Soil Mechanics/Geotechnical Engineering I

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Lecture - 09
Permeability and Seepage (Contd.)

Once again welcome you to this lectures session, and we are in permeability and seepage topic, but perhaps it will be beneficial, and maybe advantageous to you, if I can show the application simultaneously, whatever immediately after covering the topic. In the second week lecture initial portion were like three phase diagram, and void volume relationship, I have shown the application immediately.

However, for first lectures, say first week lecture, whatever I have covered in classification and other topics I have not taken any problem or application. So, before going to the seepage and permeability topic, I want to take two application that be solving problem related to soil classification and other index properties. So, for that after covering this two problems, I will take resume to seepage and permeability topic.

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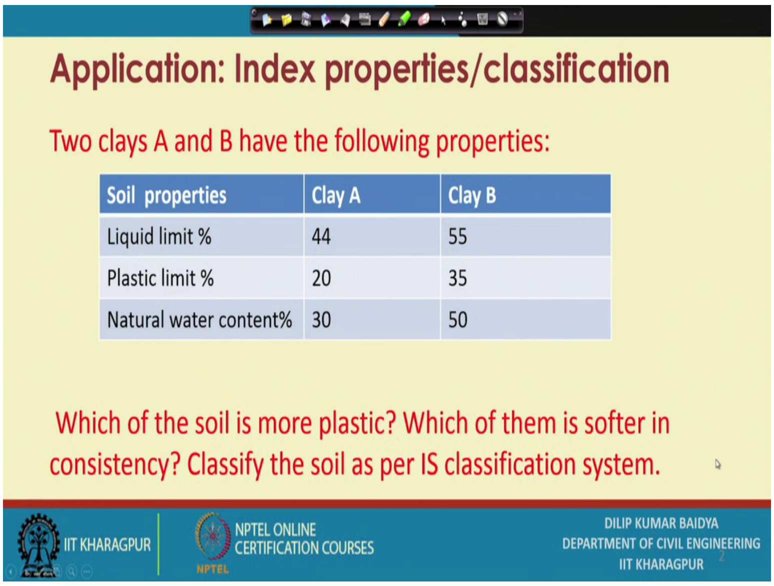

So, let us see the first problem. First problem described like this two clays A and B have the following properties, of soil properties liquid limit plastic limit natural water content and clay A and clay B. Clay A having little limit 40 percent 44 percent, plastic limit 20 percent, natural water content 30 percent, and clay B is having water con liquid limit 55 percent, plastic limit 35 percent, natural water content 50 percent. Which of the soil is more plastic, which of the, which of them is softer in consistency and classification as per I S classification system

So, for these actually as I have told you before, I have discussed before in the first week that classification soil A.

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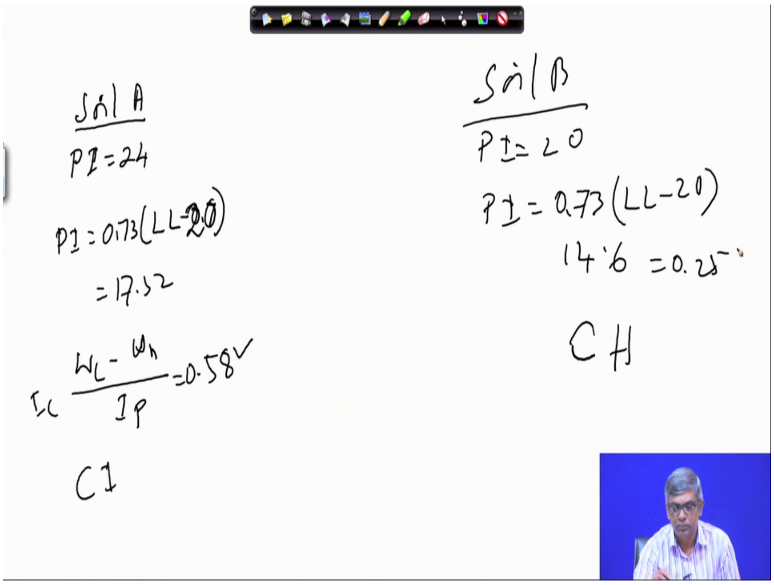

If I consider soil A you can see PI become, soil A, it is having PI equal to difference between liquid limit and plastic limit, and that is actually 24. And we know that, we have a on the plasticity chart, there is a equation that is PI equal to 0.73 liquid limit minus zero point liquid limit minus actually 20, liquid limit minus 20 actually. Now if I put this liquid limit actually equal to whatever value is given, and then if I calculate, then I will see that your PI comes 17.52. So, this means this clay is actually lying the above A line, and if the above A line the soil comes above A line, then the soil actually, that is actually your clay soil. And now the clay soil can have different consistency, whether it is soft or medium or plastic medium, medium plastic and highly plastic, and for that we see the water contain range.

Here actually water content between. Actually your, it was. Water content was actually 44 and 20. So, that is, actually liquid limit is between 44; that means, it is between 35 and 50. So; that means, it is intermediate, intermediate plastic. And your consistency, actually the expression was Wl minus Wn and divided by IP, and if I put that is Ic.

If I do based on this calculation, then it comes 0.58, and I will come back to the table which I have given. Similarly soil B will have equal PI to 20, and from PI equation; that is 0.73 liquid limit minus 20. From this calculation and it comes actually your 14.6. So; that means, this soil also above A line that will it is also clay, but from the range of liquid limit, I can decide whether it is, your highly plastic, medium plastic and low plastic, but you can see here water content liquid limit actually it is 55. Since it is more than 50, it is highly plastic

That means soil B is clay of high plasticity; that means, CH, and clay A is that is, this is CH and clay A actually this is actually is clay of intermediate plasticity. And this is Ic gave for this is 0.5, and for this Ic gave actually equal to 0.25 and if I go back to

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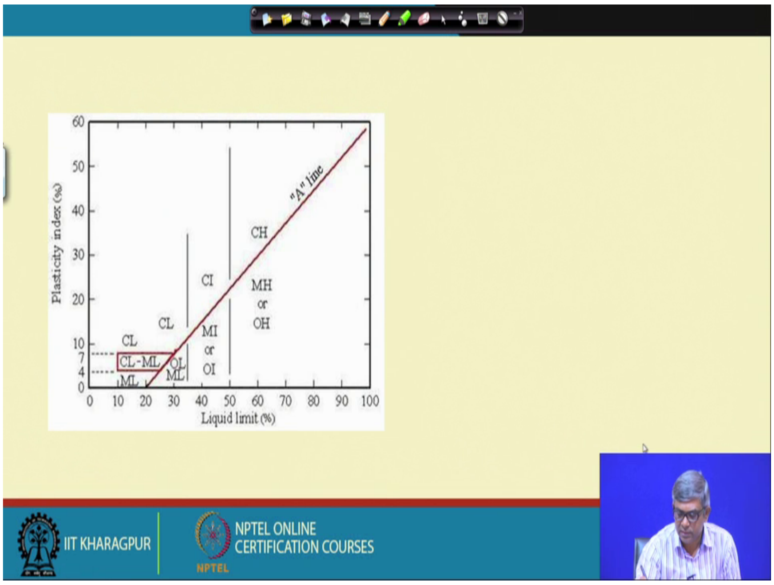

. This is the plasticity chart actually, whatever value I have got 17.52 and 14.62 if I put, one will come here, another will come. One will come here, another is coming here. So, this come, this one actually b soil is CH; that is clay of high plasticity and A is coming here, clay of intermediate plasticity. This is the classification chart, and now if you want to, that consistency if I want to see, then I can show you that next table.

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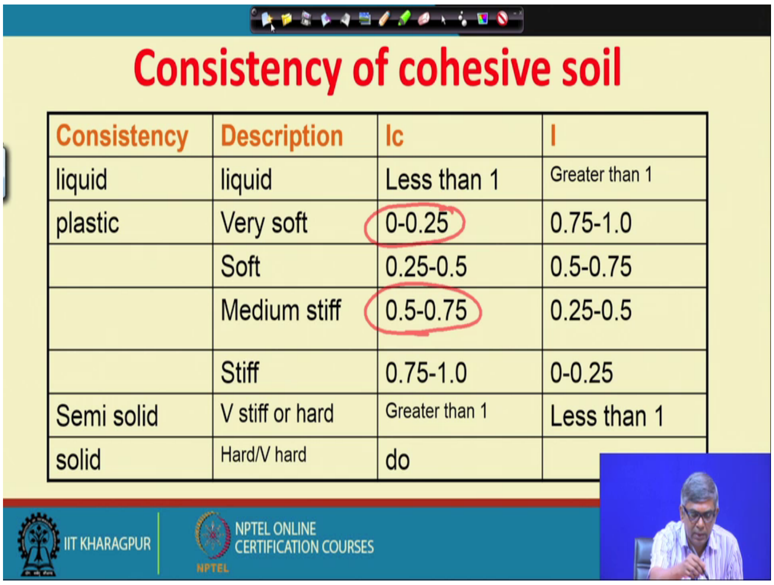

This is the table actually you can see, when I have got the value 0.58 for soil A, that 58 means, it is the this range. So, this is the range actually; that means, 5 8 for soil A. So; that means, this soil is medium stiff. Consistency is medium, medium stiff. And soil B is having 0.25, soil 0.25; that means, this one

So, this is actually consistency is very soft. So; that means, soil A is medium stiff, and soil B is very soft; that is a one thing. And classification wise, soil A is clay of intermediate plasticity, and soil B is clay of a high plasticity. So, these are actually the classification when you design that is plasticity chart.

And plasticity chart is not there then also I can find out the way I have shown the previous slide; that is you calculate a line PI equal to 0.73 into liquid limit minus 20. From that equation it is giving you line on the on the equation, but if the value is above that equation line; that means, this clay below line means, it is sealed. And again for range of liquid limit I can decide which intermediate and plastic, high plastic, medium plastic or low plastic. So, these are the things we can do it. Now we can go to

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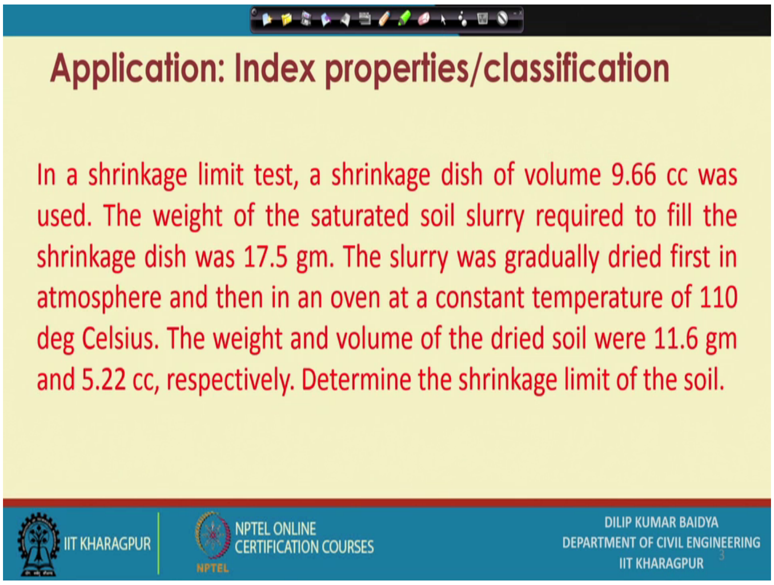

Then now we can go to next application. This is the one actually another problem was there, that in a shrinkage limit test a shrinkage dish of volume 9.66 cc was used. The weight of the saturated soil slurry, required to fill the shrinkage dish was 17.5 gram, and the slurry was gradually dried first in atmosphere, and then in an oven at a constant temperature of 110 degree Celsius. The weight and volume of the dried soil were 11.6 gram and 5.22 cc respectively. So, determine the shrinkage limit. So, this application actually we can do, the way I have defined the liquid limit, shrinkage limit, let me come to that first. You can see suppose.

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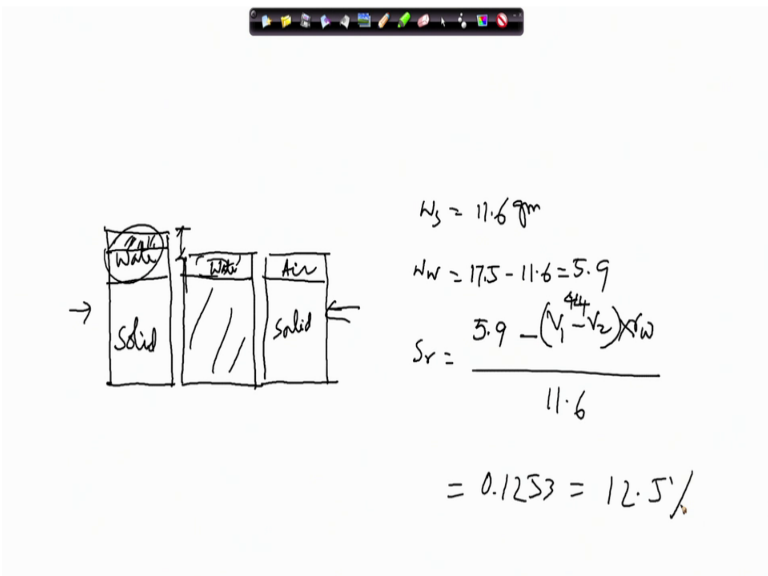

This is the one, we have the soil mass, and suppose initially this was solid, and this was water, and when water is removed in the mixer, then the volume generally reduced. And suppose as at some situation; that is lowest volume or maximum volume saturated condition, suppose this one. Then you have this is solid and this is water. And now the, and the dry condition, if I do then this is the one, this is solid and this is air

Now, actually by definition, the shrinkage limit is the actually water content at which the soil minimum value is this to minimum value, and at keeping it saturation. So; that means, this is the water we have to find out. To find out this water what you have to do. I can find out weight of this minus weight of this, then I get the this weight of this soil. Now if I subtract weight of this much soil, weight of this much water. Weight of this minus weight of this I will get weight of water of this volume.

Now if I can subtract weight of this volume; that is from here to here, then I will get the weight of water of this value. So, how to do that? You can see Ws dry weight was given 11.6 gram. And then your weight of water, if I, original weight minus final weight if I give do, then 17.5 minus 11.6, it gives you 5.9. And now your definition of Sr will be equal to, your that. This is 5.9, original 5.9 minus how to find out this volume. So, you can find out the weight of water of this volume, how to find out that. I can find out this V 1 minus V 2; that is V 1 minus V 2. This is the volume reduced, and for this much volume, what is the weight of water if I multiply it by gamma w.

So, this two volume, the two volumes also given that is actually V 1 minus V 2 actually 4.44. So, 4.44. So, if I do that, this is 4.44, and if I do all calculation by 11.6, and then I can get this calculation. And finally, it will get around 0.1253; that means, 12.5 percent. So, shrinkage limit of this soil is 12.5 percent; that means what I have to, what is the definition of this.

This is very carefully you have one has to understand that when you will be drying, soil will be reduce in volume, but there is a minimum value it reached, and it will be saturated; that is the condition you have to find out the water content, and that water content is the shrinkage limit. So, that means, this is the volume minimum volume, and this is also saturated, this much water is filled up. And another condition this is the minimum volume, but there is no water. So, I have to find out, for this corresponding to this volume what is the water present in the soil. So, that this is the step in calculation you have to remember.

Now I will resume the, your seepage and permeability topic. Let me go to that seepage and permeability.

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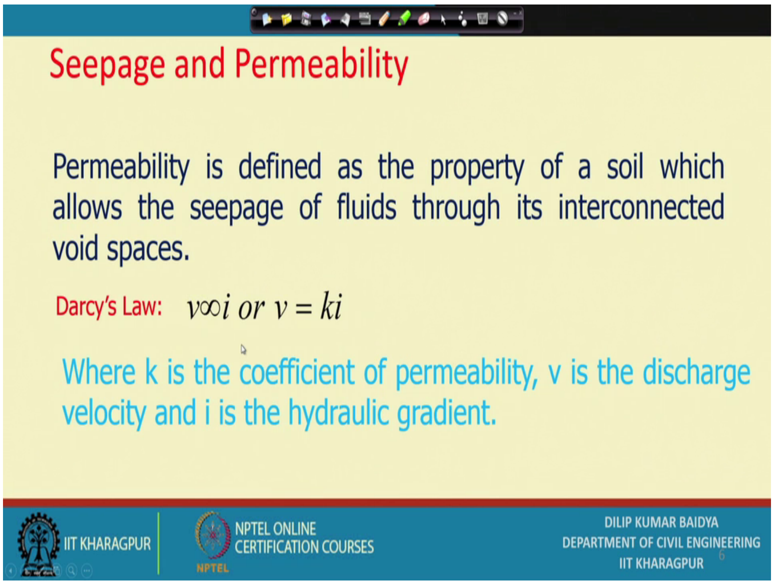

So, definition of permeability, the permeability is defined as the property of soil, which allows the seepage of fluids through this interconnected void spaces, and this is actually as per Darcy's law v proportion i, proportional to i or v equal to, if i take is equal, then this constant it will be introduced that is k into i, and that k is actually is the coefficient of permeability. Now this coefficient, where k is the coefficient of permeability, and v is the discharge velocity, and i is the hydraulic gradient.

Why hydraulic gradient actually the seepage or flow of water is only take place, when there is a change in water level among that is a hydraulic gradient; that is a water this side is something, water is this side is something, and there is a soil barrier. Then definitely, because of this change of water head, that flow, tendency of flow of water will be from higher head to lower head. So, higher is the i greater is the flow. So, that is what the i is the v is the proportional to i.

So, this is the thing, initial formula given by theory, given by Darcys there are many assumption. I am not coming at this point now.

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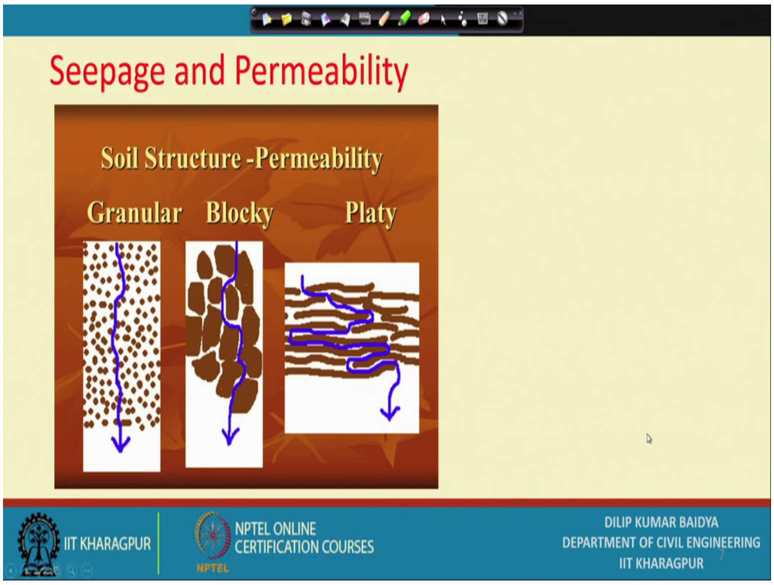

Next is your (Refer Time: 14:20) with flow actually take place through water, sorry solid. In the soil grain actually that there will be different types of grains, and this grains actually, if this is a typically this one if the granular soil then the path will be like this, where if it is a bigger block type, bigger particles then the path will be like this. And if it is a clay particles which is shown is a very enlarged way, but if you, microscopically if you see the particles will be like that, in that case the actual travel path, the water is coming from here to here, but actual traffic travel path maybe much longer. So, because of that, the seepage velocity here will be something, here will be something, here will be something. So, those things actually have to see, what are the parameters on which permeability depend on. So, we will see one by one. Let me go to next slide.

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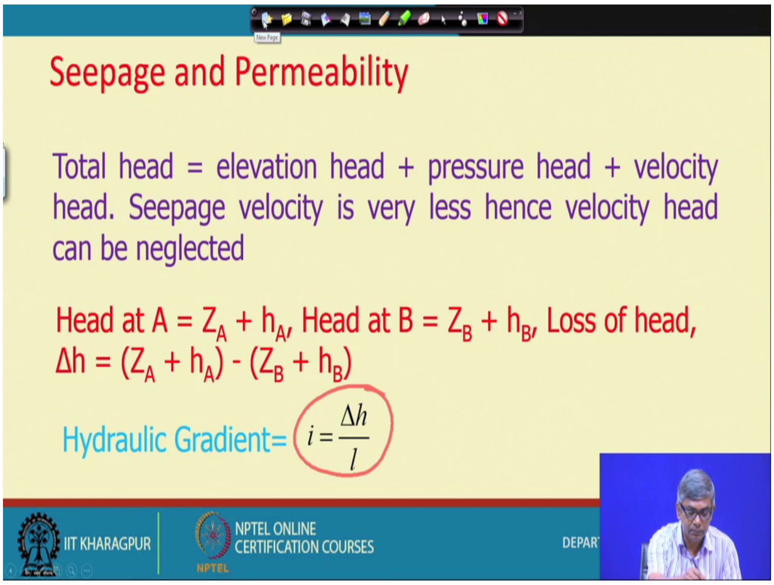

Seepage and permeability that is the, that is actually as I have told that that head cause the flow, and at any point actually one can calculate the total head equal to elevation head plus pressure head plus velocity head. And this, since seepage velocity; that means, when water is flowing through soil, the velocity is quite low, and because of that V square by 2 g, which is equal to head generally that can be ignored. And in that case if I ignore that, then head at, if I consider two different points, then headed at a point will be the datum head plus h A; that means, water head or pressure head.

Similarly head B will be ZB plus water head there. And loss of head will be difference between these two, and that is a thing can be expressed like this. And this is the loss of head, and over what length if I do that calculate this much head loss over this much length that will give you the hydraulic gradient.

And this is the figure actually I will show next. So, hydraulic gradient is here; that is what whatever I have said hydraulic gradient equal to I equal to v your delta h; that is head loss; that is delta h by l for length l.

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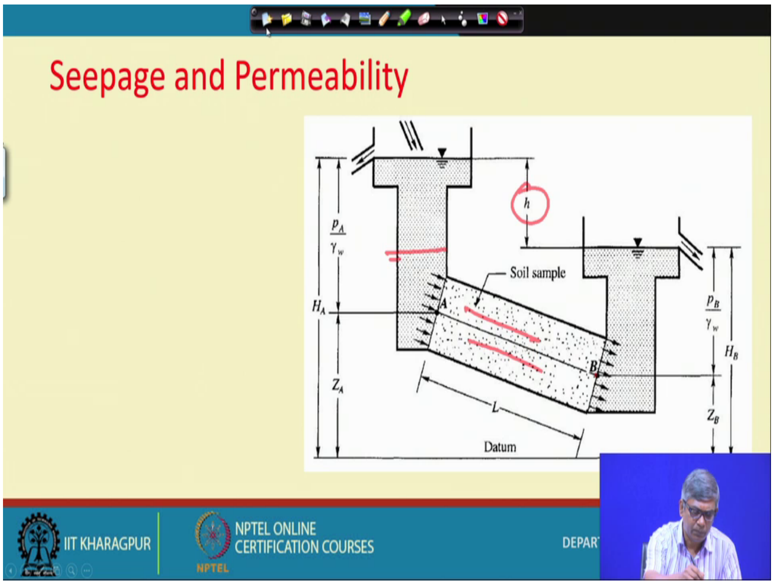

Now, let me go to next. So, this is the how to calculate the head that this figure is shown here. Suppose this is the soil mass, this is soil mass through which water taking place, flow is taking place. And if total head at this point, and total head at this point. If I lower this one lower this tank at this height equal to this, then there will be not any flow between this through this.

So, this XY here actually head is something, and this is up to the this is called datum head, and then this is pressure head, and this here actually this is the datum head, because meet point, and then this is the pressure head. This two is total head here, total head here. This difference of these two is shown as h. This h actually head difference, and to cause this head difference on, what is the length is traveling, this is l through l. So, hydraulic gradient will be due this by that.

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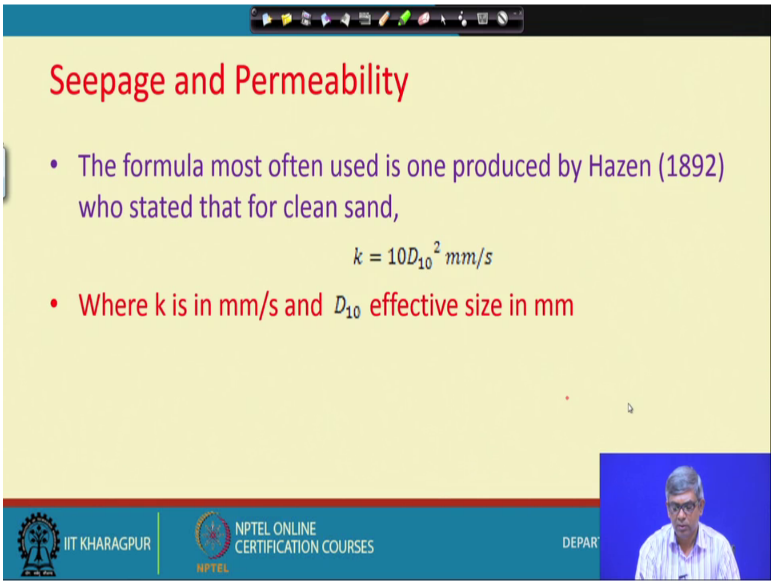

And now permeability value, just qualitatively you have told that over flow of water through this, but what is the value for different soil.

So, over the time people attempted to find out the value, and Kozeny has given one relationship; that is also empirical k equal to 10 into D 10 square, and D 10 is the effective size; that is diameter at his percent 10 percent finer. And that, since it is a empirical equation that value everything depends on the, what unit we are using here actually k is expressed in a millimeter per second D 10 also in millimeter and. So, if I put the size in millimeter, and then put this equation, whatever value we will get, we will be to get the permeability of soil in millimeter per second. And now this is actually for exam, for say, for a particular soil only applicable, but soil, different types of soil are there. So, you have to find out a permeability for different soil and.

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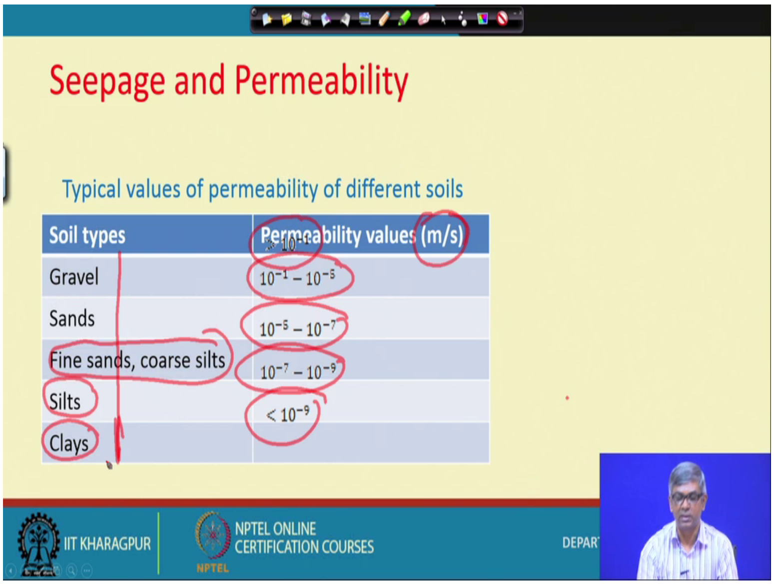

So, for that actually you can see, we have a. There is a difference, there are number of difference available, where we can find out those values. We are little disturbed, actually this table. I do not know, but anyway one shifting was happened.

So, it is given actually as, when you become a civil engineer or particularly become a geotechnical engineer. So, you have to understand the soil very well. So, particularly if I know the soil type, then I can assess, what will be the range of permeability values for that soil, or if I know the soil type and I am getting some value. Someone is reported some value if they are not matches actually.

Then as engineer actually I have to give justification of whether this value is reasonable or not. So, for that there is a guideline actually. If it is gravel actually value should be less than, greater than 10 to the power minus 1, which will be in meter per second unit, it is a meter per second unit. And when it is gravel, it is greater than 10 to the power minus 1; that is 0.1 meter per second.

And when it is sand, actually it is between 10 to the power minus 1 to 10 to the power minus 5. And when it is a fine sand, and coarse silt, then it is 10 to the power minus 5 to 10 to the power minus 7. And when it is silt, then the value is 10 to the power minus 7 to 10 to the power 9; that is meter per second, and when it is a clay the value is 10, less than 10 to the power 9. And you can see that when you are going towards the that mean coarser to finer particles, the permeability value is reducing; that is obvious.

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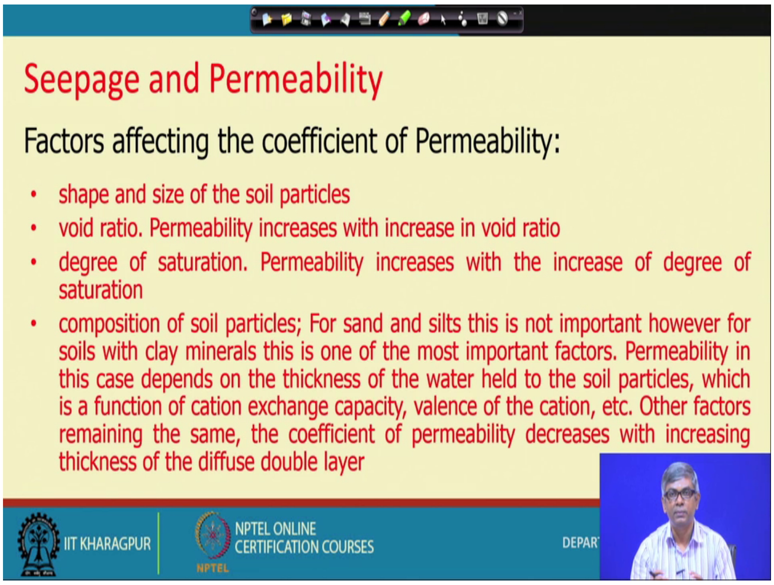

Now, factors affecting permeability. So, there I have discussed there are different, I have shown the table also, bigger the particles the more will be the permeability. Here there are number of factors on which factor of availability of soil depends. The shape and size of the soil particles; that is obvious, we can see that from that table. Void ratio; that means, how void, how much void is present. So, permeability increases with increase in void ratio obvious actually. More voids then more path to flow. So, increase of permeability also increases degree of saturation.

Again the permeability increase it with the increase of degree of saturation; that is another point, and composition of soil properties, soil particles. For sand and silt this is not important; however, for soils with clay mineral, this is one of the most important factors. Permeability in this case depends on the thickness of the water held to the soil particles, which is a function of cation exchange capacity. These are all some theories are there. We will not be able to give much detail, but only thing you can remember as a point, that composition also is a very important, particularly for fine soil, and next there are some more point I can see here.

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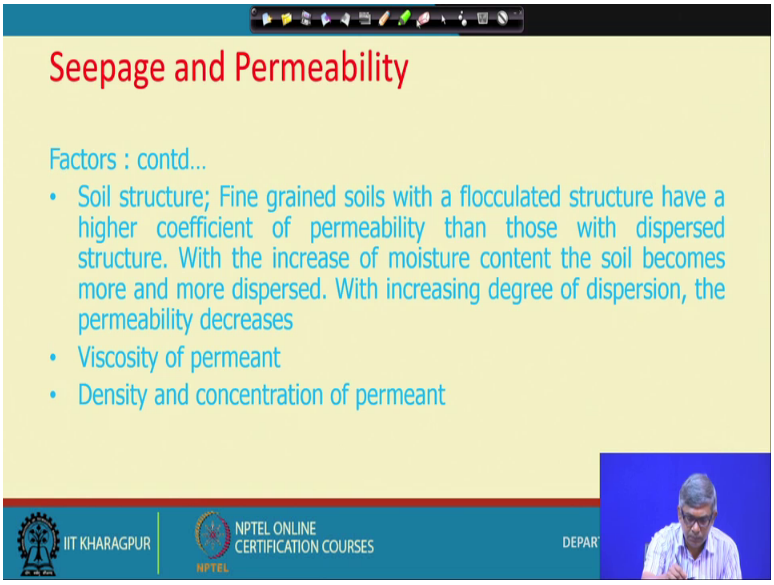

That soil structure. So, fine grained soil with flocculated structure have a higher coefficient of permeability, than those with dispersed structure. And that is there are fine grained particle, if you microscopically see there are two types of structure; that is one is flocculated and another is dispersed. And if it is flocculated actually, structure have a higher coefficient of permeability, and if it is dispersed, it will be less. With the increase of moisture content the soil becomes more and more disperse, and with the increasing degree of dispersion, the permeability also decreases.

So, this is another factor, and the viscosity also another; that is of course, not very important, but different fluid will have different permeability; that is; obviously, then from there we can conclude that viscosity is also important, and density and concentration of permeation that is also important. So, these are the different parameters or factors on which permeability of a particular soil is depends on.

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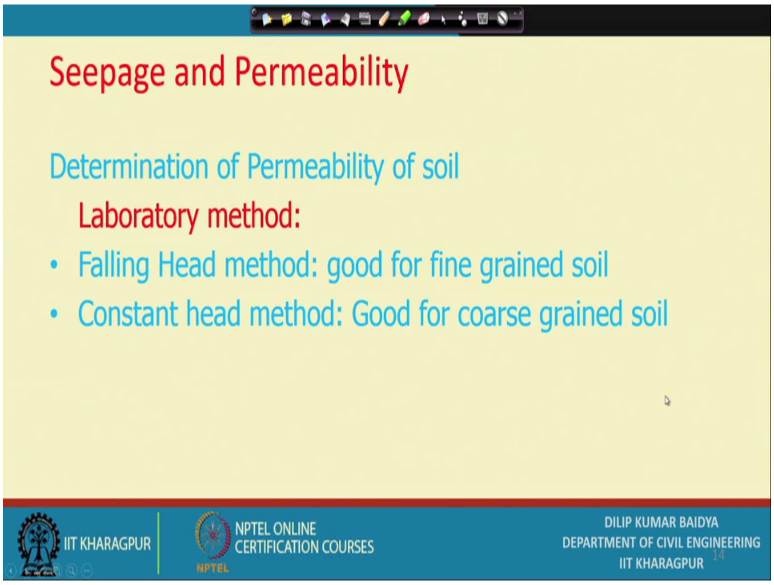

Now, seepage and permeability, seepage, then you have to qualitatively we have got some information. Now we need to quantify them that mean you have to find out some way to determine those values. And there are different methods at that. There is a laboratory method, there is a field method. So, in the laboratory actually we have two different methods; one is falling head method, and that is actually good for fine grained soil, and there is a constant head method, which is good for coarse grained soil.

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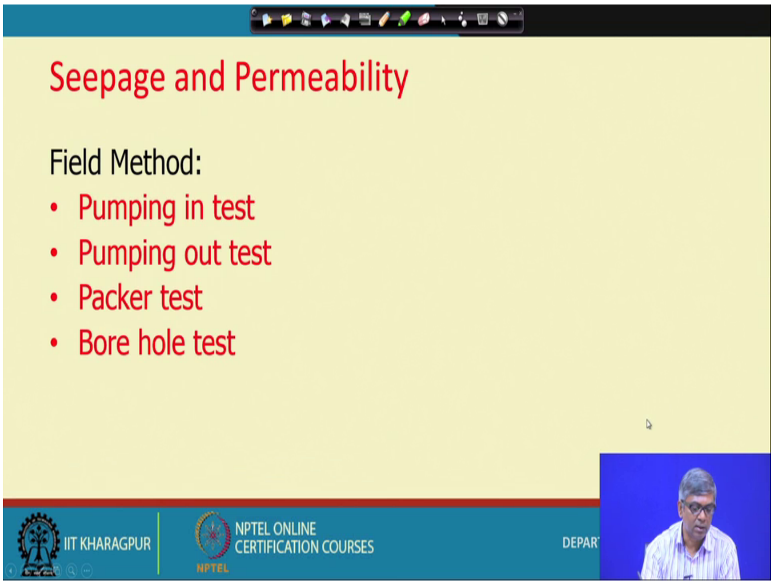

And now I will show you, and if it is a field, there are many methods are available in the field, and then out of that there is a pumping test is quite popular, pumping out pumping in test, then packet test

This packet this is quite sophisticated, and it is cost, a lot of cost also involved with special equipment is required, but we will discuss only limited, our discussion will be limited to pumping test only, and we will do that, maybe in the next lecture. And in the field method actually you have, there are pumping method all those things are there.

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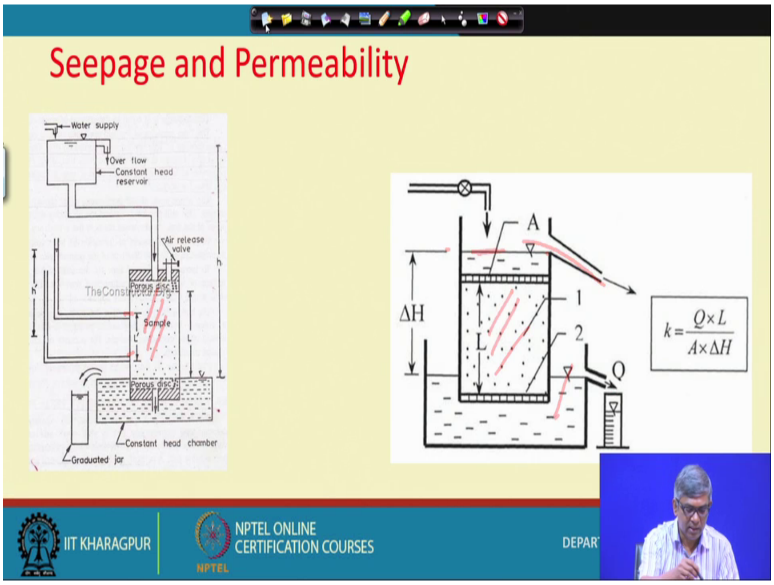

And next is; that is laboratory method. Laboratory method actually constant head method I have mentioned and falling head method. This constant head method actually two mechanism or test setup is shown here, then this is actually soil sample, and through which from here water is supplied, and taken and water is taken out, and two observation point is marked, at this point actually we try to keep the head constant.

So, on a constant head, how much flow is taking place that can be observed and alternatively this is another setup. This is actually the soil, and it is flow is given here, and flow is taken out from bottom here. And excess flow, excess water is supplied here, but to maintain the height here, we have kept a opening here, if there is excess head then it will overflow through this. So, finally, by this way we are maintaining a head here. This is the outlet and this is the inlet height. So, this is the head on which the flow is taking place.

So, now over a period of time, if I collect the quantity of flow, then I can find out Q that small k discharge. And the discharge also theoretically we know the equation, and from that I can equate, and I can get finally, the value of permeability.

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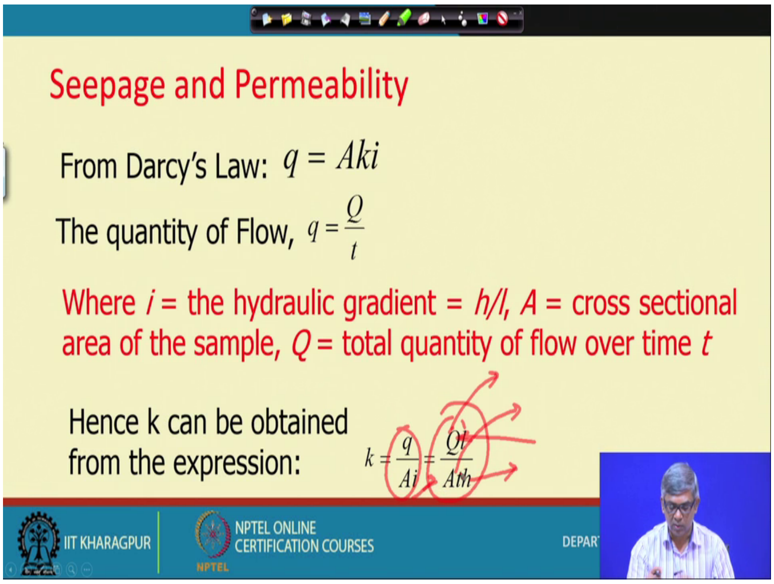

So, this is the application I will show, the equation I will show the next slide; that is you know that our equation is, k equal to your Aki, where A is the cross section area through which flow is taking place, that with Q, because V is equal to ki, and if I want to find out q, then I have multiply by A, and then this is the general formula and Q is equal to from the observation, this is a quantity over at time t I have taken.

So, this q become Q by t, and this two, if I equate, I will get this two, if I equate, then I will get the k k equal to q by Ai and equal to I equal to h by al. So, Ql by Ath, this is formula; that means what you have to do. During the test quantity of flow I have to measure, and time I have to measure, sample height. This is actually head over which flow is taking place, and length through which the flow is taking place, and cross section area.

The cross section area length of the sample head, these are the actually we can fix it, and during the test we will measure quantity and time.

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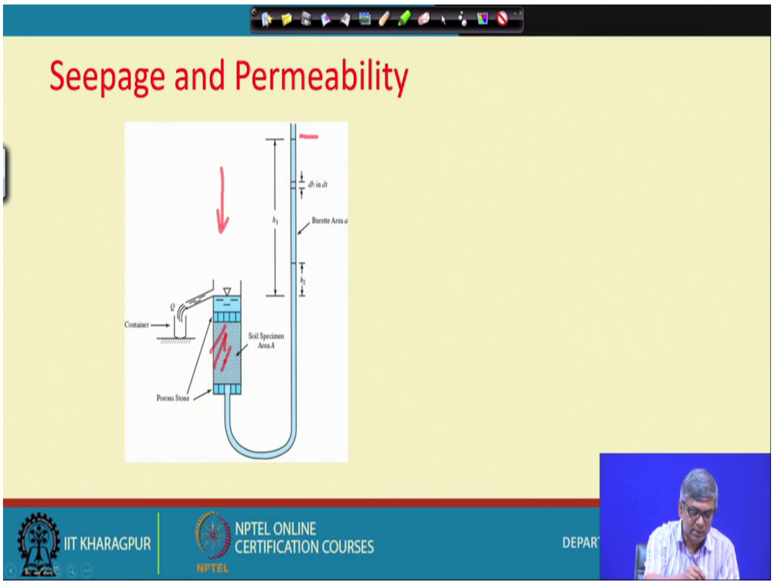

And this is the following head test actually. You can see this is a soil, this is the soil sample I kept, and this is the standpipe, and from the bottom water is supplied, and this is kept quiet high water level, and if it is there; that means, water will have tendency to flow from this direction to region, and will overflow from here. Water also can be supplied from here, then that will be sometime water will some soil particles will be flow along with the water, and then they give problem, they not get correct value.

So, because of that, sometime we give the flow from bottom, and this is the one. So, during the this flow initial head was suppose here, and final heads suppose somewhere here. And then because of this change of h 1 to h 2 how much time it is taken, that can be correlated to with the permeability equation that I will show in the next slide.

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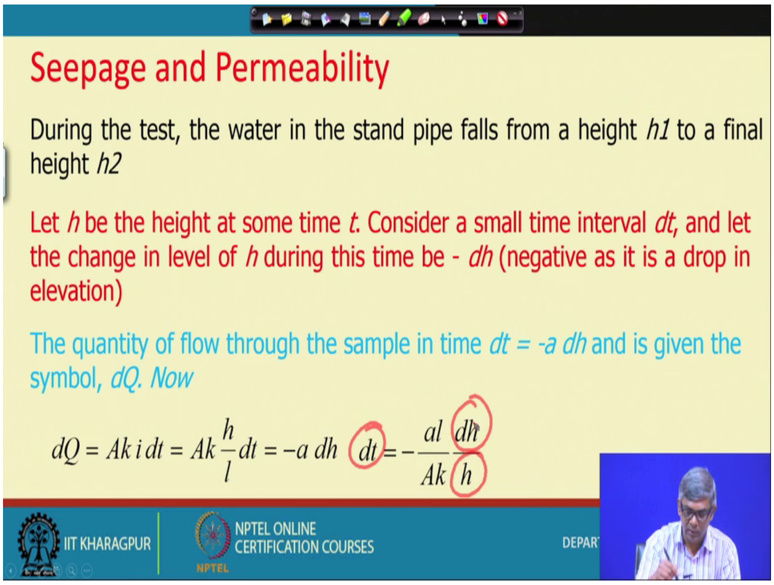

You can see that during the test the water in the standpipe falls from the height h 1 to final height h 2, and let h be the height at some time t, consider a small time interval dt, and let change in level h during this time be minus dh, why minus. We are taking negative as it is dropped in elevation, and the quantity of flow through the sample in time dt equal to; that means, standpipe. So, if the cross section of the stand potter is a, and minus dh that is the quantity of flow is given as symbol dq, and if I do that then. So, this dq will be again, will be Aki into dt. And from here I can simplify, this is the thing. And now if I go to the next slide, then it will be in the integral form. So, for

This is dt equal to this, and; that means, this is the variable actually, we are getting one dh is the variable, h is also, dt is the variable, time is changing, and h also changing, with time h is changing. So, these two are variable. So, we can change the, put the limit and from, after putting the little can correlate with k value. So, let me see that one in the next slide. So, you have to integrate 0 to t.

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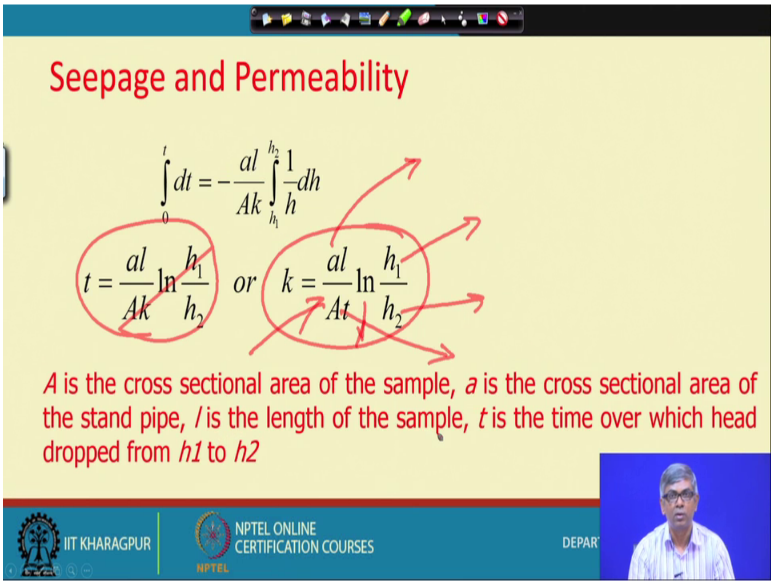

So, I have started initial time I have fixed zero and final I have time is t, suppose some 10 second or 1 day or 2 days, and h 1 and h 2 this is a two head, initial head is given 10 meter, final head given is 2 meter. So, this two to be observed, and then if I put this, then this one will be reduced to this form. And then finally, simplify this k become equal to al by At into ln, h 1 by h 2.

This is the natural log that has to be remembered. This is the cross section of the standpipe. This is the cross section of the soil sample. This is a time over head loss is observed, and this is also the initial head, this is the final head. So, all those things are also noted under here. So, from this equation one can find out the permeability value from the laboratory test.

With this is will close here, and determination of pumping test, I will do in the next lecture.