Geotechnical Measurement and Explorations

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Lecture No. # 27

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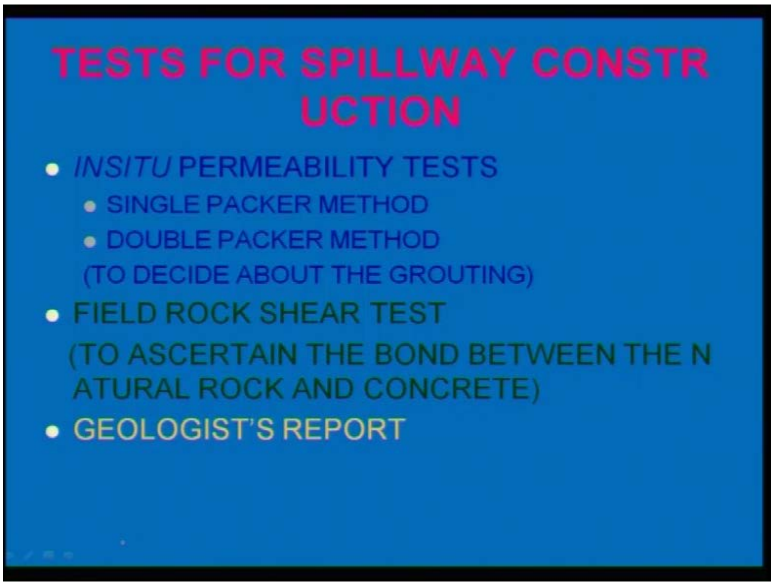

Last class we have started this tests, particularly different tests required for your irrigation or spillway constructions and that is coming under this also INSITU permeability. It comes under this and single double and field rock shear test and geological reports.

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Up to this I have discussed and test for collection of undisturbed soil and differential free swell test and if possible plate load test.

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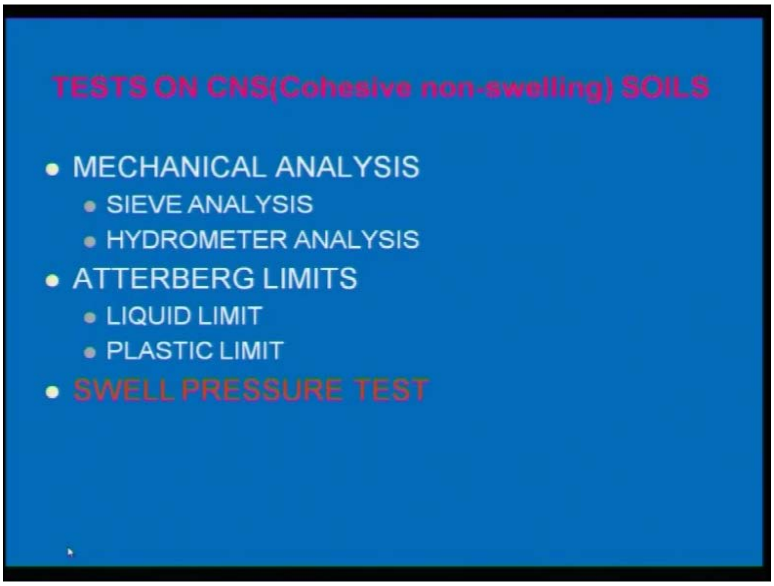

Test on CNS material cohesive non swelling soils, CNS is cohesive non swelling soils it is required these are the following tests. It means some mechanical analysis in the mechanical analysis its sieve analysis and hydrometer analysis. Then ATTERBERG limits, liquid limit and plastic limit and swell pressure test.

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These are the recommendations as per the I S Indian standard 9451, 1994. What is the best suited CNS material for that what should be your grain size distribution or mechanical analysis.

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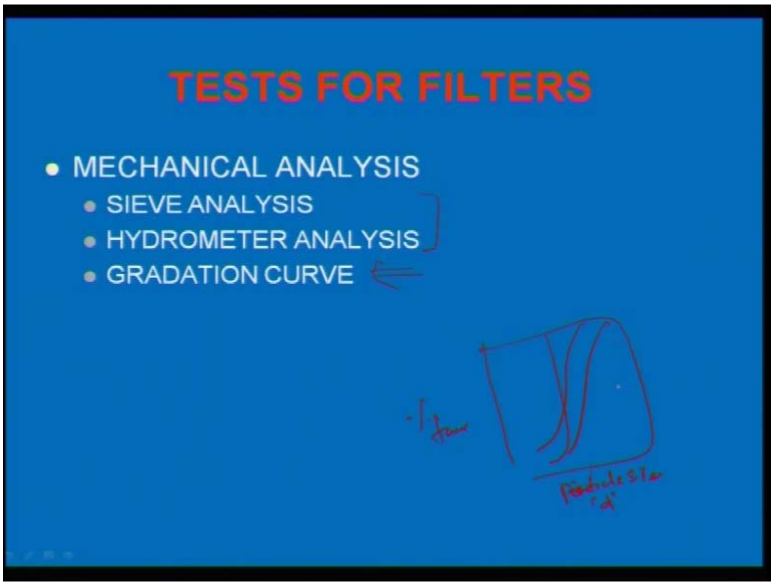

Then now, this the test for filters one is your CNS material and test for filters generally filters provided where it allow water to pass through the filters and it will also only allow water to flow, no passage of, no passage of your soil. So, generally this mechanical analysis your sieve analysis, hydrometer analysis and gradation curve based on the sieve analysis and hydrometer analysis you have to draw this gradation curve between these percentages finer, between this percentage finer verses particle size, particle size that is your diameter d.

So, you can find it out gradation curve whether it is a uniform well graded or gap graded or may be kind of a what other grade type of soil it is there. So, gradation curve is required for test for means for design requirement of your filters, then up to this we have covered.

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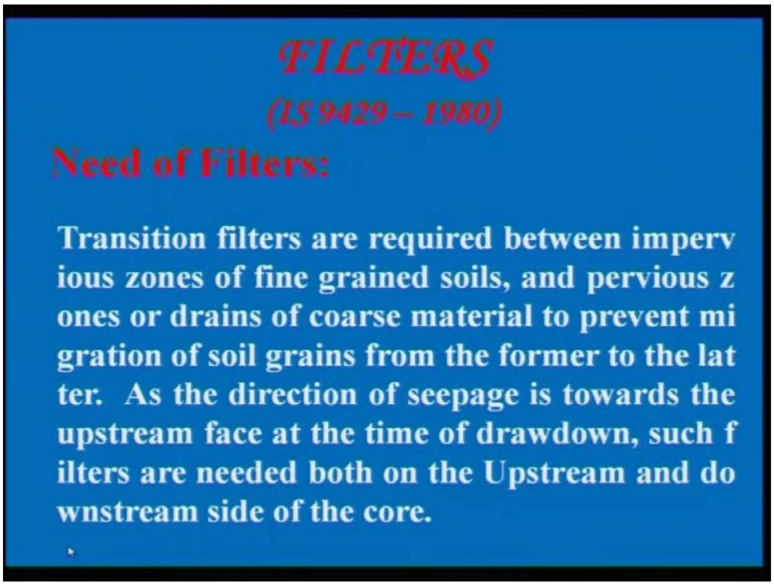

Now, need for filter if you look at this filter as per IS - Indian standard 1994 to 1998, transition filters are required between impervious zone of fine grained soil and pervious zone or drains of course grained material to prevent migration of soil grain from the impervious zone to pervious zone. That means filter is a barrier, filter is a barrier that means it allow only water to pass through this, but it will prevent soil from fine grained soil to travel or pass along with the water to your downstream or may be inside this. So, this filter is required basically it will allow only water to flow, no soil to flow or pass inside this filter.

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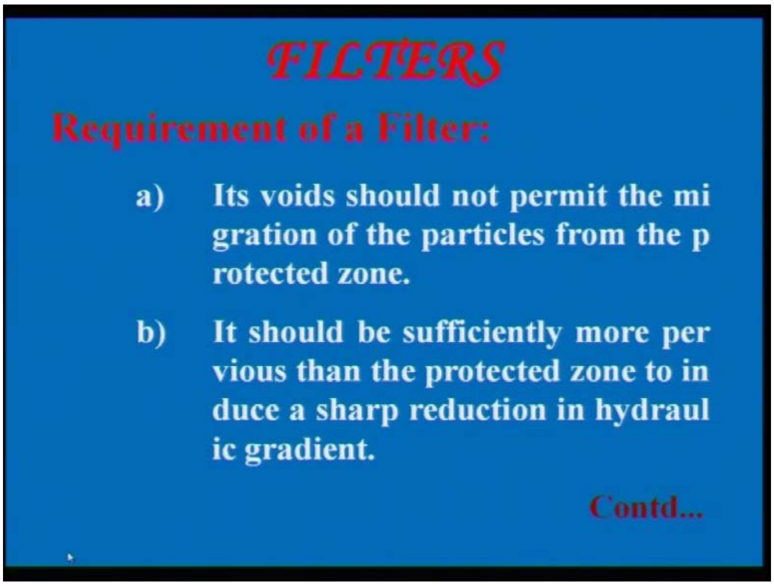

So, requirement for filters, generally for filter requirement voids should not permit the migration of particle from the protected zone. That means whatever voids inside this filter look at this, whatever the voids inside this filter it should be such way that it should not allow the migration of fine grained particles or migration of soil particles from the protected zones. That means this voids should be in such a way that it should be less than that the your fine grained soil particle size. If void is more than the fine grained soil particle size what will happen? It will allow soil as well as water to pass through these pass through the filters.

So, it should be sufficiently more pervious. Second criteria is it should be sufficiently more pervious than the protected zone to reduce a sharp reduction in hydraulic gradient. That means what will happen the movement hydraulic gradient will built out means, the movement hydraulic gradient is there. That means pure water pressure will increase soil loses its strength. So, effective stress will decrease, that means it should be sufficiently more pervious that means it will allow immediately water to pass inside this filter. So, that this there is a reduction in hydraulic gradient.

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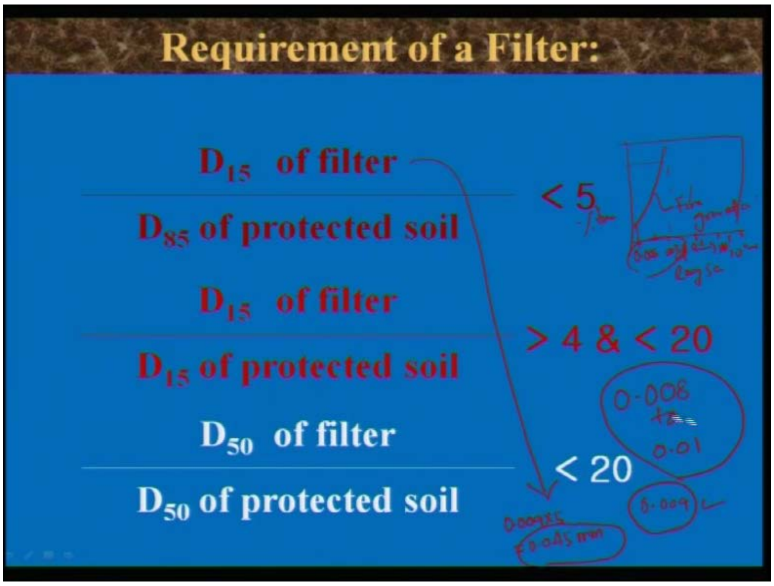

If I look at this, these are the criteria to be used or requirement of a filter. D 15 of a filter divided by D 85 of protected soil protected soil D 15 is your filter material, that means particle size of the filter material 15 percent of particle size is finer than that of the filter material. And D 85 e is your 85 percent of particle size should be finer than that it should be less than 5. Another one is your D 15 of filter divided by D 15 of protected soil should be greater than 4 and less than 20 and D 50 of filter divided by D 50 of protected soil should less than 20.

That means this is your first one that means 85 percent of soil, particularly if this is a fine grained soil. If I say this is a fine grained soil, if I plot the gradation curve that means percentage finer versus your say particle diameter in log scale, log scale suppose you are getting a fine grained soil of this fine grained soil. So, suppose say it is starting with 0.008 like this, 0.01 than 0.1 then 10 1 then your 10 then 100.

Now, if you look at this most of the particle size, most of the particularly fine grained particle size from this curve it is lying between 0.008 to 0.01 or you can say that 0.. For example, in this case 0.008 to 0.01 most of the soil particles align, if I draw it is passing here, it is passing here that means it should be design in such a way that 85 percent of the protected soil should retain.

That means only you allow 15 percent of particle size should pass through this your filter that means, if this is your 85 percent of D 85 percent of a particle size retained. That means suppose say D 85 is coming here, D 85 is coming here. So, that means it will be around say 0.009 or 0.001, 0.009 if this is the particle size that means if it is 0.009 then D 15 of the filter will be 0.009 0.009 into 5, this is your that means 0.045 mm is your 15 percent of your filter. That means it is passing through finer than that that means D 15, 15 percent of your particle size of this filter is around 0.045 m m.

So, based on this criteria you have to design what kind of filter you are going to take and what is your first first and foremost criteria, is your fine grained soil first you identify, your fine grained soil. What is its gradation curve and find it out its particle size distribution. That means mechanical analysis, sieve analysis as well as hydrometer analysis from there you find it out this particle size distribution curve find it out the gradation, once you get the gradation curve then you decide, as I explained here then you decide where is your D 85 means of the soil and what is that size and once you take that size into multiply by 5 that is your D 15 of your filter. Similarly, D 50 of the filter you can find it out.

So, indirectly you are finding out the gradation of your filter, gradation curve of your filter. Once you know the gradation curve of your protected soil indirectly you are finding out what is your gradation curve or particle size distribution should be inside this filter from this criteria indirectly you are going to find it out.

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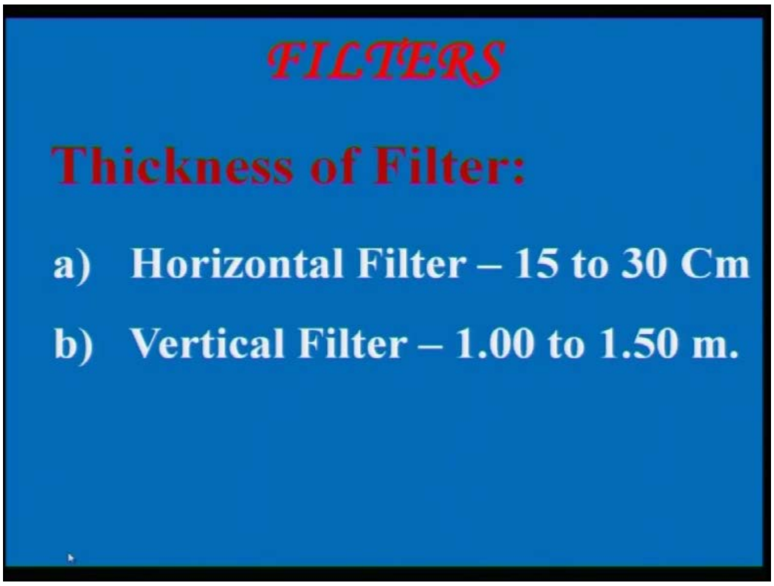

Now, in general what should be a thickness of the filter what is the recommendation of the I S code. Generally for horizontal filter it is 15 to 30 centimeter as per the Indian standard and vertical filter. So, it will be 1 to 1.5 meter vertical filter, generally this is your thickness criteria.

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Now, if you look at this over all what we have any risk co efficient of permeability and its test. What are the different co efficient of permeability to find it out.

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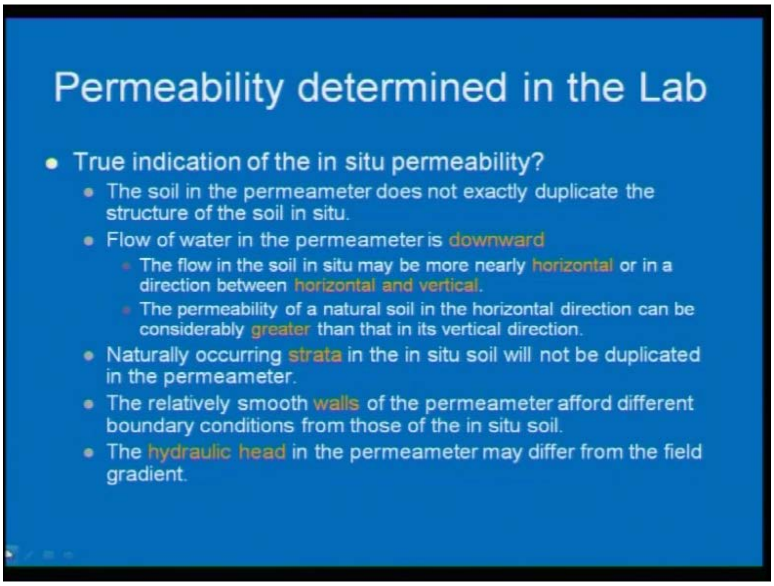

The co efficient of permeability you can find it out from the field or as well as in the laboratory. What are the test you are going to find it out, laboratory you are going to find it out by means of constant head permeability or variable permeability test. So, this is just a indication of this permeability test. So, generally we will go for three to four test from that whatever the laboratory value we are getting that should be reported as average permeability stimulate with your field conditions then in field test.

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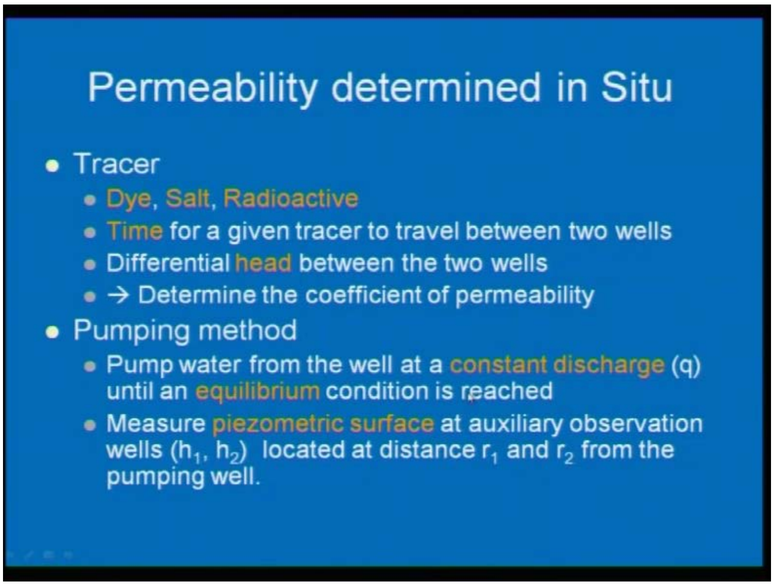

In field test I have explained already this particularly pumping borehole method and tracer methods. So, pumping means you will pump this soil pump the water and find it out how much water drop down in the observer well also bore holes. You can find it out what is the constant flow inside this borehole drop down or may be passing it and tracer test you allow some die to pass through this water. So, that we can find it out how much, where it is passing and how much. Basically in the field you are finding out discharge by the time then with these field test and laboratory test you will find it out your permeability.

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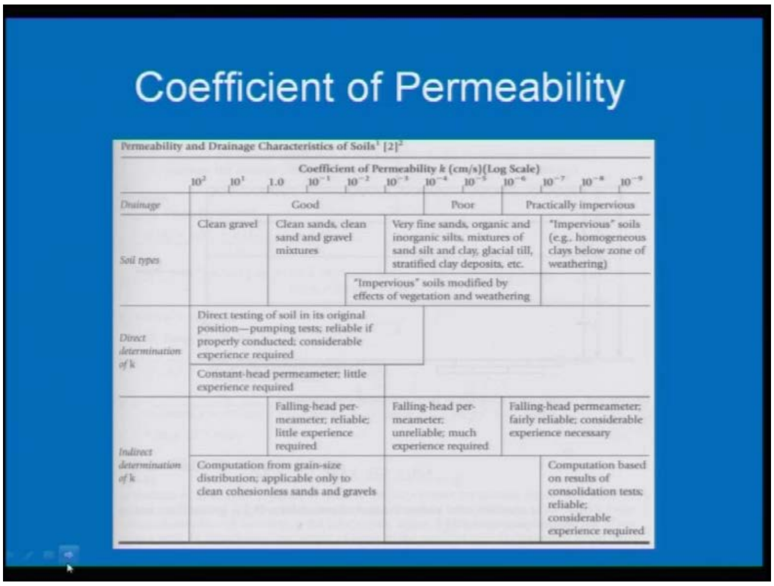

And I have discuss different examples and also there are different empirical relationship and co efficient of permeability for different sands and how to choose where is your coefficient of permeability should be there for different type of soils and what is your range. Then, related to coefficient of permeability there are two additional things permeability in vertical direction, permeability in lateral directions that also I have discuss.

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Then related to the coefficient of permeability, what are the different parts to be consider for irrigation projects one is your preconstruction, other is your during construction, third is your post constructions.

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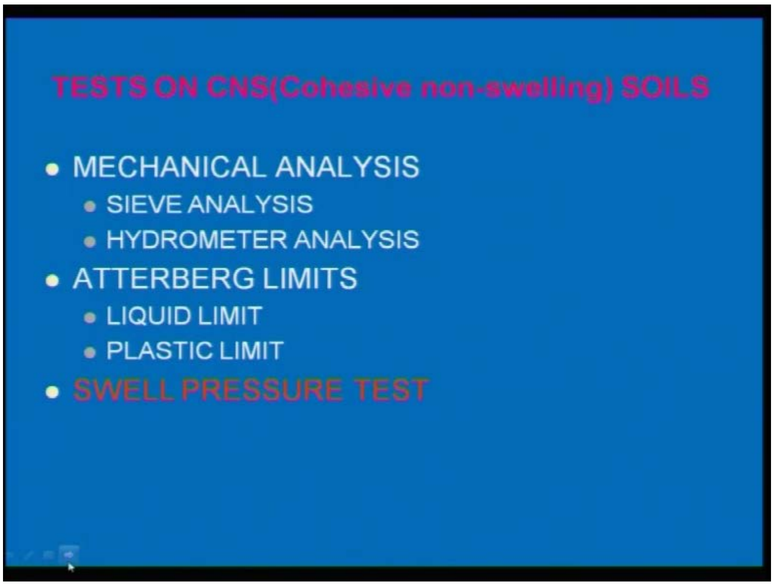

And with these what are the different test you are going to do and another part is your cohesive non swelling soils. What are the tests and what is the criteria, what is the gradation criteria for cohesive non swelling soils.

Then, last one we have finished that is your filter criteria, what should be your filter criteria and what should be your thickness based on that means. How the filter criteria will come into picture? It will come into picture from the coefficient of permeability, what should be your co efficient of permeability, 1 because the main criteria for this filter criteria is your, that means you have to reduce your hydraulic gradient, hydraulic gradient.

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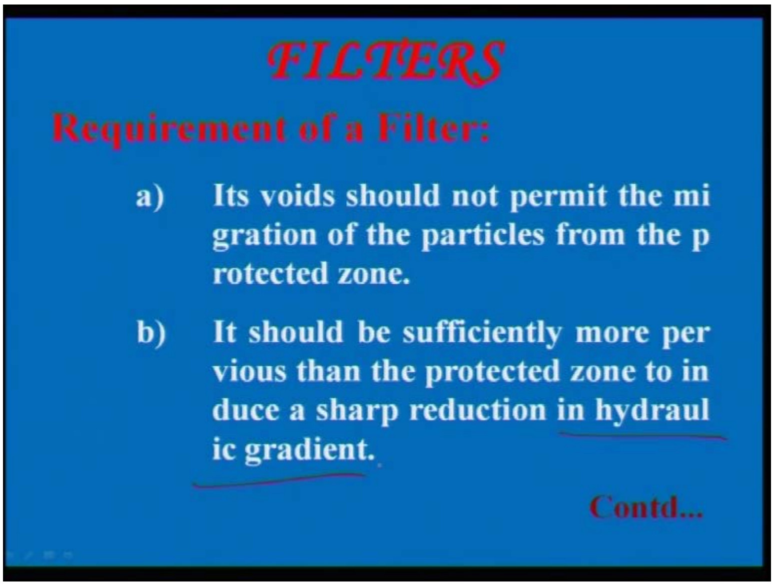

So, that the development of pure water pressure will be lower down this hydraulic gradient depending upon how much sewage, how much water to pass through this filter that means, first you will have to decide your co efficient of permeability required. Once you find it out coefficient of permeability then you can find it out your filter criteria. This is all about your co efficient of permeability to determine the co efficient of permeability in the laboratory as well as in the field. Now, we will start next one is your, this interesting one soil stiffness parameter. As far as possible we have covered most of the laboratory test and field test some other laboratory and field test we will also discuss later on. So, how to interpret soil stiffness parameter from this test? Means soil stiffness parameter is nothing, but your E and mu E is your modulus of elasticity mu is your Poisson's ratio. How to find it out soil stiffness parameter how to interpret for your modeling or for analysis?

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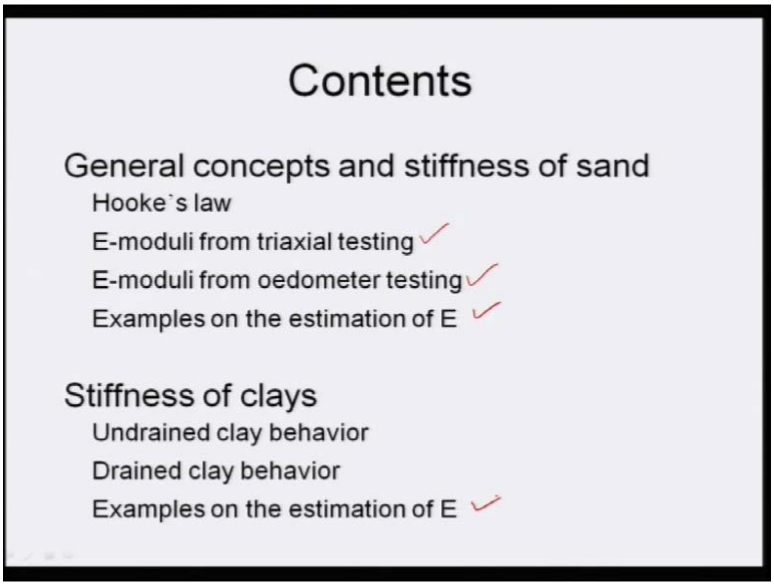

So, general concept and stiffness of sand or stiffness. If I divide into two parts of the soil one is your coarse grain other is your fine grain, coarse grain I write it for sand, fine grain I put it as a clay.

So, generally it follows this Hooke’s law E-moduli from triaxial testing, e modulus you can find it out from triaxial test. E modulus also you can find it out oedometer testing. Oedometer testing is nothing but is your consolidation testing. So, examples on the particularly estimated E with solved example and stiffness of clay that means undrained clay behavior. From there how to find it out E, drained clay behavior and examples on the estimation of E. This is the things we are going to discuss for both coarse as well as fine grained soil.

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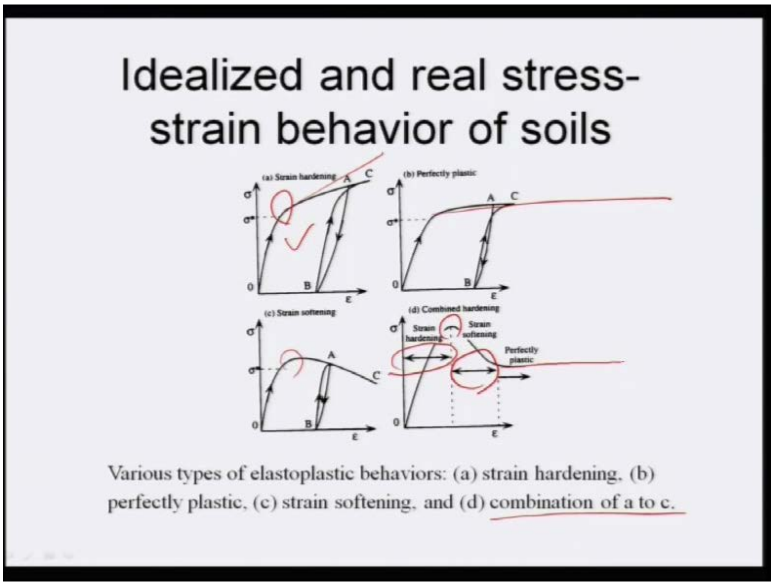

Now, idealized and real stress strain behavior of soil. If you look at this, I put it into three parts of these stress and strain behavior one is elastic, linear elastic another is non-linear elastic, elastic, plastic, elastoplastic. Now if you look at this linear elastic means the stress will increase in strain that means, the stress will increase strain as the value of strain, you are going to increase the stress also going to increase in a soil material. That means this graph will continue it is a like a straight line. That case we are generally say this is a simple case of linear elastic. Now, if I say non-linear elastic that means part A is your non-linear elastic if I say, that means some initial part of this non-linear elastic look at here, non-linear and elastic. Initial part of the curve stress versus strain it will be behaving as a linear that means as with increase in stress strain will increase.

So, it is going, going, going somewhere else it will be linear up to here, after certain part of the linear, it will become non-linear. This part is your non-linear after achieving non-linear after certain part of your non-linearity, again it become linear, again it become linear. So, that means non-linear elastic that means elasticity is there elastic is there and this elastic curve will be following linear certain part then it will become non-linear then it will follow linear.

So, this kind of behavior also we are getting for soils, another one elastic plastic means. What do you mean by elastic? Let us just think what do you mean by elastic. If I say Hooke’s law elastic, E is equal to modulus of elastic. If I say e is equal to stress by strain and if I say it is elastic then what will happen, if I remove this stress somewhere else as I increase as I apply the load this stress will increase then your strain will increase. The movement I release your load or the stress it will bounce back to the original position that is called elastic.

Now, non-linear elastic also there, elastoplasto means it will continue as an elastic then it become plastic, then it become plastic that means, if I release it somewhere else this stress here it will not return back to its original position. It will be somewhere else it will some plasticity will be there this is called elastic, elastoplastic or elastic plastic or we can say that elastoplastic. These are the three behavior generally observed or maybe I can classify or idealize real stress strain behavior of soil into three category, one is your linear elastic, your non-linear elastic other is your elastoplastic.

Now, based on that various type of elastoplastic behavior I do not want to go in detail this will be as in a part of modeling. So, basically we are idealizing how to find it out E moduli for your analysis. So, various type of elastoplastic behavior is your strain hardening, this is your strain hardening and b is your perfectly plastic. It will go elastic then it will become like this.

So, it is your perfectly plastic then strain softening, strain hardening means the with the strain it will go asymptotically up with the strain and strain softening means after peak it will come down, this is your strain softening. Then, last part is your combination of a b and c that means strain hardening strain softening as well as plastic. If you look at this last part of the curve it is increasing it is the stress is increasing linearly with your strain and it will attend a peak. Then with this peak I say that this is my strain hardening and with this after the peak soil, this will decrease and with this decrease I say that this is my strain softening based on this strain value. How whether it is increasing or decreasing.

Then, after certain part of this it will remain constant. The strain at that time I say it is perfectly plastic. So, these three may be combined together I can write it that also gives your stress and behavior of soil. So, these are just because why I am discussing this will be required while finding out E moduli. So, just to know what are the your stress strain behavior of soil so this the discussion.

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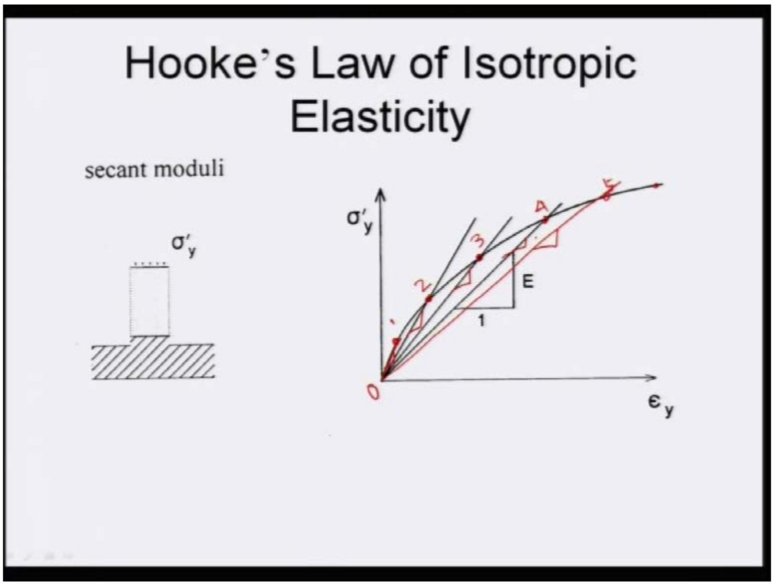

Then Hooke's law of elasticity these are all you know all about this. So, this will be E x, E y and epsilon x epsilon y and epsilon z you can find it out. From there you can find it out G K and oedometer modulus from this oedometer modulus is nothing, but your g shear modulus 2 minus 2 n u divided by 1 minus 1 nu.

Now, Hooke's law of isotropic elasticity. If you look at this as I said there are two types of moduli. You can find it out, one is your E linear moduli or E elastic moduli or second moduli E linear. First part of the moduli is that means you draw initial part of your curve at straight line you draw a straight line taking initial part of the curve, that is your linear. Draw a tangent taking initial part of your curve. What is that? From there what is your value of the slope you are getting that is your E initial. You can write it modulus of elasticity of initial. This initial value of modulus of elasticity may not be much needed during the analysis of the soil structure interaction problem. We need that is your second moduli, we need that is your second moduli if this kind of curve is there, how to find it out second moduli? This is again the question.

So, with your stress versus strain, find it out where it is required. This is a case of putting, this is a case of loading means case of where it is there find it out. Where is your ultimate load or ultimate stress or permissible stress. This point where is your ultimate load or permissible load you can take it, that point you mark it, this point has been mark as a one point and other point you can find it out, that is your other point is your half of your working stress. T hat point you find it out and join is wise straight line and slope of that that is nothing but your second modulus that means, second moduli will cover your design part which is covering with your half of your permissible stress to maximum permissible stress or maximum limit, between that you can predict what is your stress strain behavior.

Otherwise another way also you can report. That means if this is a stress strain curve of your non-linear throughout is there. Mark it, there are different points, point one, point two, point three, point four point five point six. So, because this is required in case of modeling so, join with these from o point one then join these point two point, three point, four point, five straight line, for each point you find it out E from the slope. That means along the non-linearity along the non-linear part I am getting, I am trying to find it out variation of E variation of how the elasticity is varying along the loading profile. This can be used for also in your analysis.

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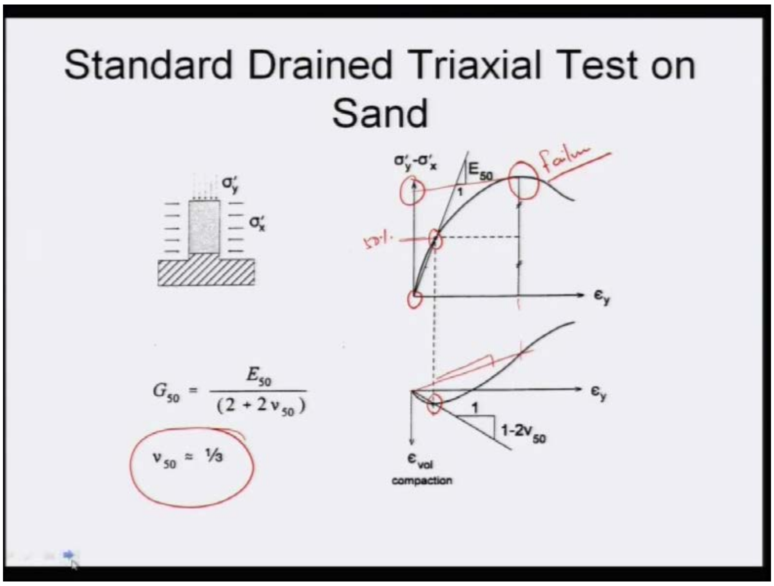

Now, standard drained triaxial test on sand, from there we will have to find it out your E. This is a typical curve of your standard drained triaxial test on sand. If you look at here that means this is my peak. That means this is peak means this I am taking as a failure right? Whatever your failure load is there take the 50 percent of your failure mark the point as I said. Draw the tangent with this point from origin to here and this is called E 50. This E 50 you can extrapolate volume versus your strain change in volume, versus your strain from there where you are getting. That means you are drawing a tangent from there you can find it out your mu you can find it out mu.

Means, where I am getting the E this E can be extrapolated this once you get. Suppose I am getting a E from here I can mark it, I can join whatever this slope you are getting that is nothing but your that slope will give your mu value poisson’s ratio value, because it is volume change in volume by your strain. So, based on the E whatever you find it out E that can be extrapolated the point where you are getting the E whether E 50, E initial or may be E final or E failure that you extrapolate with your volume versus your strain from there you can find it out mu. From here we are getting two parameters one is your E 50 another is your mu 50, mu is nothing but is your poisson’s ratio. This is your modulus of elasticity. This is your poisson’s ratio. Once you know mu and E then you can easily find it out what is the other parameter, G shear modulus you can find it out from these co-relations.

So, G 50 I got it, E 50 by 2 by 2 plus nu 50 and nu 50 is nothing but is your one third value what you are getting from there one third value.

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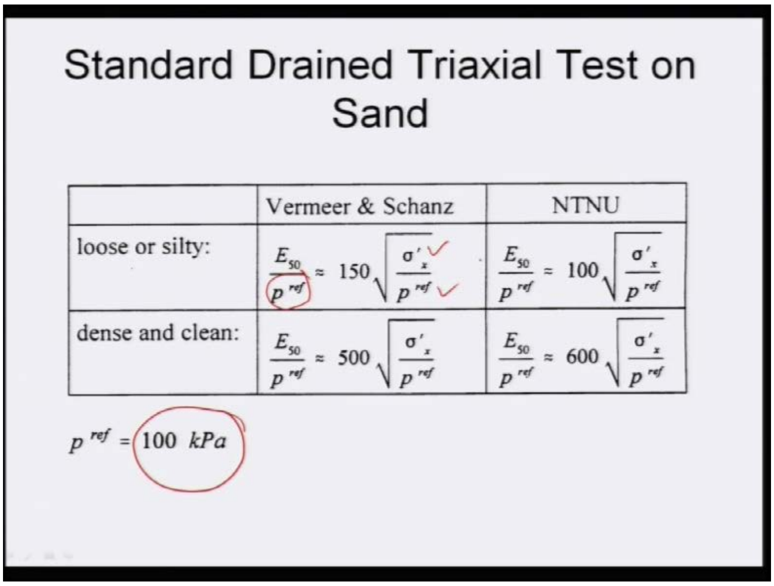

Standard drained triaxial test on sand, these are the people they have given this co relations with this from triaxial test. How to find it out E 50. One is your Vermeer and Schanz and N T N U from. Therefore, loose or silt sand and dense and clean sand E 50 in terms of effective pressure. That is your 100 k P a, they find it out in terms of overburden pressure this is your effective and p reference. These are the co relations they have given if you even if you do not have, if you know what is your sigma x and p reference, p is your 100 k P a. Once you know then you can find it out E 50, this is based on this co relation based on experimental results.

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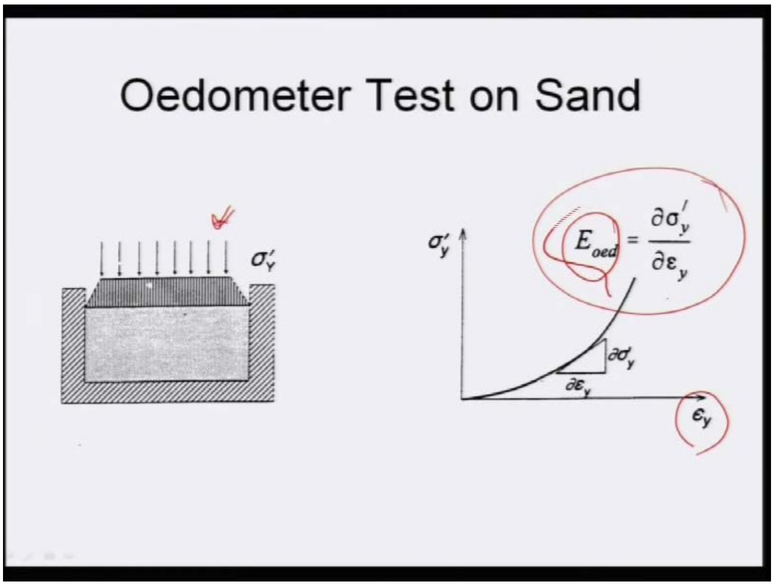

Now, next question is if suppose I do not have any triaxial test data. I am having only oedometer that means, consolidation data. Can I find it out E and mu? Yes, I can find it out E and mu. If I will find it out what value and how I am going to use. Now, from this next question is your from oedometer test can I plot stress versus strain. Yes of course, I can plot stress versus strain because each time we are giving a load increment we know the load, we know the area.

So, we are getting each time stress we are applying and by means of dial gauge as I explained earlier by means of dial gauge, we are measuring the strain, we are measuring the strain. So, with this help of that I can draw this stress versus strain from oedometer test. The diagram of the stress versus strain. Now, from there E oedometer is your change in stress by change in strain that is there you can find it out at different points you can find it out, E of your consolidation test from that, this is termed as if I am finding out E from oedometer test. Tt has been retain E oedometer or E from your consolidation test.

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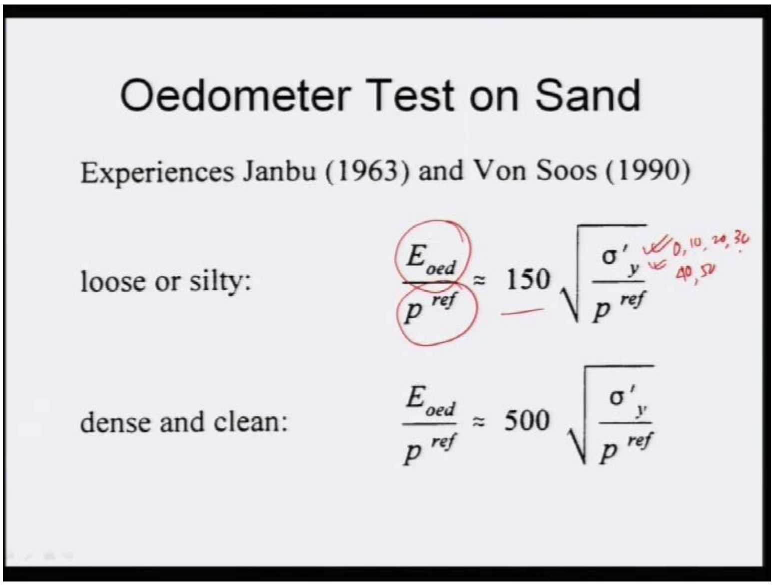

Now, from this test on sand based on the laboratory test results Janbu 1963 and van Soos 1990. They have given for loose and silty sand and dense and clean sand E oedometer by P reference is nothing, but your 100 k p a. So, 150 by sigma prime, sigma prime y by P reference that means with effective to 100 k P a this sigma one prime you can find it out. This can be used from for your model, remember this sigma one prime how we are using this E and mu in case of particularly analysis. If you look at from this experimental results E you are getting, with your 100 k P a and sigma y this stress you can vary from 0, 10, 20, 30, 40, 50 up to 100. So, that your E also vary E oedometer also vary, for dense and clean sand also E also varying. That means a co relation has been given in terms of sigma y in terms of stress, E from whatever the oedometer test is there. So, from there you can find it out your particularly E how it is varying your nonlinearly.

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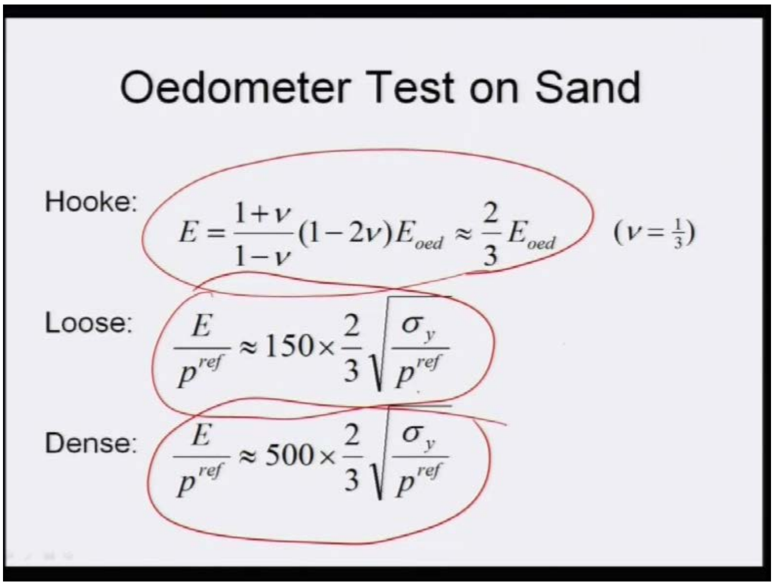

Now, by means of Hooke's law E is equal to if it has been proven E is equal to particularly if mu is constant particularly that soil E is equal to 2 by 3 of your oedometer. E oedometer remember that is your modulus of elasticity getting from oedometer test. Now, this modulus of elasticity for the soil it will be 2 by 3 of your whatever I am getting from your laboratory test, that means E of soil is equal to two third of E of soil oedometer test. You can write it E of soil oedometer test. So, mu generally taken one third from this oedometer test. So, based on that taking it that you can find it out earlier it is for your E oedometer. Then now, E of your soil that is if I take it E as 2 by 3 of E oedometer from there you can find it out e of the soil particularly loose as well as dense sand.

So, this are the parametric estimation from your laboratory test. How it is useful, particularly in modeling or analysis that I am just discussing in brief. Then major parameter of your stiffness the movement we say that this is for your static case, we are not discussing right now dynamic for this major soil stiffness is your E and mu. E is your modulus of elasticity mu is equal to poisson's ratio that is required for your analysis.

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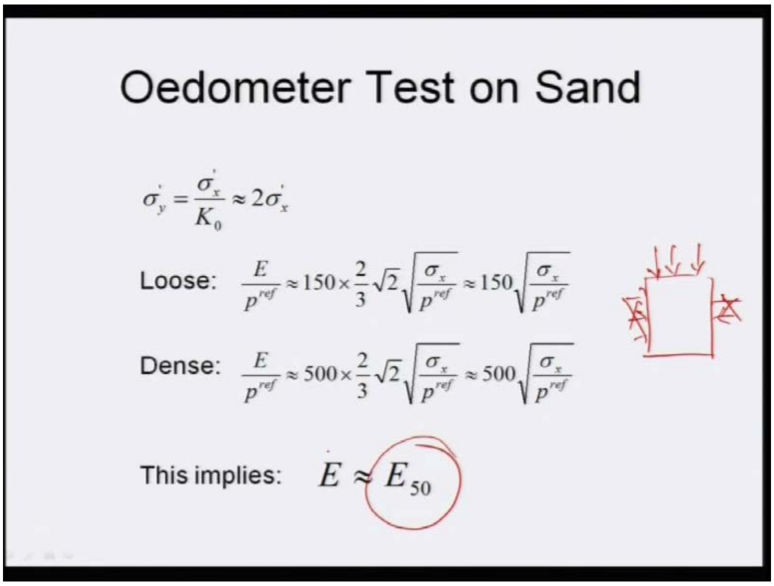

So, it has been proved that also with our as from this oedometer test. So, sigma y because in this oedometer test there is no confinement, confinement is lost at the lateral it is lost, only stress has been applied in the vertical directions. So, from that it has been found out if it is a confinement, If I correlate with your field sigma y is nothing but your two times of sigma x. So, E almost from this it has been found that E is equivalent to your this is nothing but your E 50. That means if I oedometer test if I do, if I plot this stress versus strain whatever the E value from oedometer test I will take it and apply for the modeling for particular soil, this is nothing but is your 50 percent of your E, that means stress corresponding to 50 percent value of E whatever we are getting that gives your E 50.

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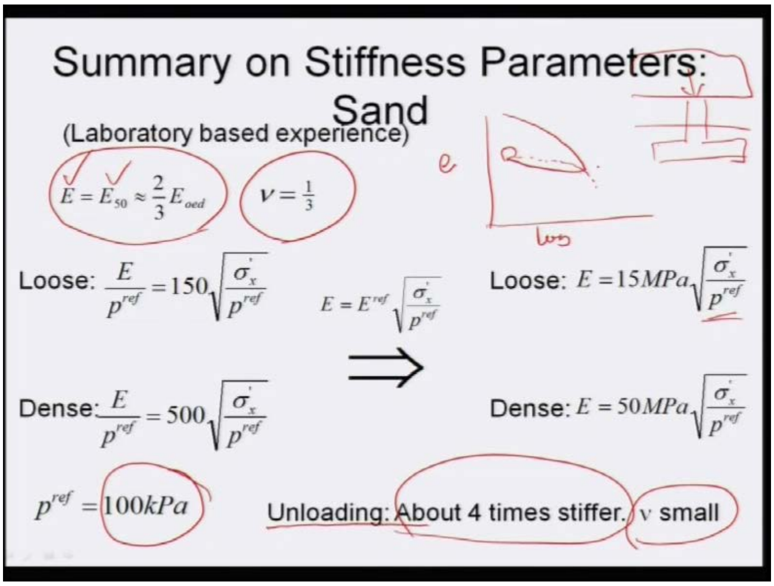

Now, summary on stiffness parameters on sand particularly laboratory based experience. So, that means if I from laboratory test that is your oedometer test if I make it into summaries E is equal to E 50 and which is nothing but is your 2 by 3 of E oedometer, mu is has been proven as it will be 1 by 3. Based on that for loose e is equal to very simple E is equal to 15 MPa sigma x, that means vertical stress or may be overburden sigma x prime by P reference.

P reference in this case is your 100 k P a and also for dense for E has been these are the co relation given based on your summary based on your laboratory experience and E is nothing but is your E 50, mu is equal to nothing but is your 1 by 3. So, this is your loading, during unloading about four times stiffer mu is very small, what will happen particularly in oedometer test and the consolidation test you are getting E versus log p. This is up to my loading, this is unloading then loading, unloading, loading and unloading. The movement I unload it, the movement I unload it is that sample has been loaded then, it has been unloaded then from this point it has been reload.

So, it says during unloading it is four times of stiffer and mu is poisson's ratio is very small during the unloading part means, this value it can take as from this value you can take it as a design parameter input. What will happen, during construction also during footing also there that means it may possible that first you exhibit, then you place your footing. That means this is your time where this is your unloading then, after placing the footing then once the construction started it will start loading that means from here to here it will start the loading. So, based on this laboratory test you can consider E should be 4 time stiffer during unloading and mu is equal to very very small.

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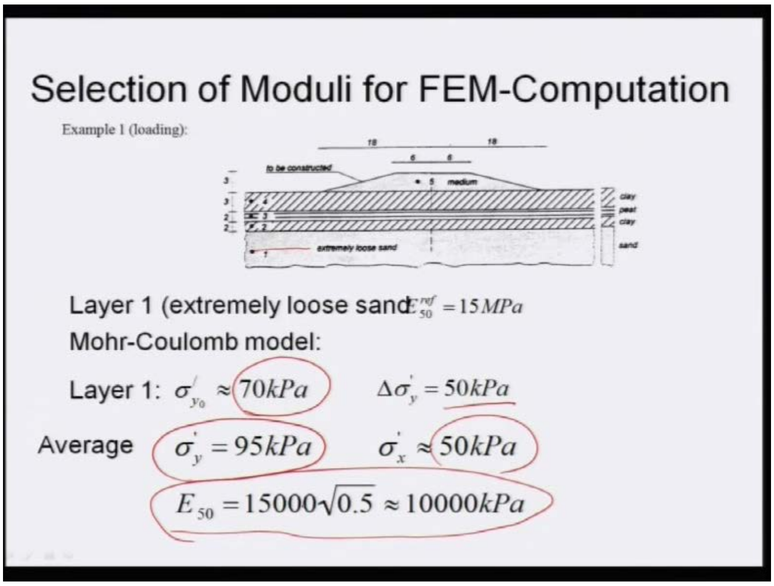

So, though this is not required just in brief means how to decide your moduli for finite element computation. So, from layer one, layer two average value of layer E 50 means, suppose if you see there is an embankment to be constructed and this is my soil deposits clay pit, clay and this is your extreme loose deposit sand. So I put it this is your layer one, sand deposit is layer one, two is your clay, third is your pit, fourth is your clay then, fifth layer is nothing but is your to be constructed embankment to be constructed.

Now, for extremely loose sand as it is extremely loose sand you can take it E 50 with reference to 100 you can find it out 15 M P a. How you are getting 15 M P a for layer one, you can find it out at this point middle of this. This is a example how to calculate. How to put for modeling at the middle of the layer, at the middle of layer you find it out what is your vertical stress. So, layer one based on the gamma you find it out sigma y is equal to 70 k P a and generally increase in your stress because of your embankment loading delta sigma y is 50 k p a. So, average of sigma y you can take is your 95 k P a. So, sigma x will be 50 k p a from there you can find it out E 50 is nothing but is your 15 M P a, 1500 MPa or 1000, 10000 k P a from this average value.

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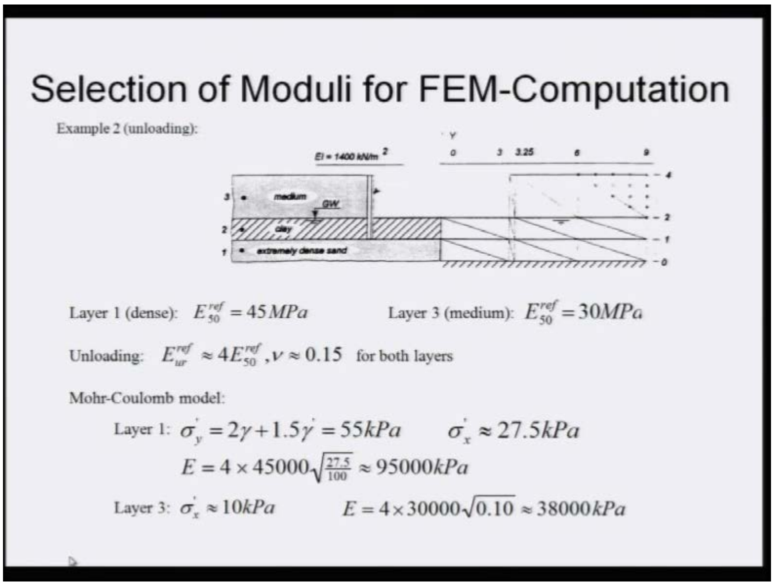

Then similarly, if layer one is extremely dense sand, in case of example two that is means of unloading if you look at this example one is your loading, example two is your during unloading. Then you can find it out during unloading so, how the case of unloading will come into picture.

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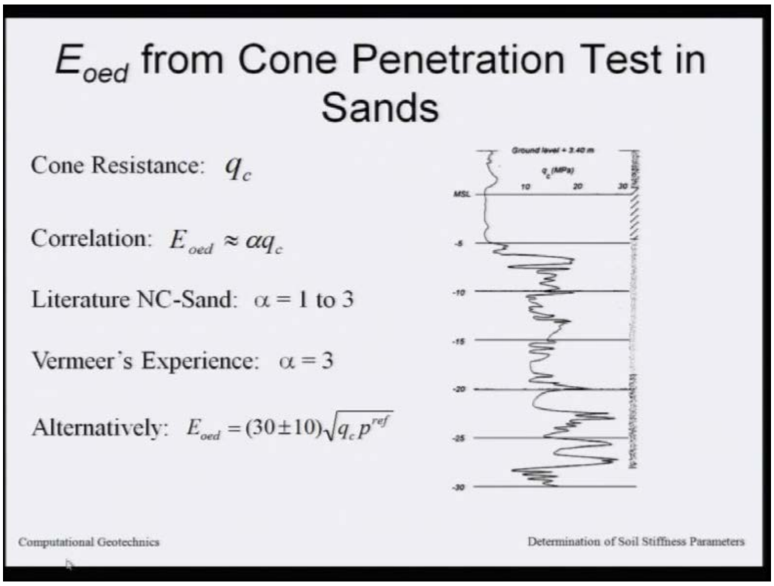

So maybe I can stop it here so, the next class I will show, little bit I can consider and I can go from laboratory test to field test. How to find it out this E value other part we will discuss.