Rock Mechanics and Tunneling
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Lecture 19
Laboratory Testing Methods (Contd.)

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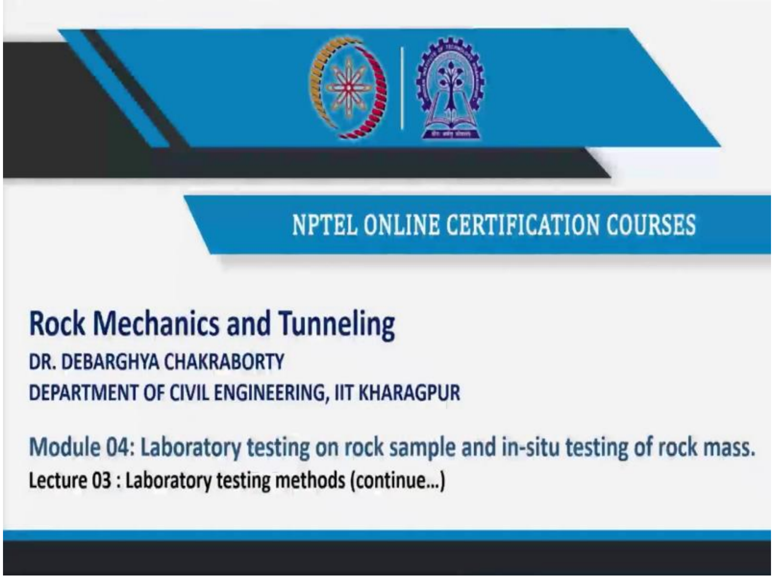

Hello everyone, I welcome all of you to the third lecture of module 4. So, in module 4, we are discussing about the laboratory testing on rock sample and in situ testing on of rock mass. So, we are discussing about the laboratory testing methods. We will continue with that only.

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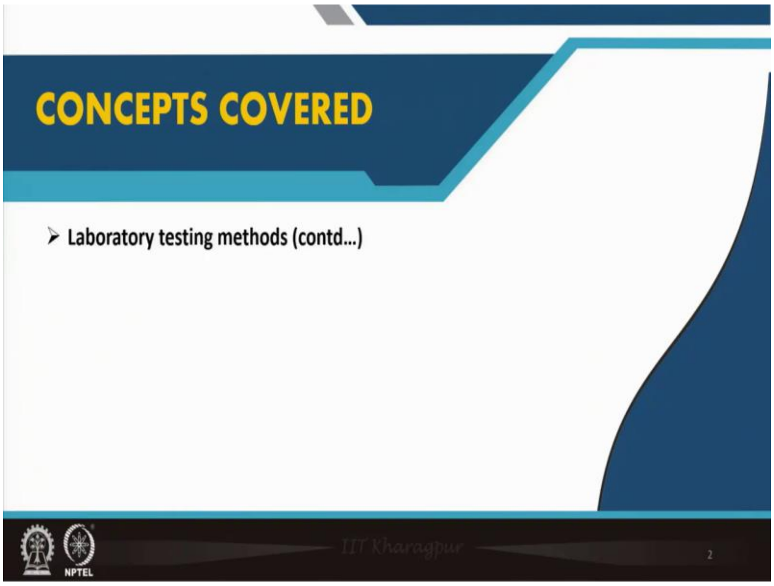

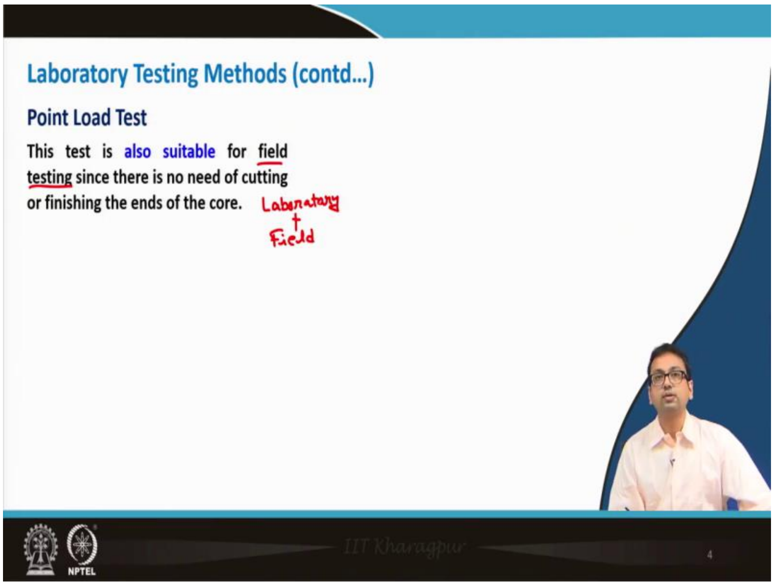

So, in our previous class, we have discussed about Brazilian tensile test, regarding that we have discussed and I told you we do a problem on that. So, the problem is like this Brazilian tensile test has been carried out to a basalt rock sample having diameter 54 mm and ratio of thickness to diameter is 0.5, if the tensile strength of the sample is found to be 20 MPa, then what will be the load applied to the sample.

So, means the P you have to find out. So, we know what are the things given to us are like the if the tensile strength of the sample is found to be 20 MPa means, it is given sigma t is equal to 20 MPa, also D is nothing but 54 mm and it is stated that thickness to diameter ratio is 0.5. So, t is 0.5 multiplied by 54 which is equal to 27 mm, these are the things known to us.

Now, what do we know, as per Brazilian tensile strength test means, we have seen the formula is σ_t is equal to twice $P/\pi Dt$. So, now, the question is applied load on the sample you have to find out. So, from here we can write $P = \sigma_t \pi Dt/2$. So, now, σ_t is 20 MPa. So, means 20 N/mm^2, then π then 54 then we have 27 by 2.

So, if you solve it, you should get it as equal to 45781.2 N. So, which is equal to 45.78 kN. So, this is my answer. So, you could able to get given the question was, if the tensile strength of the sample is found to be 20 MPa then what will be the load applied to the sample. So, this is nothing but 45.78 kilonewton load was applied, P is equal to this. So, with this we are concluding our discussion related to Brazilian tensile strength test.

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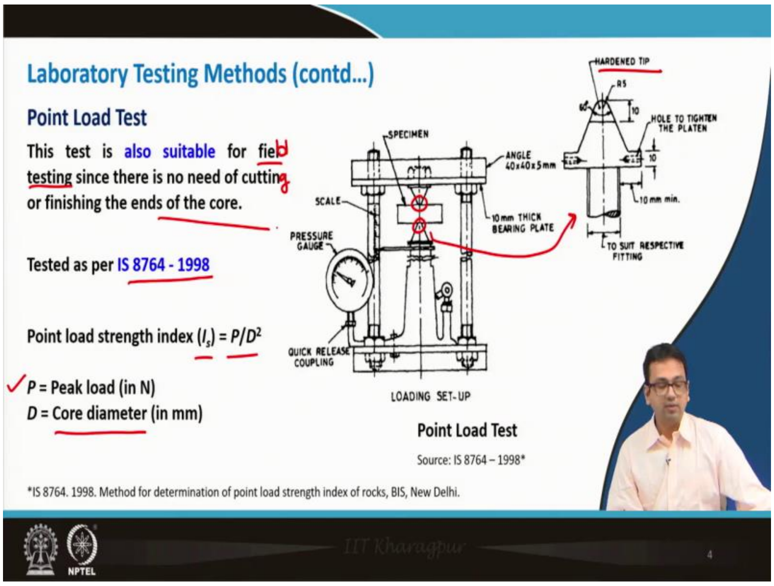

Now, we will discuss about one of the very useful tests that is called the point load test. It is extremely useful as I told you in our previous module, when I was discussing about the different mechanical properties then I just told you the point load strength index one parameter we learn in our next module. So, as I have stated this test because of the equipment or the testing apparatus is not so big in size.

So, that is why it can be easily taken to the field also, where the drilling is going on, there only we can perform the test and we can get the point load strength index and one beautiful thing you will notice that if we can find out the point or strength index, the approximate compressive strength of the sample also can be found out. Also, this test is applicable for not only like cylindrical sample for block type sample also it is useful, irregular shaped sample if it is then also you can use this method.

So, let us see, so as I told this test is also suitable for field testing since there is no need of cutting or finishing the ends of the core. So, also suitable for field testing. Definitely, laboratory testing is their laboratory plus field both, it is useful. So, now, maybe let me delete this part, so that you can see the picture clearly. So, this is the testing apparatus you see with the help of this you see this point and this point this specimen is tested.

So, the load is applied through these two points, and that is why it is point load test. So, this one again if you see it very carefully, you see it looks like this, this tip is you see hardened tip. This is made of quite hard material and this test is performed as per the means, you can refer IS 8764 - 1998 to get the guidance regarding, how to perform this test. Anyway, briefly telling what to do.

So, now, here directly you see point load strength index, if we have this is representative I_S is nothing but P/D^2. So, D is what this is nothing but the core diameter in millimetre and P is nothing but the peak load at which it is the failure load, so this is my point load strength index. So, the test is also suitable for field testing since there is no need of cutting or finishing the aims of the code that is what returned over here.

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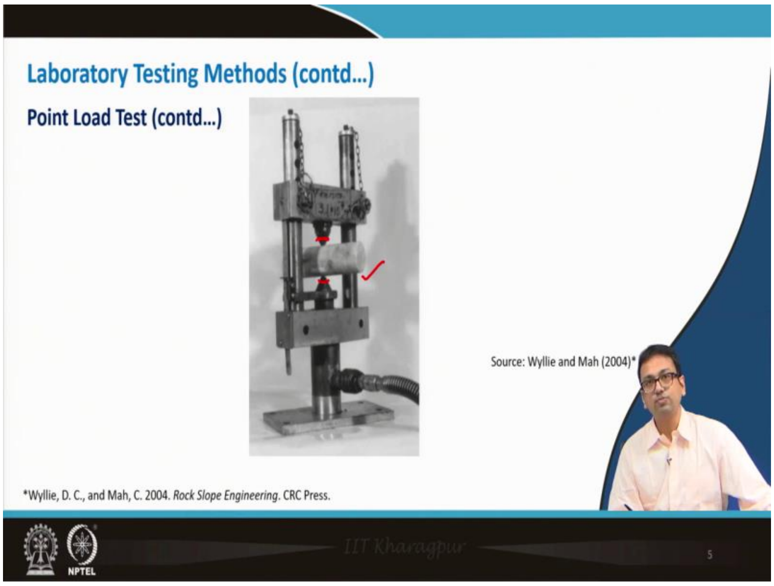

Now, this is a better picture for visualizing purpose, this is the sample it is kept in this fashion in the point testing operators, these are the points, these are quite hard, made of quite hard material. And with the help of these apparatus the testing is performed and at which means the compressive load is applied and at which it fails is recorded that is nothing but my P.

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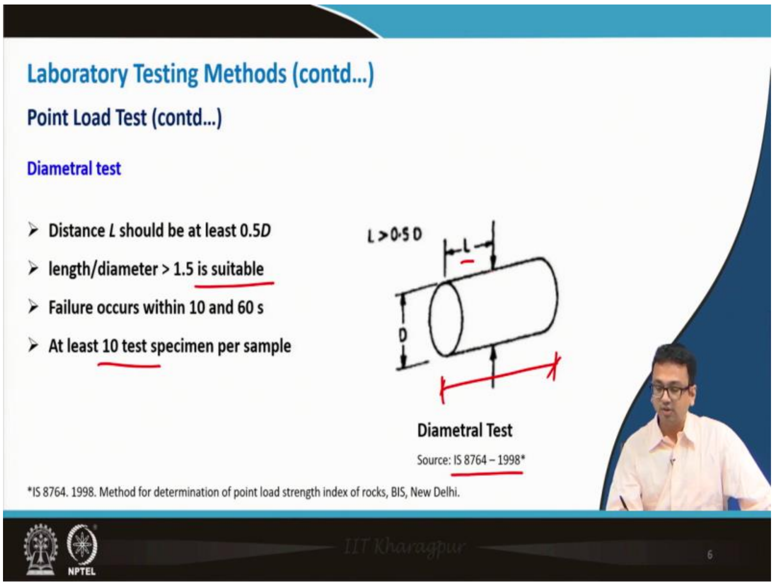

Now, this test the diagram have shown that is for diametral test, but this test can also be performed for actual orientation also. So, let us see first focus on the diametral test which is like more common. So, there are some of the specifications for it is given. So, you see the as per the IS code you can notice this also, as I have stated 8764 - 1998.

As per that, the distance L you see this is L should be at least 0.5 D this is one thing and length by diameter should be greater than 1.5 is suitable. So, it is stated means L/D, this L is up to the same where the load is applied at the half, we can understand clearly that L by D, if it is L it is D, so L by D is greater than 0.5.

So, as it is written distance L should be at least 0.5 D, but total length by diameter greater than 1.5 is suitable. The failure occurs within 10 to 60 seconds. And at least 10 test specimen per sample is preferable to test. So, from there on average basis you can conclude that the point load strength index of that particular sample, so 10 tests that are important.

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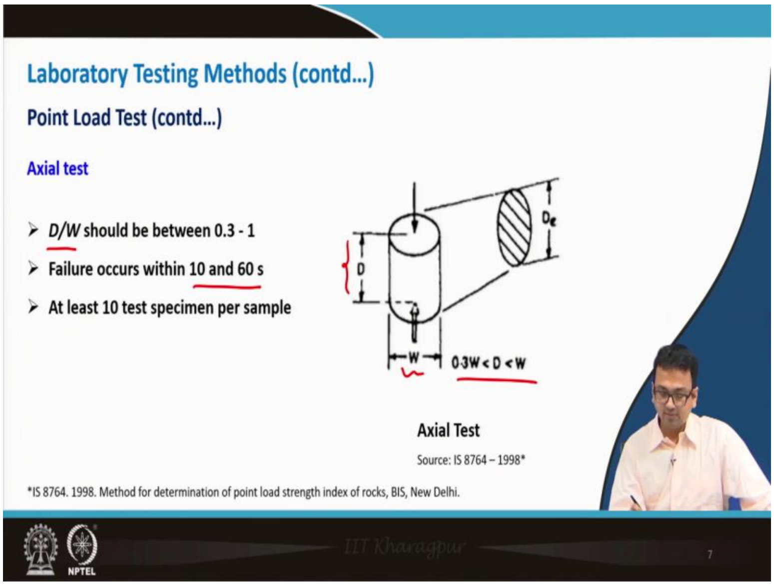

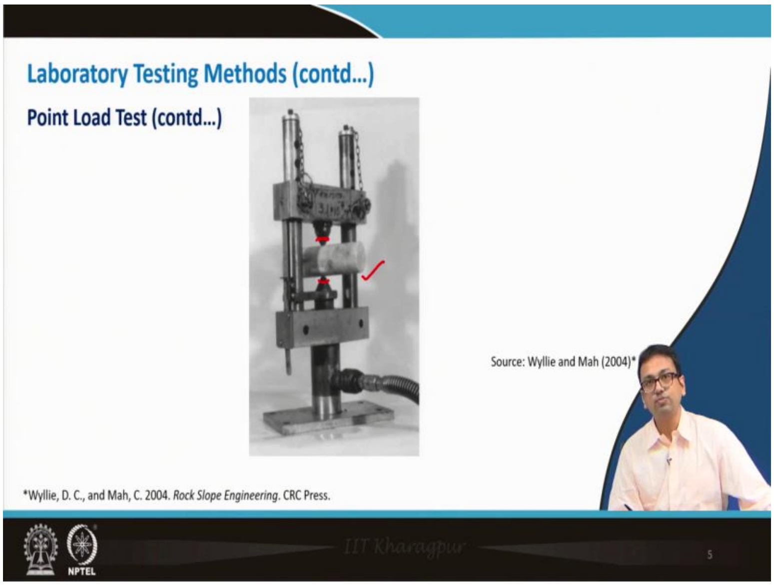

Similar to this axial test also can be performed. So, in that case you can rotate it by 90 degree and you can place it in this instrument and can perform the axial test and in axial test again there are some specifications like if this is D and this is W, then D/W should be between 0.3 to 1.

And failure occurs again, here also within 10 to 60 seconds and at least 10 specimen per sample is preferred. So, this is what we have to do in this case. And D is nothing but the distance between the point of load application that also you can think over here.

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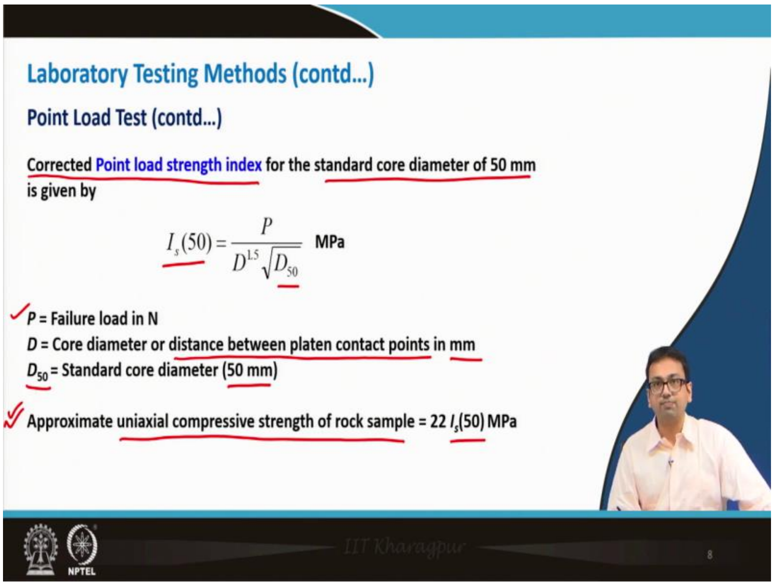

Another one, from there what we can see that it means this test can be performed on different size of the sample, but you see, we have to standardize ultimately this index. So, that is why this corrected point load strength index for standard core diameter of 50 mm is given by this formula. So, as per IS code only it is given.

So, where P is nothing but the failure load, D is the core diameter in case of your diametral test and distance between the platen contact points that is in case of axial test. So, it is also in millimetre and D 50, this D 50 is a standard core diameter which is considered as 50 millimetre, with respect to that it is standardized so, I_S 50, remember IS was P by this guy, if you remember here we have shown it to you, yeah, so, I_S was P/D^2 whereas, here it is

$$I_S(50)= P/D^{1.5} (D_{50})^{0.5}.$$

And now, another thing what is telling approximate ultimate compressive strength of the rock sample can also be obtained using this I_S50 term, I_S50 if we multiply to 22, we can get some idea about the approximate compressive strength of the sample.

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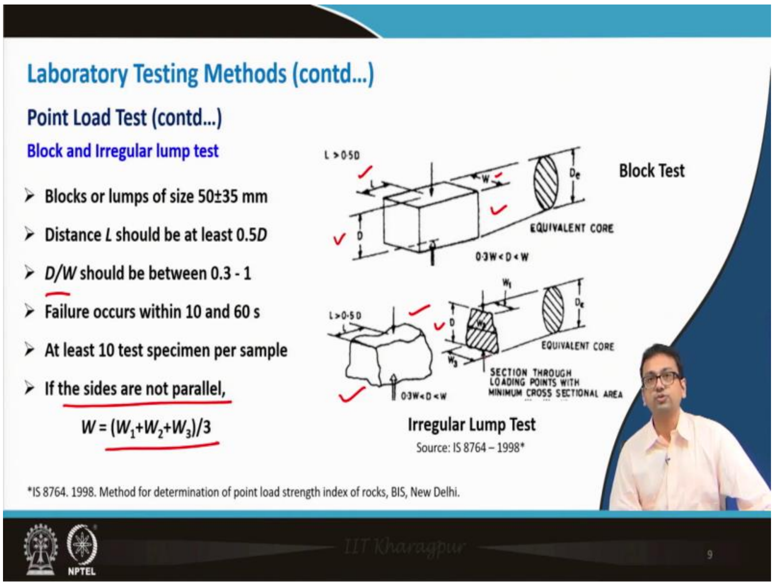

Now, as I was telling for block and irregular lump this test can be useful. So, block or lumps of size 50 plus minus 35 mm, it can be used distance L should be at least 0.5 D. So, this L, if it is L and this is D then the distance L should be at least 0.5 D. And you see for irregular sample, this was a nice block like now, if it is irregular lump sample you see the shape, how it is in this case this D/W, where W is here it is. W_2 is little more than W 1 and W 3 is even more than W 2.

So, what is done that average of these three are taken. So, it is shown over here also you see, if the sides are not parallel as it was here, if it is like this, then W we can take it as W1+W2+ W3/3. And here also failure occurs within 10 to 60 seconds and at least 10 samples you need to test for a particular rock sample and W you have to take the average in this way you have to measure the width over here in mid-way as well as at the bottom also.

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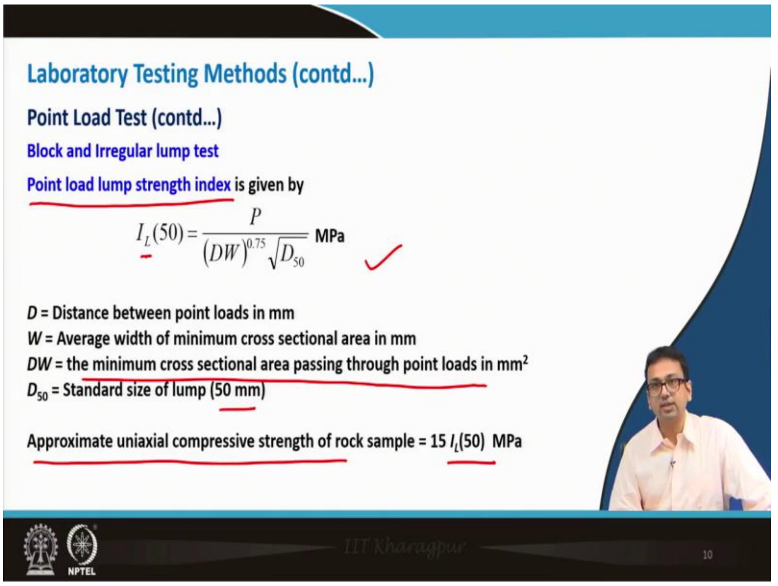

Now, from there again the point load strength index for this lump sample which is called as a point load lump strength index, it can be given as you see L will come,

$$I_L(50)= P/(DW)^{0.75} (D_{50})^{0.5}$$

Now, what are these thing, D is again the distance between the point loads means as earlier also we have discussed.W is the average width of the minimum cross sectional area millimetre.

And now, DW is nothing but the minimum cross sectional area, the minimum cross sectional area passing through the point load, D_{50} standard size of lump and 50 millimetre it is fixed with respect to the D standardize and you can get the I_L50. Now, once you get your I_L50 if you multiply that with 15 you will get the approximate uniaxial compressive strength of rock sample, approximately uniaxial compressive strength can also be obtained for the lump sample also very easily by conducting this point loads test even at the field, not only at the laboratory you can perform the test in the field and you can get a good idea about the approximate idea about the uniaxial compressive strength of the sample.

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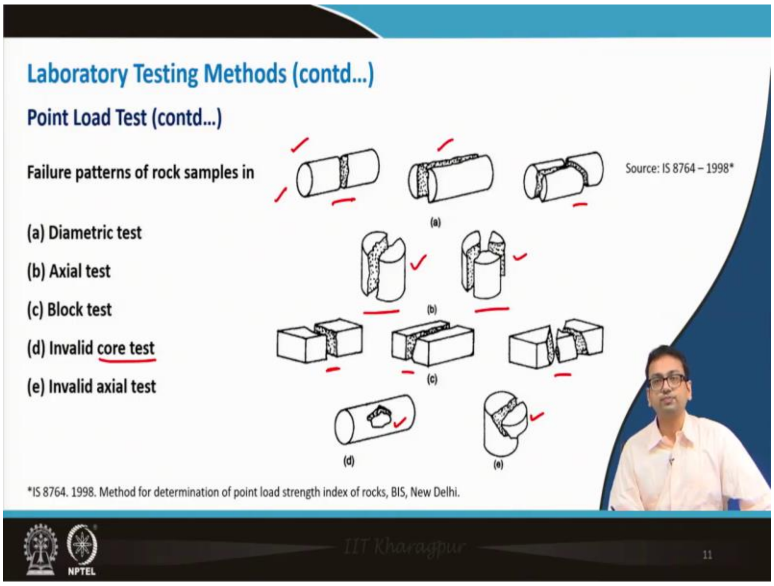

So, here different failure patterns of rock sample is shown over here, if it is like diametric test, they are maybe this type of failure. So, this braking or this type of braking or this type of braking may occur because of the application or point load as we have seen. The axial test it may fail in this fashion or like three parts as you can see here it is divided into three parts that also can happen.

Similarly, if it is a block test then you can have like quite similar to this, middle it is failing like these then similar to these and this is also similar to this one. Now, there are two figures are shown for invalid core test if you are performing for the like the only the for the core invalid, it is for the core test first one you see instead of this type of failing, failure what is happening a local failure has occurred, you see here then that is a invalid test. Similarly, for axial loading instead of this or this type of failure, if this type of local failure offer then also, we will consider it as invalid axial test.

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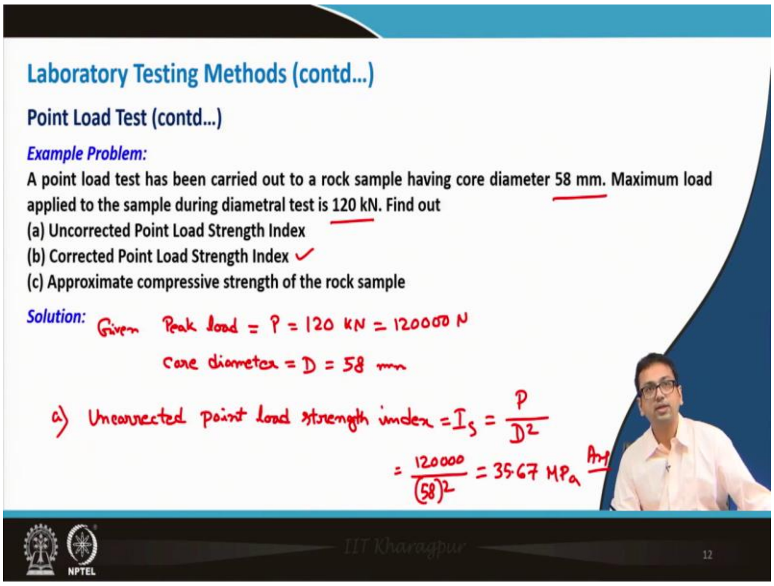

Now, based on for point load test also you can perform means we can find out some of the important things to understand how to utilize this knowledge for obtaining the compensate strain then on all other parameters. Let us take a problem it will clear our idea. So, the problem is a point load test has been carried out to a rock sample having core diameter 58 millimetre, maximum load applied to the sample during diametral test is 120 kilo newton, find out uncorrected point or straining strength index that is IS, that is equal to P by D square then corrected point of strength index I_S50, then approximate compressive strength of the rock sample.

So, quite easy means just simple application of the equation by doing that we can very easily obtain the solution. So, the peak load is given, so the given maximum load applied to the sample during diametral, just want to indicate also the given peak load is equal to P 120 kilo newton, then also the diameter D. So, the core diameter, core diameter is equal to D 58 millimetre.

So, that means, the first question means answer of (a) is uncorrected point load strength index. So, the uncorrected point load strength index which is I_S, which is equal to P by D square. So, P by D square, this is a newton, if you want to take 120000 N. So, 120000/ 58^2. So, it is giving us 35.67 N/mm^2 which is nothing but MPa. So, this is one answer very easily we can get it, the next is corrected point load strength index.

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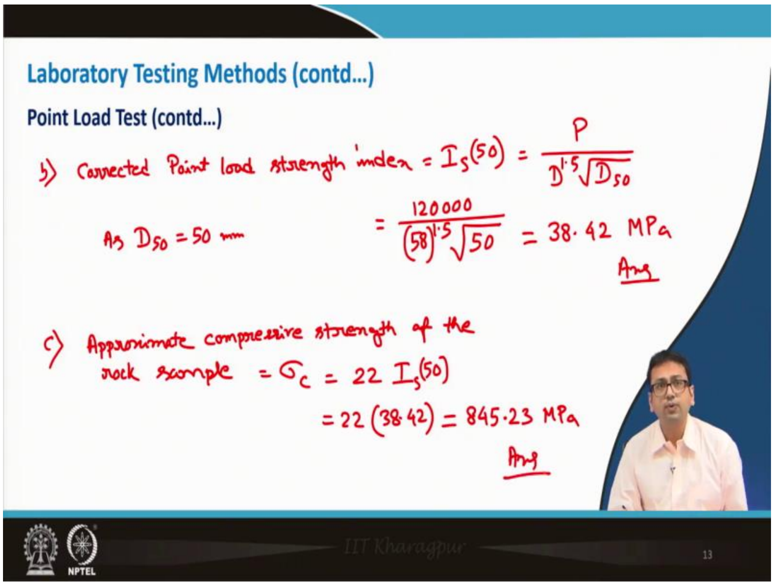

So, this is my question b. So, corrected point load strength index I_S50, this symbol we use, this is nothing but equal to $I_S(50) = P/D^{1.5} (D_{50})^{0.5}$.So, that means is equal to 120000, D is 58 to the power 1.5 and D 50. This as we know, D 50 is nothing but 50 millimetre. So, as D 50 is equal to 50 mm.

So, if we simplify this one, we should get it as 38.42 N/mm^2 and this is our second answer. And third question was to find out the approximate compressive strength of the rock sample. So, the approximate compressive strength of the rock sample. Suppose, σ_c is nothing but equal to $22(I_S50)$ is 22(38.42). It is becoming equal to 845.23 MPa.

So, this is our another answer. So, I think we have understood that point load strength index is quite important and with this problem I hope your concept is much more clear now.

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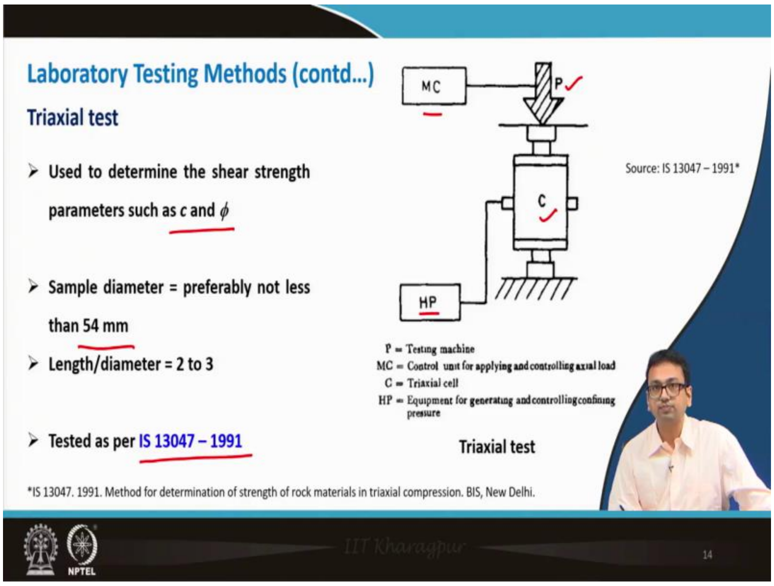

Now, we will just quickly discuss about the triaxial test, because the triaxial regarding triaxial test I think you already know how to perform it in laboratory because for soil you must perform this. So, used to determine the shear strength properties or parameters such as c and phi, as you know. And sample diameter preferably not less than 54 mm here also, and length to diameter 2 to 3, and the IS code is IS 13047 – 1991, one can refer for which means before conducting a test one can definitely refer this IS code accordingly one can perform.

Now, this the pictorial this schematic diagram is very useful, this is also taken from the IS code only. You see the here this is what this is the triaxial cell, this is the triaxial cell and P is the, here the load is applied this through this and MC what is shown over here is the control unit for applying and controlling axial load. So, this axial load is we are applying and MC is the control unit for that.

Now, what is HP, HP is the equipment for generating and controlling confining pressure as you know there are only the differences with respect to the uniaxial compressive strength is, uniaxial compressive strength is there only the axial vertical loading we have applied no confining pressure, but here in triaxial test, we apply confining pressure to simulate again the like the actual field condition and also by performing this test we can obtain the shear strength parameters also as you know. So, HP is also that is an important unit what is required in case of in order to perform the triaxial test.

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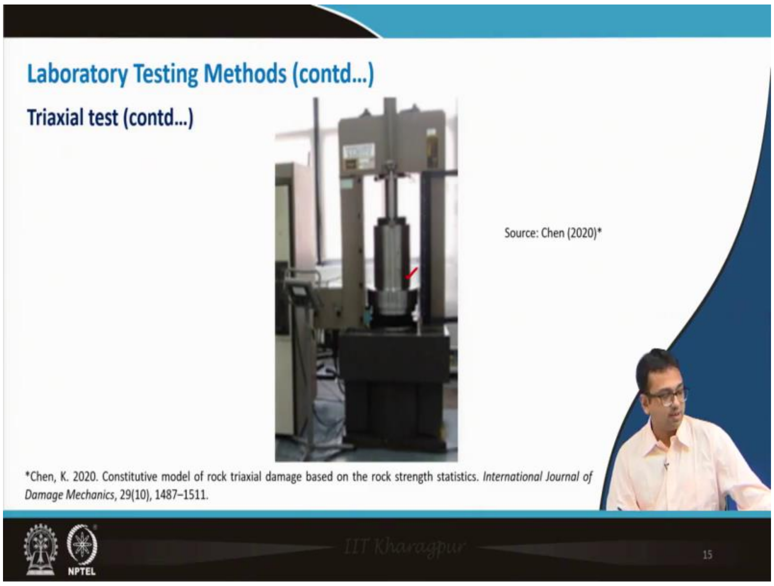

Now, this is a again a picture of real test setup, you see the cell triaxial testing cell is shown over here. So, inside that the sample is present and the confining pressure is applied also with the help of as I have shown you the arrangement it must have.

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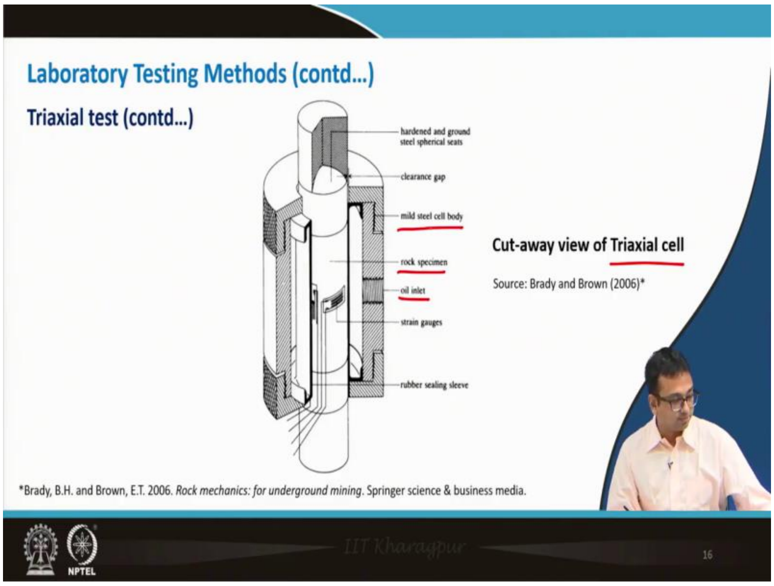

Now, this is means one thing what I think we should little bit see carefully, this is the cut-away view of triaxial cell, the triaxial cell in case of rock tasting how it look like is shown over here. So, here you see you have to test the rock sample. So, obviously the confining pressure is definitely much more, so it is the triaxial cell is also is much more robust in its design, and you can see different parts are there while inlaid is there with the help of while the pressure is maintained.

So, whereas in case of symbol soil with the help of water, as we have seen the confining pressure you apply, so here it is important then that there is so you can see the rock specimen while inlet then the sale is made up you see the mild steel, mild steel sale body. So, which is definitely a little different from our the cell what we use in case of soil testing.

So, yeah, these are the some of the important things are what are marked over here. So, this is I wanted to just show you because here the triaxial cell is a little different means made off you see the mild steel and this is the oil inlet portion is also important to observe and yeah these are the main parts.

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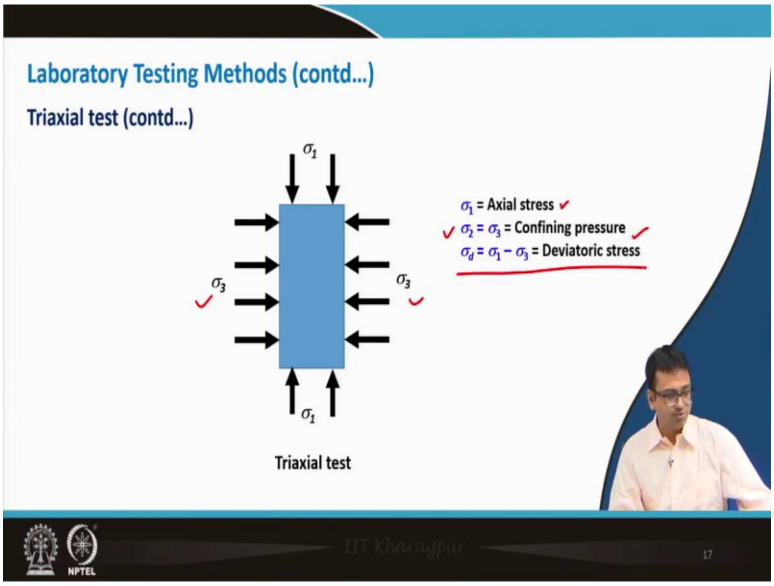

Now, again if I come back to the simple mechanics, what do we do over here, we apply the confining pressure as well as this $\sigma 3$, sigma now it is a cylindrical sample. So, $\sigma 2$ becomes equal to $\sigma 3$ and it is nothing but my confining pressure. Now, if $\sigma 1$ is my actual stress then the deviatoric stress σd is nothing but $\sigma 1$- $\sigma 3$, that we know.

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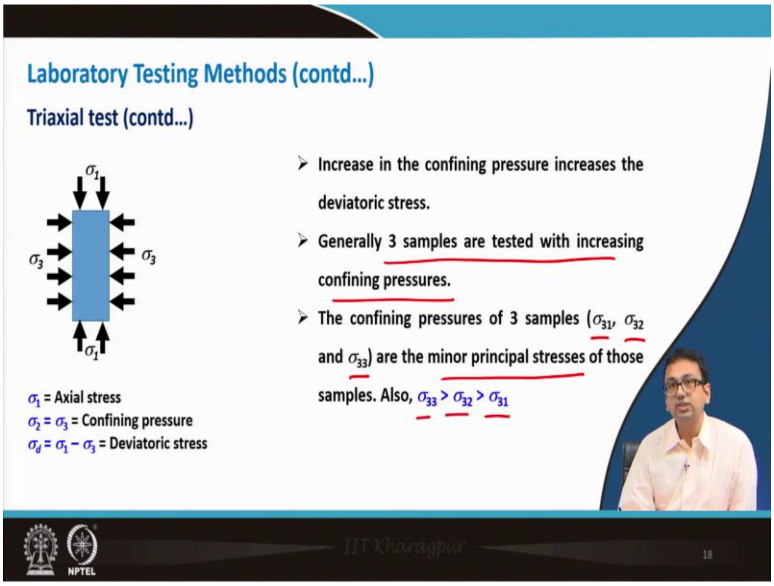

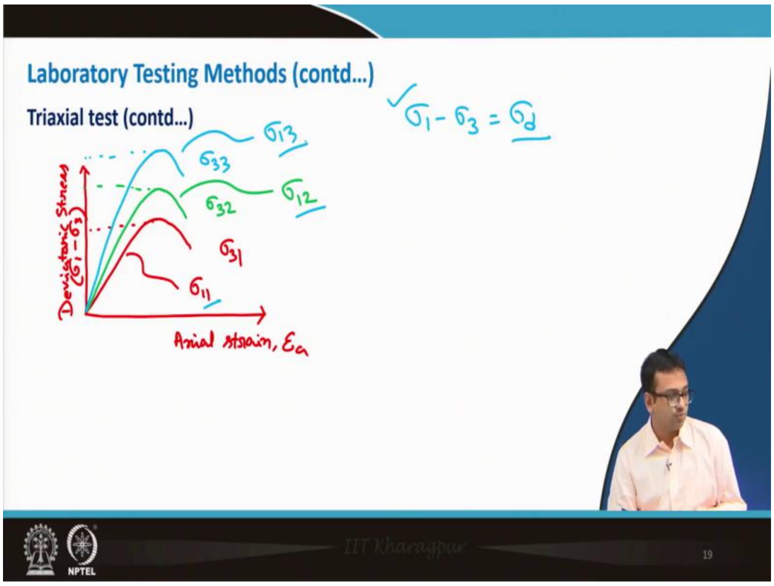

Now, what do we know. So, increase in confining pressure increases the deviatoric stress. Now, generally three tests are minimum you have to perform but better to perform around five tests. So, there are three samples are tested with increasing confining pressure, but for like better accuracy you can perform five test and maybe if you find out of that three are giving proper result you can take those three for your obtained drawing ultimately the more circles and but better to perform to extra tests also.

And confining pressure of three samples are presented in this way σ31, σ32, σ33 are nothing but the minor principles stresses of those samples and if we consider σ33 is greater than σ31, then we can little bit draw some means what we get from the test and finally, how to get the more circle that we can clear a little bit discuss though I am sure you know this, but quickly we will just discuss this one.

So, this side if we could keep axial strain and this side if it is deviatoric stress that is σ1 - σ3, then for suppose when confining pressure is suppose σ31. So, then we will get suppose this. Now, if we increase the confining pressure a little more, we will get something like this, this is for suppose σ32, and if we even use furthermore confining pressure, so we will get suppose σ33, so for that this type of plot we will get.

So, now, from here this will give us the σ11. The peak means you will get the corresponding, not these value means from you will get the deviatoric stress. So, this will give us the let me write in this way that this plot will give us σ11. So, this plot will give us σ12.

And similarly, from this plot, we can get σ13 because we will get corresponding deviatoric stresses and also corresponding deviatoric stresses will give us the from there as we know the σd = σ1 - σ3. So, from there if I suppose no σd value is known to us then obviously, we can get the corresponding σ1 value. So, from first test we can get σ11, from second test we get σ12, from third test we can get σ13, that is what you know, I am sure.

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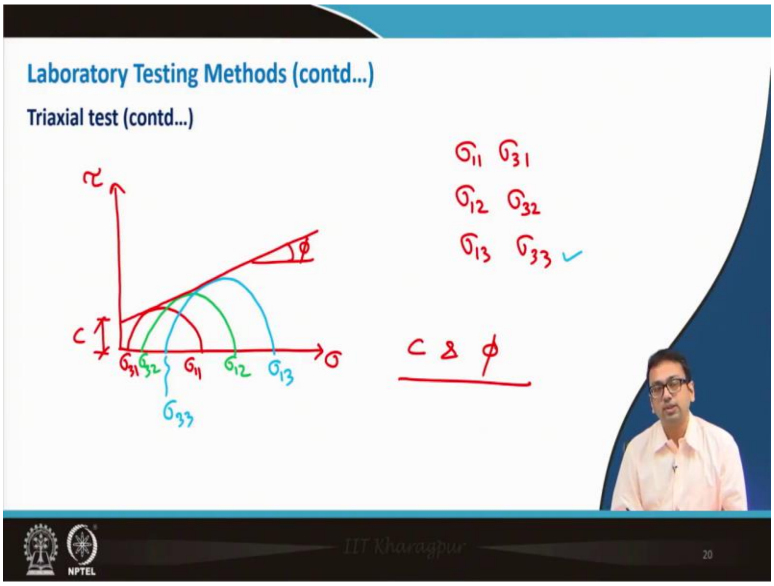

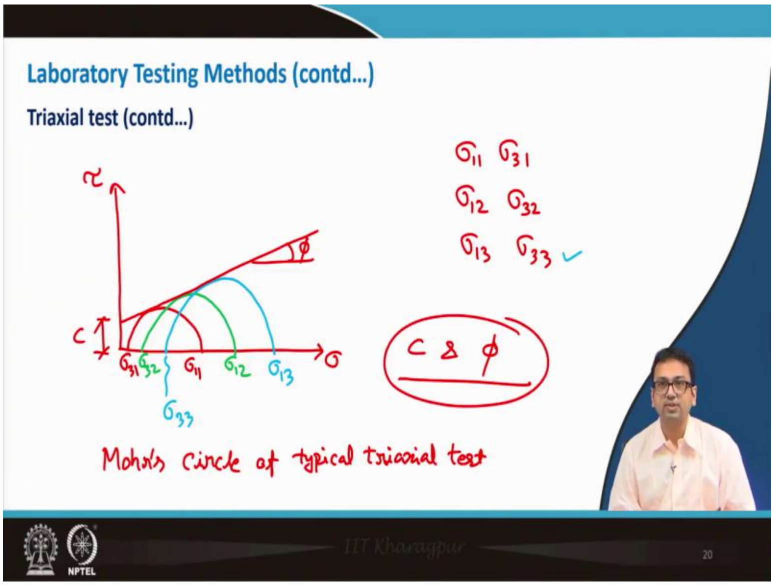

Now, from here what we can do ultimately, our objective is to draw the Mohr circle. So, for that we now have what we have σ11, σ31, σ12, σ32, σ13, σ33. So, if we have this, so then if we plot normal stress in this axis and shear stress in this axis then very easily we can get like from the first one we can get a Mohr circle like this for each.

Now, if I simply take a common tangent like this, then what we will get, this will give us the ϕ value and this intercept will give us the cohesion (c) value. So, c and ϕ values can be obtained using this Mohr circle. So, yes, I think here in this class we have learned about this point load strength index in detail as well as the triaxial testing what you already knew, just revisited only new thing was here the, the cell is little bit means as compared to soil testing here the triaxial testing cell is a little different it is made up by the steel mild steel as we have seen.

So, that is only the developer otherwise the basic procedure will remain same and the way in case of soil mechanics, you have obtained the $c-\phi$ values first drawing this diagram, this one, this one and then if you draw the Mohr circle, so this is nothing but the Mohr circle, Mohr circle of typical triaxial test, if you do that, ultimately, we will get our $c-\phi$ value which are nothing but the shear strength parameters. So, let us conclude here to this class. So, in our next class, we start with the direct shear test and after that, we will take up the field or in situ testing of rock masses. Thank you.