Rock Engineering

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Lecture-16
Shear tests-1

Hello everyone. In the previous class, we had the discussion on different tests like sound velocity test, slake durability tests, free swell test, swelling pressure test and void index test. So, now we are towards the end of these test categories and the last and the most important one is the shear test. As far as the strength characteristics of the rock are concerned concern, we already have seen the unconfined compressive strength test, tensile strength test.

So, the next one is the shear test in which we are going to get the shear strength characteristic of the intact rocks. So, we have 2 types of shear tests. Before I start the discussion on the shear test on rocks, let us take a look at the shear tests that we conduct in case of the soils. You all know that direct shear tests and tri-axial tests are the 2 types of shear tests that we conduct on soil specimen.

In direct shear test, you have a predefined failure plane that is a horizontal plane. And you apply a normal load and then the soil specimen is made to shear along the horizontal plane. That means, that the shearing plane which is the horizontal plane perpendicular to that you apply a normal load. In case of the tri-axial test, we subject the specimen to all around pressure and then we increase the axial stresses in order to shear the specimen.

So, here in case of rocks, more or less the philosophy is same but with little bit of difference. So, here the shear test, they are divided into 2 categories.

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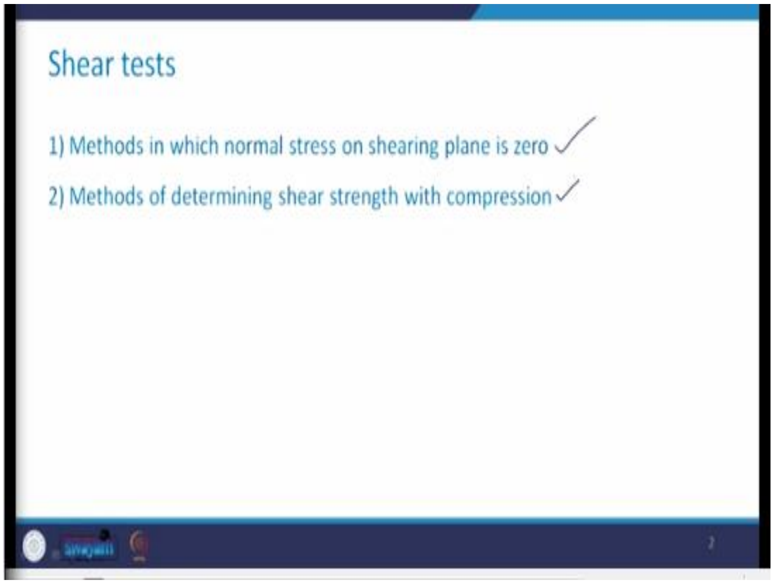

In the first category, there are methods which involve zero normal stress on the shearing plane. And the second method or the second category has the shear test where we are conducting the test with compression, like we do direct shear test in soil. So, let us first start with the first category in which you do not have any normal stress on the shearing plane. There are different types of test. First one is single shear test.

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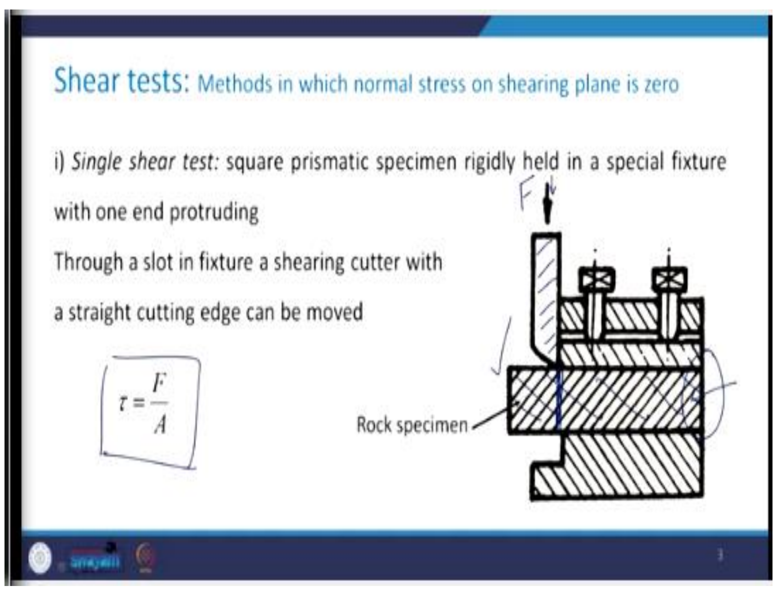

You can see here in this figure, that a rock specimen, that is this one, is mounted on this assembly which is this specimen, it is square prismatic specimen. And it is rigidly held in a special fixture with one end protruding. That means this end is protruding and this end, here it is fixed rigidly.

Now through a slot in fixture, a shearing cutter with a straight cutting edge can be moved, look at this, that this is what is your cutter.

There is a slot here and you apply the force from here and what will happen? That the specimen will be cut along this plane. The force which is applied and which is causing it to cut is F and the shear stress, τ can be obtained as F/A that is this expression

$$\tau = \frac{F}{A}$$

F is the force applied; *A* is the area of the cross section of the specimen. So, this is how the shear strength of this specimen can be obtained using single shear test.

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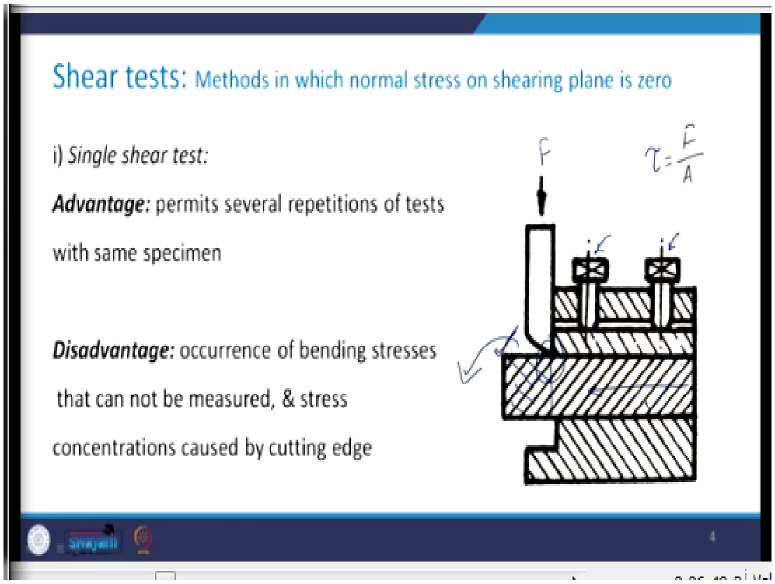

The advantage of this single shear test is, let us say, that you have conducted the test and this portion is out, this has been cut and it is out. Then we can just open these fixtures little bit, just loosen them and replace this specimen in this direction. So, again with the same specimen, I can conduct the second round of the test and find out another value of τ that is *F/A* on the same specimen.

So, the advantage of this test is, it permits several repetitions of the test with the same specimen. There are disadvantages also which are associated with this. When the load F is applied at this cutting edge, what will happen? Because this end is protruding there are going to be the occurrence of bending stresses which cannot be measured. And there is going to be high stress concentration caused by this cutting edge in the specimen which we do not want.

Because the moment such things happen, we are not going to get the actual shear strength characteristic of this rock which is not desirable.

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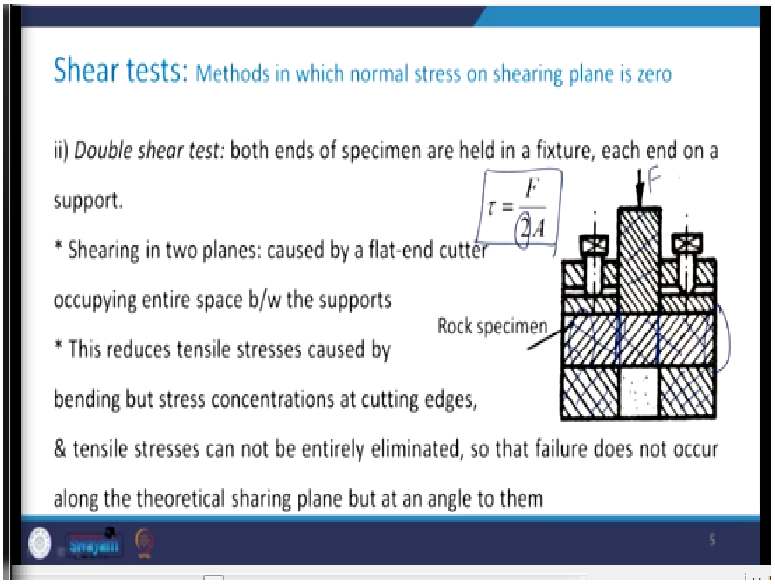

Then comes the double shear test, philosophy remains the same as the name suggest. In the first case it was single shear test, this is double shear test means, there are going to be 2 different 2 planes through which this specimen will be sheared. So, in this case, both the ends of the specimen, so this is what is your rock specimen. Both the ends they are held here, and they both are resting on the support, that is, this is the support.

Shearing takes place in 2 planes, which is caused by a flat end cutter which occupies the entire space between the support. So, you see these 2 are the supports. This is the space between these supports. So, this cutter is occupying this whole space which is there in between these 2 supports. Now this test when we conduct there are 2 planes through which the shearing will take place here, this one and this one.

This reduces the tensile stresses which were caused by bending in case of the single shear test. However, the stress concentrations are still there at the cutting edges and tensile stresses also cannot be eliminated completely. So, what happens because of all these reasons is that the failure does not occur along the theoretical shearing plane, that is, it should be ideally along this but then at an angle to them.

The moment this happens, again we are not going to get the correct shear strength characteristic of the rock. This is the expression

$$\tau = \frac{F}{2A}$$

to be used to obtain the shear strength of this rock specimen. This is the *F* that is being applied, why we are dividing it by 2? Because here there are 2 cutting planes through which the shearing of that specimen is taking place.

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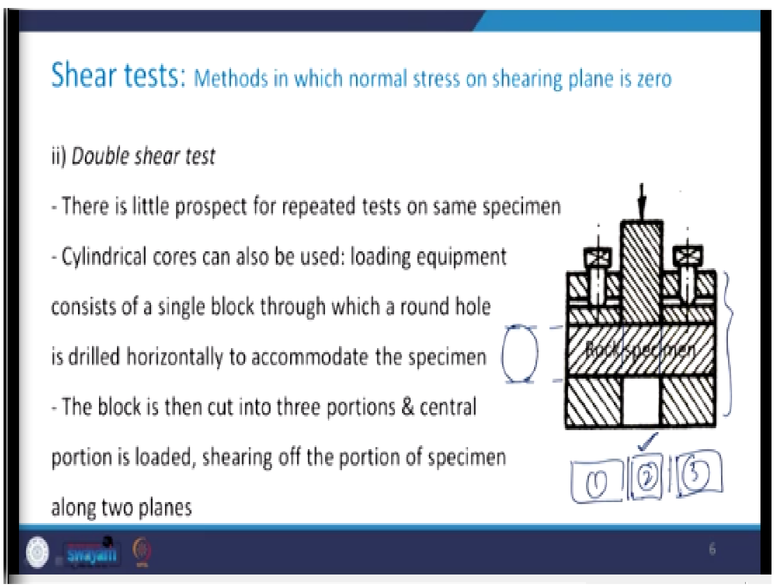

In case of the double shear test, you cannot repeat the test on the same specimen because the moment it cuts, so you get three portions of the specimen like this. So, in this case cylindrical cores can also be used. So, for that, this is the loading equipment is there and through which here if you just see here, I take this side view. So, here this is a circular hole can be made in the horizontal direction to accommodate the specimen.

Then the block is cut into three portions. The central portion is loaded and the shear of the portion of the specimen along these 2 planes. So, this is better than the single shear test but it also has it is share of disadvantages.

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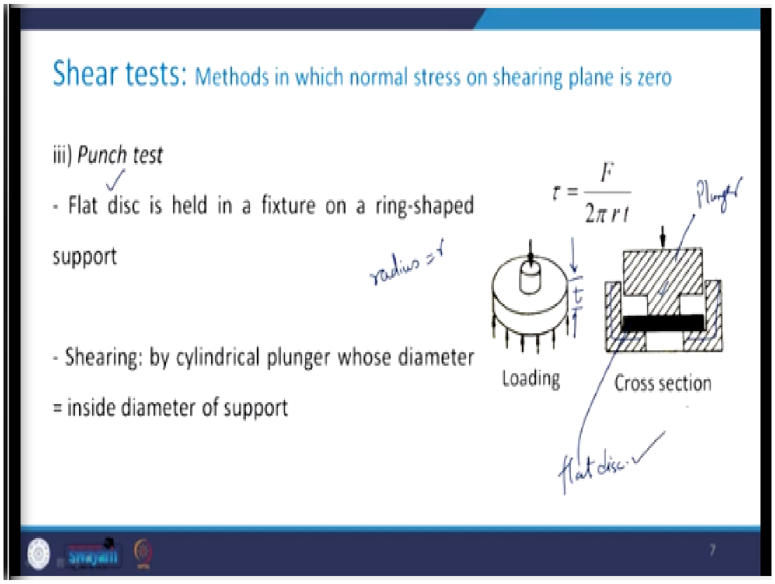

Next category of the test is the punch test. In this case, you need to have the specimen in the form of a flat disc which has a thickness of *t* and the radius *r*. And this is fixed on a ring-shaped support. You can see here that this is what is your support. It is if you see in plan it is a ring-shaped support. And the shearing takes place using this cylindrical plunger whose diameter is equal to the inside diameter of the support.

$$\tau = \frac{F}{2\pi rt}$$

So, you see that, this is your flat disc. This is the plunger. These are the support system and through this it will be sheared, this flat disc specimen will be sheared.

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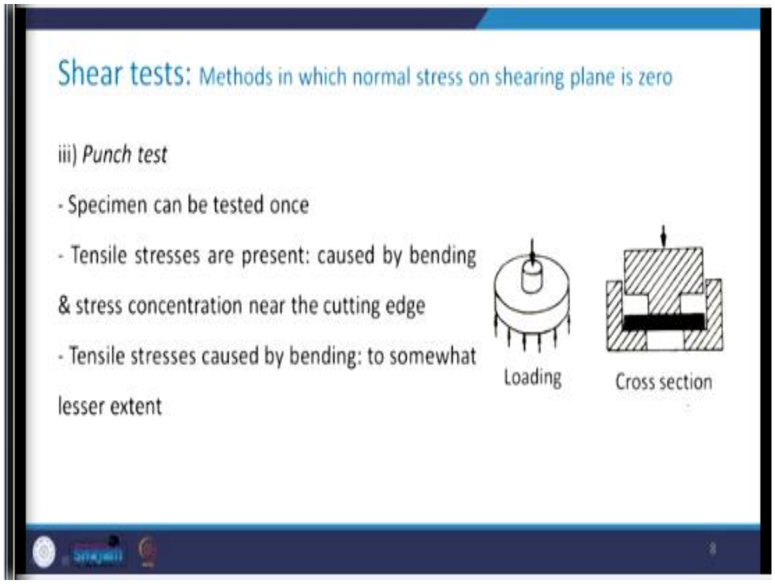

In this case also the specimen can be tested once. Tensile stresses are present. These are caused by bending and there is a stress concentration near the cutting edge as it was there in case of the earlier 2 tests. But the advantage of this test over the earlier 2 tests were that the tensile stresses caused by bending. They are to somewhat lesser extent as compared to the single shear test and the double shear test.

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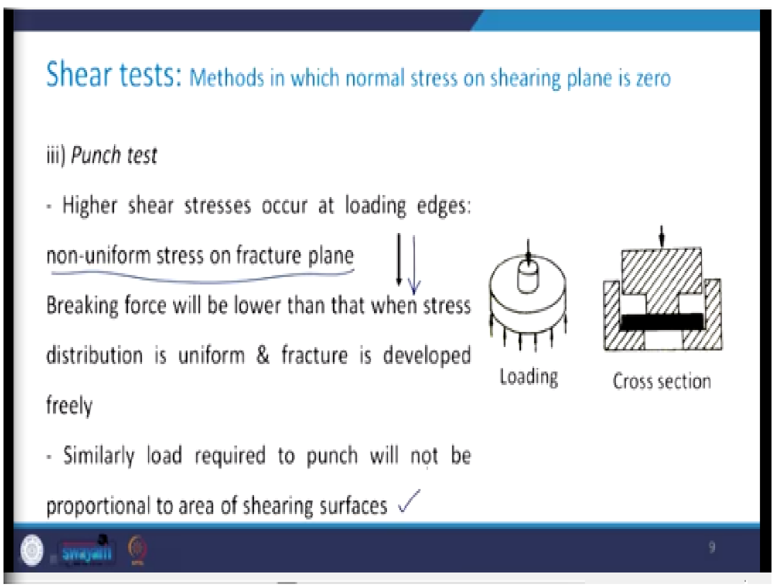

High shear stresses, they occur at the loading edges, and what they do is? They cause non uniform stress on the fracture plane. And because of this, this is what happens that the breaking force becomes much lower than what exactly it is, if this would have been the uniform stress distribution and fracture would have developed freely. So, similarly load required to punch will not be proportional to the area of the shearing surfaces.

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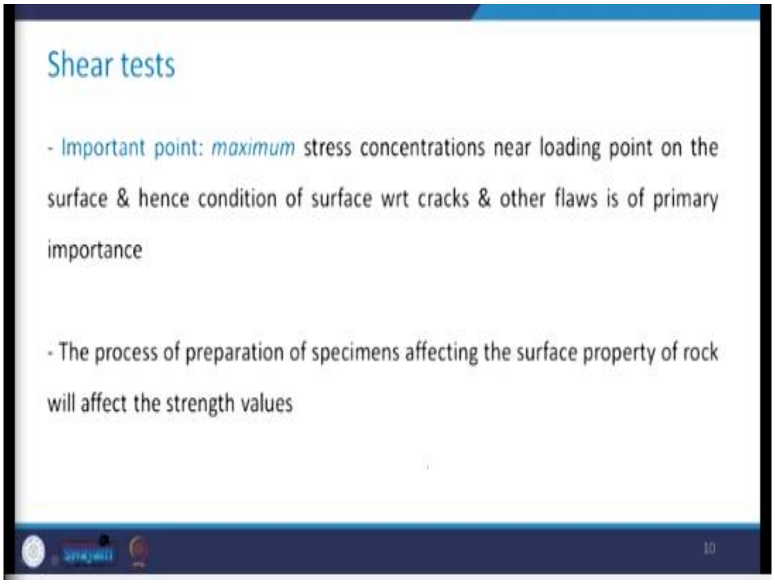

So, these are some of the limitations of the punching test. The important point from the outcome of these tests where there is no normal stress on the shearing plane. Neither of these test single double and punch test, they had normal stress on the shearing plane. So, the maximum stress concentration, they were occurring near the loading point onto the surface. And therefore, the condition of surface with respect to cracks and other flaws, they are of primary importance.

Let us say that, during the process of preparation of a specimen, if there has been a damage to the surface of the specimen that will have direct effect, if you conduct these types of test. So, you see that the process of preparation of these specimens affecting the surface property of the rock will also affect the strength value, which is really not desirable one needs to avoid that. So, in order to eliminate the unknown tensile stresses, which may lead to results to the lower shear strength as compared to what exactly is there of the rock that we are testing.

The method for determination of the shear strength with compression they were developed. That means, because when you have zero normal load on the shearing plane, there are other problems associated with the generation of tensile stresses. And then because of the factors during the preparation of the sample, the factors which are influencing the surface, they are also influencing the shear strength characteristic.

To do away with all these difficulties, the methods were developed for the rocks to determine its shear strength with compression on the shearing plane. Now with these methods, compression stresses, they can be calculated in the shearing plane and this eliminates completely the unknown tensile stresses. So, all the problems which were there because of these unknown tensile stresses, they can be overcome with the use of second category of the methods in which you have the determination of shear strength with compression.

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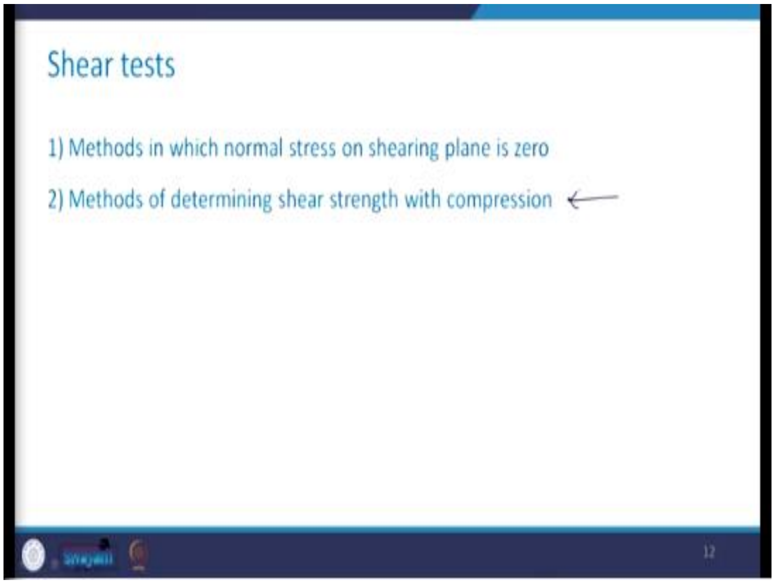

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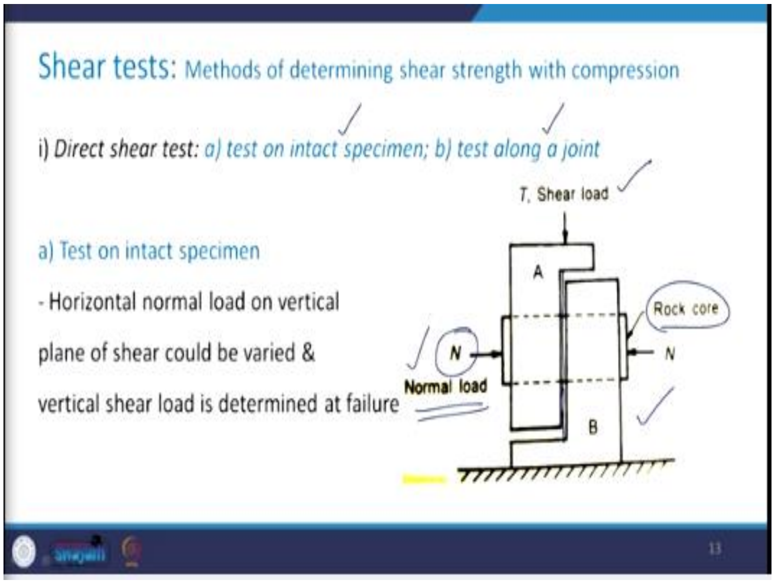

Take a look we have many methods in this. So, first one is the direct shear test and this test can be conducted either on the intact specimen and this test can also be conducted along a joint. So, first we will take the first category that is test on the intact specimen. You can see a line sketch here where the rock core has been mounted and this is what is a shear plane. Along this plane the shearing is going to take place.

So, you see that perpendicular to that, now the normal load end has been applied in this case, which was not there in the earlier cases. So, in this case the horizontal normal load on the vertical plane of shear is applied and that could be varied. Vertical shear load is determined at the failure and this is what is your rock core. You know what is going to be the shearing area. And add the failure if you divide these loads that is shear load and the normal load by the shearing area, you are going to get the shear stress and the normal stress respectively.

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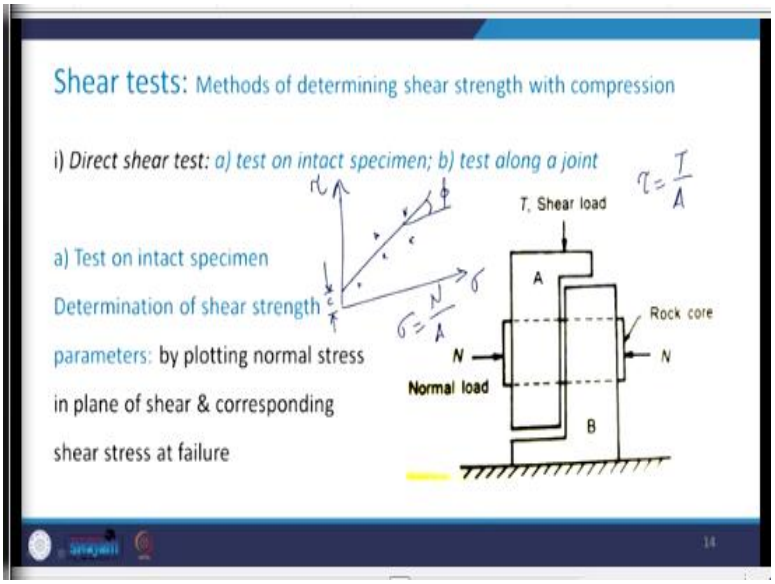

So, here we find out the shear stress that is

$$\tau = \frac{T}{A}$$

$$\sigma = \frac{N}{A}$$

And if we plot these, let us say in this manner, here it is σ and you have τ at the failure let us say, I test 3, 4 or 5 specimens, say I get some this kind of curve. I can fit a straight line and then assuming that it is following the Mohr coulomb failure criteria, I can find out the shear strength characteristic by finding out this intercept c and this angle ϕ. So, this is how that we can interpret the results from the direct shear test which is conducted on an intact specimen of rock.

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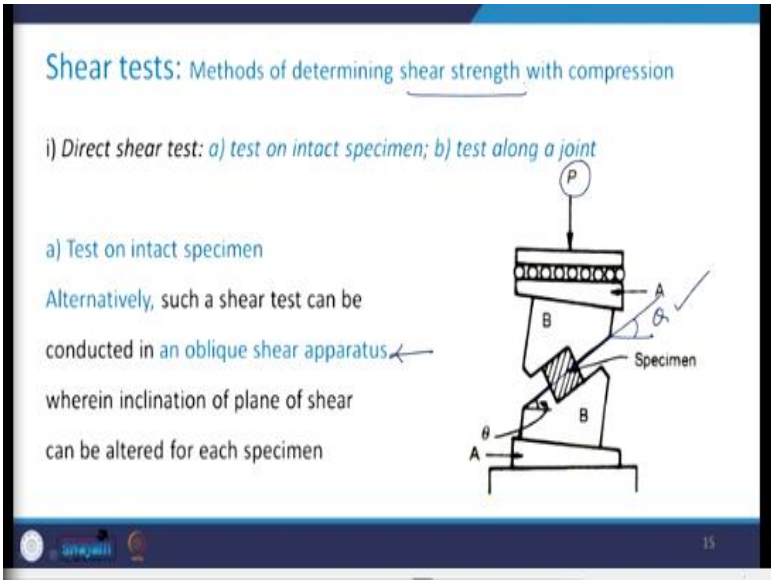

Another category on the test on specimen, intact specimen of the rock includes this the test that is conducted in an oblique shear apparatus. This is more common and it is carried out in the lab. So, instead of having a vertical plane of shear, here we have inclined plane of shear. So, you see that, this is the plane of shear whose inclination is θ and the arrangement in the apparatus is in such a manner that this angle θ can be adjusted.

And the shearing can take place along the desired value of this θ. How this is done? Take a note of it that the load is applied in the vertical direction only. Now, the question is I am saying that I am discussing the shear strength test with compression. So, where is that in this picture? It is not really visible right now, let us go ahead.

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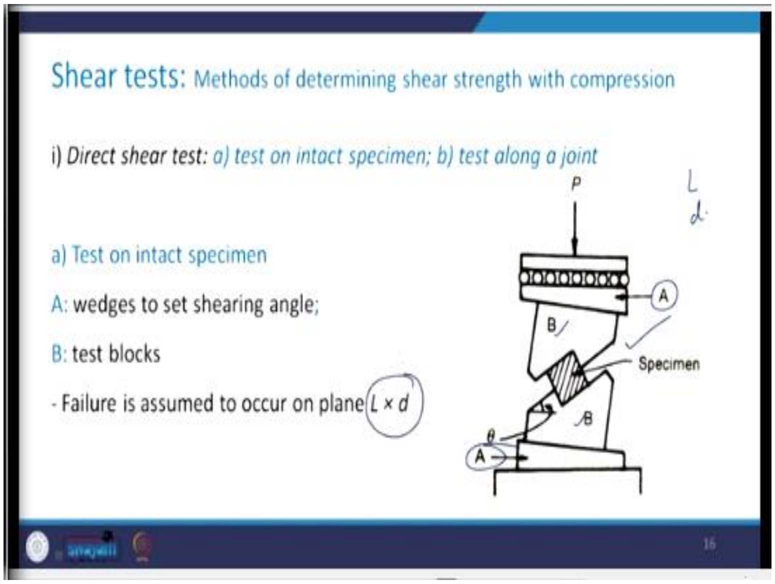

So, basically this apparatus has wedges, here A wedges, 2 wedges are there, A wedges, they are there to set the shearing angle, B is the test block which holds the specimen in this position that is it is making an angle θ, like shown in this figure. One assumption which is made is that the specimen is cylindrical and it has L length and d be the diameter of the specimen. So, the failure is assumed to occur on the plane L x d.

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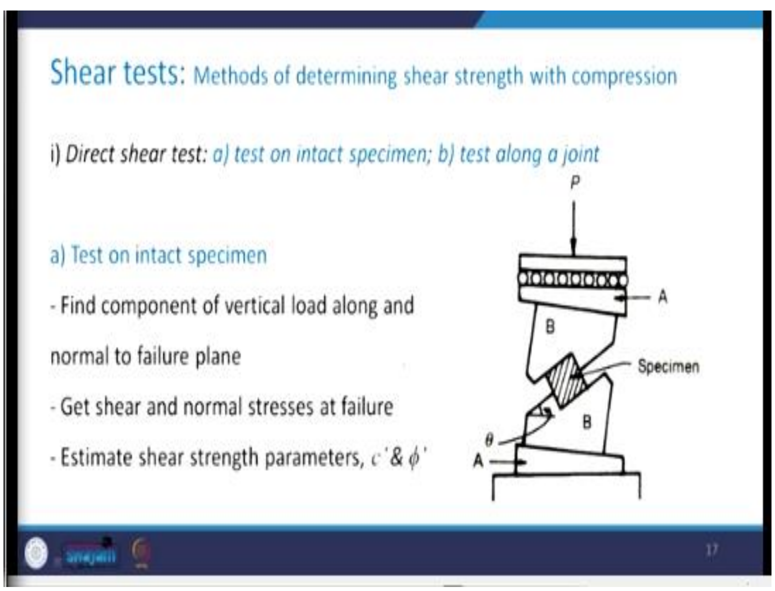

So, what we need to do is? We need to find out the component of this vertical load along and normal to the failure plane. And then we can get the shear and the normal stresses at failure and we can estimate the shear strength parameters.

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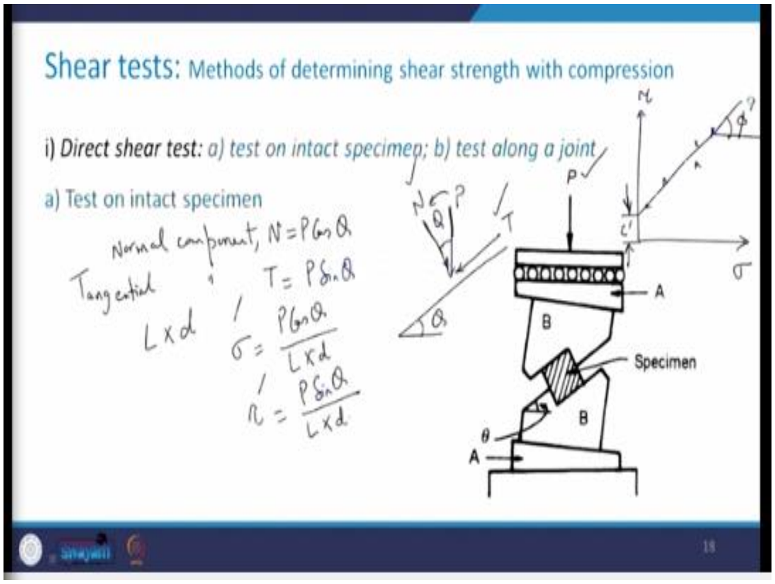

Let us see how this is done. So, you see that we have this plane where this angle is say, θ and on this plane this vertical load is acting say this is P. So, I can find out the component of this load that is normal component and the tangential component. So, the normal component which is say N that is going to be, see this angle is θ, so this angle will also be θ. So, its normal component N will be

$$N = P\cos\theta\,;\; T = P\sin\theta$$

T is the tangential component.

Now the area along which the failure is assumed to occur is L x d. So, what is going to be the normal stress σ, that is

$$\sigma = \frac{P\cos\theta}{L \times d}$$

and the shear stress τ is going to be

$$\tau = \frac{P\sin\theta}{L \times d}$$

So, this is how when P is acting in the vertical direction. I will find out the component in the normal and the tangential direction to this plane, and I can find out what is the value of σ and τ at the failure for this specimen under this oblique shear test.

So, what we do the next is we can plot. Here is τ and then here you have σ. So, whatever is the let us say the value say I have conducted say ϕ test, so it looks like as if a linear I mean a line will fit here. So, accordingly if it is following the Mohr coulomb criteria, I can find out the shear strength parameters like this from the test results. So, we discussed about the shear tests. 2 categories of the shear test. One category we do not have the normal load on the shearing flame.

And the second category includes the shear strength determination with compression. In the first category, we had single shear test, double shear test and punch shear test. And we saw that the unknown tensile stresses are getting generated and which are not giving us the exact value or the actual value of the shear strength parameters as that of the actual rock. And therefore, the other category of where the test is conducted when you have the compression on the shearing plane that was devised.

In that one we started our discussion with the direct shear test, which can be conducted on the intact rock specimen or the jointed rock. That intact rock specimen, we saw that when the plane or the shearing plane is vertical, how this is to be done? If it is inclined, that is oblique shear test, how the test data is to be analyzed? That I explained to you. In the next class, we will see that how this test can be conducted on a joint and that would be followed by our discussion on tri axial test. Thank you very much.