Geotechnical Measurements and Explorations

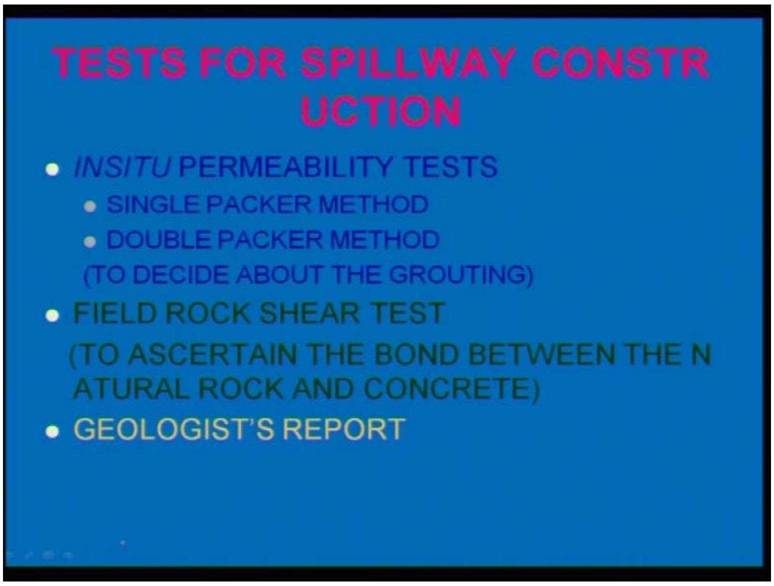
Prof. Nihar Ranjan Patra

Department of Civil Engineering

Indian Institute of Technology, Kanpur

Lecture No. # 36

(Refer Slide Time: 00:27)

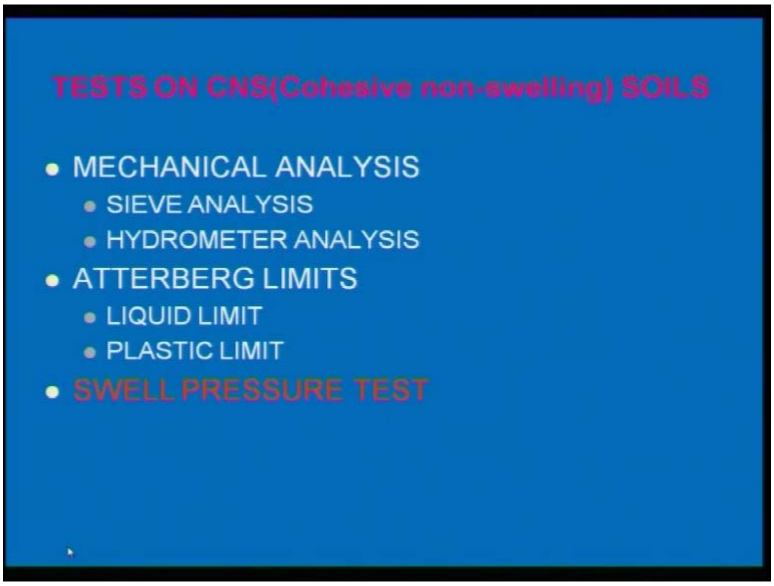


Last class, we have started this tests; particularly different test required for your irrigation or spillway construction; and that is coming under this also INSITU permeability, it comes under this; and single packer, double packers; and field rocks shear test, and geological reports; up to this, I have discussed.

(Refer Slide Time: 00:39)

And test for collection of undisturbed soil and differential free swell test, and if possible plate load test.

(Refer Slide Time: 00:48)

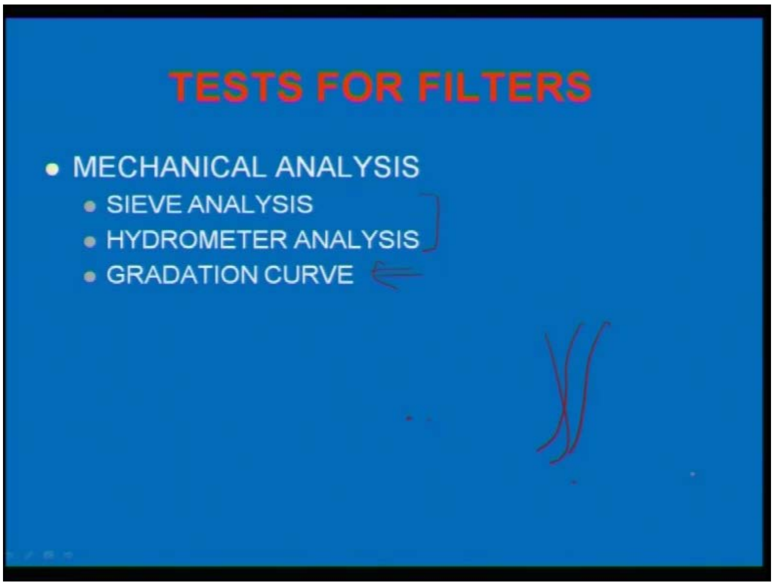


Test on CNS material - Cohesive non-swelling soils; CNS is Cohesive non-swelling soils; it is required, these are the following tests that means mechanical analysis; in the mechanical analysis, it is sieve analysis and hydrometer analysis; then atterberg limits - liquid limit and plastic limit; and swell pressure test.

(Refer Slide Time: 01:13)

These are the recommendations as per the IS - Indian standard 9451 – 1994; what is the best suited CNS material? For that, what should be your grain size distribution or mechanical analysis?

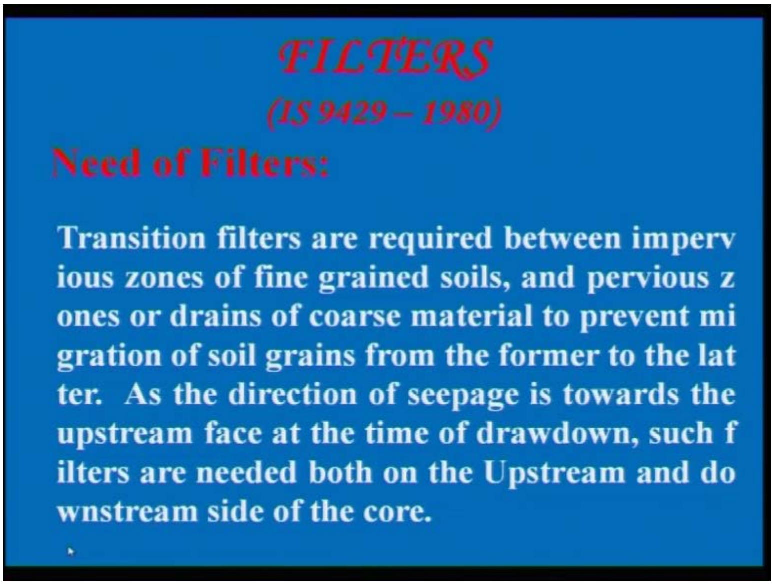
(Refer Slide Time: 01:30)



Then now this is the test for filters; one is your CNS material and test for filters. Generally filters provided, where it allows 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, hydro meter analysis and gradation curve;

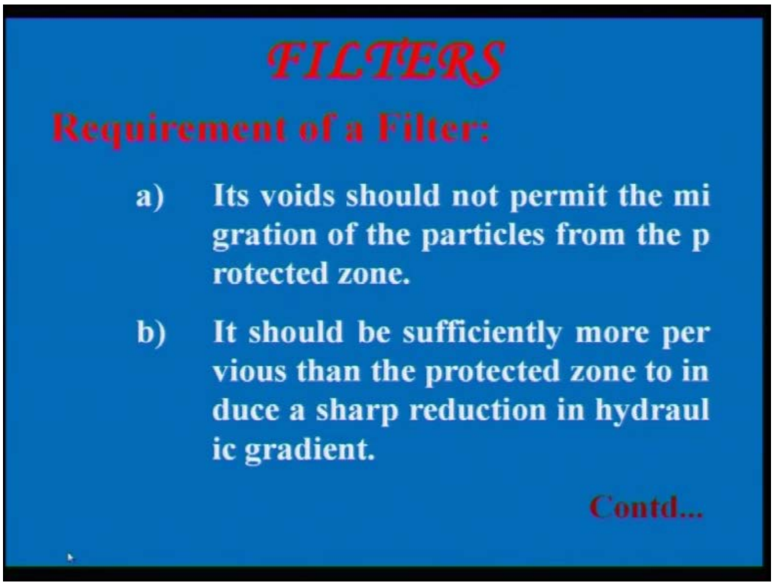
based on the sieve analysis and hydrometer analysis, you have to draw this gradation curve; between these percentages finer between this percentage finer versus particle size particle size that is your diameter d. So you can find it out gradation curve, whether it is a uniform well graded or gap graded 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.

(Refer Slide Time: 02:39)



Now, need for filter: If you look at this filter as for IS - Indian standard 9429 - 1980, transition filters are required between impervious zone of fine grained soil, and pervious zone or drains of coarse gain material to prevent migration of soil grain from the impervious zone to pervious zone; that means filter is a barrier filter is 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.

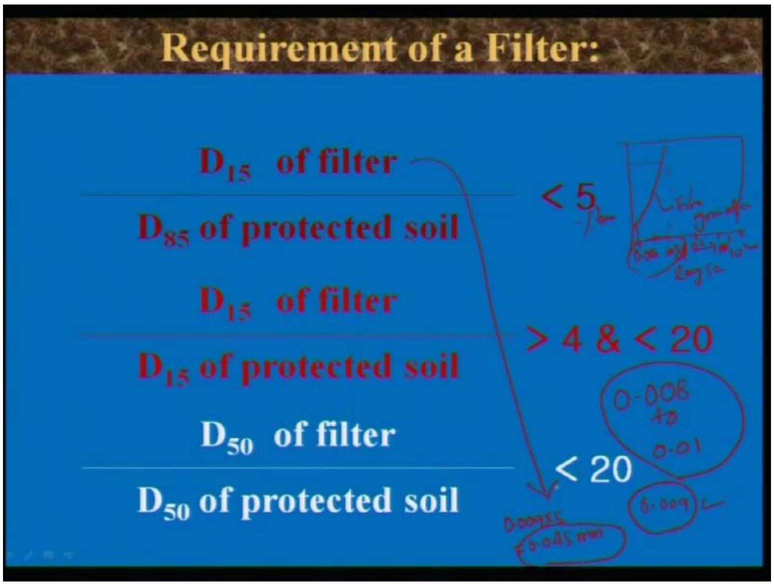
(Refer Slide Time: 03:35)



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 your fine grained soil particle size.

If void is more than the fine grained soil particles size, what will happen? It will allow soil as well as water to pass through this, 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 moment hydraulic gradient will built up, means the moment hydraulic gradient is there. That means, pore water pressure will increase; so 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.

(Refer Slide Time: 05:07)

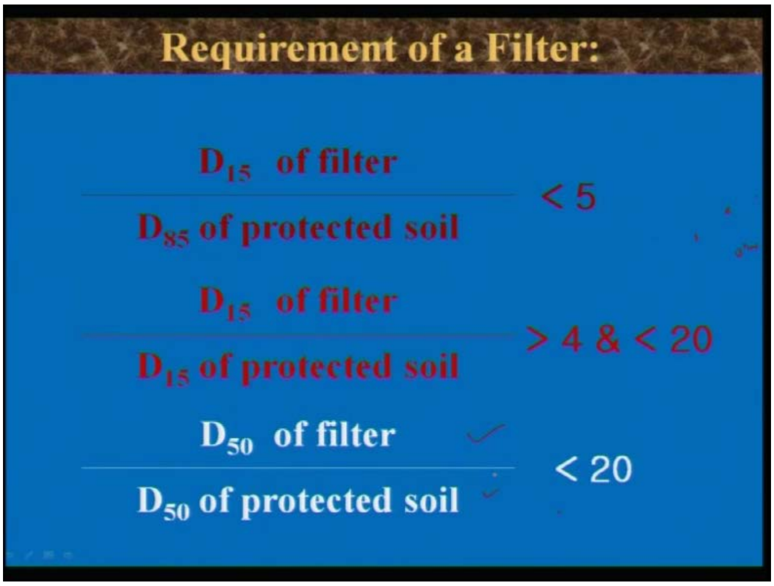


If I look at this, these are the criteria to be used or requirement of a filter D 15 of a filter divided by D 85 of protected soil protected soil. D 15 is your filter material; that means, particle size of the filter material, 15 percent of particle size is finer than that of the filter material. And D 85 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 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 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, then 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 zero point for example, in this case 0.008 to 0.01, most of the soil particles are lined; if I draw it, 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 retained; 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 your 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 D 15, 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 mm. So based on these criteria, you have to design what kind of filter you are going to take.

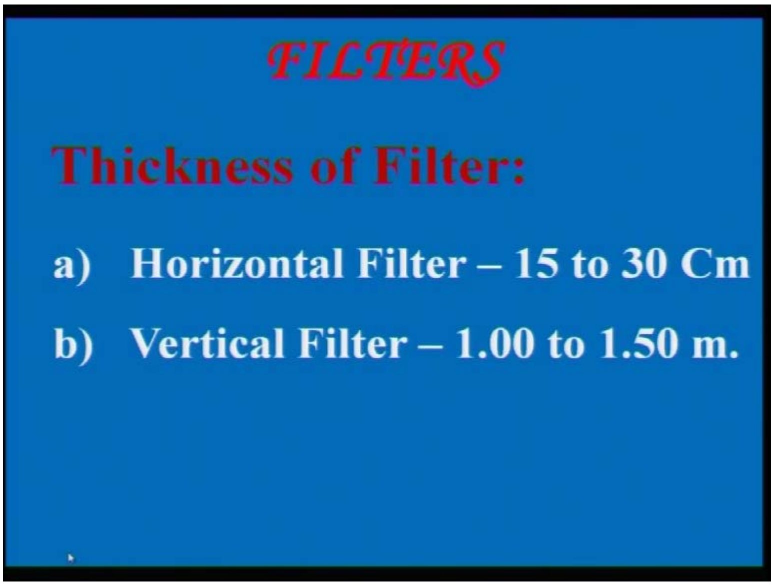
(Refer Slide Time: 08:56)



And what is your first first and foremost criteria is your fine grained soil, first you identify your fine grained soil that what 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; from 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, 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.

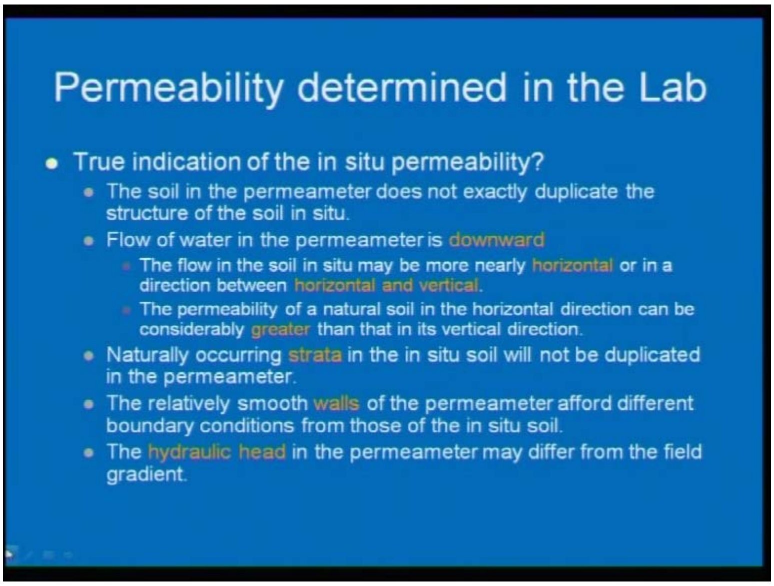
So, indirectly you are finding out the gradation of your filter, gradation curve of your filter. Once you know the gradation curve of your protected soil, indirectly you are finding out what is your gradation curve; or particle size distribution should be inside this filter; from these criteria, indirectly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

(Refer Slide Time: 09:59)



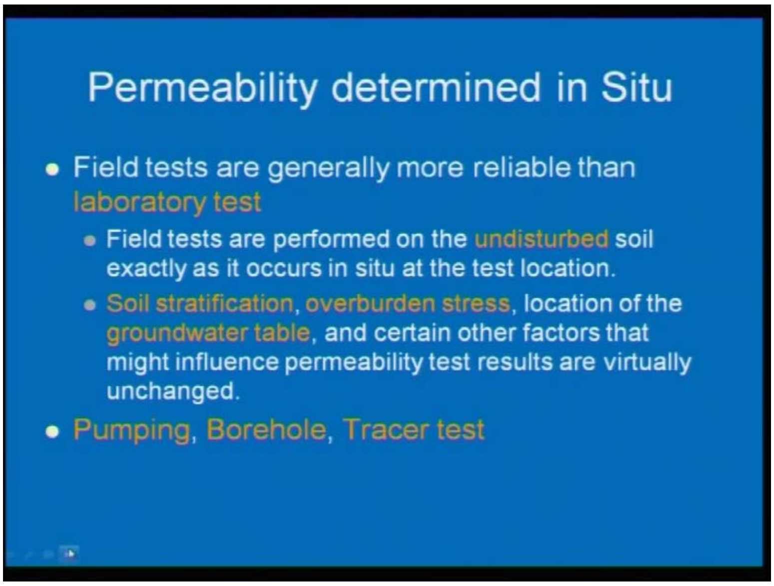
Now in general, what what should be your thickness of the filter, what is the recommendation of the IS code? Generally for horizontal filter, it is 15 to 30 centimeter; as per the Indian standard. And vertical vertical filter, so it will be 1 to 1.5 meter vertical filter, generally this is your thickness criteria.

(Refer Slide Time: 10:25)



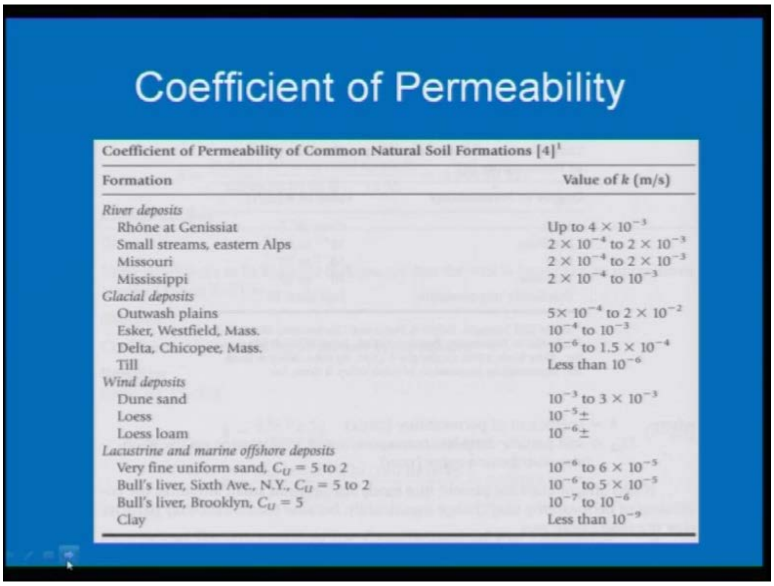
Now if you look at this over all, what we have (( )) this coefficient of permeability and its test, what are the different coefficient of permeability to find it out? The coefficient of permeability you can find it out from the field or as well as in the laboratory, what are the test you are going to find it out? Laboratory you are going to find it out by means of constant head permeability or variable head permeability test. So, this is just indication of this permeability test, so generally we will go for three to four test from that whatever the laboratory value you are getting that should be reported as average permeability, simulate with your field conditions

(Refer Slide Time: 11:04)



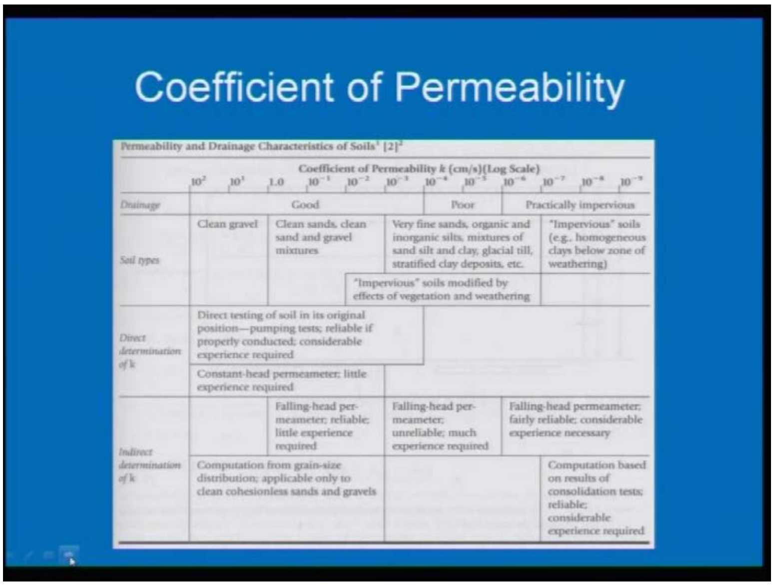
Then in field test, in field test, I have explained already this particularly pumping, borehole method and tracer methods. So pumping means you will pump pump the soil, pump the water, and find it out how much water drop down in the observer well also bore boreholes, you can find it out, what is the constant flow inside this borehole draw down or may be passing it. And tracer test, you allow some dye 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.

(Refer Slide Time: 11:44)



Then with this field test and laboratory test, you will find it out your permeability; and I have discussed different examples. And also there are different empirical relationships, and coefficient of permeability for different sands.

(Refer Slide Time: 11:54)

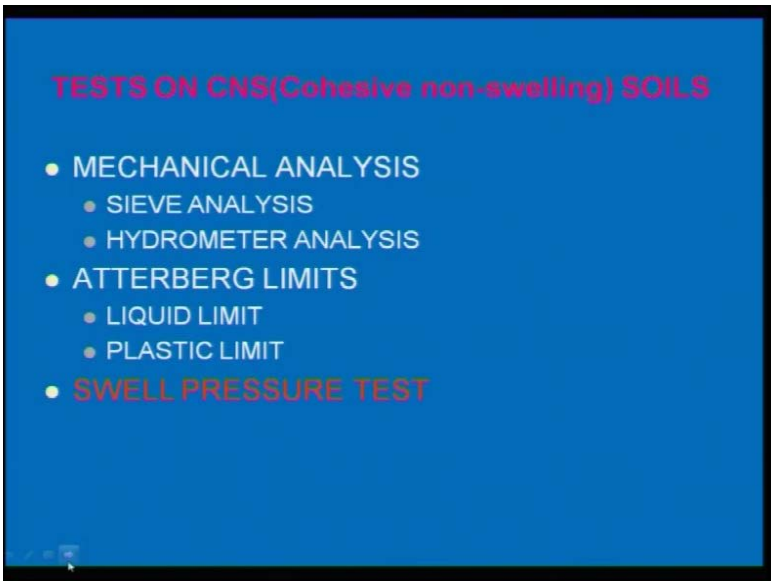


And how to choose where is your coefficient of permeability should be there for different types of soils, and what is your range. Then related to coefficient of permeability, there are two additional things; permeability in vertical direction, permeability in lateral directions that also I have discussed.

(Refer Slide Time: 12:06)

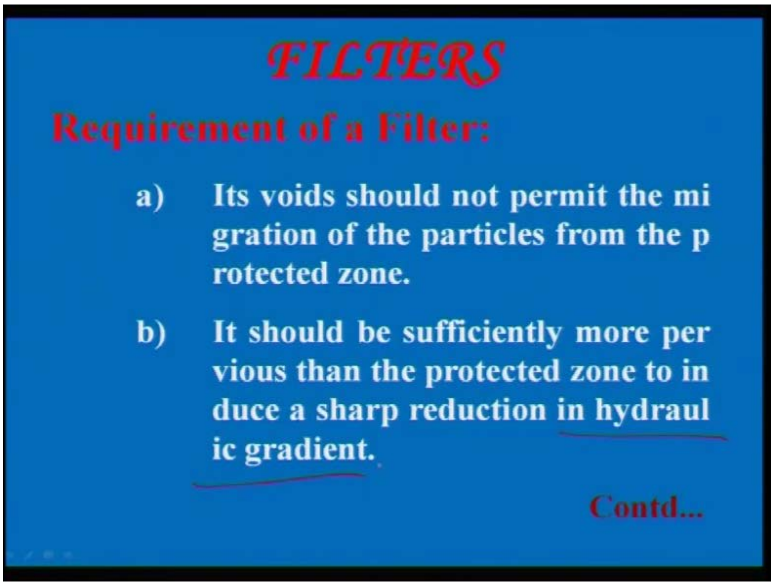
Then related to the coefficient of permeability, what are the different parts to be considered for irrigation projects; one is your pre pre construction, other is your during construction, third is your post constructions.

(Refer Slide Time: 12:28)



And with these, what is your what what are the different test you are going to do; and another part is your cohesive non-swelling soils, and what are the test, 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 coefficient of permeability you want.

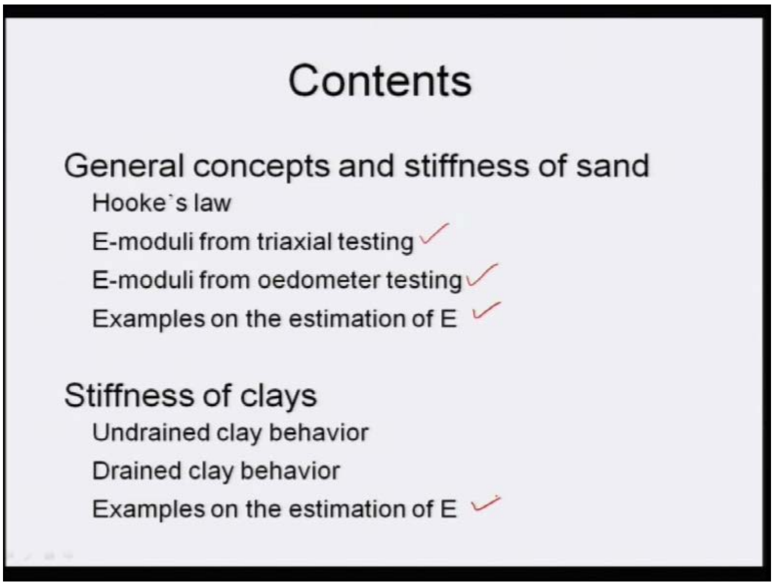
(Refer Slide Time: 13:00)



Because the main criteria for this filter criteria is your that means, you have to reduce your hydraulic gradient hydraulic gradient, so that the development of pore water pressure will be low down, this hydraulic gradient depending upon on how much sewage, how much water to pass through this filter. That means first you will have to decide your coefficient 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 coefficient of permeability to determine the coefficient of permeability in the laboratory as well as in the field.

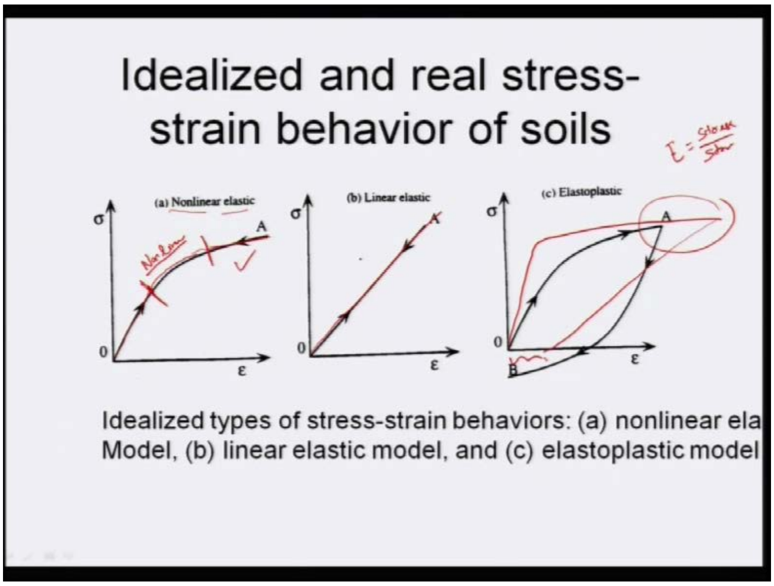
And now, we will start next one is your this is interesting one, soil stiffness parameter; as far as possible, we have covered most of the laboratory test and field test, some other laboratory in field test we will also discuss later on. So how to interpret soil stiffness parameter from these test means, soil stiffness parameter is nothing but your E and nu; E is your modulus of elasticity, nu is your Poisson’s ratio. How to find it out soil stiffness parameter, how to interpret for your modeling or for analysis?

(Refer Slide Time: 14:27)



So general concept and stiffness of sand or stiffness of 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 grained I put it as 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’s. So examples on the particularly estimated E, we will solve the example. And stiffnesses of clay that means undrained clay behavior; from there we have 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 fine grained soil.

(Refer Slide Time: 15:20)

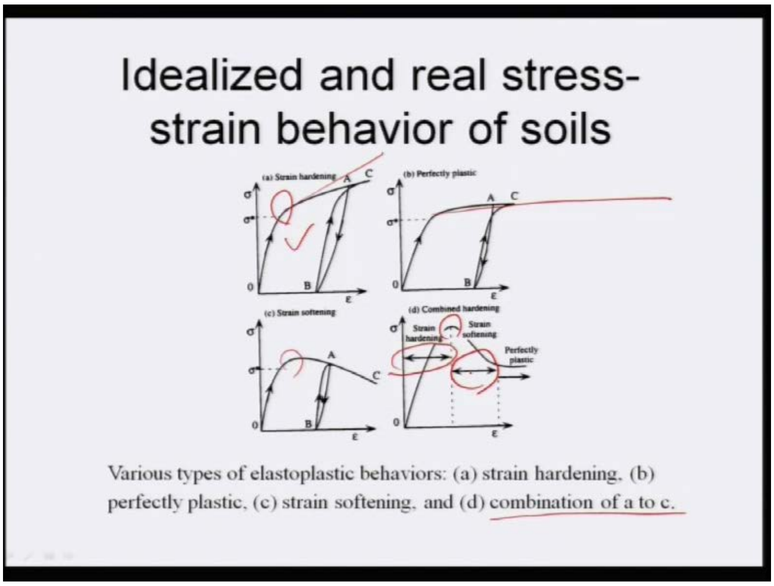


Now idealized and real stress-strain behavior of soil; if you look at this, I put it into three parts of these stress-strain behavior; one is elastic, linear elastic, another is non-linear elastic, another is elastic and plastic, elastic and plastic. Now if you look at this linear elastic means, this stress will increase with increase in strain; that means this stress will increase with increase in strain. As the value of strain you are going to increase, this 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, 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, going somewhere else, it will be linear up to here; after certain part of the linearity, 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 follow 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; elastic plastic means, what do you mean by elastic? Let us just think what do mean by elastic? 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 then what will happen? If I remove this stress, somewhere else as I increase, as I apply the load, the stress will increase, then your strain will increase. The moment I release your load or the stress, it will bounce back to your original position that is called elastic. Now non-linear elastic also there; elastoplastic 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 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, other is your non-linear elastic, other is your elastoplastic.

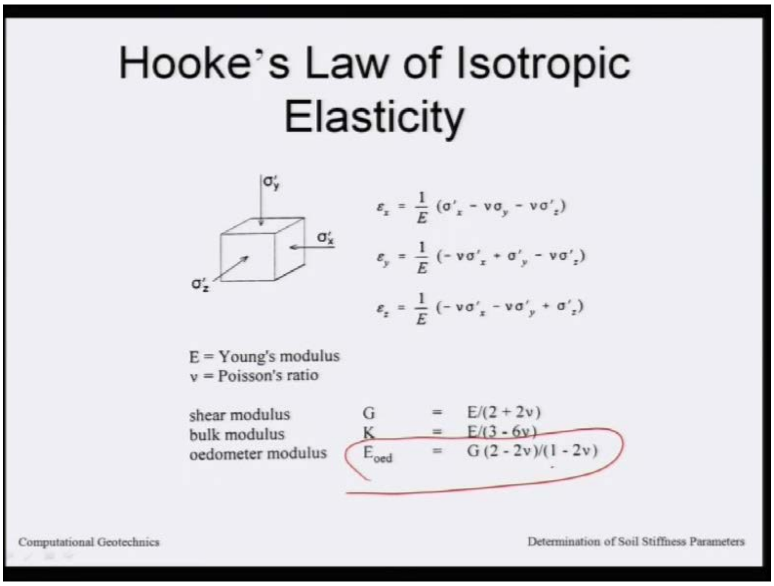
(Refer Slide Time: 18:46)



Now, based on that various type of elastoplastic behavior, I do not want to go in detail; this will be as in part of modeling. So basically we are idealizing how to find it out E moduli for your analysis. So various type 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 this strain, it 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 it is the stress is increasing linearly with your strain, and it will latent at peak.

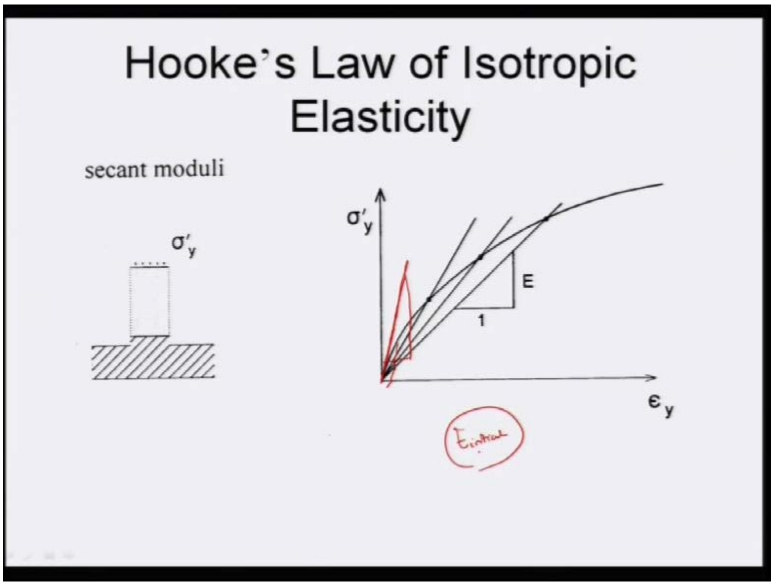
Then with this peak I say that this is my strength hardening; and with these after the peak the soil, this will decrease; and with this decrease, I say that this is my strain softening. Based on the strain value, how whether it is increasing or decreasing, then after certain part of this, it will remain constant this strain; at that time, I say it is perfectly plastic. So this three may be combined together I can write it, that also give your stress behavior of soil. And so these are just because of why I am discussing, this will be required while finding out E moduli. So just to know, what are your stress-strain behavior of soil; so this is the discussion.

(Refer Slide Time: 20:37)



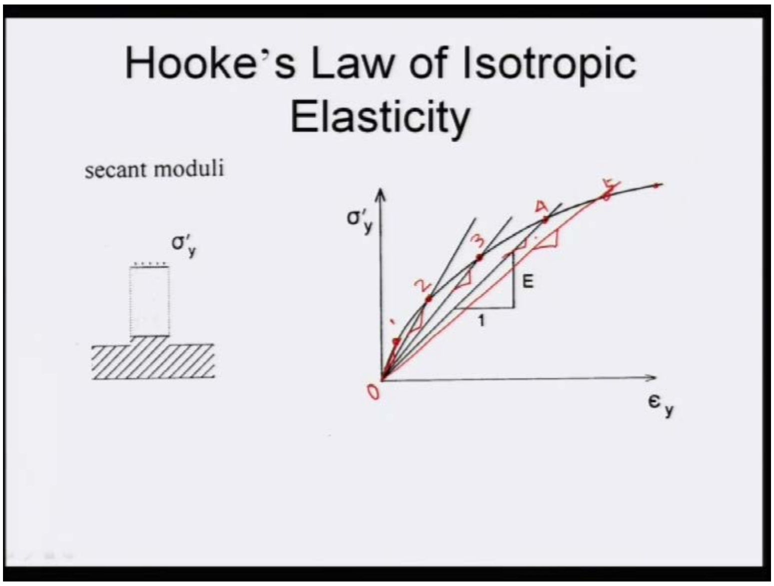
Then Hooke's law of elasticity; this this these are all you know all about this, so this will be E x E y and epsilon x epsilon y and epsilon z, you can find it out; from there you can find it out G, K and oedometer modulus; from this oedometer modulus is nothing but your G shear modulus 2 minus to nu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

(Refer Slide Time: 21:02)



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 secant moduli; E linear first part of the moduli is that means you draw initial part of your curve a 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 a 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 secant moduli, we need that is your secant moduli, if this kind of curve is there, how to find it out secant moduli, this is again the question.

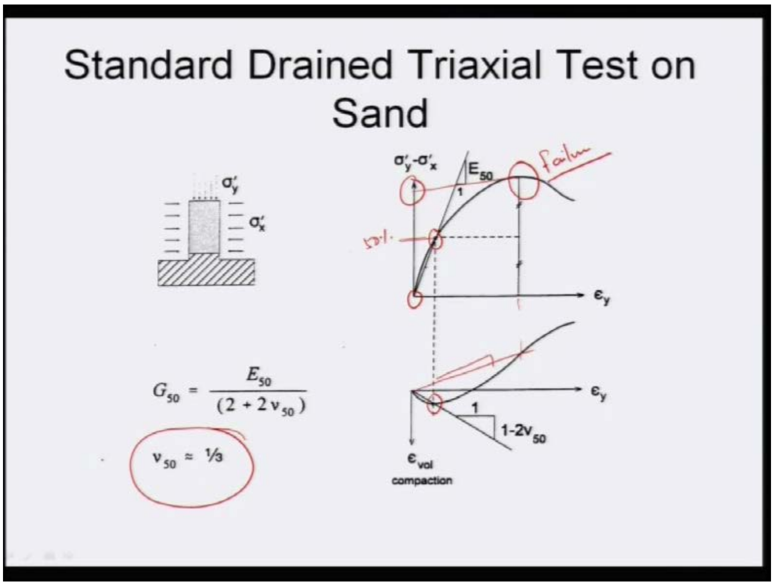
(Refer Slide Time: 22:18)



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 I mean in 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, that point you find it out; and join is by straight line, and slope of that that is nothing but your secant modulus. That means that secant 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 and behavior. Otherwise another way also you can report that means, if this is s stressed and curve of your non-linear throughout is there, mark it; there are different points; point 1, point 2, point 3, point 4, point 5, point 6.

So because this E is required in case of modeling, so join with this from o point 1, then join this point 2, point 3, point 4, point 5, straight line. For each point, we 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.

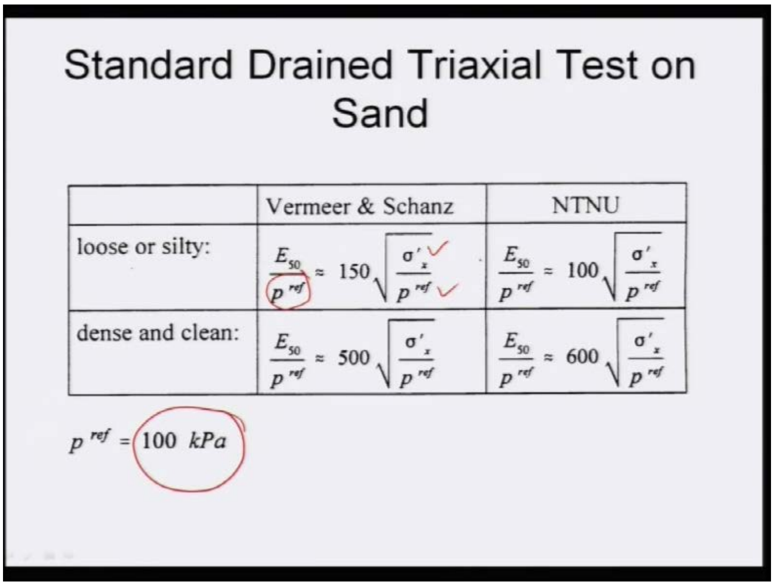
(Refer Slide Time: 24:15)



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, these I am taking as a failure right whatever your failure load is there, take the 50 percent, take your 50 percent of a failure, mark the point, as I said draw the draw 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 nu; you can find it out nu. Means, where I am getting the E? This E can be a extrapolated. This once you get the E, suppose I am getting E from here, I can mark it, I can join, whatever the slope you are getting that is nothing but your that slope will your nu value, Poisson's ratio value will because it is volume change in volume by your strain.

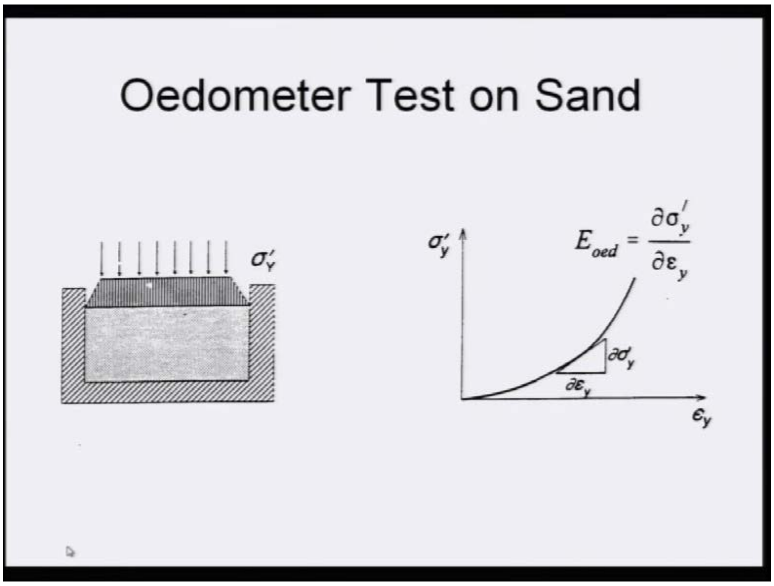
So based on the E, whatever you find it out E, that can be extrapolated the point the where you are getting the E, whether E 50, E initial or may be E final or E failure, that you extrapolate with your volume versus your strain, from there you can find it out nu. From here we are getting two parameters; one is your E 50 another is your nu 50; nu is nothing but is your Poisson's ratio; this is your modulus of elasticity; this is your Poisson's ratio. Once you know nu and E, then you can easily find it out what is the other parameter, G shear modulus you can find it out from this correlations. 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.

(Refer Slide Time: 26:53)



Standard drained triaxial test on sand: These are the people, they have given this correlations with this triaxial test; how to find it out E 50? One is your Vermeer and schanz, and NTNU; from there for loose or silt sand, and dense and clean sand, E 50 in terms of effective pressure that is your 100 kilopascal, they find it out in terms overburden pressure, this is your effective and p reference. These are the correlations they have given, if you even if if you you do not have if you know the what is your sigma x and p reference, p reference is your 100 kilopascal. Once you know, then you can find it out E 50, this is based on this correlations, based on your experimental results.

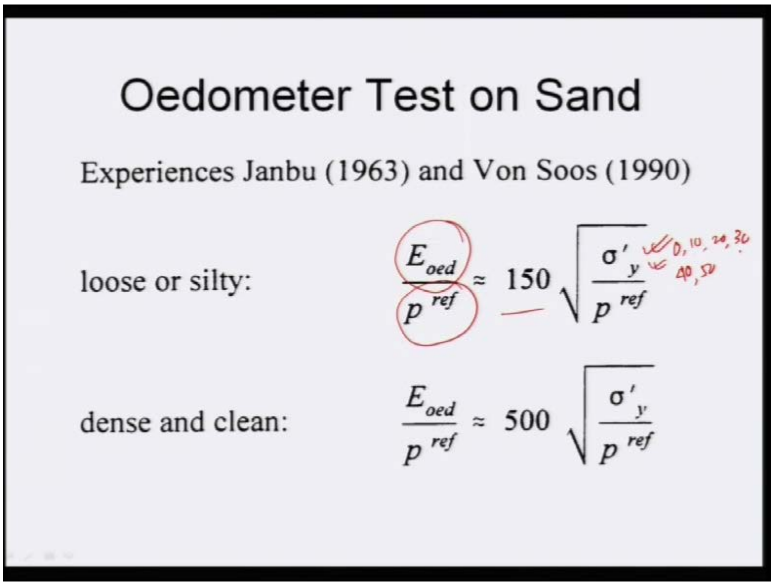
(Refer Slide Time: 27:43)



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 nu? Yes, I can find it out E and nu. 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 load, we know the area, so we are getting each time a stress we are applying; and by means of dial gauge, as I explained earlier, by means of dial gauge, we are measuring this strain, we are measuring this strain. So, with this help of that I can draw this stress stress versus strain from oedometer tests, the diagram of the stress versus strain.

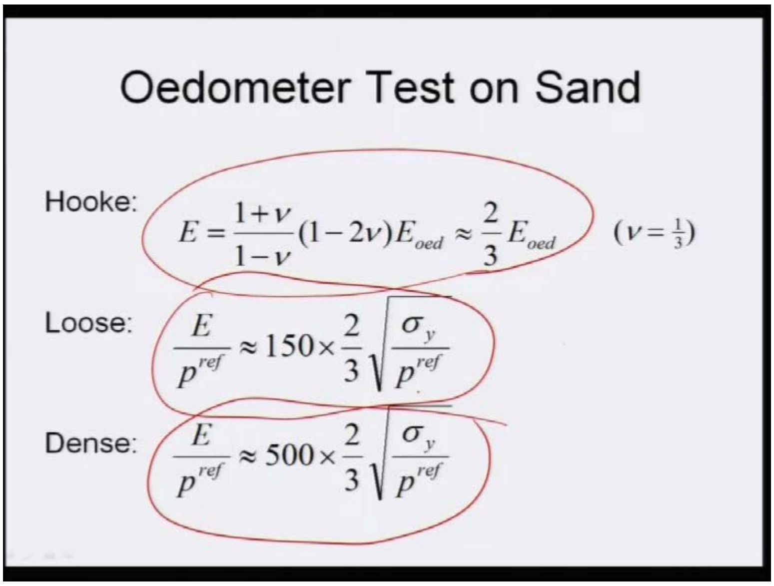
Now from there E oedometer is your change in stress by change in your strain that is there you can find it out at different points you can find it out; E of the your consolidation test from that, this is termed as if I am finding out E from oedometer test it has been retained E oedometer or E from your consolidation test.

(Refer Slide Time: 29:06)



Now from this test on sand, based on laboratory test results, Janbu 1963 and Von and Soos 1990, they have given for loose and silty sand, and dense and clean sand; E oedometer by p reference, p reference is nothing but your 100 kilopascal. So 150 by sigma prime sigma prime y by p reference; that means with effective to 100 kilopascal this sigma 1 prime we can find it out; this can be used from for your model; remember this sigma 1 prime, how we are using this E and nu in case of particularly analysis. If you look at from this experimental results, E you are getting with your 100 kilopascal 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 varying; for dense and clean sand also, E also varying. That means a correlation 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 your particularly E how it is varying your non-linearly.

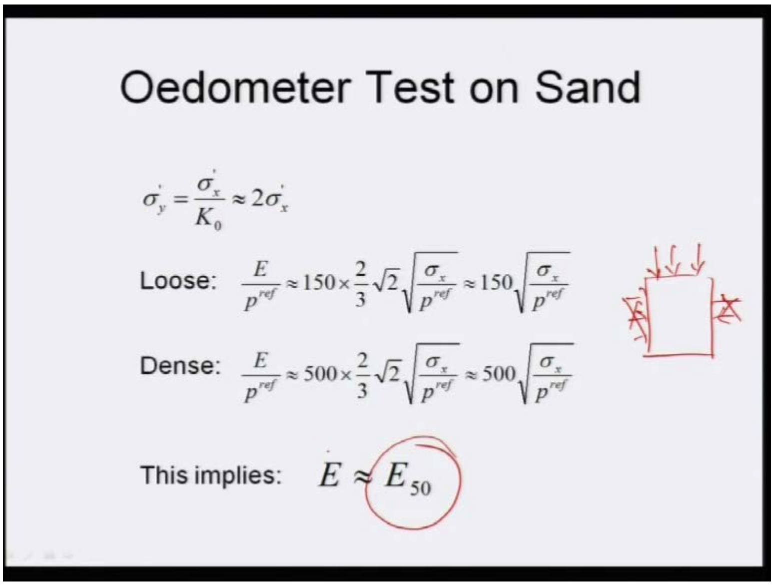
(Refer Slide Time: 30:27)



Now, by means of Hooke's law, E is equal to if I if it has been proven E is equal to particularly if nu is constant, particularly that soil E is equal to two-third 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 two-third 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 tests; you can write it E of soil oedometer test; so nu generally taken one-third from this oedometer test. So based on that, taking in that, you can find it out earlier it is for your E oedometer.

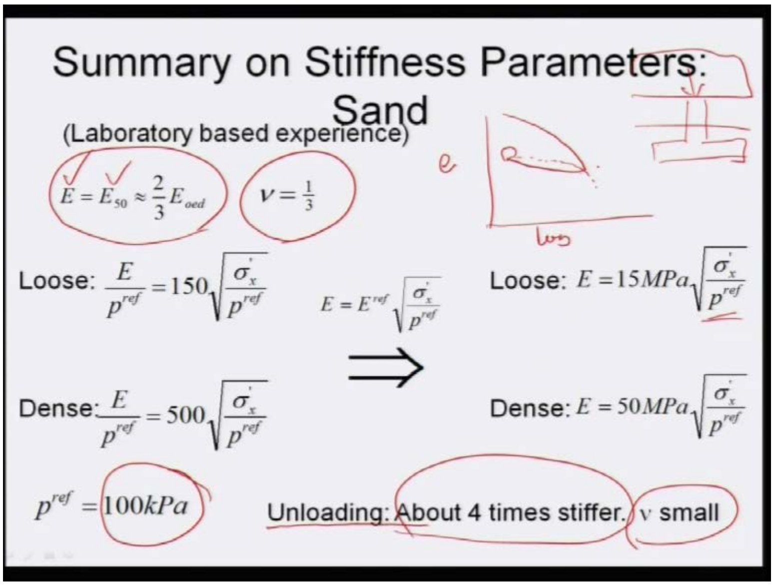
Then now E of your soil that is if I take it, you E as a two-third of E oedometer, from there you can find it out E of the soil particularly, loose as well as dense sand. So, this are these are the parametric estimation from your laboratory test; how it is useful particularly, in modeling or analysis that I am just discussing in brief. Then major parameter of your stiffness, the moment we say that this is for your static case, we are not discussing right now dynamic; for you for this, major soil stiffness is your E and nu; e is your modulus of elasticity, nu is equal to poisson's ratio that is required for your analysis.

(Refer Slide Time: 32:05)



So, it has been proved that also with your 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.

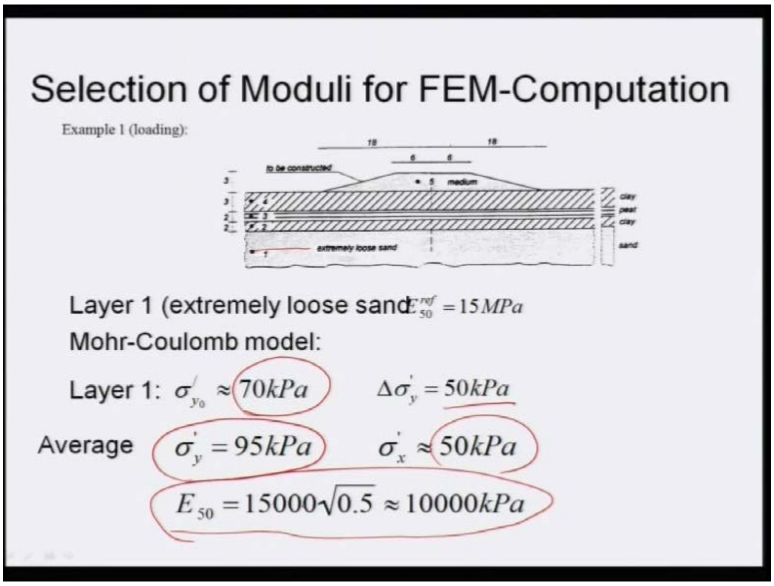
(Refer Slide Time: 33:10)



Now summary on stiffness parameters on sand particularly laboratory based experience; so that means if I from laboratory test that is your oedometertest, if I make it into summarize, E is equal to E 50, and which is nothing but is your two-third of E oedometer; nu is has been proven as it will be one-third. Based on that, for loose, E is equal to very simple, E is equal to 15 megapascal, sigma x that means particle stress or may be overburden sigma x prime by p reference; p reference in this case is your 100 kilopascal; and also for dense, for E has been. These are the correlation given based on your summary based on your laboratory based experience. And E is nothing but is your E 50, nu is equal to nothing but is your one-third. So, this is your loading; during unloading about four times stiffer, nu is very small; what will happen? Particularly, in oedometer test, in 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 moment I unload it, the moment I unload it, it is 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 nu is poisson's ratio is very small during the unloading part means, this value you can take as as x from this value, you can take it as a design parameter input, what will happen? During construction also, during footing also, they are 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 four times stiffer during unloading, and nu is equal to very, very small.

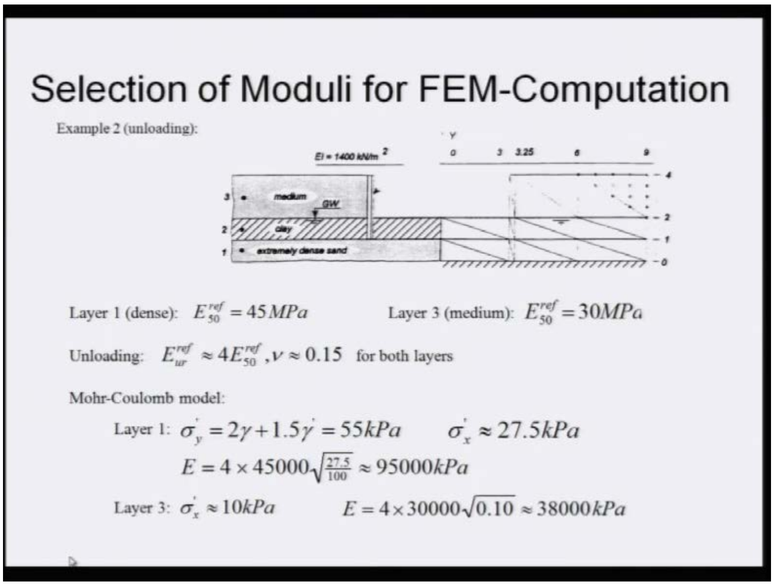
(Refer Slide Time: 35:36)



So, though this is not required, just in brief means, how to decide your moduli for finite element computation? So from layer 1, layer 2, average value of layer E 50 means, suppose if you see there are there there is an embankment to be constructed, and this is my soil deposits, clay, peat, clay, and this is your extreme loose deposit sand. So I put it this is your layer 1; sand deposit is layer 1; two is your clay; third is your peat; 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 megapascal. How you are getting 15 megapascal for layer 1? 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 1, based on the gamma, you find it out sigma y is equal to 70 kilopascal. And generally increase in your stress, because of your embankment loading, delta sigma y is your 50 kilopascal. So average of sigma y, you can take is your 95 kilopascal, so sigma x will be 50 kilopascal. From there, you can find it out E 50s nothing but is your 15 megapascal, 1500 megapascal or 1000, 10000 kilopascal from this average value.

(Refer Slide Time: 37:21)



Then similarly, if layer 1 is extremely dense sand; in case of example 2 that is means of unloading; if you look at this example 1 is your loading, example 2 is your during unloading. Then you can find it out during unloading. So, how the case of unloading will come into picture? So, may be I can I can stop it here. So next class, I will I will show a little bit I i can consider, and I can go from laboratory test to field test for how to find it out this E value. Other part, we will discuss.