Foundation for Offshore Structures
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Module 01
Lecture 06
Basics of Soil Mechanics VI

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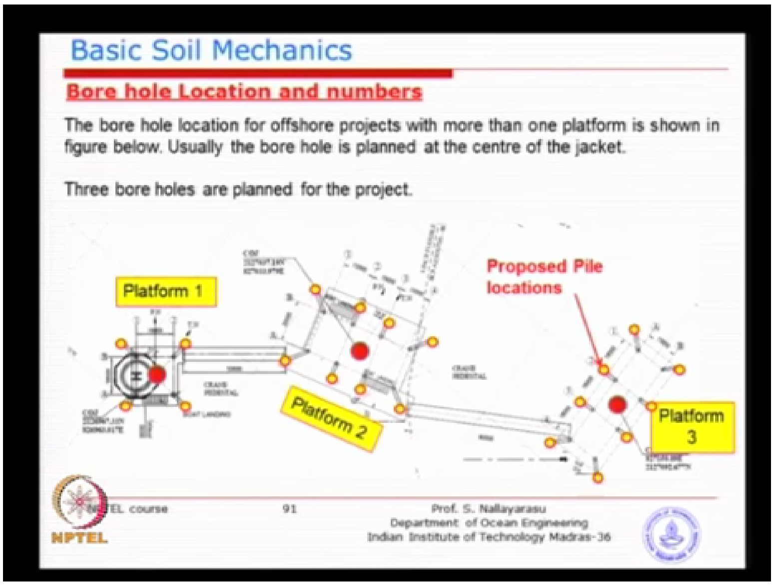

So I just wanted to show you in in a typical case how the bore hole located for offshore platform, you can see here, we have pre platforms for this particular field. Each platform is different in nature, number of piles orientation, location. So we can see here platform 1,2,3, the one got only 4 piles located approximately about 30 meter by 30 spacing whereas we come to the second platform slightly bigger, but got piles space that typically 60 meter by 40 meter and another platform similar in nature and got many number of piles.

Now if you actually strictly speaking, you would like to do a bore hole at every pile location in the vicinity so that when you are driving the pile, 2 things you are able to drive according to this what you have done in the design and also the capacity predicted would be similar to what you have calculated, you know. So basic idea is if the capacity is not adequate, you have a choice of doing two things either you can increase the diameter or increase a penetration for that particular pile, but normally offshore platforms what we do is keep the pile diameter same for all of them and try to increase or decrease the penetration, according to the load it carries, because all these piles are not going to carry the loads in a equal manner depending on the wave loads and the gravity loads.

So many occasions we do not change the diameter, but you can adjust the penetration. To adjust the penetration if the soil parameters are different then you can use that parameter to calculate. So the best practice is to do a bore hole at every pile location, but normally we do not do it, because the distance is quite closer, we try to use the common bore hole, which represents that particular platform.

Of course then you can ask a question why not we do only one and that may represent the whole area, which we do not know, all depends on the variability and the distribution of the stata (())(2:18) profile along the. So sometimes what we do is if we have 3 are bore holes like this, you can actually make profile and see the trend of change. What will happens to the layer 1, layer 2 and layer 3 and then you can come up with the common design profile, but highly variable in nature.

So you have to be cautious in using this. I just wanted to show this picture so that you can understand how we planned a bore hole location and the numbers for a typical offshore project is something like this irrespect to the number of piles you try to use one of them. Of course, the best practice could be individual or a medium, basically you can do one here at the one corner, you can do another one. Then you can get up, you know profile for each platform which will represent all the number of piles so that your risk is reduced. All depends on how much risk you want to do and how much risk you want to get away.

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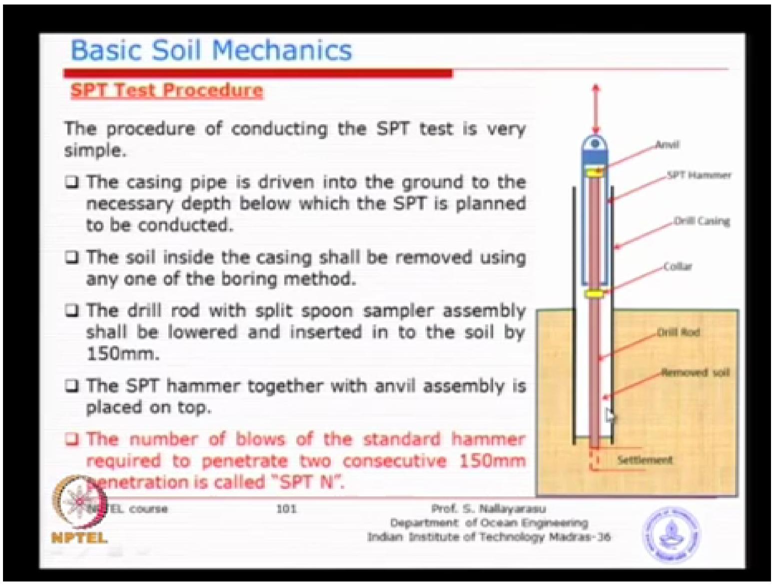

The next thing, I just wanted to highlight the importance and the differences in carrying out SPT test, because we are going to do a correction factor for SPT later on when we are doing empirical correlation. So the test procedure is very simple you drive the casing to a depth where you want to do SPT and then remove the soil either by agar boring or by wash boring methods and then lower the sampler together with the drill rod and you place your SPT hammer on top of the drill rod with an angle normally to avoid damage and then you use either a machine, here (())(3:52) machine of the camp or you use just human person to lift and lower.

So basically the number of blow counts not normally taken for 130 centimeters, you divide them into 2 groups, first 50 second 50, but the first 150 millimeter the rod should have penetrated. So if there is a totally 45 centimeters 15 centimeter is going down by (())(4:20) and the second and the third is taken as the count for the SPT. This you need to remember, because sometimes the bore hole reports will show 2 numbers you need to add them and the average them. So this SPT number count is taken for 2 consecutive 150 centimeters of penetration by the hammer blow. The number of blows is taken as SPT. This is a standard, because the weight is standard. The height of draught is standard.

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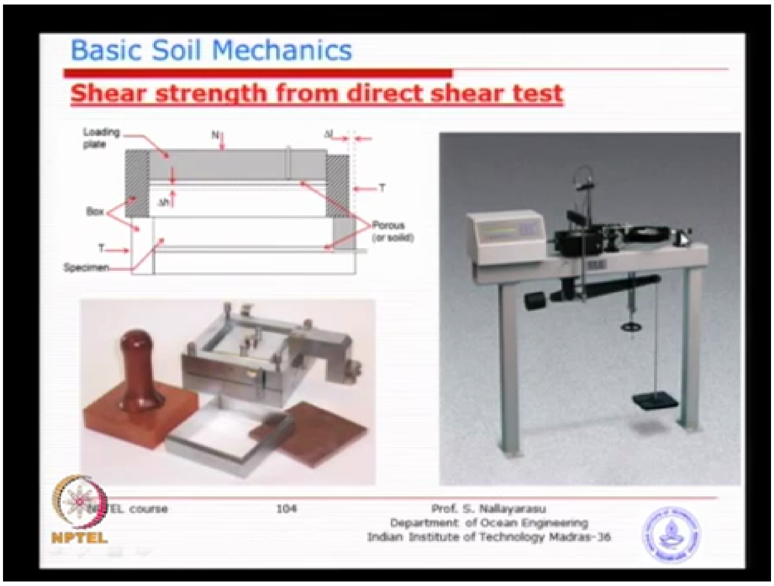

And then we will go into shear test, then I think I have shown you the picture that the previous class for just the understanding little bit more on how the test is carried out. So you have got the sample placed inside here and typical setup will be something like this.

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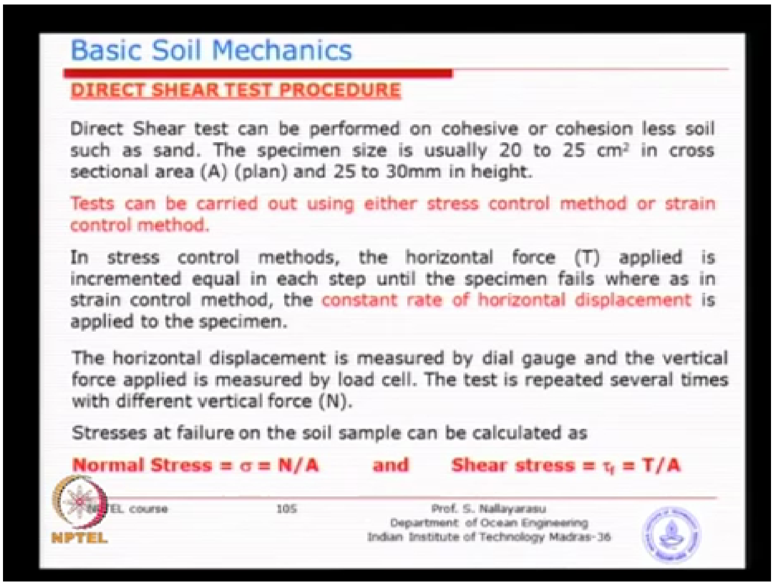

So the test can be conducted by standard method by (())(5:10) codes. So the typical area in plan view will be around 20-25 square centimeters, you can adjust and the height is something like 20 to 30 millimeter height split into 2 half and test can be done by either stress control or by strain control either by moment control or by force control either way you can prefer.

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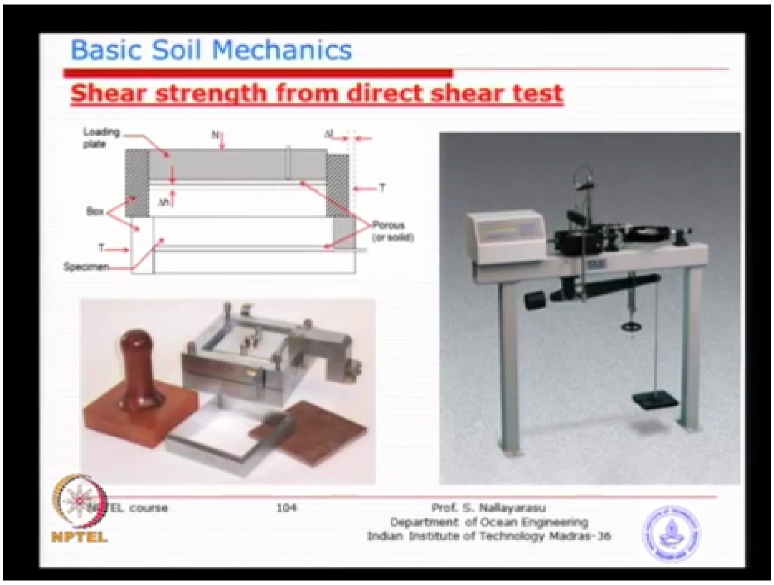

This setup what you have is the force control

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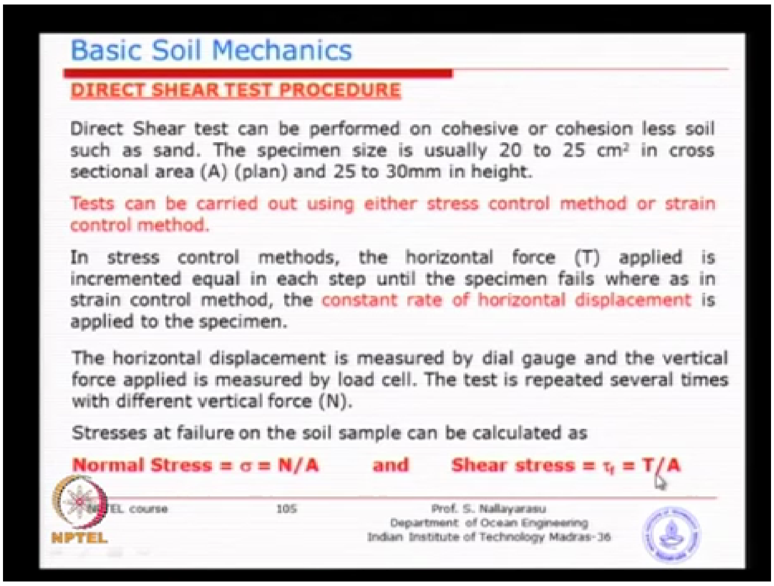

And basically the normal stress is calculated as the applied force divided by the planned cross sectional area. Similarly the shear stress the horizontally force F divided by area. So you know you can have a (mul) combination of this. If you have larger the normal force you will see lesser or higher effort to break this.

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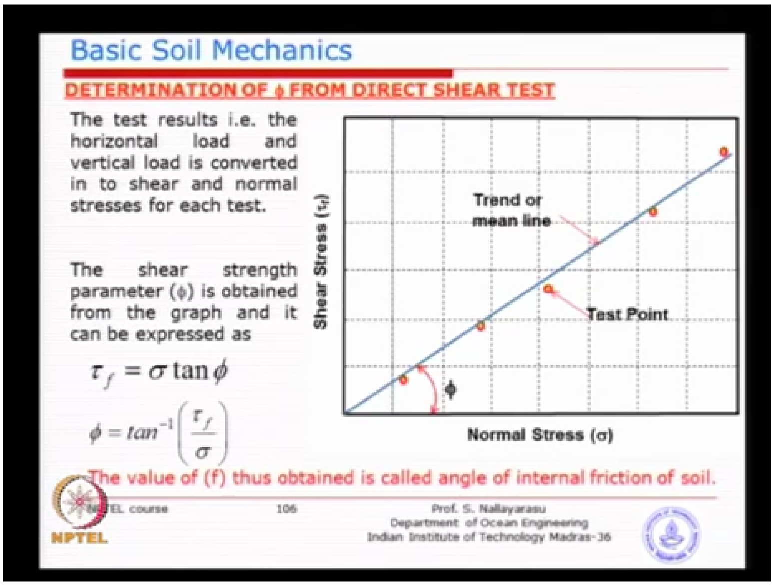

So you can have multiple points on a graph which you can plot it something like this in order to get the shear strength value which is angle of internal friction, which we are looking at. So you have see you have to see this particular picture, you repeat the test with the different normal stress, you get the shearing stress and get a trend line or an average line so that you can predict the values. So if you happen to have nice test results which coincide this like a sandy material, then the you take that tri angle the angle will be proportional to the shear stress and the normal stress which is just and you can find out the angle of internal friction by this method, which you can compare with material type as well as the natural test of angle.

So this basically simple means of trying access the shear strength value, which is very easy to do it. One of the problem with you know most of the foundation design when we are looking at for example spread footing (())(7:07) or a pile foundation what we require is not the soil to soil friction angle, what you see here is actually soil to soil friction angle by which the soil will try to fail, but now we have go slightly more, because what we are looking is this soil to structure or soil to foundation friction angle, you know that is what is going to be failing (())(7:28), for example, you have a pile inserted into the soil and try to apply loading the pile will fail once the friction is overcome by between the soil to pile. So we are not looking at soil to soil failure, we need soil to foundation failure.

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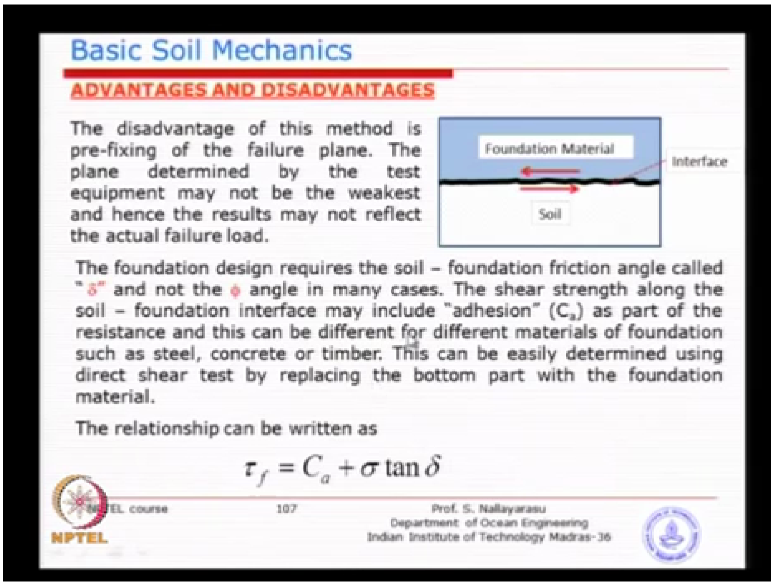

So in order to determine this particular test is very helpful, for example, you have a foundation material something like this for area of (())(7:53) or a gravity foundation. When you are trying to fail, it has to overcome the friction between the soil and the so that particular angle is not angle of internal friction is actually foundation soil friction angle which we need to find out, which can be easily found by using the same test method.

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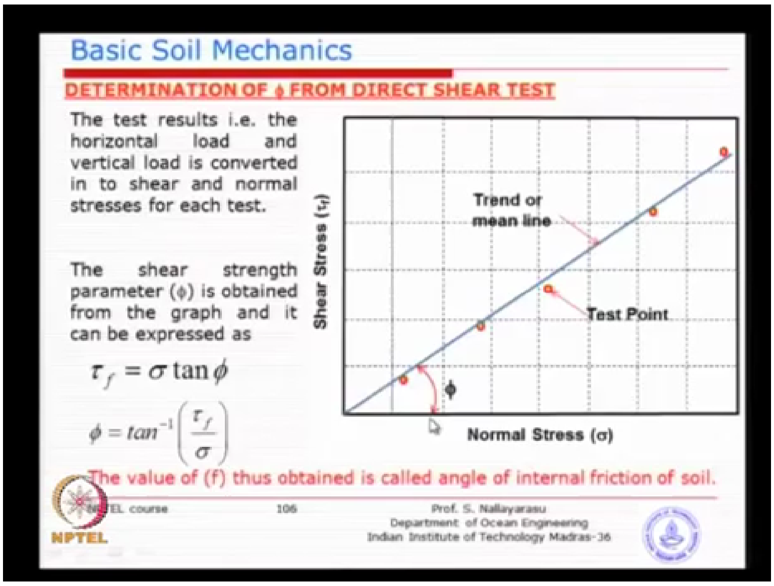

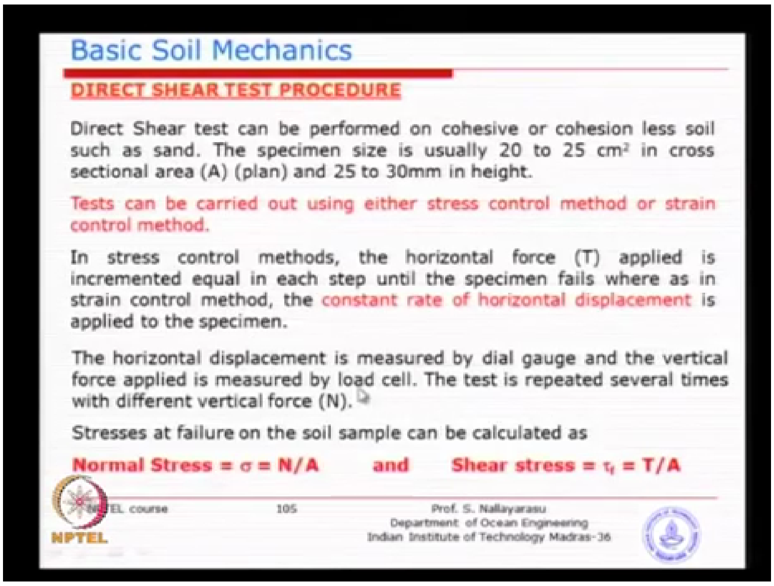

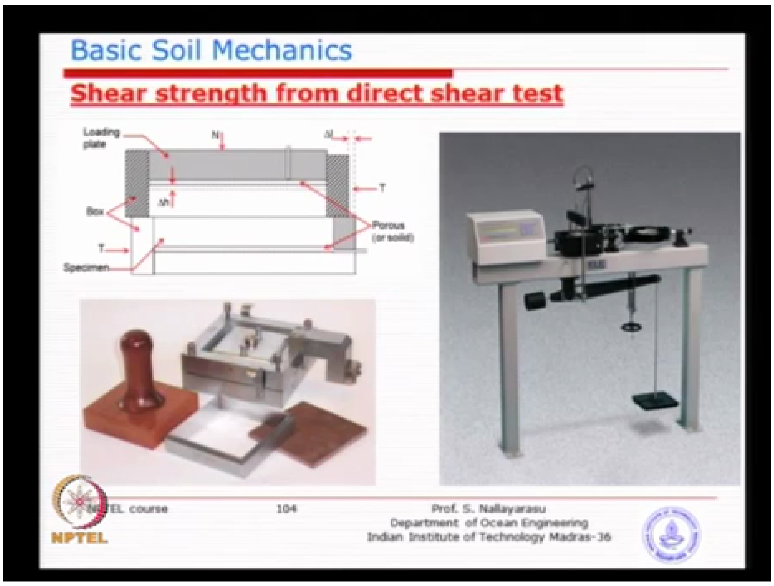

We can do this by just replacing the bottom portion with the foundation material instead of soil you just replace it with concrete, for example if it is a concrete footing and filled with the soil. So the soil will start failing only when it over comes the friction between the foundation material on the soil.

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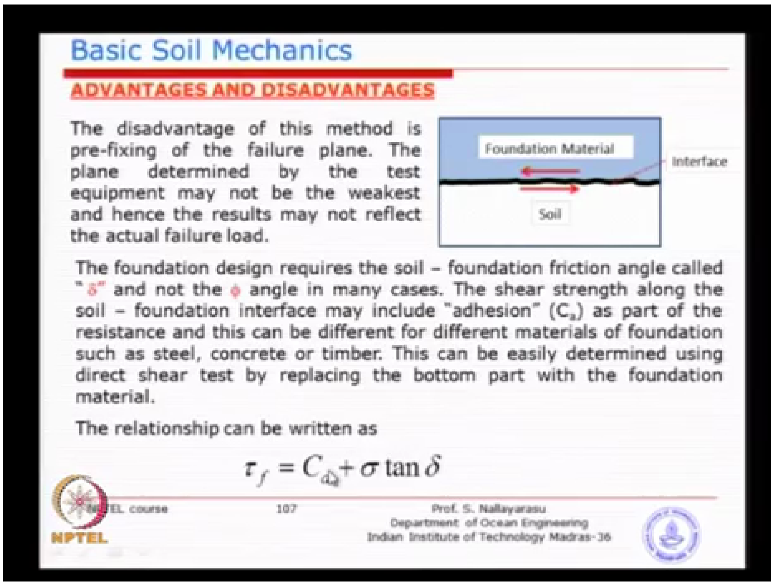

Basically that is the idea behind a simple shear test can also be used to do or carry out or arrive at the soil pile or soil foundation friction angle, which is of more important for us and basically it may contain two components one is friction component the other one is the (()) (8:49) components. Suppose if you have a clay sand or mixture of sand and clay, you may have a little bit of (())(8:55) and the remaining part which will be friction. So you can find out both together. So that test is basic idea is you could do this only with this test not with any other forms of test, which I just wanted to highlight. The disadvantage of method, I think I have already explained last class is only the problem of pre-fixing the failure plane, which may not be the actual failure plane that you think, which is not a good idea, but then that is a weakness of the method itself.

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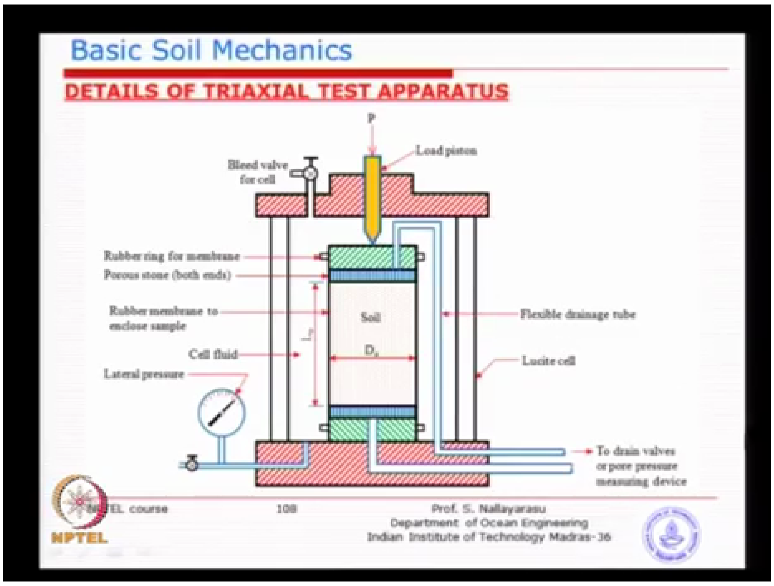

The next one I think we try to go for quickly understanding the triaxial test. This test can only be perform, if you have undisturbed sample brought to the laboratory and normally this sample is placed inside rubber membrane of very thin rubber membrane so that it can keep the shape in same condition until it is tested and this will be placed inside which can actually be pressurized for external pressure and we will have bottom and top porous material so that when you are doing the compression testing, the pore water pressure can be relived either from the bottom or top depending on wherever is higher.

So basically when you are compressing, it can get consolidated and can relive the pressure or you can actually do the test by closing the valve you do not allow the drainage to happen. So you have one option whether you want to do drained test or undrained test depending on the situation, as I explained in the previous class, you know if you look at on-shore condition, for example a partially saturated soil when you are trying to compress, you may actually evacuate the pore pressure by means of drainage, it may go away or it may just come up, but whereas in soil conditions in marine situation, you have a equal hydrostatic pressure everywhere. So the water cannot escape. So 100 percent you will have a undrained situation, you may not be able to drain, because the pressure is everywhere similar and that is one of the reason most of the marine soil samples we do undrained conditions.

So you have option of draining or undraining depending on where what you want to do number 1 and you also have an option of doing external cell pressure and most of the soil samples we do a external cell pressure, but there are cases where you want to avoid external cell pressure we can do with the un-confinement that means you do not apply the outside. So what you see here between this and this will be filled with fluid. So we can just have a you can increase the pressure by means of an extremal compressive device or by means of hydraulic fluid.

So we can just keep approach and the pressure is applied uniformly throughout the cylindrical surface of the this specimen and the normal force is applied from the top by means of either a piston or again by hydraulic cylinder or sometime by a dead weight we can just plays one by one step by step various methods are available and you can measure the cell pressure by means of dial gauge and you also can measure the pore water pressure and you will have a load cell at the top, which will measure the force applied and you will have a device to measure the height or consolidation. So lot of instrumentation will be involved which you will be able to see in one of the test setup in laboratories.

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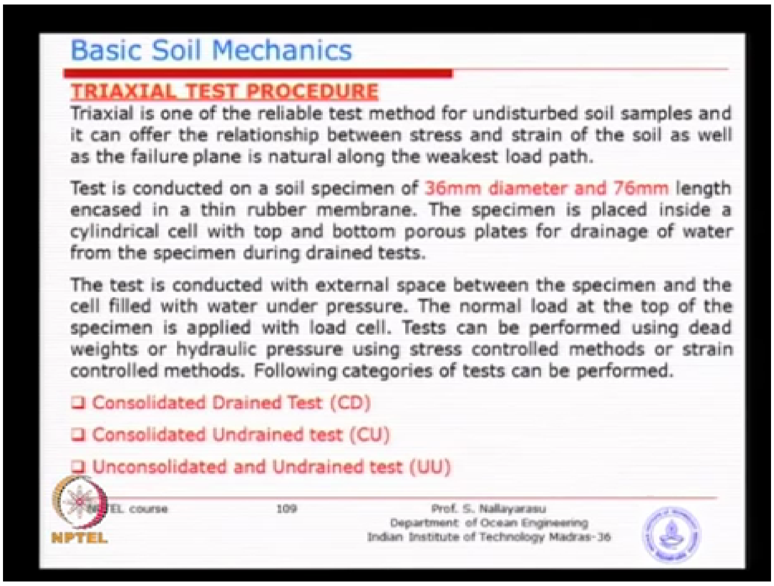

The test can be conducted as I mentioned earlier on, you can have consolidated or un-consolidated that means the soil sample is consolidated prior to loading or un-consolidated and also drained or un-drained during the loading itself. So there are two stages. The soil sample is placed you apply the external pressure and this external pressure during the process of increasing the pressure from 0 to the test pressure, you allow the soil sample to consolidate or un-consolidate that means drain is allowed or not. If you do not allow the drainage even during the increase of pressure that means, it is not allow to consolidate it will be just there and then during the process of application of normal loading at the top.

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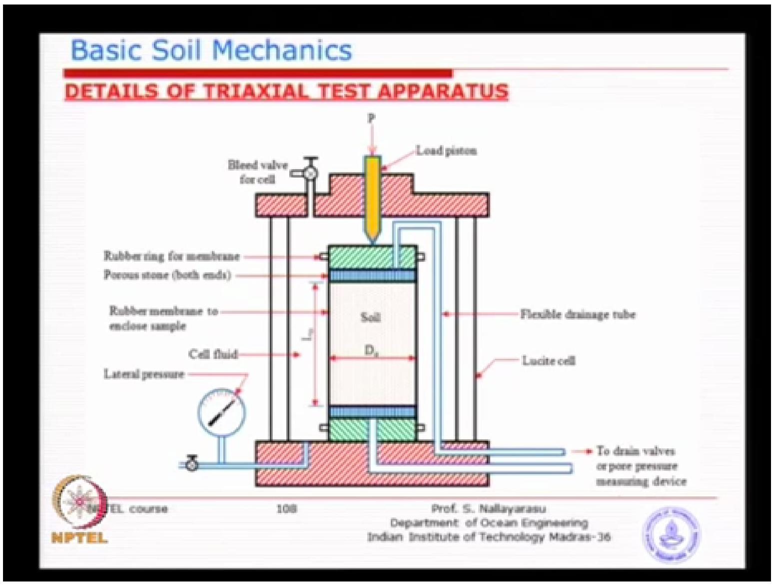

This loading at that time whether you open the drain valve or not will actually desired whether it is drained or un-drained. So that means on the time of loading you may allow consolidation, but the time of pressurizing you may not allow.

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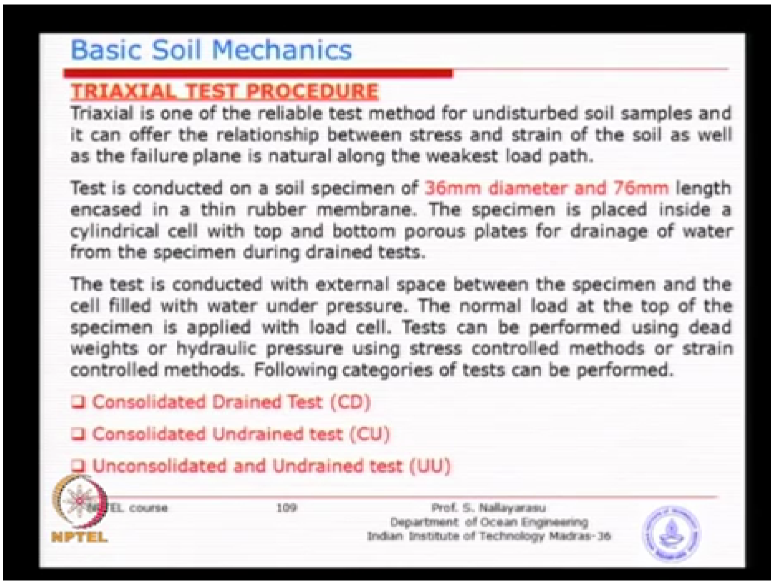

So there are two stages. So that is why you need to be little bit careful. So there are three types of test consolidated drained, consolidated undrained and then unconsolidated and undrained completely the drain valve is closed. All the time even during the initial pressurization cell pressure application as well the normal loading. In this particular case as you can see here, the diameter of the specimen is only 3 and half centimeter 36 mm is quite small and then 76 mm in length, because to bring a bigger soil sample also not very easy, you know especially when you are doing marine bore hole to bring a larger size sample. So that is a standard size for the triaxial test, most of the time use this.

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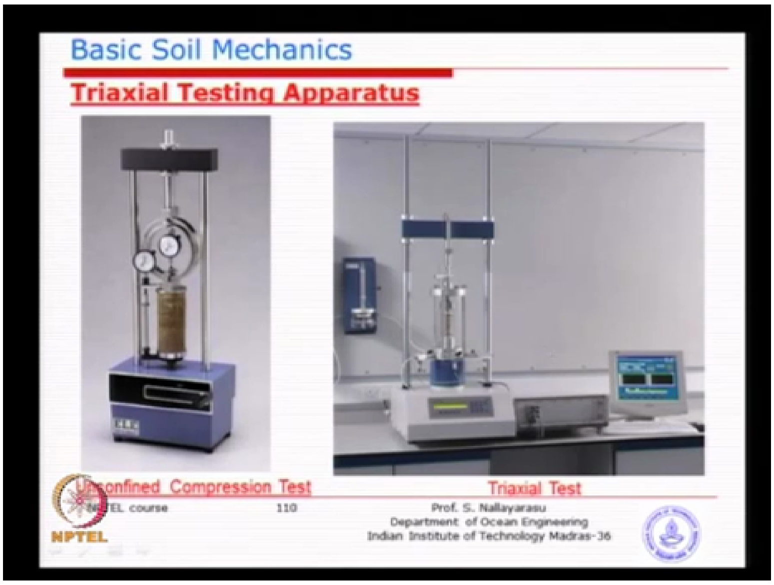

Typical test setup you can see on the right hand side that is the one you see extremal cell whereas this one, you do not see here external cell, which is normally used for un-confined which we will talk about it little later. Mostly we use it stiff clay or sometime or in fact rock also is tested using this for barring capacity un-confined compression strength. So this type of test apparatus, you can see fully computerize in nowadays. So we can get all the test results in computer.

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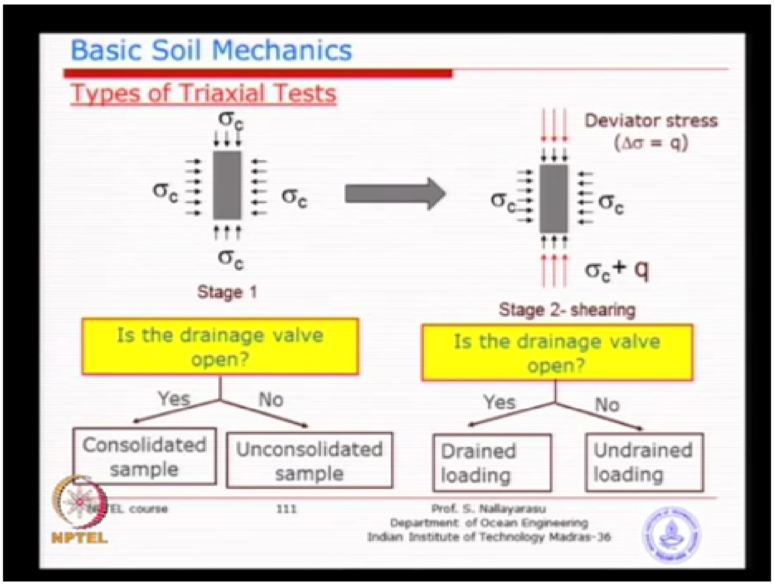

So the idea behind the more the pressure that you apply the external cell pressure it can take a different types of failure load. So that is why we can repeat the test in 2,3 similar setup, similar soil samples so that you can plot the results in more circle to get the trent line or so called to the failure envelop. So stage one whether when you are increasing the pressure from 0 to sigma C whether you allow the drainage or not that is the procedure for consolidation during the initial stage.

So if the drain valve is not opened is basically un-consolidated. If the drain valve is open, it is consolidated during the process of initial increase of pressure from 0 to sigma C all around the sample. This is not during testing and then basically when you are applying the normal stress at the top and at that time again you see whether you are allowing drainage. So you have a choice of allow drain in the initial stage and then close it and then during the testing you can open or close. So that is basically drained loading or undrained loading. So these are the two things that you need to remember when you read the results, because sometimes you may have a different type of results and you need to correlate with the results that is applicable to marine conditions.

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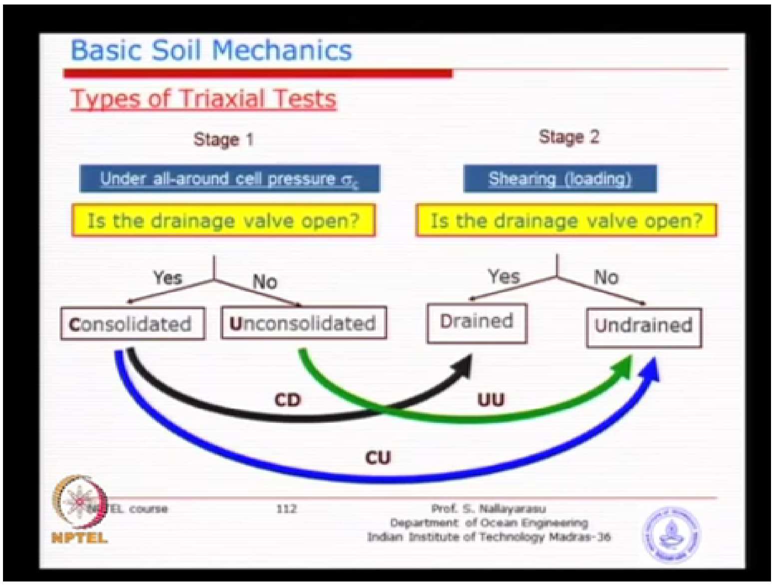

Similarly you can decide all three cases consolidated just pictorial view to give you one idea that what we need to look for, CDs or CU and UU is commonly used as I mentioned which will be similar to the marine situations. So stage one, stage two is application of pressure and the stage two is the failure of specimen by means of application of load.

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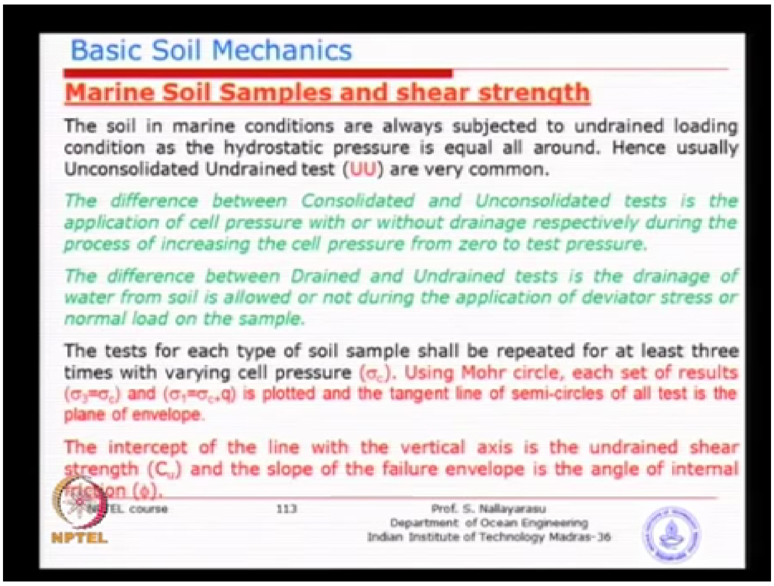

So marine samples we normally use UU conditions which is very very close to what we have. The difference between consolidated and un-consolidated, I think I will already explained. It is the application of cell pressure and the drained and un-drained during the process of loading you try to allow drainage or not and you can use these results the application of external pressure will be your you know basically sigma 3 the lateral pressure and sigma 1 will be your applied principle stress in vertical direction, you can go to more circle and plot and you can draw that failure envelop for various normally we do 3 test at least minimum to get the trend line and the intercept with the vertical axis is your un-drained shear strength and the slop of line of failure envelop will be your angle of internal friction something like this.

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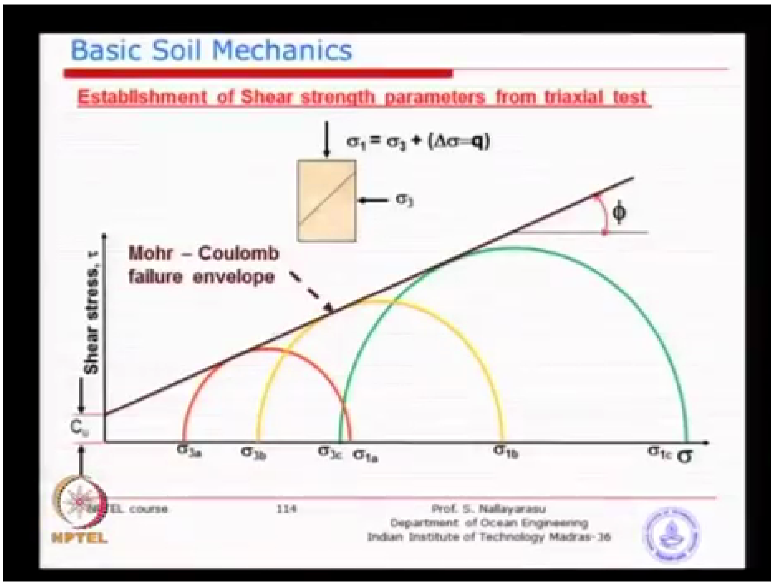

So each test will have sigma3 and sigma1 applied. So you can just plot it on a more circle which you can get and take the tangent line this you have to find out and take it to the intercept to the vertical axis, which is your shear stress and which give you to see the undrained shear strength and the angle you can take it as phi value which is going to the represents C phi soil. So this particular soil has got undrained shear strength or shear strength and some angle of internal friction that means it could be a sand clay or clay sand of particular fraction.

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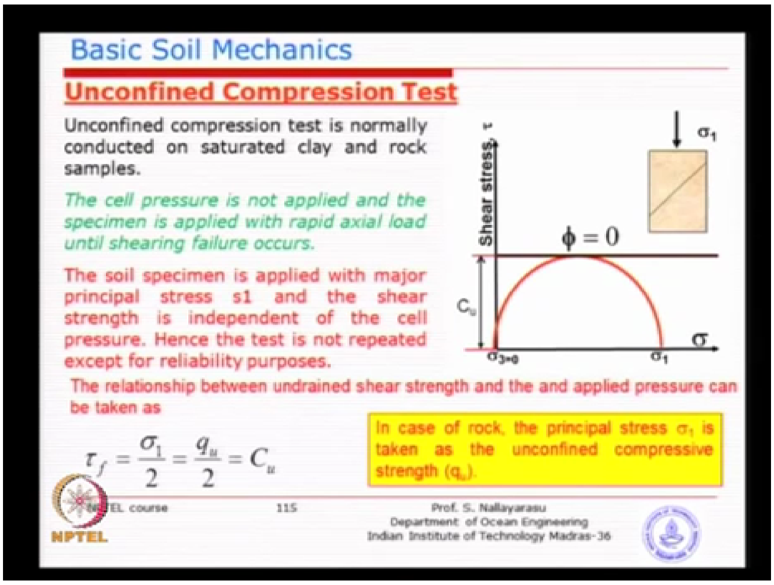

In case of you know if you want to do a test quickly, because the drainy conditions take longer time, because if I just what I have mentioned is not the time inside their, the drained procedure can take several hours several days depending on the type and the type of soil and amount of points (())(18:21) fines present in the material whereas if you do not want to do drained condition, simply remove the external pressure and break the specimen only by means of compression and this is more you know common for the rocks, but also can be used for clay material and uh basic idea is you do not have sigma3, sigma3 is zero and apply only the vertical a load which will make the specimen to break at a particular natural angle of failure and plot it in more circle you can see, this the phi is becoming 0, because it is horizontal and the intercept to the vertical axis will be your Cu.

Now it is not going to be directly you are going to get, because sigma1 is here and its half of it is Cu, but the idea behind, this can also be used for rocks. The notation given for rock is basically unconfined compressive strength and when you want to relate for soil type of material, half of it will be your undrained shear strength. So the relation between unconfined compressive strength and the undrained shear strength is 1 by 2 and many time you need to remember, because to look at some of the codes they actually give the unconfined compressive strength rather than undrained shear strength. So you have to relate it.

So whenever you have this test results of unconfined compressive strength tis results for soil or rock, we take half of it for shear strength, but in case of rock we do not go to Cu, we actually use the unconfined compressive strength to find out the values of point index, I think that is going to give you your barring strength you know, if you are designing a foundation to rest on a rock then the design procedure is slightly different, which I think will be taking up in later stage of the course.

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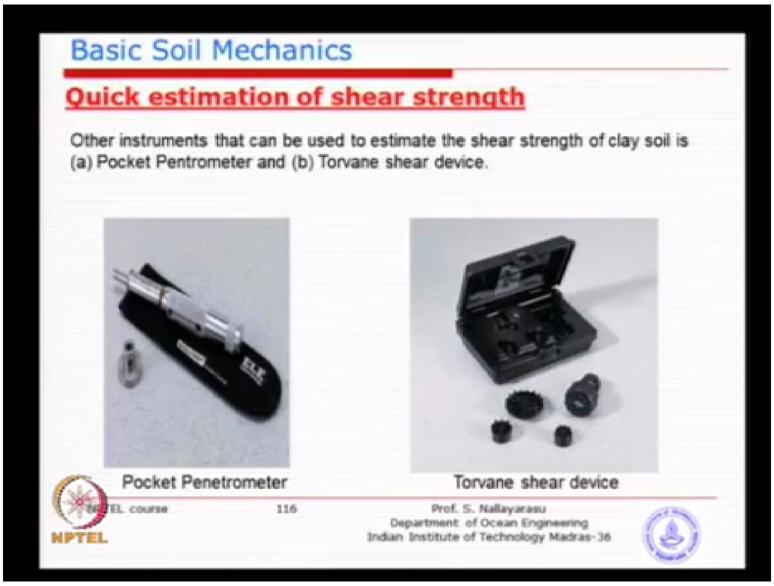

Sometimes you also have handy tools. So among all these test mostly you can also have very Quick estimate of shear strength using packet penetrometer or torvane. It is actually a mini device just insert into the soil, but of course these are all very useful for shallow foundations when you are doing in a field survey you just make a small pit and try to do a this kind of test results quickly to access.

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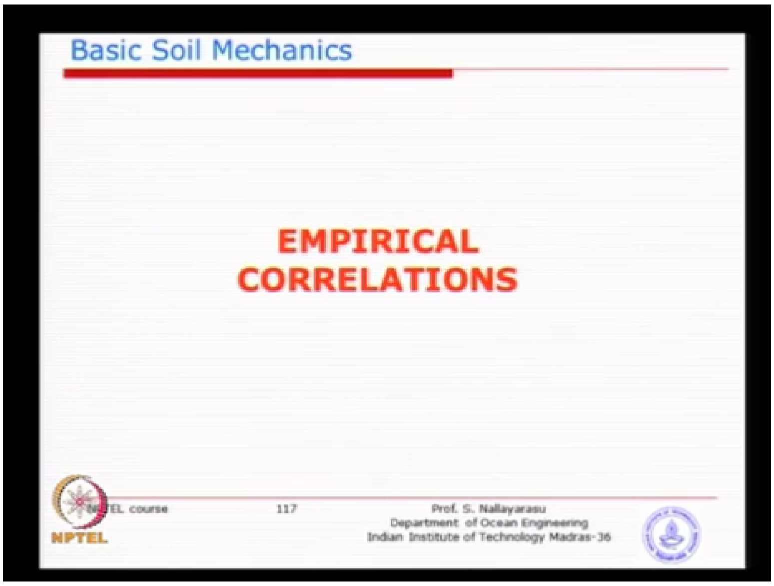

What we are now going to look at is you know basically having done so many tests. How do we arrive at relationship for design parameters for design.

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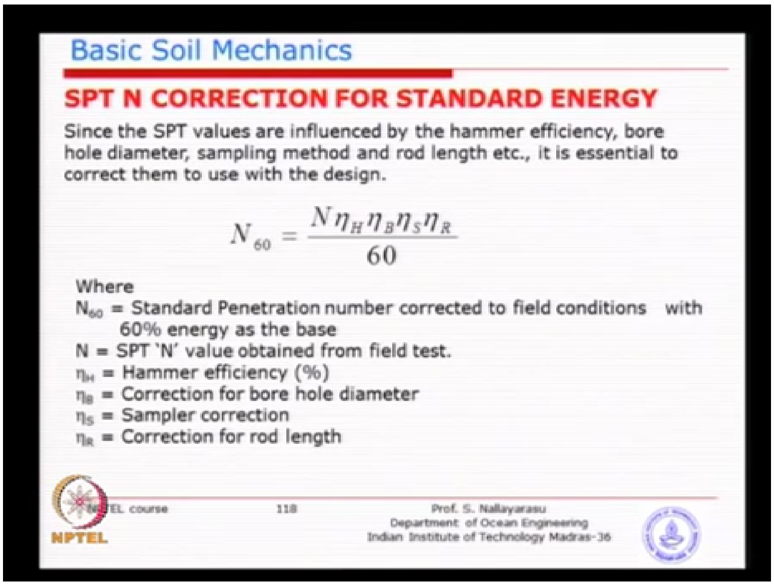

So the first one will be your SPT, I think which we have got some idea about it right now. Now when you are doing this boring we are doing a SPT at say 10 meter below ground level you have removed the soil, because you cannot carry out SPT test unless you remove the soil you reach the 10 meter depth with this SPT machine or SPT boring. So basically you have to remove the soil. So what you are doing is not doing the testing in the natural condition of the soil. The soil over burden pressure or the weight of the soil on top is removed.

So once you remove the soil definitely will become different of course, it might get disturbed that is one side of the issue, but the weight of the soil on the top of the test point itself is removed. So that is one issue and also many of the text books they do not refer or many of the references literature, they do not use the SPT value as measured at the site or as tested by the geotechnical company for several reasons probably historically people were using the number of blows at 60 percent rated energy of the hammer. The reason was you know when the SPT started several decades back, each one was using different hammer weight each one was using different draught height depending on what is possible with the setup that they had and then they had a different N values for a similar type of strength of the material.

So then early stages you know the literature proposed that you convert all your different energy, different wall height, different weight to 60 percent of the standard weight, which is prescribed by the (())(22:46) codes. So everybody have to convert it back to the N60 that means different energies use to different blow counts on you obtain, but finally comeback and correct it. So for that we need a factor to correct which is just a pro-writing of your energies.

So from normal N value obtained from your testing you are multiply with some parameters. So one of them is the hammer efficiency, which I think we spoke about. The second one is a correction for 4 bore hole diameter, you make a bigger bore hole, smaller bore hole, also you can make a difference, because then you all of free to soil to give (())(23:24) up, if it is a very open cut, for example you make a 5 meter by 5 meter cut doing an SPT there is different from 100 mm bore, which will not allow the soil to give up (())(23:34). So that is something, because the over burden is removed for a larger extent when you have open cut whereas when you have a smaller bore hole still the side over burden pressure is around which will not allow the soil to give up (())(23:46) easily and then the sampler correction factor instead of using standard split spoon sampler some people use non-standard sampling devices and correction for large (())(23:58) length.

The standard (())(24:00) machine only allow shallow or very limited height as you drive through. If you have for example, offshore bore holes go 100 meters you need a rod of 100 meter deep. So how the energy is transmitted by that rod is going to be difficult task. So all those corrections are given by in the literature, but more the most very important one or the common one is the energy efficiency, which you need to convert divide by 60. Now once you obtained this N60 what is missing here is the correction factor for the over burden which we have removed. The soil has been removed which has not been accounted for.

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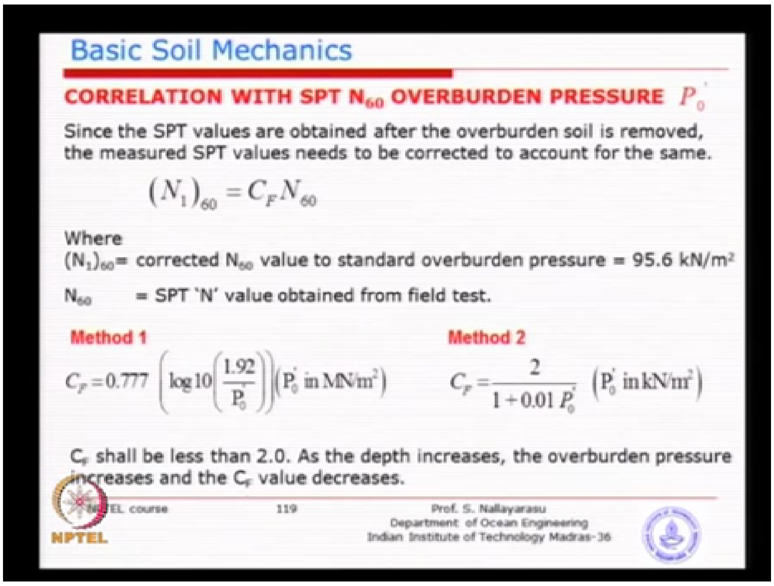

So which several methods are there, I have just picked up, because everyone has proposed something of different equations, but ultimately result in similar values of reduction factor. So the N1 with a notation subscript 1 is nothing but is taking into account there the reduced over burden pressure at the time of testing, but in nature it is actually having that pressure. So you will be having a correction factor. After getting the energy correction you use that and multiply by a correction factor for over burden.

Now this over burden I have just picked up 2 **2** equations one of them is expressed as. This is a empirical equation. So you would be careful, you have to use the units given by them you know, basically in this particular equation they ask as to use p not in mega newton per meter square, whereas this particular equation, you have to use it in kilo newton per meter square and that where you are to be in cautious the hole of soil mechanics, you will find several empirical equations or semi-empirical equations or unit dependent. Many times you will find uh units in keeps feet as you can see from the literature. So you have to be careful convert your units. Now the Cf value maximum you know some literature gives 2, some literature gives 1.7, but it has to be less than that so basic idea.

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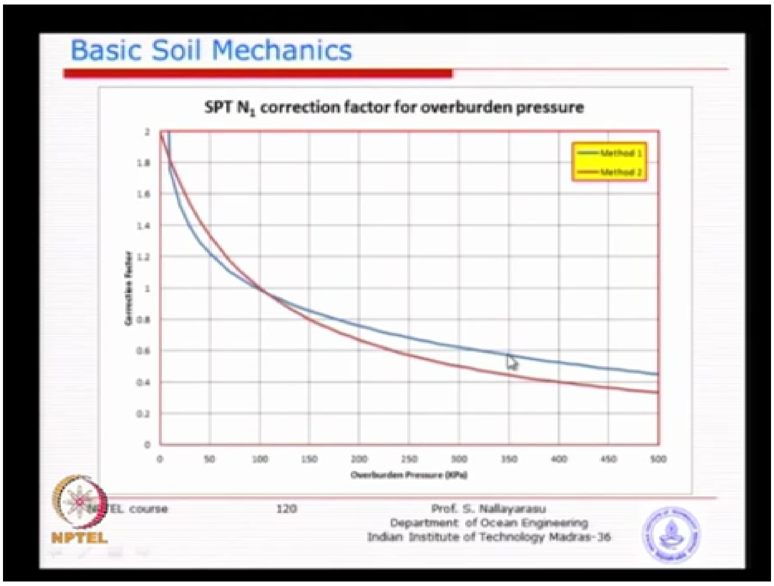

So when you actually calculate and compute something like this so you see here the values start with 2 and goes almost as the over burden pressure increases that means as you go deeper and deeper you have removed larger soil and thus basically the over burden pressure is higher and the computational factor is less than 1.

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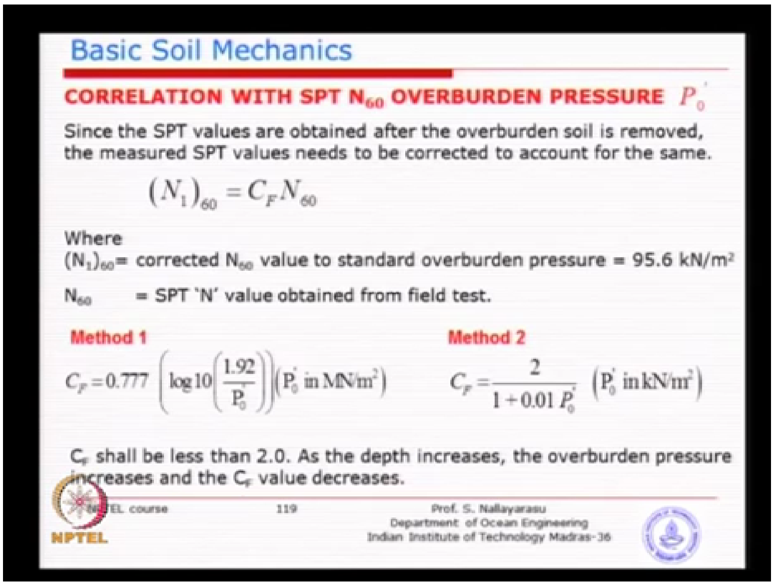

So this you have to multiply with the values that you have obtained from SPT original test and energy correction after that.

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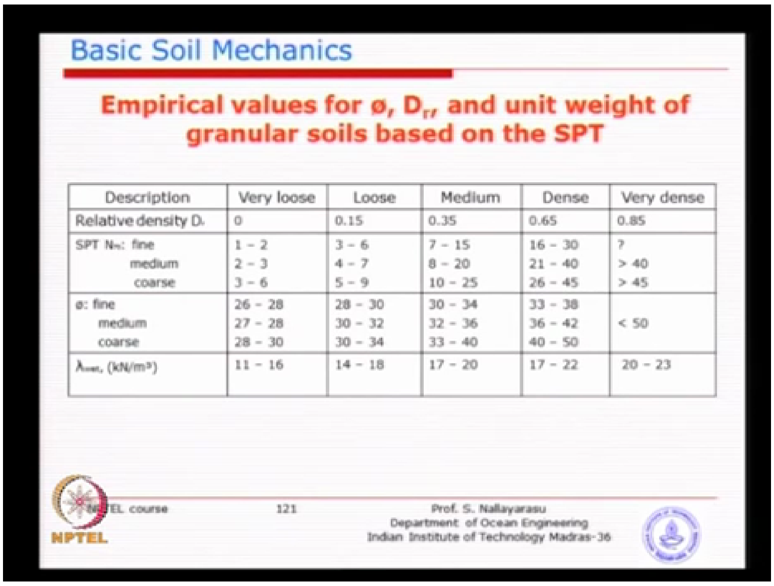

Description	Very loose	Loose	Medium	Dense	Very dense
Relative density D_r	0	0.15	0.35	0.65	0.85
SPT N: fine	1 - 2	3 - 6	7 - 15	16 - 30	?
medium	2 - 3	4 - 7	8 - 20	21 - 40	> 40
coarse	3 - 6	5 - 9	10 - 25	26 - 45	> 45
ø: fine	26 - 28	28 - 30	30 - 34	33 - 38	
medium	27 - 28	30 - 32	32 - 36	36 - 42	< 50
coarse	28 - 30	30 - 34	33 - 40	40 - 50	
λ, (kN/m^3)	11 - 16	14 - 18	17 - 20	17 - 22	20 - 23

This table you will find it in many of the text books. So you can see here this particular literature is using N70 instead of N60, I purposely wanted to show, because many of the text and references you will find different correlations. So you should be able to and you should know how to calculate or you know basically transfer your references to your requirement, because if you have say for example, if you find this table is very useful for your design purpose you have all the parameters are given in this table, but then you do not have N70, you only have N value. Then you should know how to convert from N to N60 or N70 and then bring it here, because if you are unable to do it or if you do not know how to do it then you will not be able to use this, because this particular reference they have done the testing. They have collected information with respect to N70 only.

So you cannot simply use your normal N value may said at site and state away go into this table, because is going to be a incorrect you know the relationship. So in here you have one parameter called relative density then SPT value and your phi value and also the density. So (you has) you have a 4-5 parameters linked together and if you are able to get one you can enter into other. So basic and you also have the description which is very very useful as from the site when you are doing the bore hole if you are able to get what type of soil, then if it is say medium dense.

So you are not going to look at the other columns, you will look at this, but then you will select based on what is the SPT value that you have got or otherwise if you are able to get the relative density from your (())(28:28) analysis or from your density analysis, then you can come back and then look at. So this table will be very useful and can be used for you know.

So when you are actually doing your design as per API (())(28:41). API also does gives this similar kind of table we are not going to give you a direct design parameter, they will give you a relationship, then you will have to go and select which parameter of choice depending on what description. What is the value that you have been given, for example among this all of them are not going to be available, one of them will be available you can go and read.

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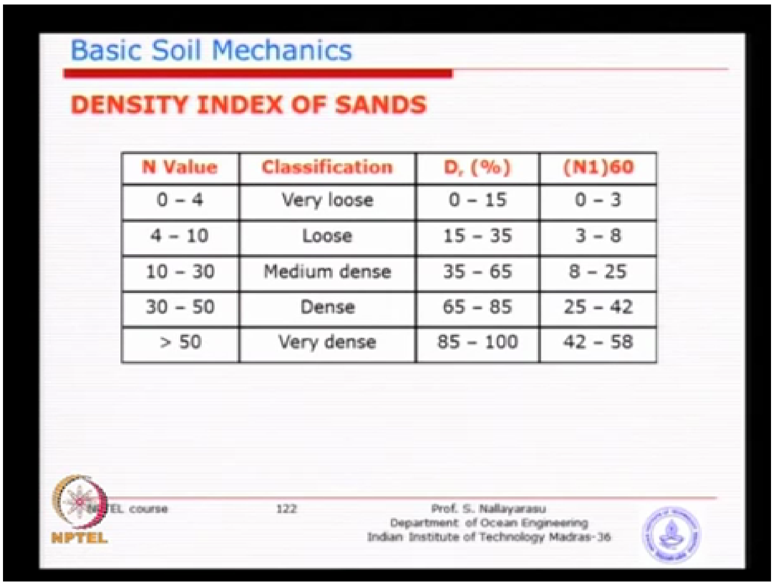

N Value	Classification	D_r (%)	(N1)60
0 – 4	Very loose	0 – 15	0 – 3
4 – 10	Loose	15 – 35	3 – 8
10 – 30	Medium dense	35 – 65	8 – 25
30 – 50	Dense	65 – 85	25 – 42
> 50	Very dense	85 – 100	42 – 58

This another table where standard N value is used, but then you can see slightly different relative density and also the relationship between (N1)60 is given. So this is from another textbook. So you will find variety of informations from different textbooks. One thing you need to remember, you can see here N, the standard SPT value normally greater than 50 means you should think twice before designing a foundation to penetrate through, because SPT value higher than 50 means. It is almost impossible to derive any type of pile for that matter.

So you just keep it in mind that if you encounter such material is really dense whether it is clay or sandy clay or clay itself. If you encounter SPT value of that kind is going to be very very high resistance against N barry that means it will be almost closed to like a PCC concrete. So that is where you have to think about SPT values higher than 50, you may actually want to terminate the foundation there itself and you can see here, the relative density is so high nearly to 90 to 100 percent that means the material cannot be packed any further even if you are actually compress or you know vibrate the material can never get any better than the state of the material at this time. So that is the meaning of the highest relative density means the material has achieved reasonably high dense state and you can see here the

SPT value in the corrected form is slightly higher does not matter. So the idea behind is uncorrected SPT value is nearly around 50.

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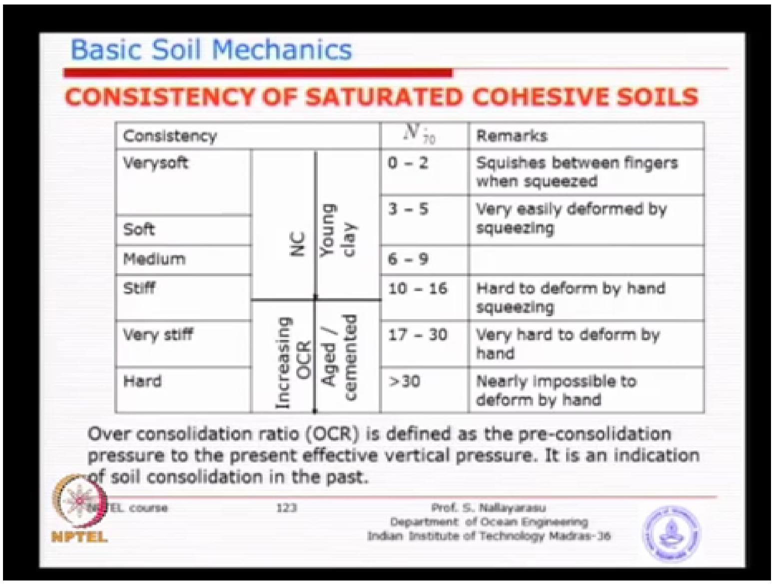

The third table is predominantly used for clay type of material you know consistency of material related to SPT as well as the young or older clay you know I think, there are 2 things one you need to understand. They have used in this particular textbook is N70. So you need to correct it and bring it back to N70 from the standard N value and as you can see here from very soft to hard and you can see the SPT values are slightly lowered compared to a sandy material where you have actually gone to a stiff state or hot state by N value is 50 whereas the same thing the clay type is slightly lowered.

It has got greater than 30 and again no consolidation or basically the over consolidation you know the difference between the young and the old clay, as I was talking about I think several classes before when the material is getting deposited in several 1000 years back and eroded and basically the over burden is removed. So that means over consolidated in the past and the present state, it is actually the consolidation pressure is removed that is called over consolidation ratio.

In many cases, you find that in a sedimentary basins in close to coast lines you know you might have a big over burden in the early stages of formation of the earth crust and has got eroded or removed or dislocated in the recent time, where you are going to put your structure, the soil actually has good consolidated status where compared to if you go to river or river mouth. Probably there is no consolidation has happened, because the deposition has happened over last few years or last few decades, where claimed clay that means the potential chance of that clay get consolidate is more compared to age or old sedimentary material where consolidation further may be very limited.

So from this you can actually find out whether the soil is good or bad. So many times over consolidation ratio will be helpful to identify though, it is a clay we can say whether it is better clay or the bad clay whether you would like to design a foundation there and what type of foundation and basic idea is you can see the numbers, I just spent few minutes 0 to 2 very soft. So that means when you place this SPT hammer in (())(33:34) we just going to when you tang one blow, it just going to go 30 centimeters state away as I talking about the one of the test case in this few years back. We were doing a project somewhere in the east coast, you know basically when we step into the clay you will sink you know that is the kind of material. Many times you actually get in the coast line and you will have to treat the material before you can construct a foundation. So SPT lower in terms of 0, 2, 3, 4 means the foundation soil is very weak.

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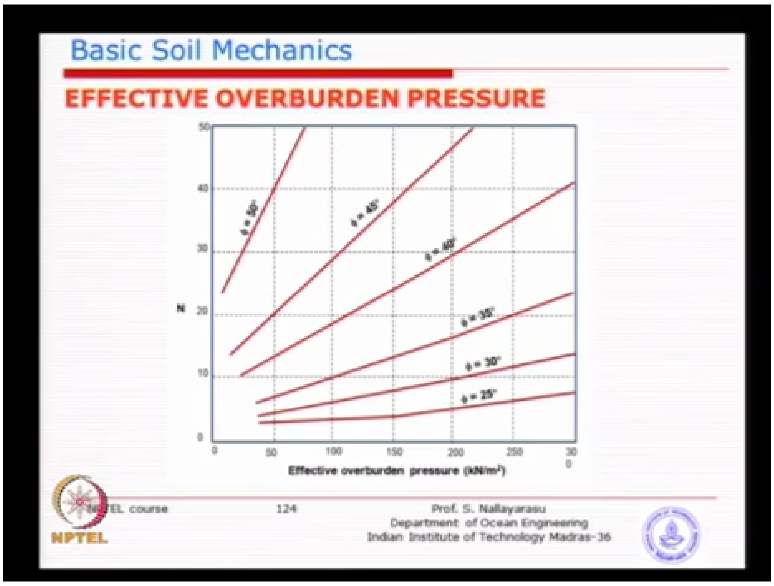

The third or fourth graph that you can see here in a with respect to SPT value and the over burden pressure and you can see here, the N value is go as much as to 50 such standard SPT value and angle of internal friction is as highest 50 and you can see here as the over burden pressure comes down, the material actually has the lower angle of internal friction and if you go on deeper and deeper we can see it is slightly increasing and the increase is very sharp when you actually have a larger SPT value, which is true, because when the soil is at the 50 meter below is already taken compression, because of the over burden pressure and is going to be very hard to displays any further. So that is the idea behind. This chart you will find from original proposed I think original proposed by (())(35:01). He actually had published one of the textbook and he presented to I think one of the academy and this particular one you will find in many textbooks now, because copied from there.

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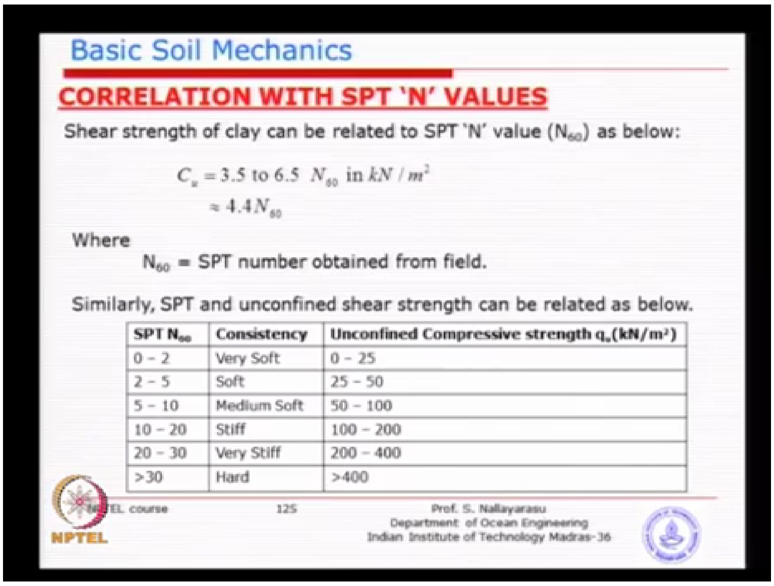

And then the correlation with C values directly for obtaining you know the undrained shear strength from the SPT you will find the many many formulas, I have just picked up from 2 of the references, one by Mayer half (())(35:30) other one by you know basically (())(35:34). So you can see here, he used unconfined compressive strength are those days that is the kind of test available with this kind of cell pressure and enhanced testing with respect (())(35:46) simply break and find out what is the breaking strength and that is the unconfined compressive strength and from you are consist the results you classify then the SPT values are given there.

So this table you can use it slightly careful because, you have to you have to convert the SPT value to N60 then only you can enter here or you can use this empirical equation basically 3 to 6.5 is the multiplication factor when you obtain N60 and the units are in kilo newton per meter square, I just converted from in fact one of the paper original paper was given in queues (())(36:25), I have just converted to kilo newton per meter square. So you can use it for your design purposes which will be very useful.

Many times you will get SPT value as the test results from your bore hole or you can enter here, which is almost going to produce similar only thing is from unconfined compressive strength you need to divide by 2 to obtain your C value. So you cannot directly use it and. So this is one of the useful information whenever you still have SPT value and you are not able to do a laboratory test, because you could not bring the soil samples in undisturbed manner and that is a time that you will find that this SPT value is very useful. That is why many times when you are doing a bore hole, you take the sample as well you conduct this test, because if you think you can take a undisturbed sample and when you by the time it comes out. It is already disturbed or not able to use it, if you have forgotten to do the SPT; it will be very difficult to get any design parameter. So his SPT is quite useful in understanding the strength of the soil.

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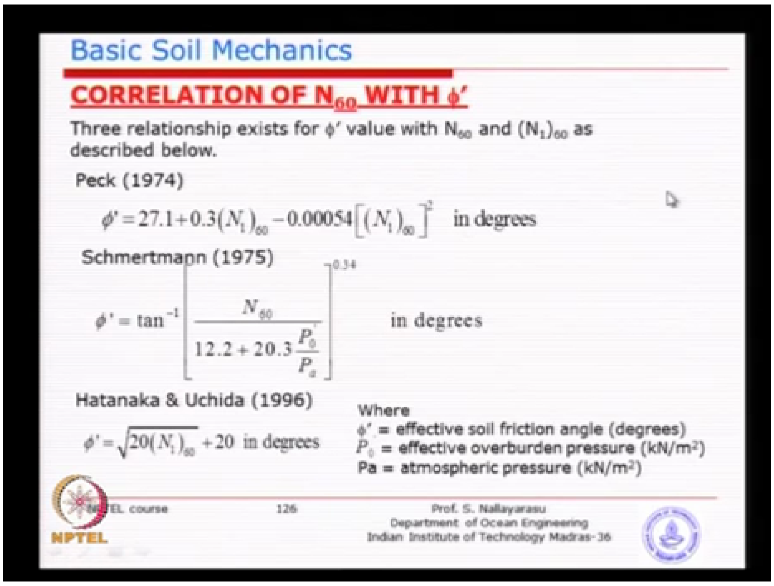

Also correlation with some empirical equations to obtain phi value if you are not going to read the charts or the tables, you could use this empirical formulas to get the phi dash value, phi and phi dash we will talk about in the next class. Basically several of them were there, but I have just picked up 3 of them which is commonly you will find in the text books. So we can see here relationship between phi with numbers and this answer is in degrees, again converted to degrees from radians. Similarly here phi dash with respect to another empirical formula, you will find it very very often such type of formulas to be used in soil mechanics in foundation design.

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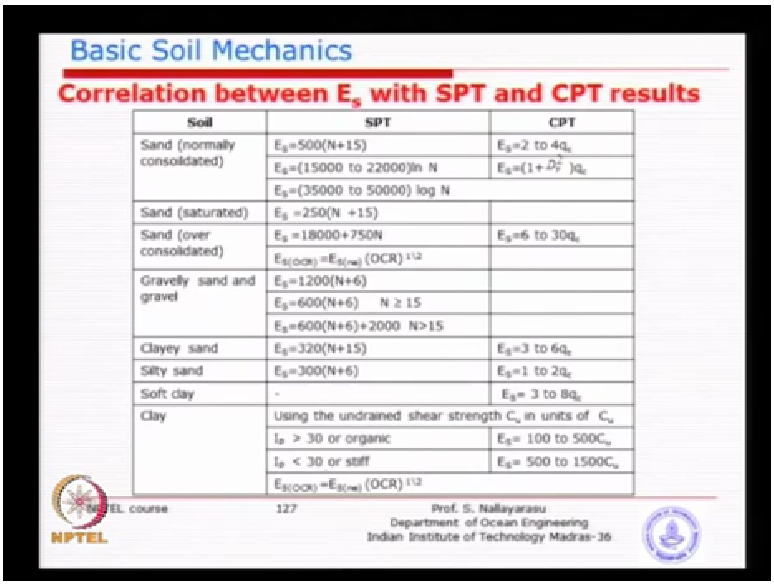
Basic Soil Mechanics

Correlation between E_s with SPT and CPT results

Soil	SPT	CPT
Sand (normally consolidated)	E_s=500(N+15)	E_s=2 to 4q_c
	E_s=(15000 to 22000)ln N	$E_s=(1+D_r^2)q_c$
	E_s=(35000 to 50000) log N	
Sand (saturated)	E_s =250(N +15)	
Sand (over consolidated)	E_s =18000+750N	E_s=6 to 30q_c
	$E_{S(OCR)}=E_{S(nc)}(OCR)^{1/2}$	
Gravelly sand and gravel	E_s=1200(N+6)	
	E_s=600(N+6) N ≥ 15	
	E_s=600(N+6)+2000 N>15	
Clayey sand	E_s=320(N+15)	E_s=3 to 6q_c
Silty sand	E_s=300(N+6)	E_s=1 to 2q_c
Soft clay	-	E_s= 3 to 8q_c
Clay	Using the undrained shear strength C_u in units of C_u	
	I_p > 30 or organic	E_s= 100 to 500C_u
	I_p < 30 or stiff	E_s= 500 to 1500C_u
	$E_{S(OCR)}=E_{S(nc)}(OCR)^{1/2}$	

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The next one is basically the modulus value, very similar to the concrete and steel, you remember the values or the slop of the stress-strain diagram, which is definitely required if you are interested in deformation characteristics. One is strength parameter which you already have some idea, without which you cannot carry out any displacement calculations, for example, when you design a foundation, you want to find out under this loading how much is the foundation settlement then for that we definitely need, the settlement characteristics to obtain the stress and strain. So you apply a stress. What kind of strain is induced on the soil so that you can estimate the that displacement.

So unfortunately getting this Es value by direct measurement of (stray) from the test is difficult. Of course from triaxial test we can get the initial slop of the load and the displacement. So when you do not have when you really have not able to do a triaxial test in laboratory what else can be done? So you can relate with the SPT values and that is what the many people have proposed different formulas for different material is a collection of all the formulas together wherever you have SPT unable to do triaxial test or shear test or no laboratory test is (())(39:45) and that is the time you will look for this because, you will be a hardly having any information for design.

So in this particular table, variety of formulas for different material which can give you the modulus of elasticity with respect to the measured SPT values from the field test. Also for clay type of material, directly based on your plasticity index and over consolidation ratio, some empirical formulas are proposed to arrive at the values of Es, you will find this table extremely useful when you are not having good field testing and laboratory testing.

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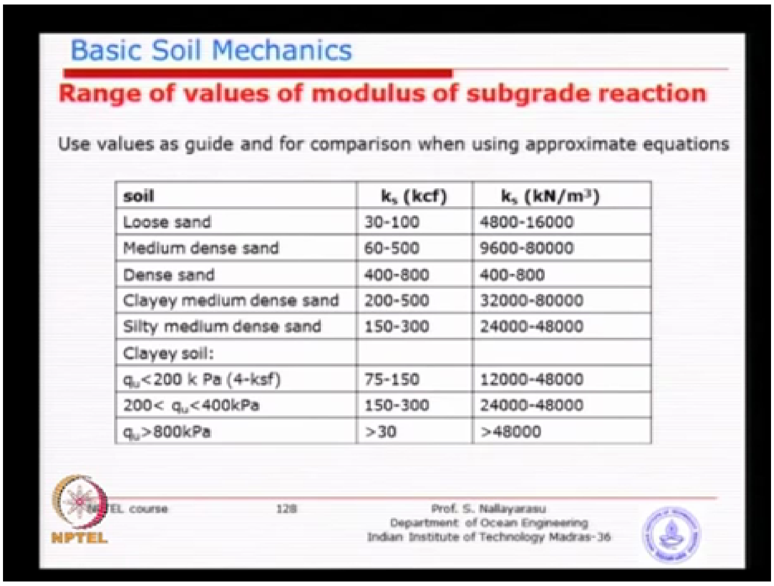

Another table which you are not just now familiar with this values of modulus of subgrade reaction. Of course it is very important for design of piles but, it will be introduced during the pile design procedure. What is so called modulus of subgrade reaction? It is exactly similar to the elastic modulus, only thing, it is going to be a horizontal loading instead of vertical you will find this is modulus corresponding to lateral displacement, which is also very useful and I have taken from several references for reference purposes in English units converted to the metric units. It is quite often useful in design purposes later you will use this table.