values from the results of UCS test?

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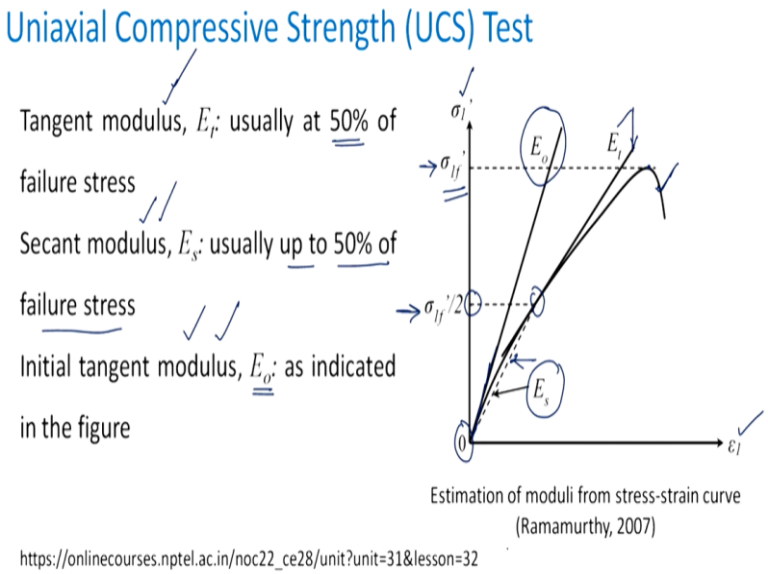

So, what we do is we plot σ_1' versus the axial strain for this purpose, and this is what is the variation. So basically, 2 types of modulus, they are defined the first one we call as the tangent modulus this is usually at 50% of the failure stress. So, you take a look on this figure so the maximum point here this corresponds to the failure stress that is represented by σ_{1f}'.

So, we take 50% of that, and it corresponds to this level, and we just take this point to this plot draw the tangent, and whatever is the slope of this that is E_t that is tangent modulus. Then, the second one is the secant modulus that is usually up to 50% of the failure stress; how to determine this? So, we have this level of the 50% of the σ_{1f}', which is the failure stress.

So, we join this origin to this particular point, and the slope of this dotted line gives you secant modulus E_s. Then one more modulus is defined, which is the initial tangent modulus E_o, and see this is indicated in the figure that how we can determine? So, we draw a tangent in the initial portion of the stress-strain curve, and the slope gives me the value of E_o. So, when you have to determine the modulus, so you need to specimen that which modulus that you want to find out whether it is tangent modulus, secant modulus, or initial tangent modulus.

So, in case if you need to know more details about this UCS test, you can refer to this link because many factors which influence the UCS test all these various aspects have been discussed in detail in this particular lecture. So, what we discussed in this lecture is that how to get the sample from the field, we need to be careful while transporting it. And then how we can prepare this specimen in the lab from these samples and how we can get the uni-axial compressive strength, and the various moduli in case of the intact rock.

So, in the next class, we will take up some more lab tests to determine the tensile strength and the shear strength parameters with reference to the intact rock. Thank you so much.