Engineering Geology
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Lecture - 39
Index Testing of Soil & Rocks

Here, we are going to give the demonstrations on different simple laboratory testing for classification and identification of key soil parameters and rock parameters. So, with that said, we are going to move on to the first laboratory experiment involving sieve analysis which is carried out to find out what is the distribution of grain size or representation of different grain sizes within the soil matrix for coarse grain soils.

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These are the higher standard sieves used for finding out the grain size distribution, as I was saying before, for coarse grained soils. What we have got here is a stack of different standard sieves which has got different opening sizes mentioned on the labels here. And you can see the opening of individual sieve from this pore set sieve that is being shown now and we can show now what is the appearance of the finest sieve used for finding out the grain sized using sieve analysis.

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This is the 75 micron opening size sieve, whereas the first one that you saw was for it had an opening size of 4.75 millimeter as mentioned on the label. And now, you can get the idea and you look at the labels of different standard sieves and you can see that it actually goes down in size from the top; starting from the top are the coarsest sieves at the top and the finest sieve size is at the bottom. And at the bottom of the 75 micron sieve is a pan which will collect all those soils, all those particles which are finer than 75 microns. So, what we are going to do?

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Here we are going to take about 500 grams of coarse grained soils composed mainly of sand here. As it is shown here, this is basically quartz and feldspar sand. We are going to dump it on the coarsest sieve like this and then we are going to subject this set of sieves, we are going to cover it up because we do not want to lose any finer soils into the atmosphere being blown away by wind. We are going to take this sieve set, place it on a mechanical shaker and shake it for ten minutes and find out what is the weight of soil retained on each individual sieves. And from that we will get a grain sized distribution of this particular soil sample.

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Now, you see that we have put the sieve set that you saw earlier, on which we took 500 grams of soil sample, on the mechanical shaker and we are going to subject it to mechanical shaking for about 10 minutes and after that we are going to find out what is the weight of soil retained on each individual sieve. And from that we are going to construct the grain sized distribution. So, just we will start the shaking now. You just watch it and then we are going to come back .

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So, you see now after shaking of 10 minutes, we got the sieves back and as you recall that this was the coarsest sieve and in this one we do not have any coarse soil retained. (Refer Slide Time: 04:35)

Then we move on to the next one which is a 2 millimeter opening size IS standard sieve and here you can see that we have got a little bit of soil on retained here. So, what we are going to do? We are going to take the weight of this much of soil and whatever is the weight we are going to divide it by the initial total weight of the soil taken, and from that we can find out what is the gravimetric percent of soil retained on sieve size 2 millimeter. So, then we are going to proceed to other sieve sizes similarly.

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You can see here that there is a little bit of soil retained passing past actually 75 micron size sieve and the grain size of this particular fraction is going to be determined not from sieve analysis typically. We are going to need to go on for another laboratory experiment which is called involving hydrometer for finding out the grain size distribution of the fraction of soil which is finer than 75 micron. So, then as I mentioned, we are going to proceed to weighing of the percent of soil retained on each one of the individual sieve size.

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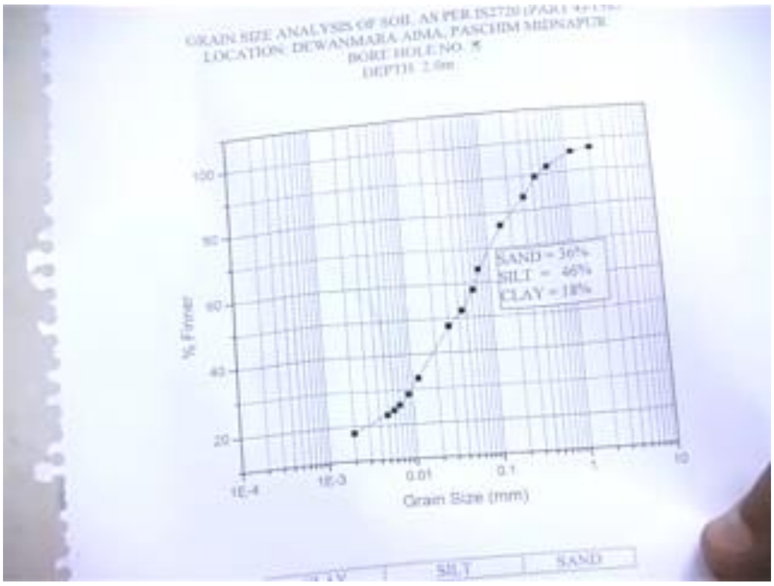

Finally, using the data, we are going to be able to generate a distribution, grain size distribution curve like this which plots the percent finer by weight on the vertical scale and the opening size of the sieve on the horizontal scale, as you see on this particular plot. So, using that we get a, we construct a grain size distribution and this allows us to classify coarse grain soils as I indicated earlier in one of the theoretical sessions in the course.

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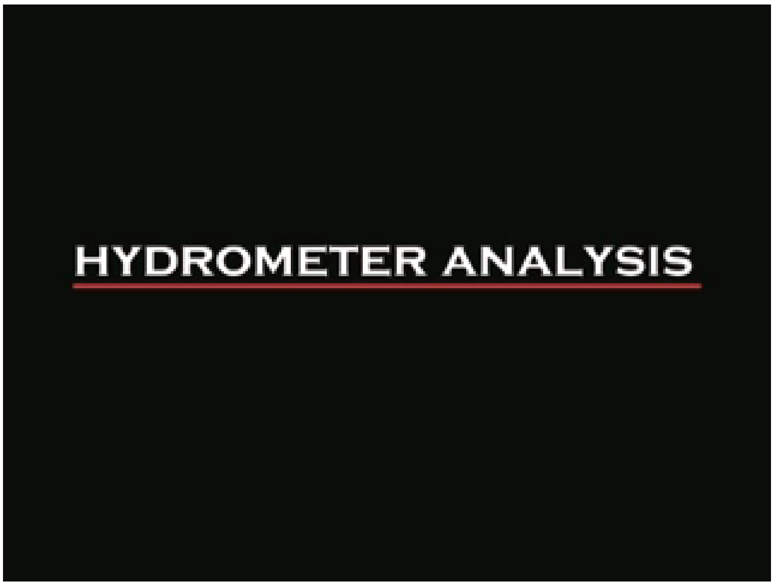

So, here is the setup for hydrometer analysis for finding out the grain size distribution of soil samples, which has substantial amount of particles finer than 75 micron and this one actually is one such sample of silt and clay.

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And what we are going to do with this particular sample is we are going to prepare a slurry of this particular soil sample, which has got, for which we want to find out the grain size distribution by taking 50 grams of the soil and making it mixing it up with water to make slurry of approximately one, exactly one liter. And we are going to place it, place the slurry making sure that soils are not readily settling in a sedimentation jar.

We also actually mix it up with about 20 ml of sodium Hexametaphosphate solution, which acts as a dispersing agent, so that individual soil particles did not cling together forming clots, so that the settlement rate is wrongly measured, because the clots are going to settle at a faster rate than the individual fine grained soil particles. So, we mix up a slurry involving 50 grams of approximately 50 grams of soil and substantial amount of water to make a slurry of one liter and that includes about 20 ml of dispersing agent as I just mentioned.

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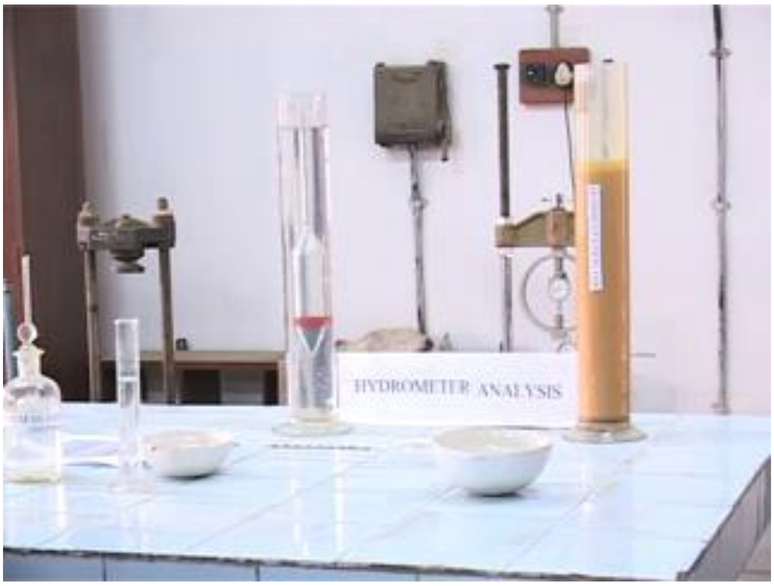

Then what we are going to do?

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We are going to, before soil starts settling, we are going to place a hydrometer like this into the slurry and find out what is the reading that we observe at a particular time on the stem of this hydrometer. And from that reading, we can get, we can calculate the reading to the specific gravity of the slurry at the center of the hydrometer bulb and from that we can find out what is the representation of a certain grain size within the soil sample using Stokes law of settling spheres. Approximating the soil particles as settling sphere, we have got theoretical solution available for that type of problem and from that one using that solution, Stroke solution, we find out what is the grain size distribution of the slurry.

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Now, you see that the hydrometer is being inserted very gently into the soil and what we are going to do? We want to make sure that the hydrometer does not bob up and down when the when it reached its equilibrium position. So, we have to be very careful with this thing and you can see the reading at the meniscus for this hydrometer position is about 1009 for the level for the water, for the level of the slurry that intersects the hydrometer stem.

And this reading is, you should note that this reading is going to change with time because the density of the slurry at this center, at the elevation of the center of the hydrometer bulb is continuously changing with more and more soil settling near the bottom of the sedimentation jar and the reading at a given time actually correlates to the percentage of a given soil sample, of a given size of soil that was there in that soil sample taken originally.

You should also note that the reading has to be corrected for the temperature at the date and time of testing because that is going to affect the specific gravity of the or the viscosity of the slurry which is required in application of Stoke solution to this particular problem.

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So, here we have got the demonstration for the experiment which we use for finding out the liquid limit of fine grain soils. This test is applicable for soils which has got grain sizes finer than 425 micron typically. So, if you have got in situ soil which has got some representation of coarser particles, the soil is washed to remove particles which are coarser than 425 micron and what we have here is a sample which is already screened through 425 micron and this is the sample.

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And what we are going to do? We are going to make a pat of this particular soil sample in this pan here.

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This is the casagrande apparatus which includes a hard rubber base, black hard rubber base and it has got a brass pan. This pan is of standard dimension and it has got a certain standard fall. So, it goes up; when it is cranked up using this particular handle, it goes up a standard amount of height and that height is given by this dimension here. This is the standard tool used for grooving. As you are going to see in the next little bit, it is called the grooving tool and this thickness at the end of the handle of the grooving tool is used for adjusting the height of fall of this particular pan.

And what we are going to do? We are going to prepare a pat and we are going to count the number of blows. We are going to, actually we are going to, open up a groove near the center of the pat as you are going to see in the next little bit and we are going to find out the number of blows required for the groove to close over a distance of about half an inch which is about 12.5 millimeter as you are going to see in the next little bit. And we are going to count, we are going to prepare a plot against the number of blows required for a given amount of moisture content within the sample versus the number of blows required for the closure of 12.5 millimeter.

You can imagine that as the soil becomes drier, you are going to require more and more blows for closing the groove and we are going to plot it up in a semi logarithmic scale. And we are going to find out what is the number of blows required for what is the moisture content required for 25 number of blows closing the groove by 12.5 millimeter. You are going to see that in the next little bit.

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So, now, you see now we are preparing the pat in the pan making sure that there is no air entrapment within the volume of soil and the surface of this particular pat should be approximately horizontal. And then we use the grooving tool, as you see here, to cut a groove at the center of the pat, of the clay pat or pat of fine grained soil, and this is the groove that we construct, that we have constructed here using the standard grooving tool.

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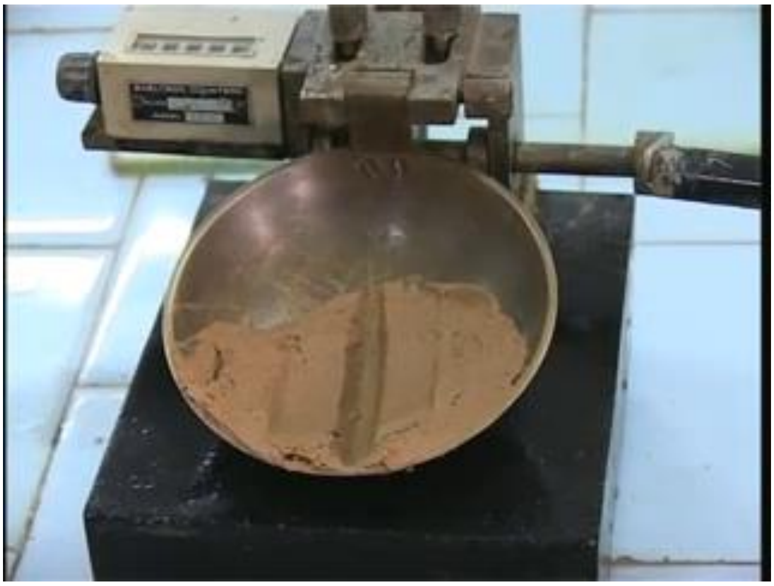

And then we are going to bounce it, bounce the pan up and down, bounce the pan up and down and count the number of blows that is required for the closure of the pat by an amount of 12.5 millimeter. You can see that the pat is gradually closing.

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And you see here the pat is closed by an amount of approximately 12.5 millimeter and closure is approximately counted from there to about there and the number of blows in this case is much larger than 25. And what we are going to do? We have to keep on adding a little bit of water to the sample until we get the groove to close by 12.5 millimeter exactly on the 25th blow. And for doing that, what do we do?

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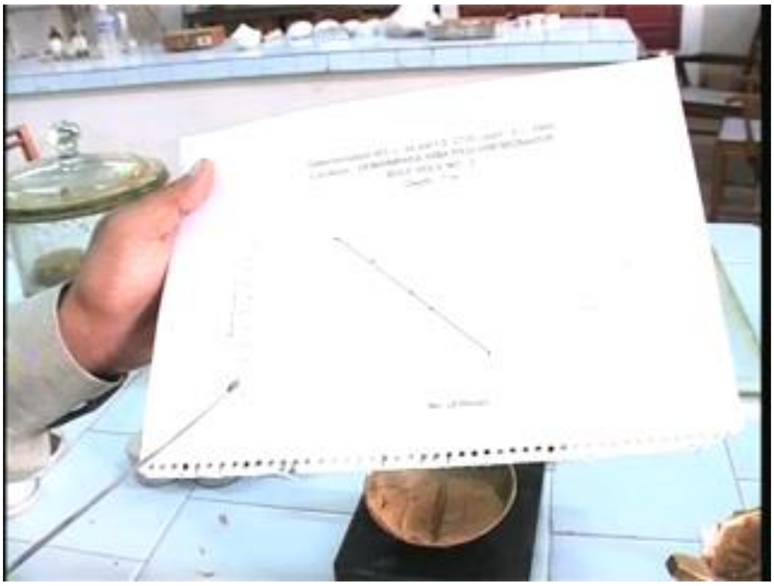

Actually, we are going to go on adding. We are going to add water and we are going to get. We are going to plot the number of blows required for the closure of 12.5 millimeter in this type of plot. This is called the flow curve where the number of blows are plotted on a logarithmic scale in the horizontal axis and the moisture content of the soil sample for that particular number of blows is plotted on the vertical axis like this one. So, from this pack, in fact, we are going to save some sample for finding out the moisture content that we are going to plot in the vertical axis, as I was mentioning.

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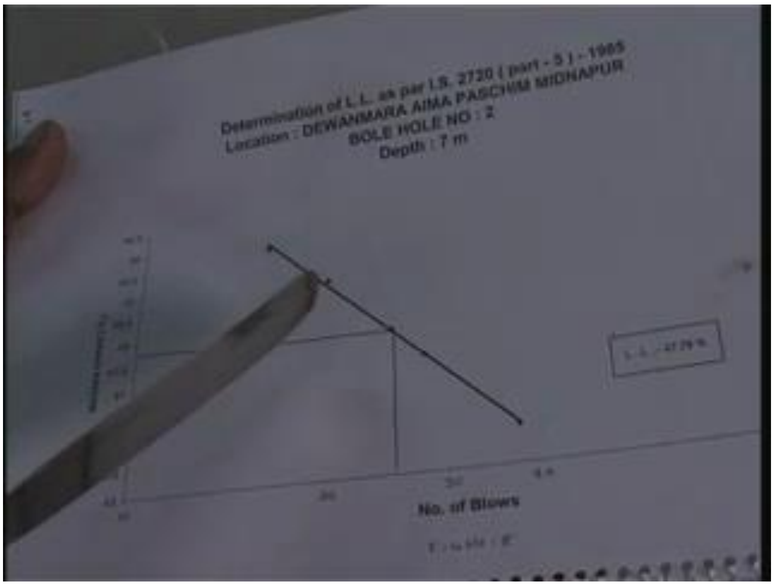

And then, we are going to prepare a plot like this and this is called a flow curve and you see that on the third, these are the data points; the data points are shown with the solid diamonds here. And for this particular sample you see that 25 number of blows was obtained at a moisture content of between of got 47.8 percent which is from this particular chart flow curve, and so the liquid limit of this particular sample becomes equal to 47.8 . So, that is how we get the liquid limit from Casagrande apparatus.

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So, here we have got the setup of determination of plastic limit. So, what we do here is more proved actually in comparison with the setup that we used, I should say. For liquid limit, it is probably a little bit more difficult because of the subjectivity involved in this one. So, here what we do? We take a sample of soil and we try to roll a thread which has got a diameter of 3 millimeter exactly; means if we can roll a thread with the sample of soil which has got 3 millimeter diameter, then we say that the soil is at plastic limit. And in fact, if the soil is at plastic limit, then it needs to just start cracking as soon as we reach 3 millimeter diameter, in fact, we will not be able to roll a thread which is finer than 3 millimeter size. So, how do you roll a thread? That is being demonstrated by my colleague here.

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And this is the pat of the soil that we that we have here and we just try to roll a thread by the procedure like that, and you can see that as the thread becomes finer and finer, it will have a greater likelihood of cracking. So, here we have got a thread which is probably about twice as thick as the standard 3 millimeter diameter piece of wire here.

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And let us see a little bit more of that rolling action here. What we want to see is when at what diameter it starts to crack. So, probably it can go a little bit finer still because it is yet to crack, and you can see that this could be actually rolled to 3 millimeter size and the sample did not crack. So, we need to have a little bit of drier sample and if it is a little bit slightly drier than that one, then we will not be able to roll a thread of 3 millimeter size. You will see that in the next little bit.

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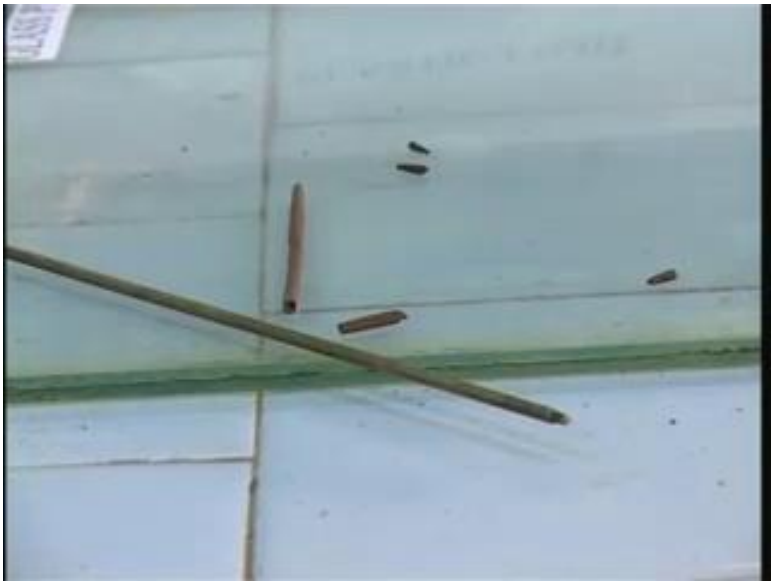

And you see here that the sample has been dried up and it started to crack. The thread has started to crack as soon as it has reached about 3 millimeter diameter and the cracks are starting to appear on the thread, as you can see from the from the thread that my colleague was rolling that I am holding now in my hand.

So, this moisture content is barely allowing us to, the moisture content of this specimen is barely allowing us to a roll a thread of 3 millimeter diameter as soon as we try to go finer starting to crumble. So, the moisture, this moisture content, moisture content of this piece of thread is going to be the plastic limit.

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We are going to save enough of such sample in moisture content pans like this one and we are going to find out what is the representative value of moisture content from a large amount of soil by rolling several different threads because that is going to allow us to minimize the amount of error in the experiment because if we just take this much of sample, then the amount of soil is going to be very much less. So, the amount of error is going to be large. So, we take, we roll several different threads and we try to determine the moisture content based on the several different threads like this one. So, that is it.

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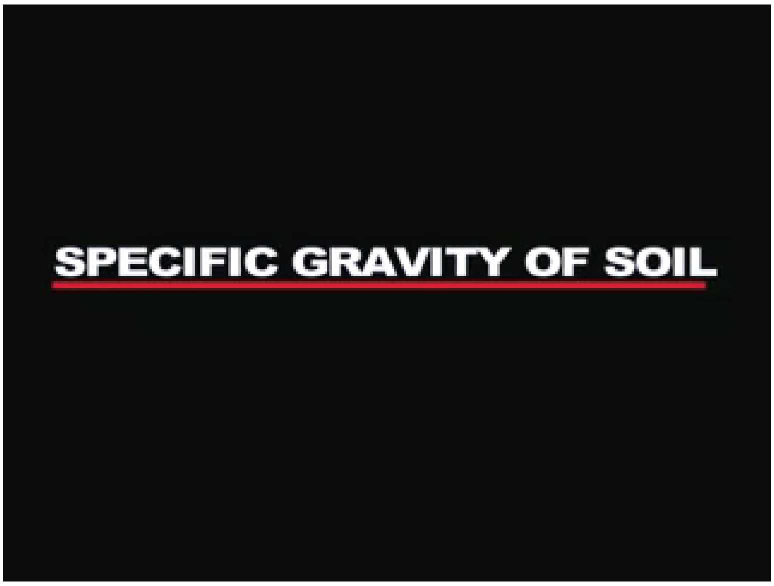

So, here we have got the setup for finding out the specific gravity of soil solids. So, this is the sample that we take in this particular experiment. So, what we do with this one is the procedure involves taking about, actually comparing the weight of some known volume of distilled water.

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In fact, this particular flask is calibrated to be of 250 milliliter of volume at 27 degree Celsius and you can see that there is a mark on the stem of this particular flask and we are going to take distilled water exactly up to that mark. We are going to find out what is the weight of the flask plus distilled water and then we are going to take the distilled water out of there. We are going to take a representative amount of soil in the flask and then we are going to top it off with distilled water upto the mark that we saw there on the stem of this flask. We are going to keep it under suction to deair the water so that there is no bubble of air included in between individual grains of the soil because that is going to introduce some error in the reading. By comparing the weight of the distilled water and the weight of distilled water plus soil, we can calculate what is the specific gravity of the soil. So, that is how we obtain this specific gravity of soil solids.

And as you have seen that this particular property is required in finding out several different index properties such as the total unit weight of soil and void ratio of the soil, and in fact for saturated soil, that is also required for finding out the, for relating the moisture content and the void ratio. So, that is about the specific gravity.

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So, here you see that the soil is kept under a vacuum pump kept under vacuum here and that is being shaken by my colleague here, so that the water, so that the mixture does not have any intrusion of air because that might actually, as I was mentioning that might, introduce some error in the estimated specific gravity of solids..

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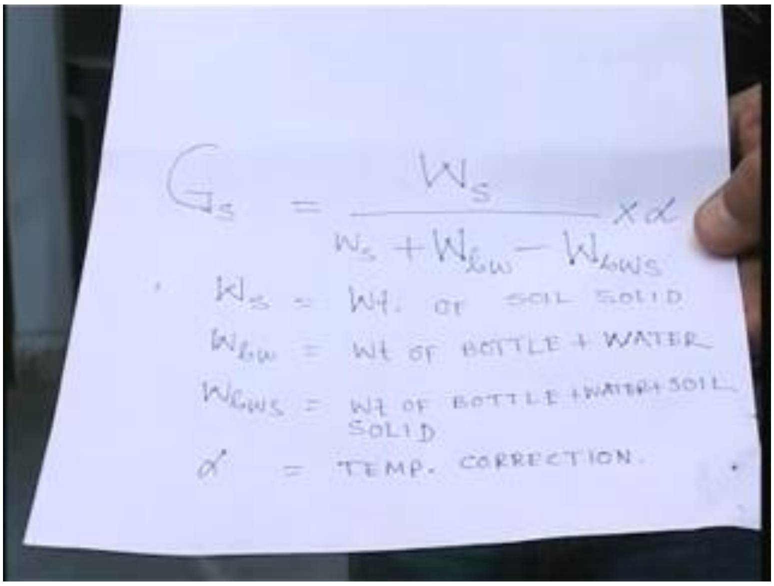

This equation, this is the equation that we use for finding out the specific gravity of soil solids and which is given by w subscript s divided by w subscript s plus w subscript bw minus w subscript bws multiplied a quantity alpha. So, the explanation of these different symbols are also there at the bottom. w subscript s means the weight of soil solid taken in the flask. w subscript bw means weight of bottle or the flask that we had there plus water and w subscript bws is weight of bottle plus water plus soil solid and alpha as I was saying is temperature correction.

There are standard charts available to standard charts available for alpha because if you recall from your under graduate, other under graduate courses, the volume of water expands with temperature increase, change in temperature, and alpha is a factor that accounts for that volume expansion.

Thank you.

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So, this is the demonstration of actually undrained unconsolidated triaxial test. So, what we have here is a loading frame.

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And we have already mounted the triaxial cell on the loading frame. What we do here is we apply a displacement in the axial direction and you can see that inside actually. So, this is the demonstration of un consolidated undrained triaxial test. What you see here is a triaxial cell and the triaxial cell is essentially a flexi glass cylinder which is in between, sandwiched in between the top cap and the bottom cap and it is filled with water as you can see here. And inside the triaxial cell also is a cylindrical soil sample which is wrapped up in the white membrane. In order to seal it off from the water which is there in the triaxial cell is a couple of orings and you can see one oring, dark oring at the at the bottom and the top oring is actually covered by the membrane here in this particular case. And you have there is a brass cap through which the load or displacement is applied axially to the sample and there is a bottom plating also which is covered in this particular case by the membrane.

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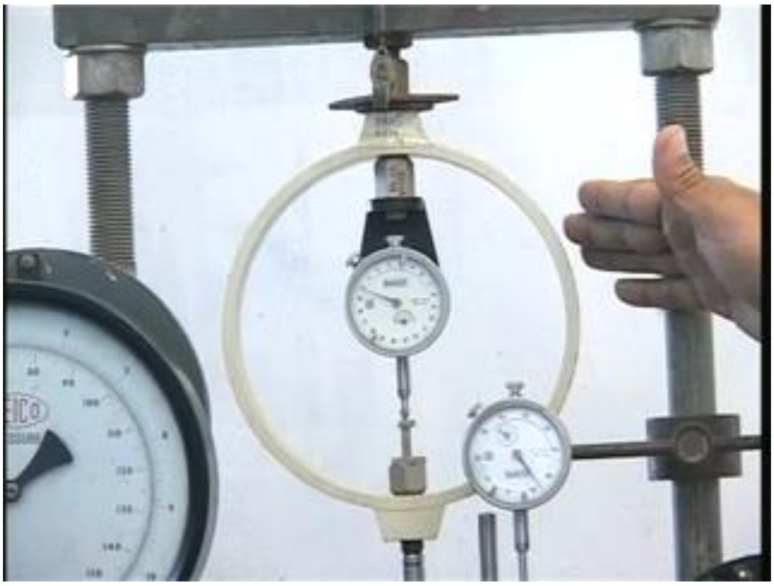

Now, we need to measure the axial stress on the triaxial sample for which we make use of a proving ring here and that is calibrated in such a manner that from the reading on this particular dial gauge, we can find out what is the stress, actual stress on the triaxial sample. Then we have got the displacement. We make use of this particular dial gauge for finding out what is the axial displacement of this particular triaxial set up.

We also have got another connection from the bottom of the cell and that connects to a pressure gauge. As you can see here, this allows us to keep track of the pressure that is there in the water inside the triaxial cell and we can pressurize the water to our required level using a compressor, which is further to the left of this particular set up.

So, you see now that we are going to connect the pressure, connect the compressor, compressed air, connect compressed air to the triaxial cell and then we have applied here a load of about 10 pound per square inch which you can see from the pressure gauge. We are going to see that the axial displacement is going to start climbing and that is being measured on this particular dial gauge and the load also is increasing, as you can see from the movement of the proving ring dial gauge there. But the cell pressure in this particular case is kept constant as you can see here. There is no movement on the pressure gauge and we are going to continue this test until we see no further increase in the proving ring dial gauge.

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You can see that the loading range here is gradually decreasing. In other words, it is taking more and more movement to mobilize a certain amount of soil reaction. It is virtually stand still; it is not increasing any more. So, we are going to terminate the test here and you can see the deformed pattern from the bulging out as I was mentioning before of the sample.

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The way the data are analyzed is by calculating what is the axial stress the sample is being subjected to and plotting the axial stress versus the axial strength which is the changing length of the sample in the axial direction divided by the original length of the sample.

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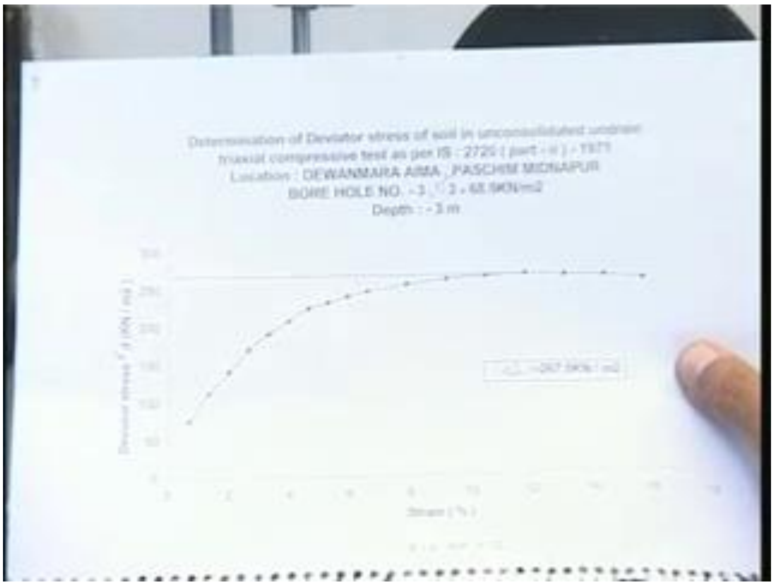

We prepare a plot of this type which is a plot of the axial stress minus the cell pressure that gives us the deviated stress, in this particular case, versus the axial strain. And as I was mentioning before we read the streak of this particular plot and that is, that gives us an estimate of that. From that, we can get an estimate of the undrained shear strength of the sample.

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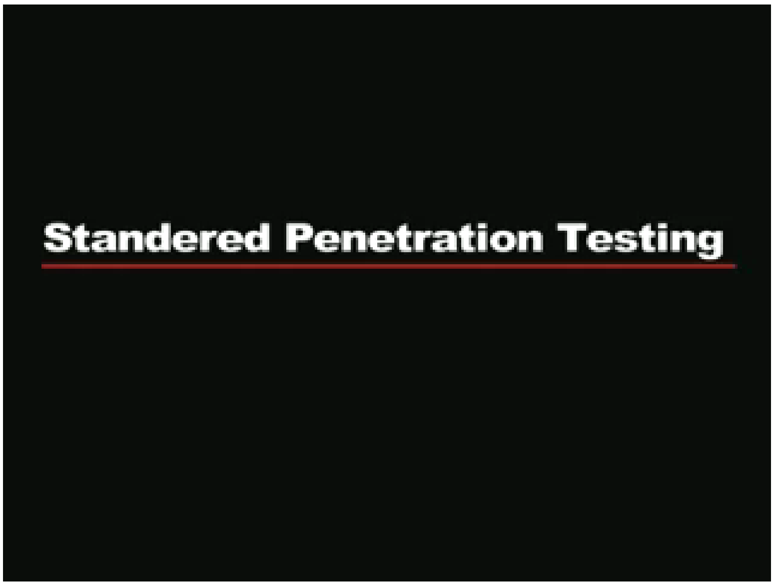

So, here you have got the demonstration on standard penetration testing. If you recall, I told you in the class that we drive a split spoon sampler into the ground using a standard spt hammer. So, this is the split spoon sampler which is of dimension which I have already mentioned and we are going to disassemble the sampler in order to illustrate what are the internal parts.

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So, this is the cutting shoe which comes of like that and then the socket which connects the sampler to the spt rod. That also comes from the other side and then the portion in between splits into two different parts as you are going to see in the next little bit. You need a rod to do that and this is the two portions which split up like this one.

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And then we assemble the stuff to and then then drive it into the ground to retrieve the soil sample. Now we can reassemble the stuff. So, this is how the sampler is assembled.

And what we are going to do? We are going to drill a hole in the ground and we just lower the sampler to the depth like this and drive it, connect it to the hammer, spt hammer with the standard rods and drive the setter, drive the assembly with standard spt hammer as you are going to see in the next little bit.

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So, now, we have got the setup into the ground and what we have got here is a standard spt hammer mounted on the spt rod.

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This is a hammer called donut hammer. This hammer has got a weight of 65kg. It is going to fall through 750 millimeters onto the hand wheel here which is underneath the hammer, which may not be visible from where the camera is.

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And what you have, what you also see is that we have got three markings at 150 millimeter spacing. One at the top of the hole, then 150 millimeter above, next one 300 millimeter above, and the third one at 450 millimeter above the top of the hole. So, what we are going to measure? We are going to measure the number of blows required for the penetration of this length from here to here; then the number of blows required for penetration from here to here, and finally, the number of blows required for penetration from here to here.

So, now you just be with us and we are going to take help from two f my colleagues who are going to lift the hammer up to 750 millimeter markings which is also marked on the rod and they are going to drop it on the hand wheel and that is going to drive the sampler into the ground and we are going to count the blows as you are going to see in the next little bit.

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So, you see that the first 150 millimeter penetration is completed with only one blow; the soil is quit soft here. Then we are going to go with the next penetration of 150 millimeter.

So, that one also basically is penetrated for with one blow only.

Yes

So, this one did not get penetrated in one blow. So, we are going to perhaps need a few more blows. Let us see how many.

Yes.

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So, that is it. So, the number of blows if you recall, we required only one blow for the penetration of first 150 millimeter. Then we required one blow for the penetration of next 150 millimeter, and finally, we required two blow two blows for penetration of the final 150 millimeter. So, in this particular case, the spt, raw spt blow count is going to be recorded as the total number of blows required for the penetration of the second and the third 150 millimeter blow count, 150 millimeter penetration, which is 3. So, in this particular case the uncorrected spt blow count is 3. So, that is the demonstration of the standard penetration testing and we are going to move on to the next demonstration now.

Now, we have got the soil sample from out from the ground and we are going to disassemble the sampler, and we are going to see how the sampler looks, how the soil sample looks. So, this is the soil sample that we got from down there.

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This particular sample is visually identified in the field and it is also saved. Some of the samples is also going to be saved for moisture content determination. So, if you recall this is the bottom end of the sample and that is the top end of the sample.

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And you can see that the sample was moist near the top and it was becoming dry as we went downward. So, this has got a lot of sand and silt and other fine grain soils. It has got some cohesion as well and that is how we identify the sample and this is the sample which is near the bottom end of the sample.

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So, this sample is saved for grain size distribution and finding out the natural moisture content of the specimen. That is it.

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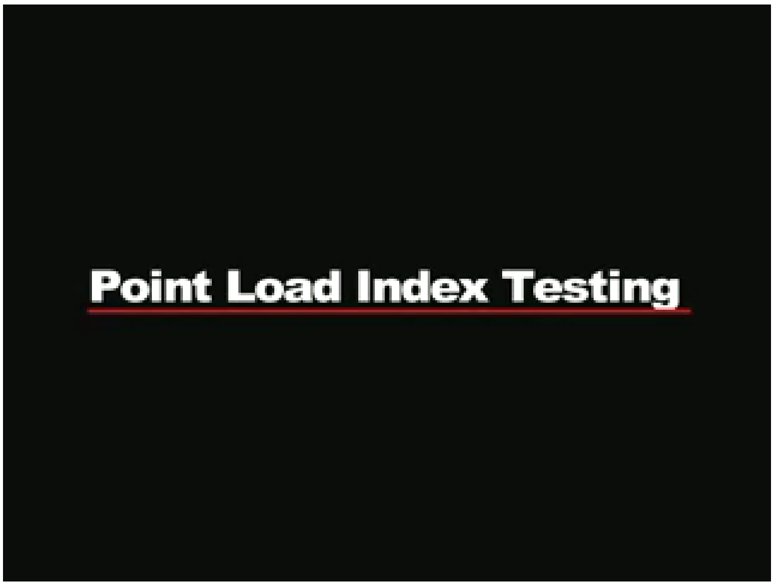

Then, we are now into the demonstration of point load index testing. In this particular test, if you recall from our earlier laboratory, earlier classroom lesson we have we basically do we try to break a core sample in between two points by applying a compressive load through the points. We are going to see that in the next little bit how and from the load at which the sample fails we have got a correlation between that load and the unconfined compressive strength. Now, basically the calculation, if you recall, that is involved in this particular case.

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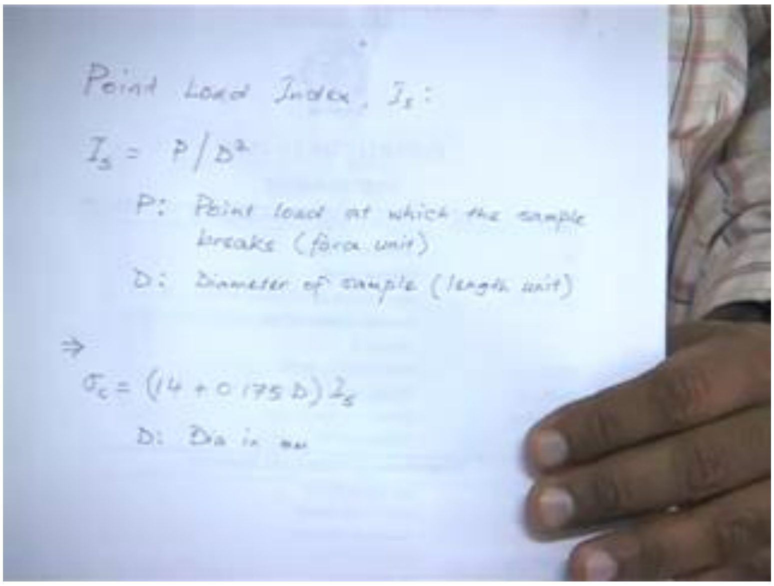

The calculation to jog your memory involved in this particular case first requires calculation of the point load index i subscript s given simply by p over d square, where p is the point load at which the sample fails. That is going be recorded in force units although in the next little bit we will see that we are going to read that thing of a pressure gauge. So, we have to multiply the pressure recorded by the diameter of the ram of the hydraulic cylinder to get the value of p and then d is the diameter of the sample and this one here is in length unit.

Finally, from the point load index, we calculate the uniaxial compressive stress sigma subscript c using the formula at the bottom near the bottom of this particular handwritten note which is 14 plus 0.175 times the diameter of the sample multiplied by the point load index, where d is taken in millimeter.

We are going to get into the testing now. These are the core samples that we are going to test today in the point load index testing machine. Now, both of them are basically sandstone samples.

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If you look at this particular sample carefully from the knowledge that you have got on rock samples, you will see that this is a fairly coarse grained, grey colored sandstone and this one here on my in my right hand is a relatively finer grained sample which has got a few quartz grains. What is also to be noted here is that the samples that we have chosen has got a length of at least 1.5 times the diameter of the specimen; that is one of the requirements of point load testing.

So, if you recall, if you recall, the point load index is basically point load divided by square of the diameter of the samples. So, we need to find out what is the diameter. Although both of these samples were obtained from a drilling investigation, using (( )) bit. So, we know roughly the diameter of the sample will be about, will be a 55 millimeter. But we need to we need to take a careful measurement of the diameter. So, for that what we are going to do?

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We are going to use this pair of calipers here and try to determine the diameter. So, here, what we got? The main scale reading of the calipers is 53 millimeter for this sample and then the fractional reading I am getting is 0.36.

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So, the sample diameter in this particular case is 53.36. I want to take a few more readings. So, here I am getting a value in this direction. In other orthogonal direction, I am getting a value, different value. Here it is 53.26. So, by taking such measurement in at least four orthogonal directions, whatever average diameter you get, you need to use that average diameter in your point load index calculation.

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So, here again we are getting a readings of roughly 53.26 millimeter. all right. So, let us say, let us say the diameter of this sample is about 53.3 millimeter and we are going to use that 53.3 millimeter in our point load index calculation. So, this one, this sample here is 53.3.

Let us measure the diameter of the other one. Notice that this sample was also obtained using the same, the same, actually same bit. Here, what we are getting? The diameter is likely larger, in fact, than 55 millimeter, getting 55.08 and other direction again I am getting 55.1.

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So, this sample, although it was obtained using the same reading, similar very similar reading, that similar reading equipment, the diameter is slightly larger than the one on my left hand and that is because of the durability of this sample. This, the sample that I am holding in my left hand is slightly more friable and slightly less durable than the one that I am holding on my right hand here. all right. Now, let us do the testing.

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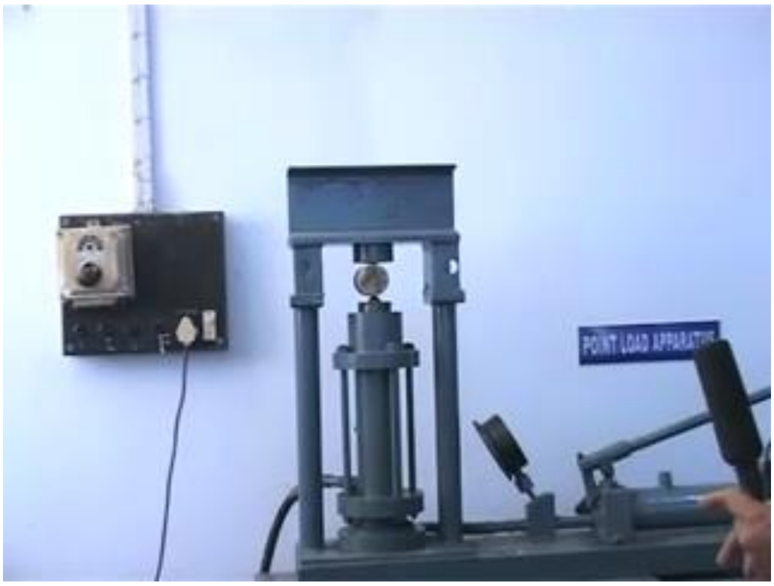

The sample is in between two points. You just observe the sample. It is going to crack once the point load reaches the failure value; the sample failed and the reading was roughly about 14; 14 kg per square kg per square centimeter at which the sample failed.

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So, this is the face where the sample broke and we are going to record the point load, actually the pressure which is 14.7 kg per square centimeter at which the sample failed. So, I am recording it here.

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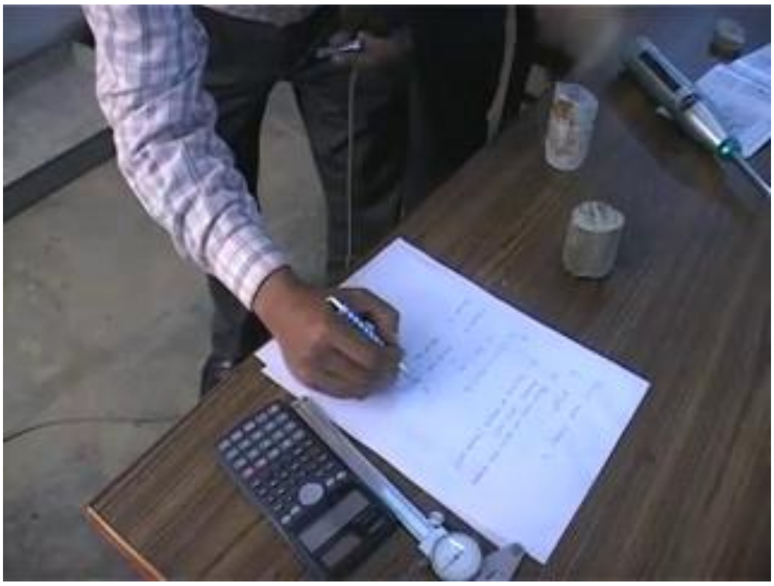

So, this is 14 kg per square centimeter. I am going to actually use it in the calculator. I am going to show the calculation as well later on. Now, what we are going to do? We are going to test the second sample.

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We have got the second sample and now we are trying to note the point load. You just look at the dial gauge reading. It is going to start mounting and when the sample fails, it is going to suddenly drop.

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It actually did not even go upto the extent of the previous sample. So, here, we got a reading of approximately is 8 kpa; 8 kg per square centimeter.

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This is the instrument that we are going to use for nondestructive testing of a rock mass. It is very simple index really. So, what happens here is that we are going to push the instrument in and we have to make sure that this particular knob is stressed when the rebound occurs in order to measure the rebound value and the reading is going to appear on this particular scale here.

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And we did the testing on the floor.

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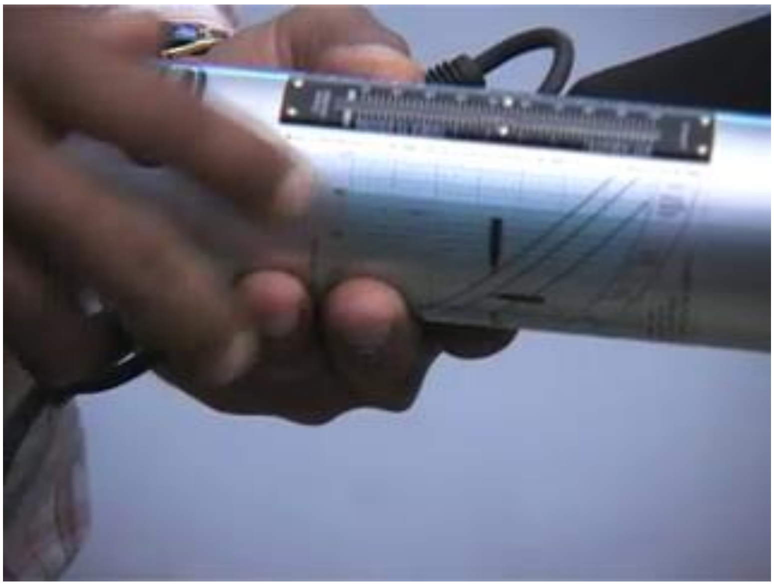

So, the strength, the strength here index is 52. The value of the value is 52.

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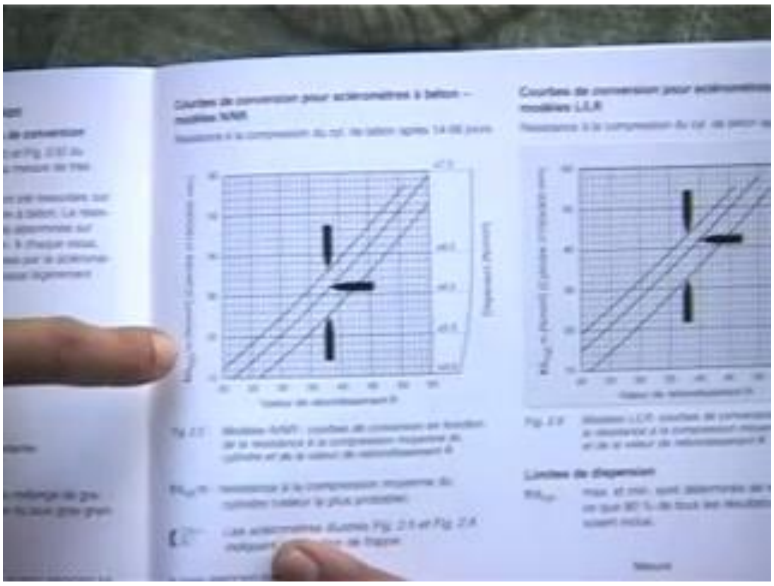

And then this value gets converted from a standard chart which is also given by the manufacturer. You have to read off the value of the ucs from looking at the appropriate curve.

For example, this curve the one at the top this curve is appropriate for the configuration of the testing that we did in this particular case. And here we had a demand value of 52 and 52 comes roughly about here and that translates to a uniaxial compressive stress of about 56 mva for this instrument. So, that is a nondestructive testing in which we do not have to bring in a sample and subject it to a set of deformation process which destroys the sample. So, this is, this type of testing is called nondestructive testing.