Drilling and Blasting Technology
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Lecture – 06
Rock Properties & Testing- 1

Let me welcome you to the 6th lecture of Drilling and Blasting Course. In this lecture, we will cover off Rock Properties and Testing. This is the 1st lecture on this. This lecture will continue to the next lecture also.

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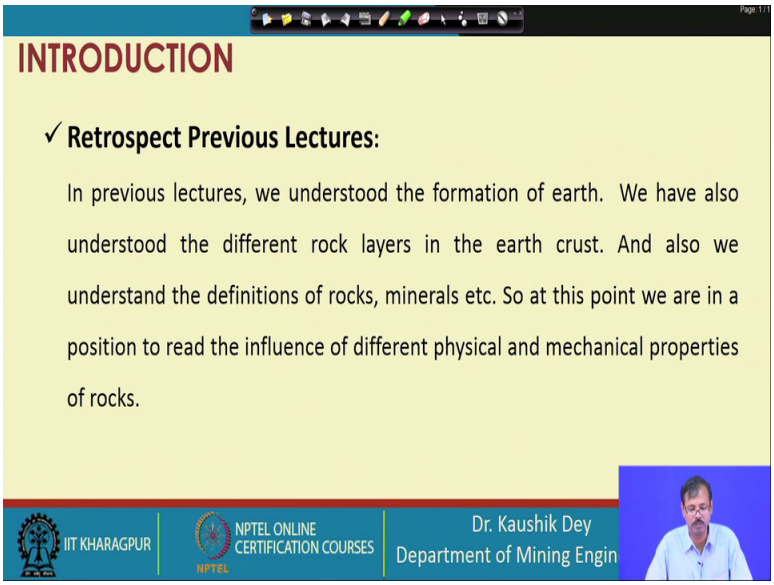

So, like every class what we do let us see retrospect our previous lectures. In our previous lectures, we understood the formation of earth. We have seen the central part of the earth is almost in the liquid or semi liquid stage. Then, the solid part is the outer what and the rocks are formed the solid part of the outer what.

So, basically there are earth crust is basically formed by the rock. We have also understood the different rock layers in the earth crust and also we understand the definition of the rocks mineral etcetera in the last class. And at this point, we are in a position to read the influence of different physical and mechanical properties of rocks particularly, while we are trying to understand the drilling operation.

So as in the introduction class, we have understood the drilling is carried out in the rock, so that we can place explosive inside the rock to blast it. So, how different rock materials; rock properties are basically influencing the performance of a drill, performance of the drill machine, performance of the drill tool.

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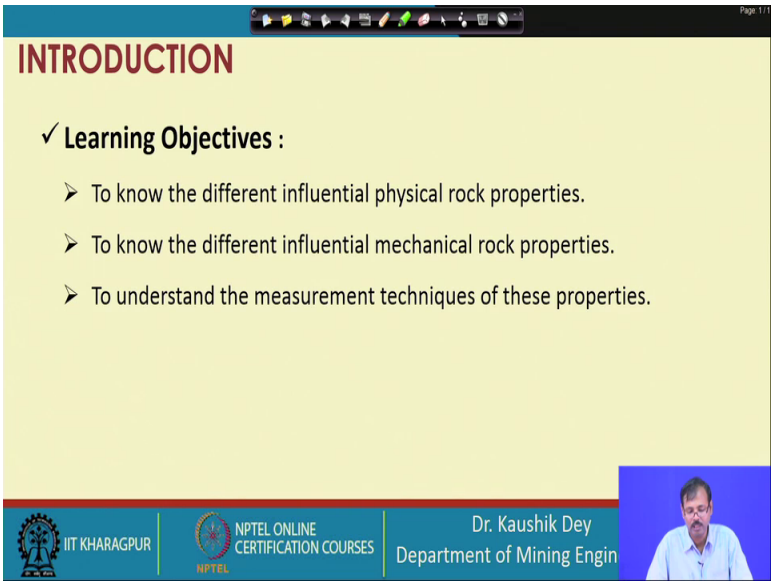

We are trying to understand those things in these lectures. So, our learning objectives are to know the different influential physical rock properties, to know the different influential mechanical rock properties, and we must understand how to measure these properties of rock. So we are trying to understand this.

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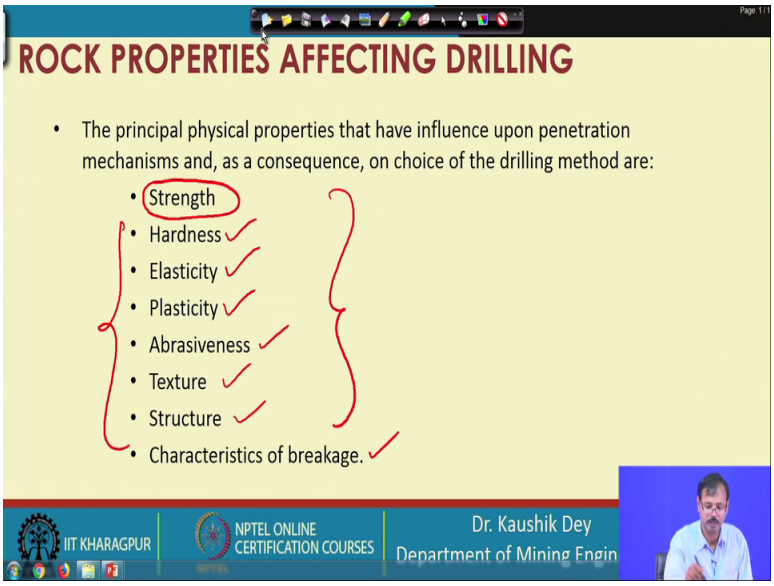

Let us see, what are the different influential rock properties, which are affecting the performance of a drill machine: the first major one which is basically principally influencing the performance of the drill is the strength, then the hardness, elasticity, plasticity, abrasivity texture structure and characteristics of breakage.

Among these obviously, the major one which is influencing is the strength. And basically rest are more or less related to each other. Say abrasiveness, hardness, texture structures these are interrelated and these are having significant influence not only on the performance of the drill machines. In that particular rock, but also the economics of the drilling is more or less depending on this. So, this all these parameters are having significant influence and we will discuss, how they are influencing the performance of the drilling, but presently we are considering about the definitions and the procedure of the tests.

So, first let us consider about the strength properties in fact, in this lecture we will cover only the strength properties. Rest other properties we will discuss in the subsequent lectures. So, first consider the strength properties.

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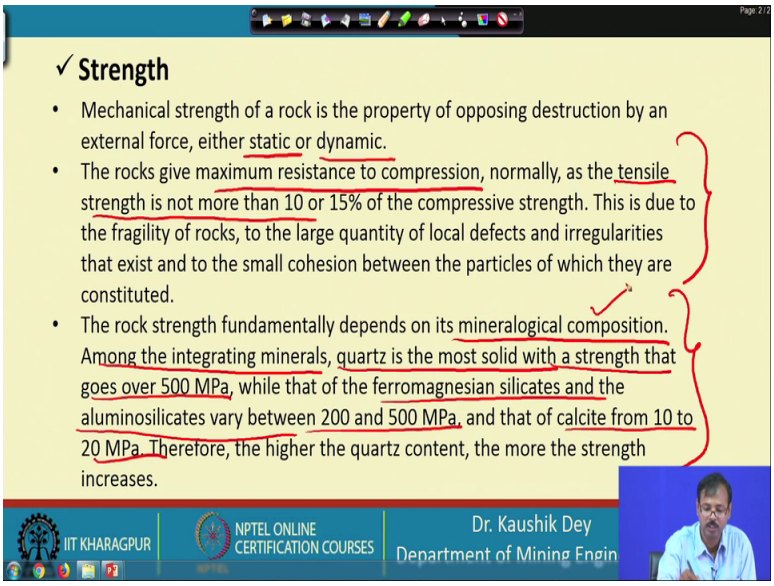

Basically, strength property is the mechanical strength of a rock is the property of opposing destruction by an external force, either static or dynamic. So this is very important, the type of force it may be static it may be static it may be dynamic.

So, the strength of a rock is that much at what force? Or what stress the rock is subjected to fail? So, mechanical strength of the rock is basically defined by the maximum stress that is withstand by that rock specimen subjected to a static loading or to a dynamic loading. Basically, the difference between a static and dynamic loading is depending on the loading rate; that means, how quick we are increasing the rate of loading that is basically differentiating the static and dynamic loading.

However, presently all the mechanical testing is being carried out or the static loading. And they are the dynamic loading is very very in laboratory scale generating a dynamic loading setup is very very difficult. That is why dynamic strengths are being assessed through indirect method, not to the direct method.

So, basically all the measurement of strength which we will discuss in this lecture are the static measurement. So, the measure strength whenever, we are talking about the strength, it is always understood that this is the static strength of that rock. It may be either in compression or in cr or in tensile. And we will discuss, how these are this can be distinguished, but at this point, let us know that the maximum rock gives maximum resistance to compression and least resistance in case of tensile; that means, if a

specimen is tried to be pulled away by taking it is 2 part the strength requirement will be minimum, but if we try to break it by compressing this to through to end, it the resistance it will so the maximum.

So, you can see the maximum resistance is under compression minimum least resistance is under tensile. In fact, it is almost 1 10th or 1 12th time of the compressive stress. And this is happened mainly due to the facility of the rocks, to the large quantity of the local defects and irregularities. Basically, a rock is a material which show almost a Poisson's ratio of about 0.2, 0.15, 0.15, 0.2, 0.2, 2.5 like that.

And rock strength fundamentally depends on the mineralogical compositions. Among the integrating minerals quartz is the most solid with a strength that goes over 500 mega Pascal. And ferromagnet magnesium silicates and the alumina silicates vary between 200 to 500 MPa calcites are almost the weak rocks and coal is also very very weak rock.

So, basically you can see the compressive strength of the rocks varying almost less than 1 to 500 mega Pascal; that means, from very very soft to very very strong rock conditions. Basically, that measures the integrity of the rock. Rock strength also depends on the mineralogy not only in the mineralogical compositions, but also they are formations if you will in general, we will find the rock formed under volcanic eruptions under high temperature pressure that, in general shows high rock strength than the rock formation in some sedimentation or etcetera.

So, like this way rock strength depends on the rock formation, depends on the mineralogical characters, depends on the integrated geological disturbances in the sample. So, it depends on a number of factors.

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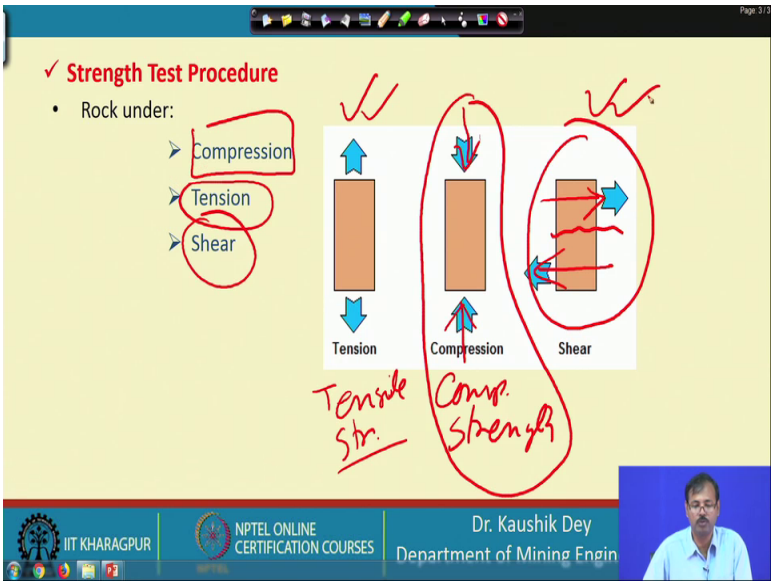

But let us see, what are the different raw strength test we carry out in general in our lab. We classify our strength under compressive, under tension and under shear.

So, this is the compressive when is allow the rock specimen to be subjected under a compressive load. And see the load at which the rock fails is considered as the compressive strength compressive strength. And if we subject it to a tension, then it is called tensile strength. But, shear one is little bit difficult, we carry out shear test either a direct shear test or through the triaxial test.

We try to find out the shear strength of the rock where top part of the specimen is subjected to a load under this direction, the bottom part is subjected to a load under this direction. And we try to observe the shear along this plane of the material. So, this is the shear way we try to find out the shear strength of the specimen. So, basically compressive strength, practicing compressive strength in the laboratory is very very easy, but doing this two are little bit difficult. And often that is why we go for the indirect testing methods for this so that, we can have some these values, but through some other way.

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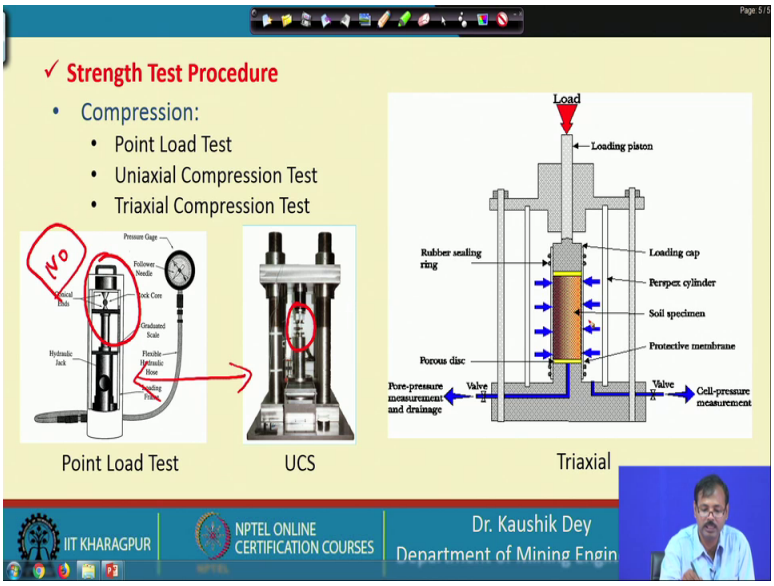

So, for compressive testing we are generally carry out point load test, uniaxial compressive test and also triaxial compressive test. So, these are the apparatus, this is the point load apparatus where the conical ends are there under which the rock specimen is subjected to under loading. Here, a regular specimen is subjected to load under a uniaxial compressive chamber. And in triaxial, we allow the lateral pressure fixed lateral pressure while, the specimen is specimen is allowed to be loaded under a compressive load.

The differences among these three, is that, in point load test, we can carry out point load testing in the irregular sample also. The testing procedure is very easy; sample specification requirement is less that is why huge number of specimen can be tested which gives a fairly good result to relate this result with the compressive test.

Compressive test, the problem is thus preparation of the sample, this sample preparation is little bit problematic. Where n, number of cares has to be taken on the smoothness of the sample, dimension of the samples, linearity of the samples. So, this special this care should be taken prior to carrying out the test of the sample.

Similarly, in triaxial also sample specimen sample preparation is difficult. After that, the experiment procedure is also difficult. Where, the triaxial load has to be hydraulically provided using some external means. So, that is why this triaxial cell has to be essentially required to carry out the triaxial test, under the same uniaxial compressive testing machine.

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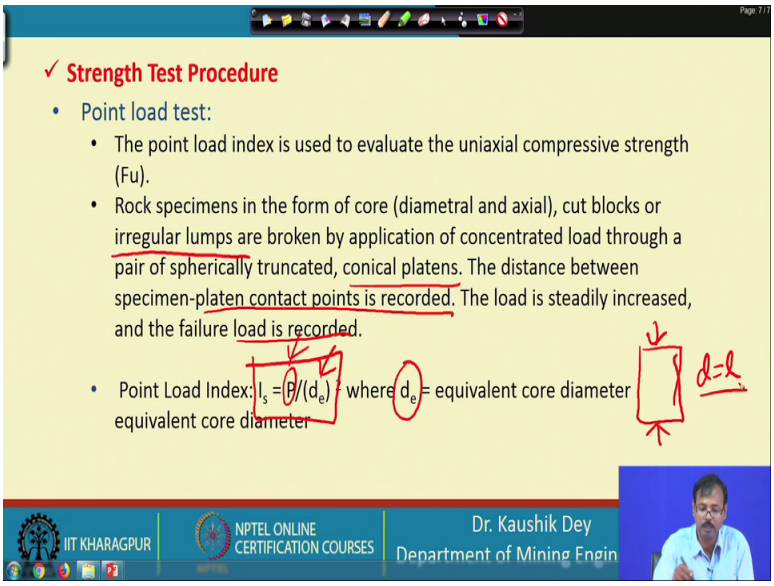

So, this is the point load test where the specimen is used to evaluate the uniaxial compressive test. And rock specimen is in the form of core sample or may be the cut blocks even if, irregular lumps are also taken for carrying out the point load to carrying out the point load test.

Here, the samples are samples are placed under the conical platens. And the distance between the specimens of the platens is recorded. So, this is the initial record then, this recorded one considered as this one. This is this recorded distance and then the load is steadily increased failure load is loaded.

So, failure load this is the P is the failure load and dividing it by the distance of the initial chronic conical platent distance that square of that. It gives us the point load index for irregular sample, if we go for diametrical loading of the core sample then is the equivalent core diameter or if any specimen which is placed here, that is the same. So, in the in case of standard specimen it is loaded axially, not in the diametrically. So, it is axially loaded on the standard experiment with d is equal to l loading. In that case that is called identical if that is the standard loading of the point load test, but point load test can be carried out irregular samples. Because, it is very very important the same sample shows different values of strength when it is loaded in different directions.

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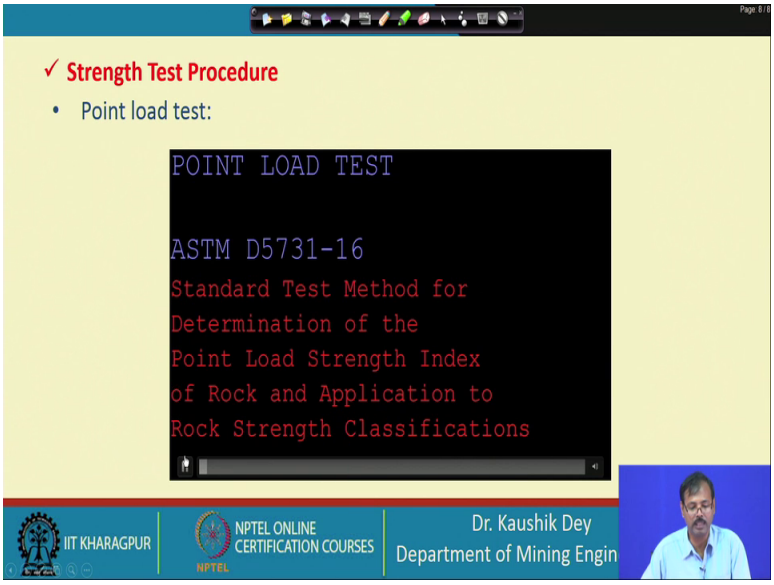

So, that is why point load testing is very very important, point load index can be directly related with the uniaxial compressive strength. We will discuss that at a later part let us see this video which is giving us the.

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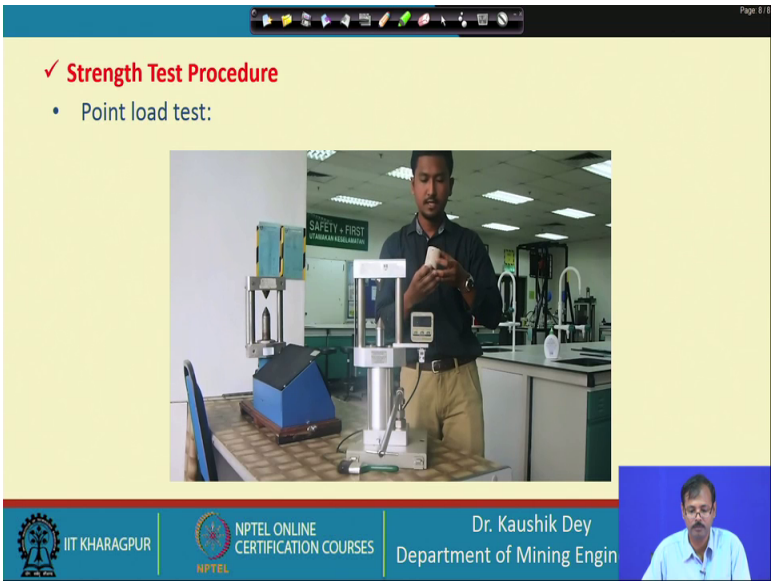

I want to show you the next laboratory test which is fine load test. So, this test is used to determine and specify the strength index of rocks. You can see here I have a scepter of rock, which is marble which specified as metamorphic rocks by these sample has been treated to a specific dimensions.

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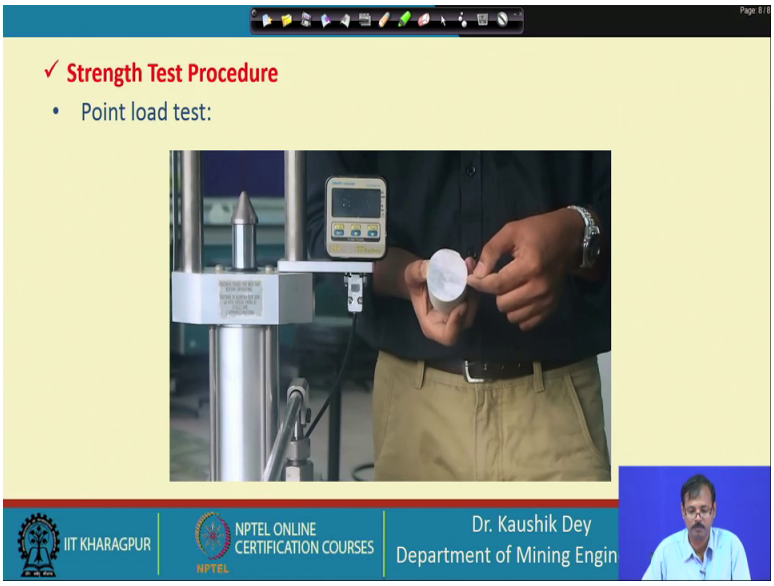

This is a diameter of the samples and this side is the length of the samples. So, the ratio of the sample is 1 2 and 5 to the meter.

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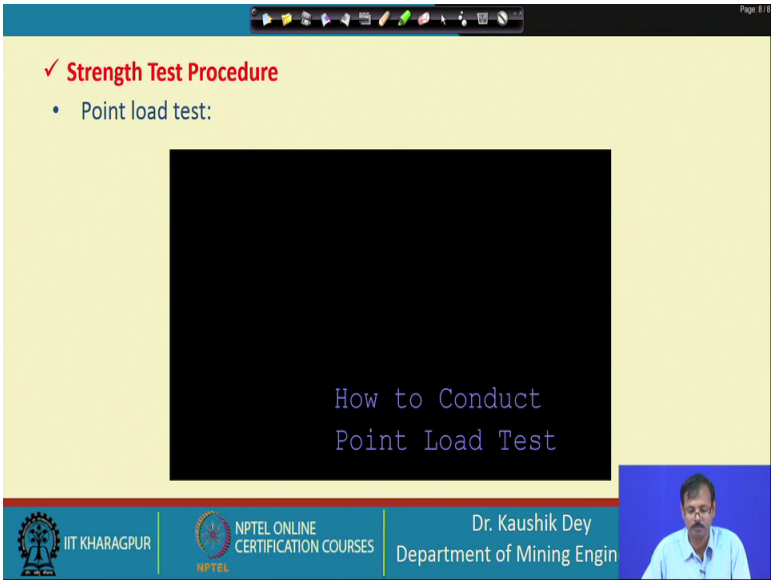

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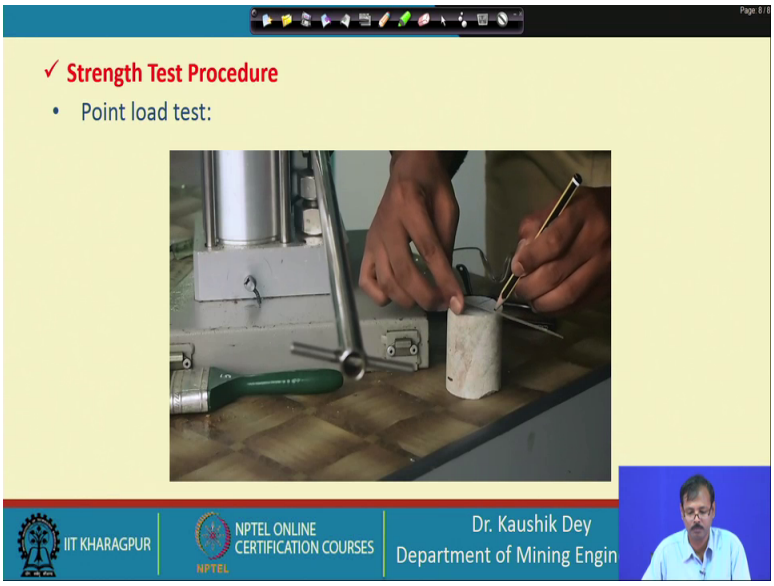

The test part with marking the center point on the samples by using a pencil and ruler, find a midpoint of the top sample based on this causation line. And with the same thing to the bottom one, this is important in order to get a good result and through mode or failure.

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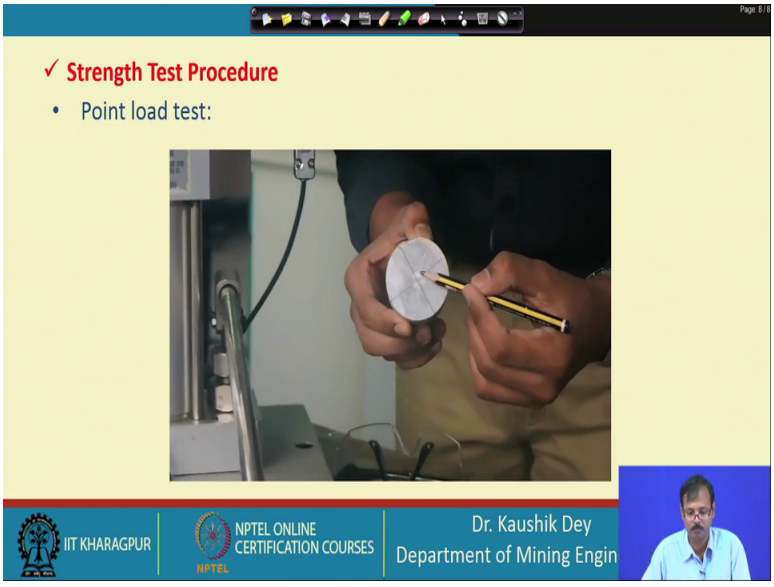

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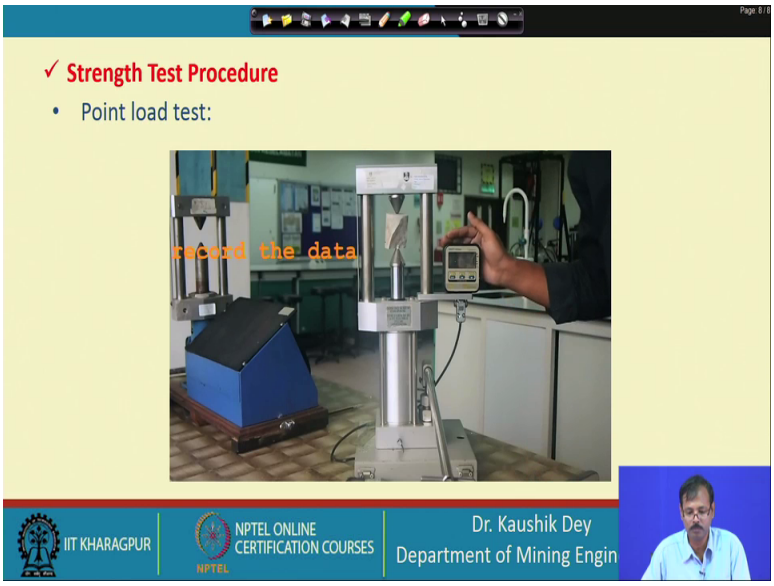

Then place this rock sample in between the sharp edge and you can see here bottom and top edge. Then give a little pressure so that the sample is properly located and cannot move anywhere.

After that set the gauge reading to 0 usually the units this is a single unit which is Newton's. Then continue the test by increase the load and you will feel that this route getting harder and harder until the sample fail. And as you can see now the sample is already filled and break apart. And lastly, take the reading of maximum point load recorded in gauge. So, you can observe how the point load test is being carried out.

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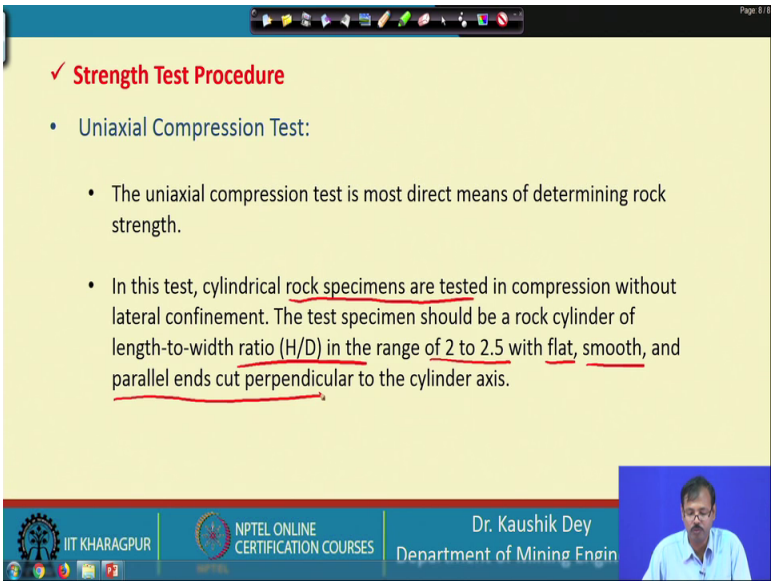

Point load test can be correlated with the uniaxial compressive test for say like coal missile rock if, point load index can be multiplied with the 24 to get a uniaxial compressive test this type this constants are basically calculated through the statistical analysis. And basically point loading index is directly, linearly correlated with the uniaxial compressive value.

So, these are the possible the test, that is why point load is very very easy and may replace uniaxial compressive test, if it is carried out in a good number of samples. So, let us now see what is uniaxial compressive test, uniaxial compressive test is the direct measurement of the rock compressive strength. In this test cylindrical rock specimens are rock specimens are tested, where with l by d ratio of 2 to 2.5. It must be flat, it must be smooth and parallel lengths must be there.

So, there should not be any eccentricity of the sample foil it is the loading is being carried out. And their tolerance limits are already given in ISRM standards HTM standards that must be followed while the test is being carried out.

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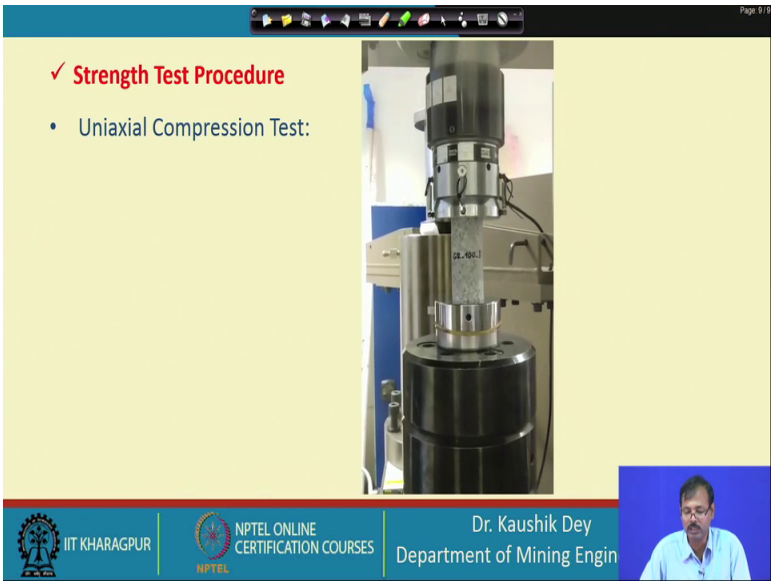

In this test you can say this is the one video of the test; in this test you can see the loading is being carried out for a compressive test sample. So, this sample is placed there is no eccentricity the plates are parallel to each other, while it is under loading. And gradually with a fixed loading rate the load is being increased on the sample.

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Failure of the sample suddenly the load is released from the sample.

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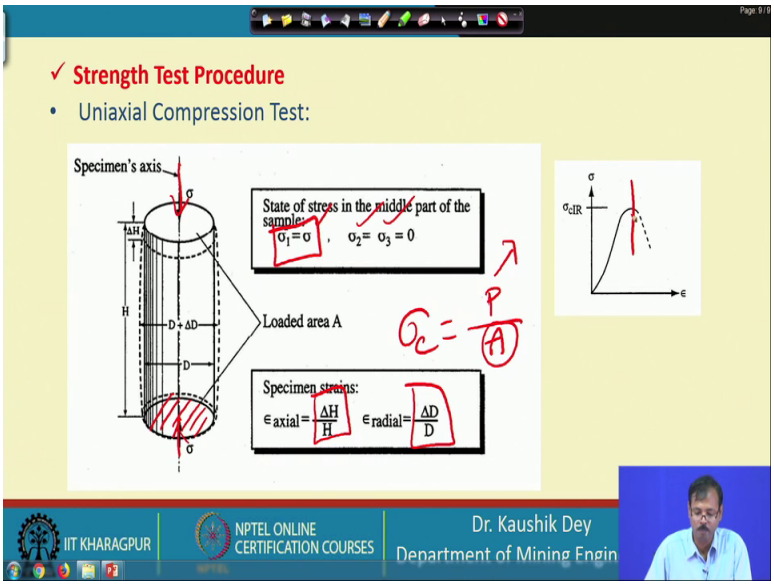

So, this is the so this is the specimen which is subjected to a compressive load and the compressive strength can be assessed by using the formula P is equal to strength is equal to P by A. Where, P is the failure load failure load A is the area cross sectional area of the specimen.

So, in this case the loading is given uniaxiallly the loading in other 2 direction is not available. So, the uniaxial loading is this one and specimen is subjected to load. So, this is the strain can be easily calculated using this is the radial strain and this is the axial strain. And if you plot the curve between stress and strain, you will find out the failure is like this so there is a sudden failure of the material if it the material is brittle in this place.

So, this is common characteristics of a compressive testing.

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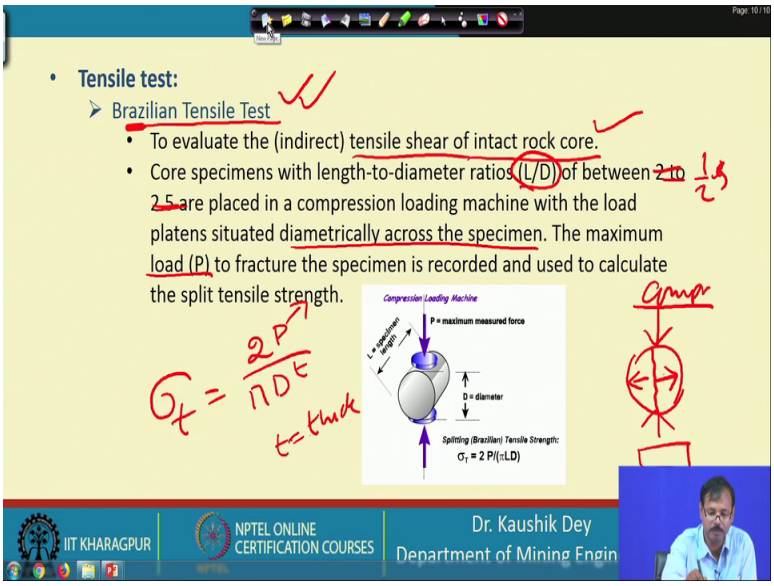

Tensile testing is basically carried out where, direct tensile testing is not always possible. So, indirect tensile testing is carried out in Brazilian test sample. In Brazilian test sample, where the specimen is placed specimen is placed like this and it is loaded radially. So, what is happened? Though the loading is given compressive, but the specimen fails on that plane where, the forces are acting in a tensile force.

So that is why, this strength parameter is basically observed is the thus is the tensile strength not the compressive strength. So, Brazilian tensile test is basically an indirect tensile strength measurement procedure. Where, the indirect tensile shear of the intact rock core is carried out, so in this test core specimen with L by D ratio, with L by D ratio. It is mistakes are there half is taken L by D ratio of half is taken a under compressive loading machine and it is platens are diametrically placed diametrically across the specimen.

So this is the platens, platens are placed diametrically across the specimen and the load maximum load to fracture the specimen is recorded. And the tensile strength is computed as sigma t is equal to 2P by pi D t. Where, t is the thickness where t is the thickness that means, the length of the sample d is the diameter of the sample and P is the. So, basically this is the P is the failure load, this is the formula to give us the tensile strength of the rock specimen.

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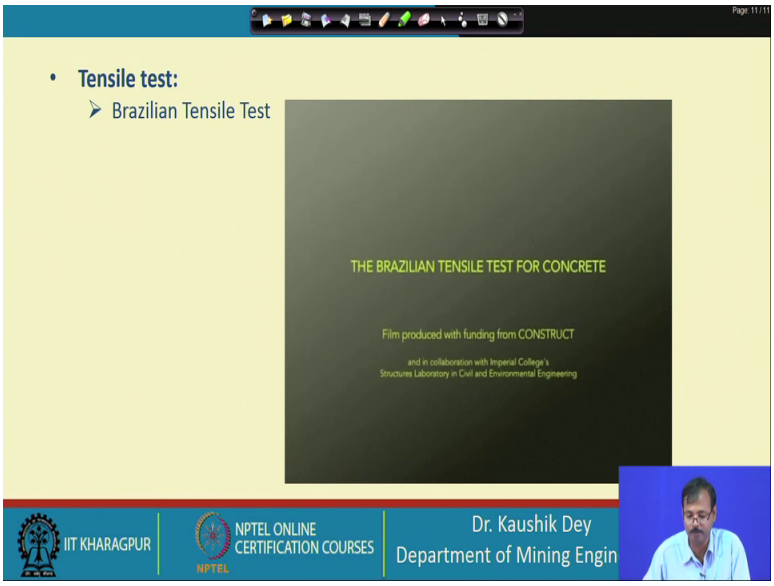

So, let us observe let us observe, one such video available in the YouTube for the tensile strength measurement of some concrete specimen.

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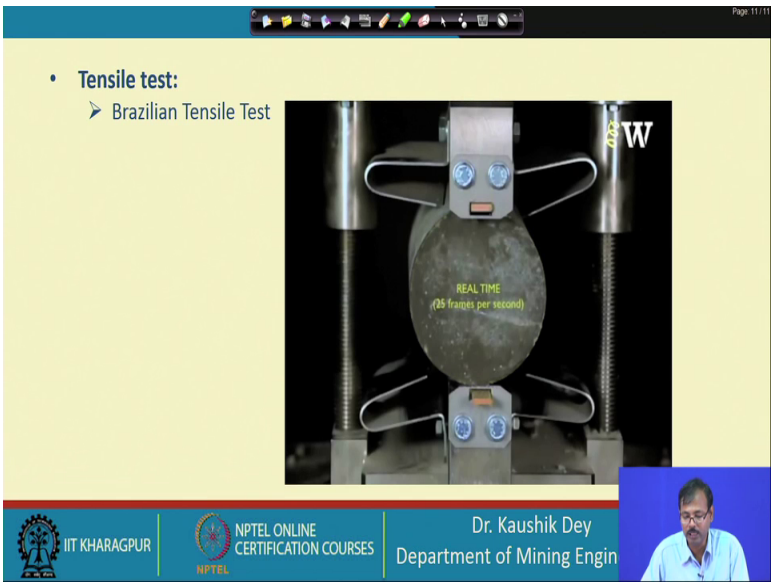

So, here the YouTube of this video is that in this video you can observe this in a slow space also.

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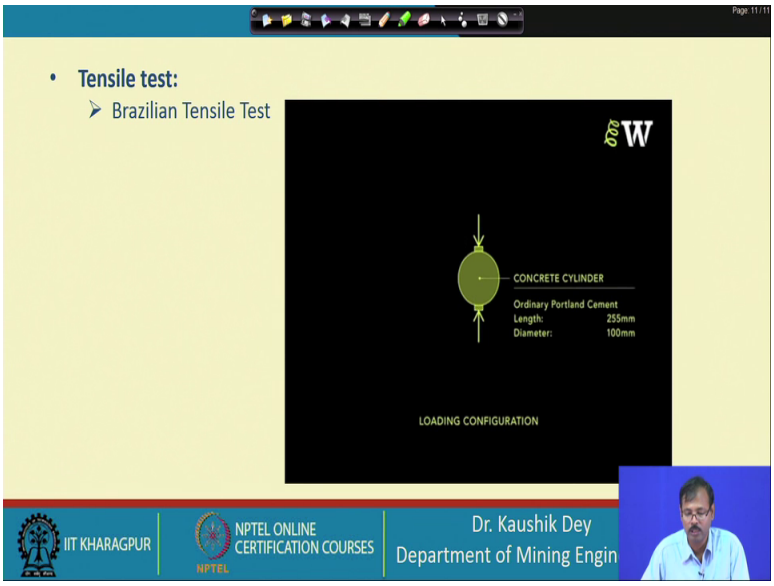

Revinded in a slow space so this is the cylindrical sample of prepared with ordinary Portland cement and you can see the real time video of 25 fps of this failure. So, as the specimen is subjected to load you can see the tensile cracks are created across the diameter.

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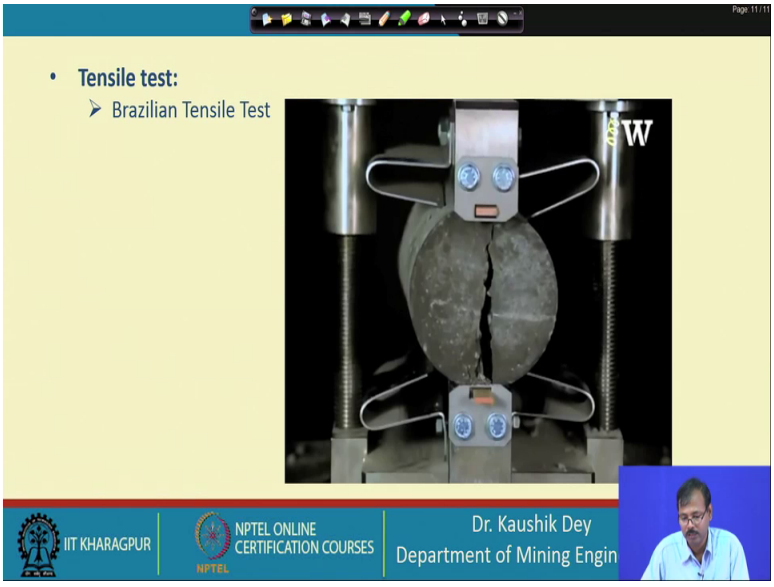

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And the in a specimen fails under tension.

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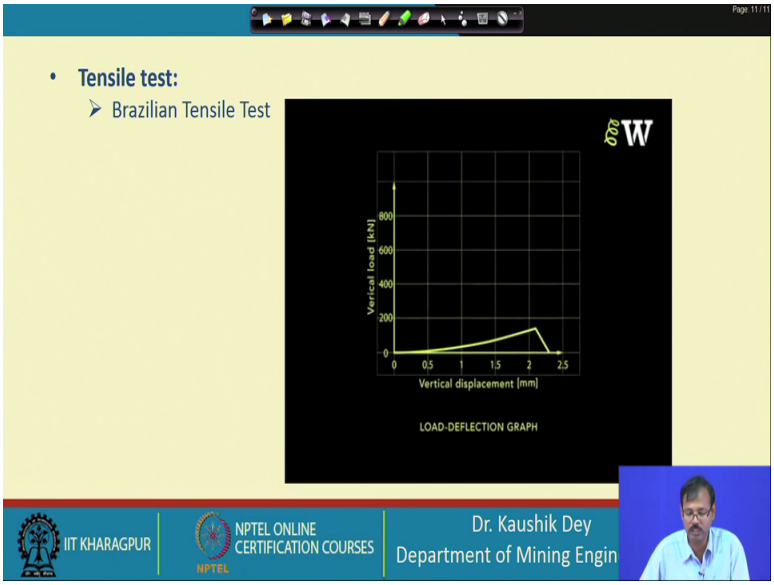

So, this is the slow pace you can see propagation of the cracks in the specimen, you can see the cracks are being widened gradually. And finally, the specimen fails so this is the vertical load versus vertical displacement graph.

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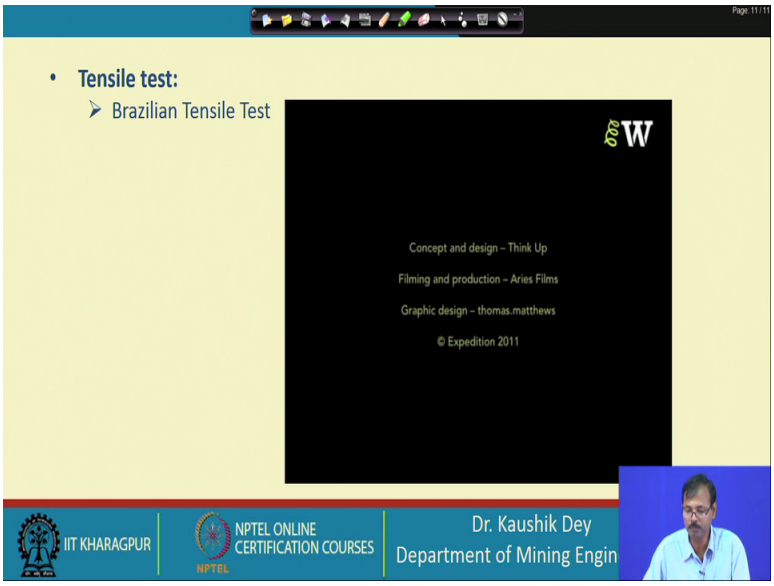

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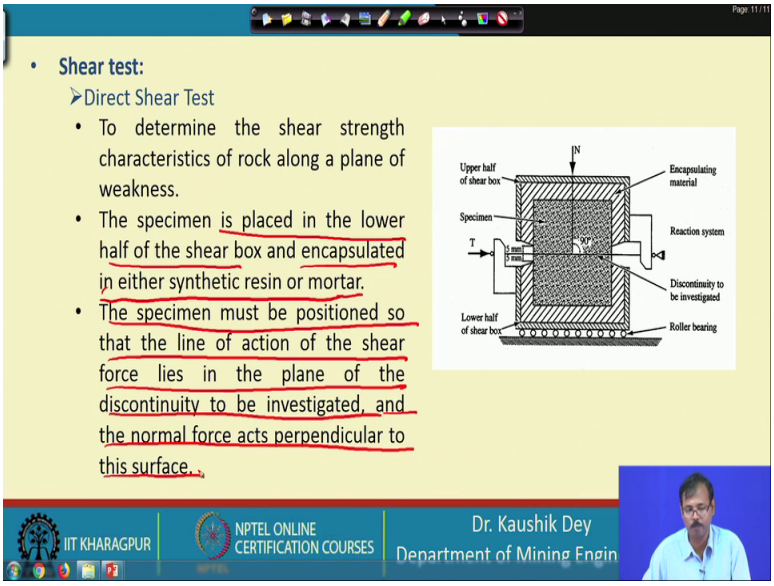

So, this is the direct shear test in general, tensile failure is very rarely occur in the rock. Most of the time we provide the compressive load on to the rock and rock fails under compression, but sometimes rock fails under tension also; while we will discuss about the tensile slamming zone of the blasting, where the rock fails on the tension.

The difference between compressive failure and tensile failure is that when rock fails under compression it disintegrated into a number of pieces where it fails under tension it disintegrate into only 2 pieces, not a number of pieces. So, basically tensile failure gives

us a long crack while compressive failure gives the n number of smaller fragmented material. So, that is why compressive failure the facility is that it is compressive load can be easily given onto the material and it is difficult to provide the tensile load onto the material.

However, compressive strength is maximum for the rock, tensile strength is the minimum of the rock. So, though tensile strength of the rock is minimum, then also it is not commonly practiced, because that providing a tensile load onto the material is difficult. So, hammering etcetera all these are the failure of material under compressive the load, not the tensile load.

So basically, in between this 2 strength there is the shear strength the general value shear of stress shear strength of the rock is lesser than the compressive strength, but higher than the tensile strength. Rock fails under shear also sometimes rock fails under shear most of the times because of the shear n number of loads are acting on the rock, in on in situ condition. And that is creating a shear loading on the rock as sometimes it is happened because of the heterogeneity of the rock.

The direct shear is measured on the direct shear test apparatus; however, direct shear test apparatus is applicable for the loose material, for the soft material only because otherwise it this cannot be utilized. So, in direct shear test there is a thus a shear strength is determined the characteristics of rock along the plane of weakness. The specimen is placed in the lower half of the shear box and encapsulated in either synthetic resin or mortar.

The specimen must be positioned so that the line of action of the shear force lies in the plane of the discontinuity to be investigated, and the normal force acts perpendicular to the to this surface.

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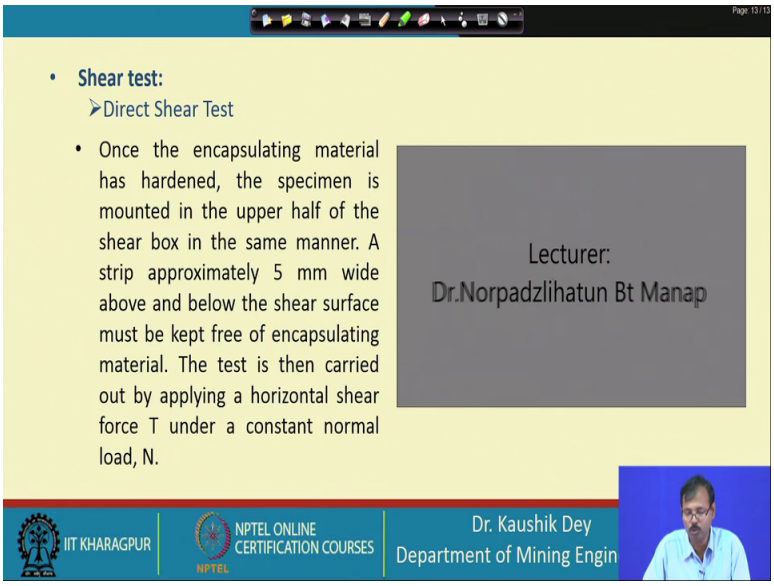

So was the encapsulated material encapsulated material has hardened? The specimen is mounted in the upper half of the shear box. In the same manner a strip approximately 5 mm wide above and below the shear surface must be kept free of encapsulating material. The test is then carried out by applying a horizontal shear force T under a constant normal load. So, this is the essential requirement that it must be carried out in a standard normal load. Now, you can see this video where, the direct shear is being carried out of a loose material Sand material so this is to determine the shear strength.

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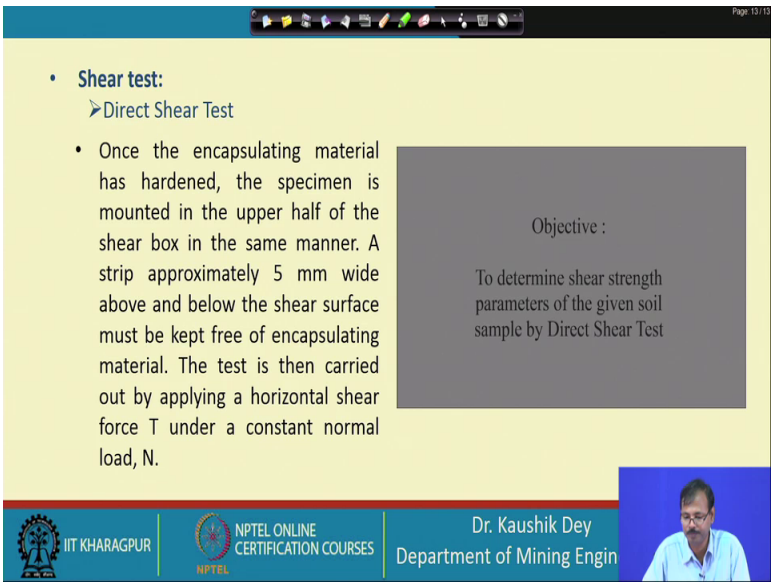

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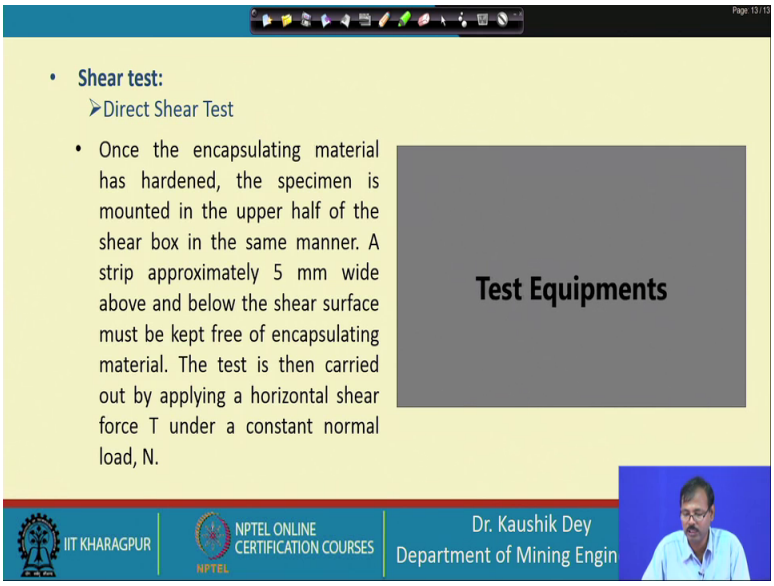
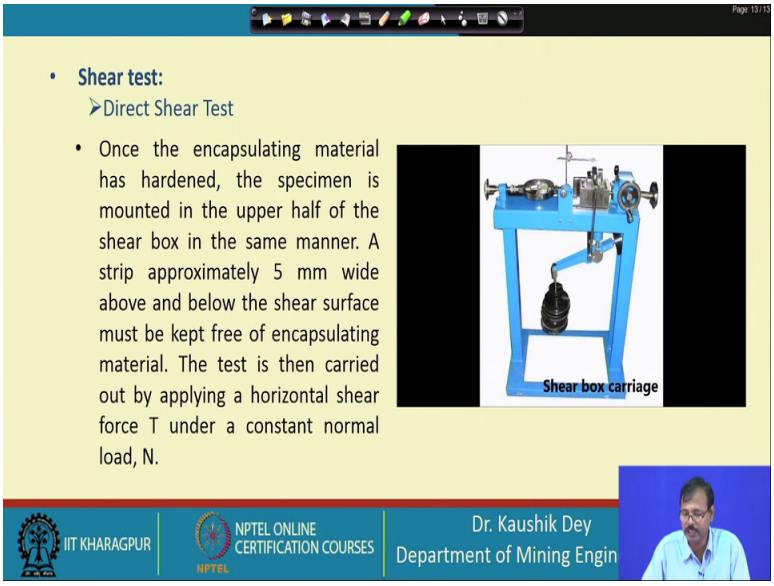
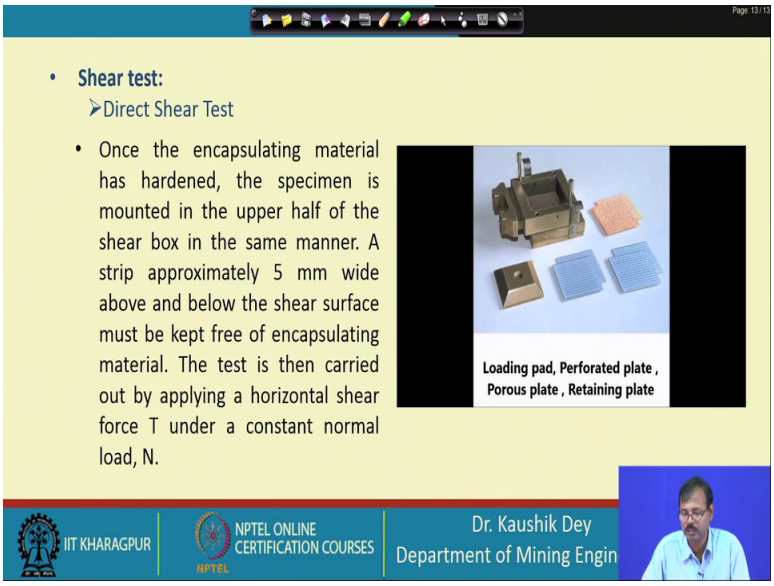


(Refer Slide Time: 30:04)



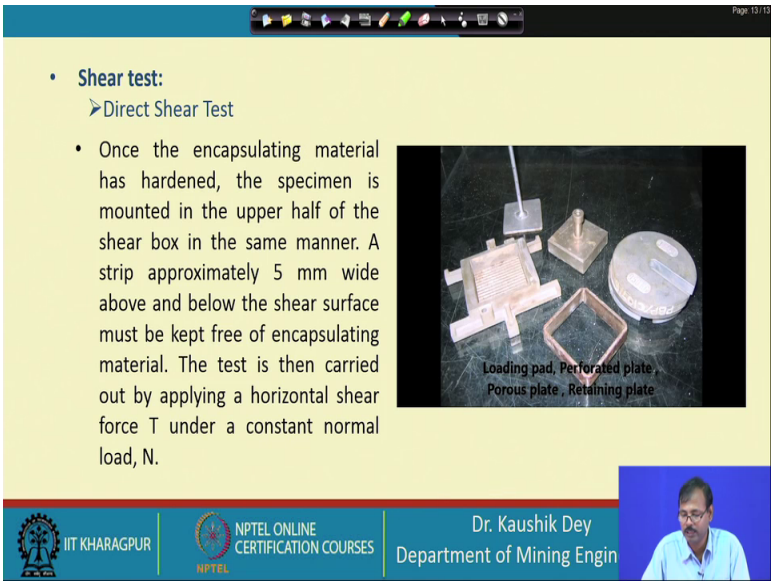
This is the direct shear operators.

(Refer Slide Time: 30:06)



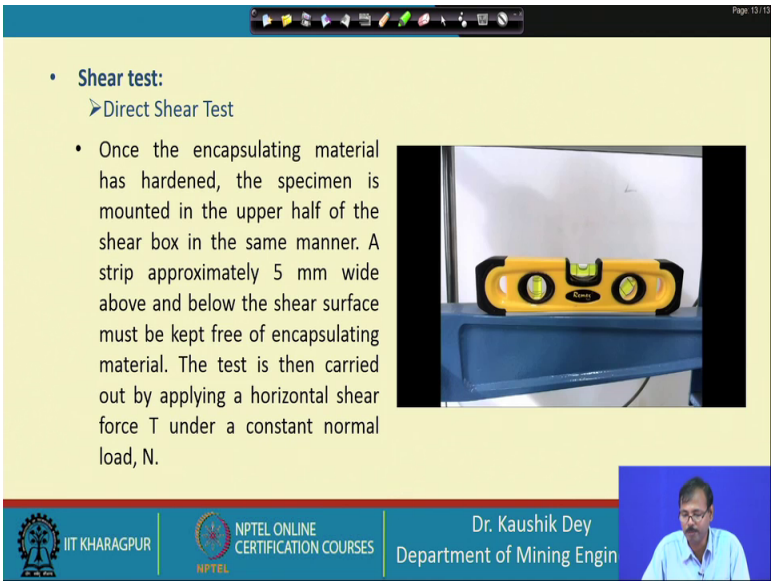
These are the loading pad.

(Refer Slide Time: 30:08)

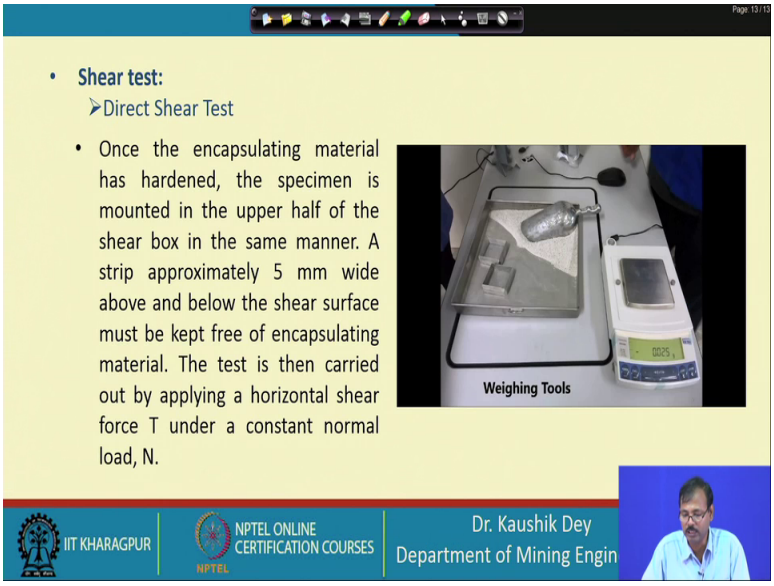


Perforated plates etcetera.

(Refer Slide Time: 30:10)

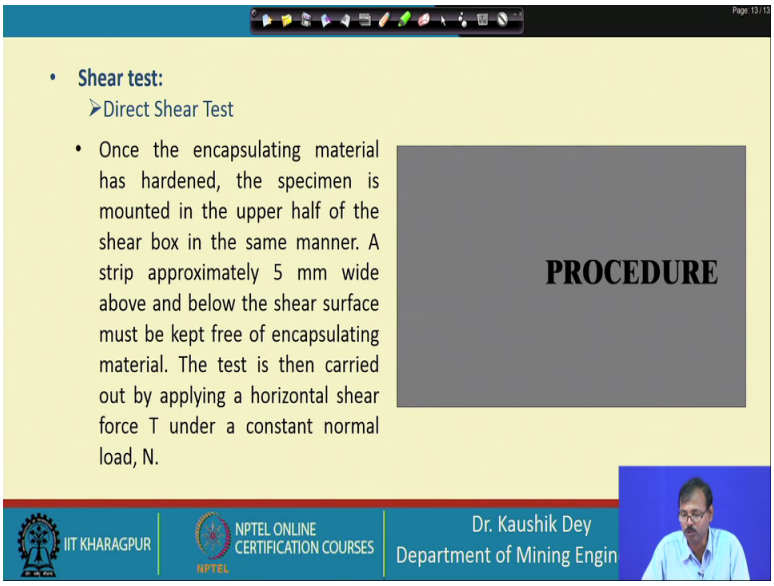


(Refer Slide Time: 30:12)



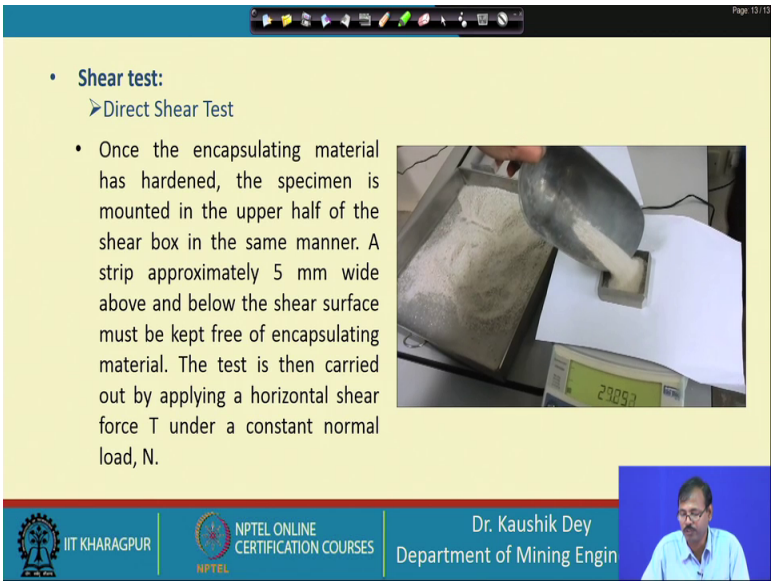
This is the hoeing machine to use the.

(Refer Slide Time: 30:13)



Way the material lose material.

(Refer Slide Time: 30:16)



So, sandy soil material is taken of fixed quantity.

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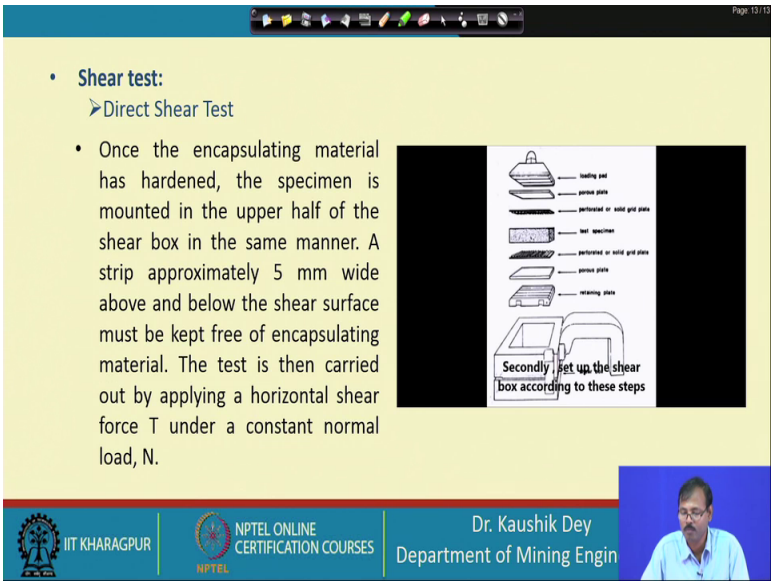
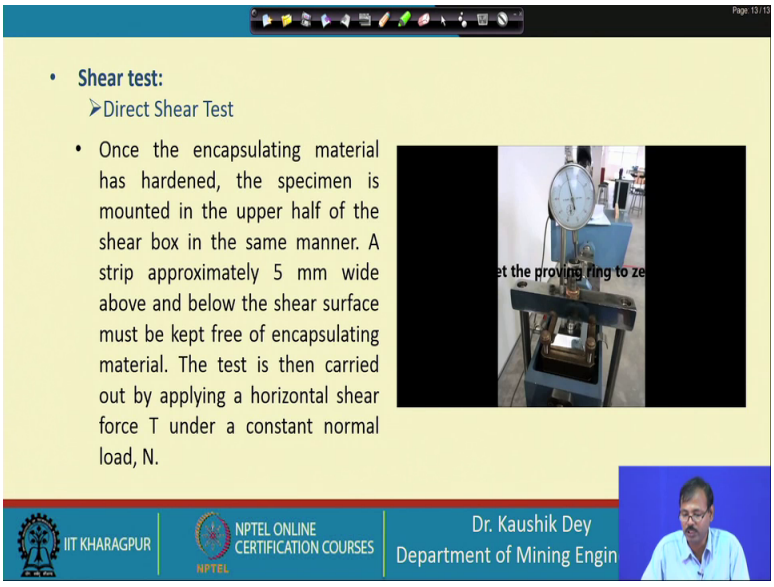


Then the shear box is set.

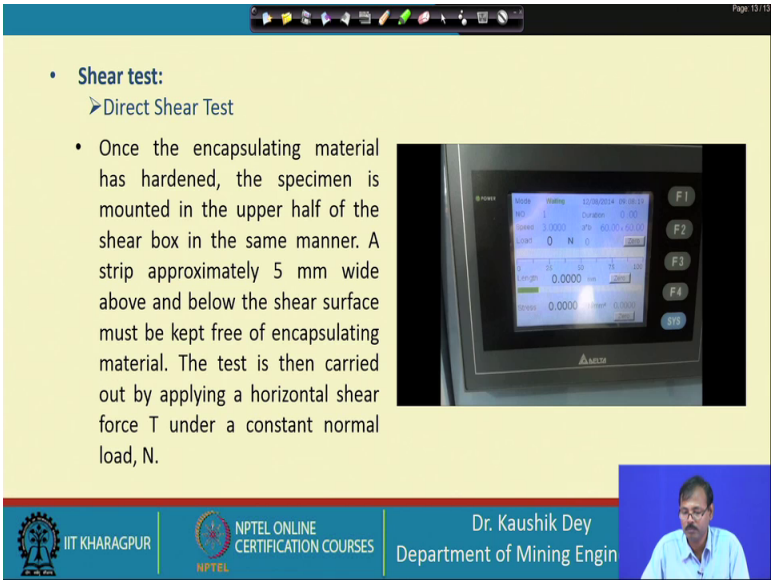
(Refer Slide Time: 30:34)



This is the shear box then first the retaining plate has to be provided then the perforated plate or solid grid plate, then the material will be placed on that, then the material will be compacted. So that, the above perforated plate will be placed on this then the upper plate will be placed on this.

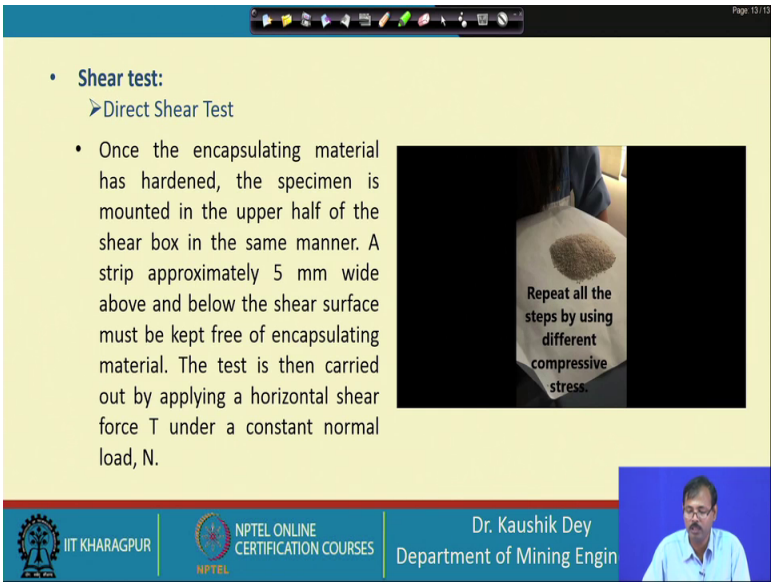
Now, the loading pad will be placed on that. Then, the normal load is which is under hanging condition will be placed on this. Now, the desired normal load may be suspended from this plate.

(Refer Slide Time: 32:16)



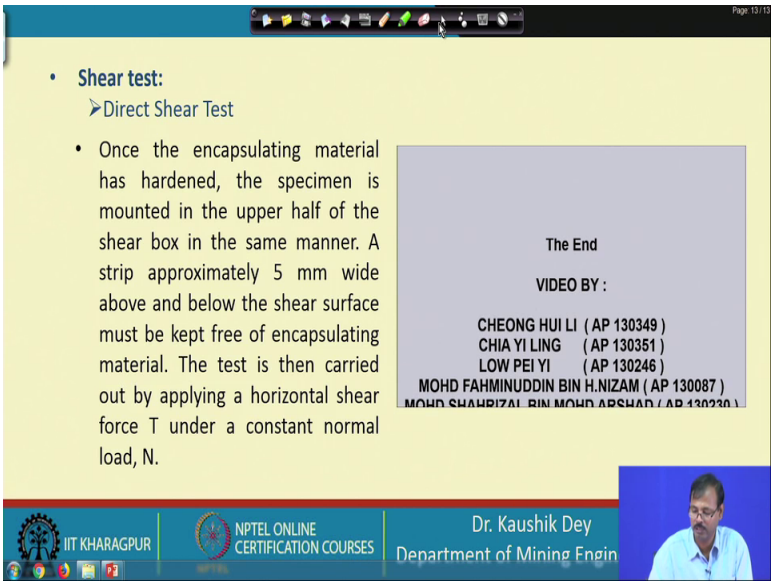
So, these are the normal fixes for fixing the normal load, then the horizontal force will be given from the hydraulically operated motor and the failure load will be recorded

(Refer Slide Time: 32:36)



So this is the direct shear test can be carried out on the sample.

(Refer Slide Time: 32:41)



So, let us stop at this position from this for this lecture. We will continue to see the influence of other properties in the next class.

Thank you.