Foundation Design
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Lecture - 3A
Subsoil Investigation or Site Investigation
Part-05

Last class, I have finished plate load test. Now next field test is your standard penetration test.

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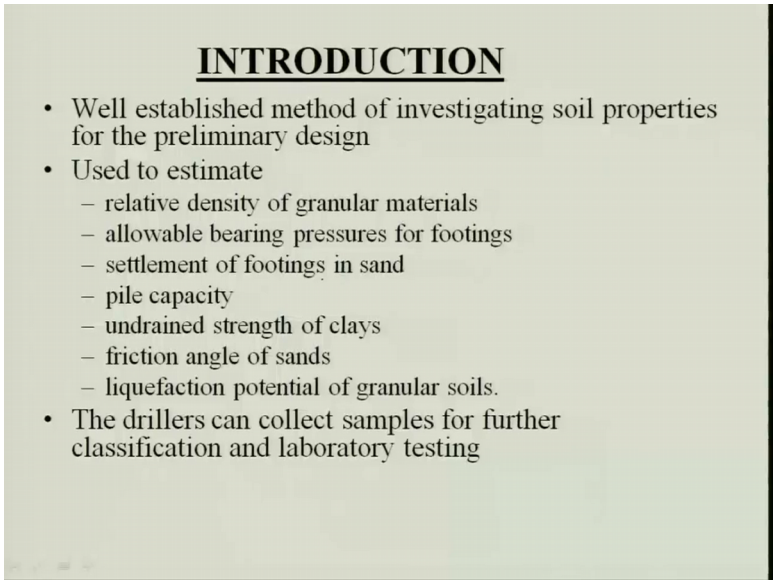

So, it is a well established method particularly investigating soil properties for the preliminary design. General it has been used to measure relative density of granular materials, allowable bearing pressure by means of a core illusions, pile capacity, friction angle of the sand. Basically it gives value of N penetration resistance n, with respect to n. Then phi can be find it out, then liquefaction potential of granular soil.

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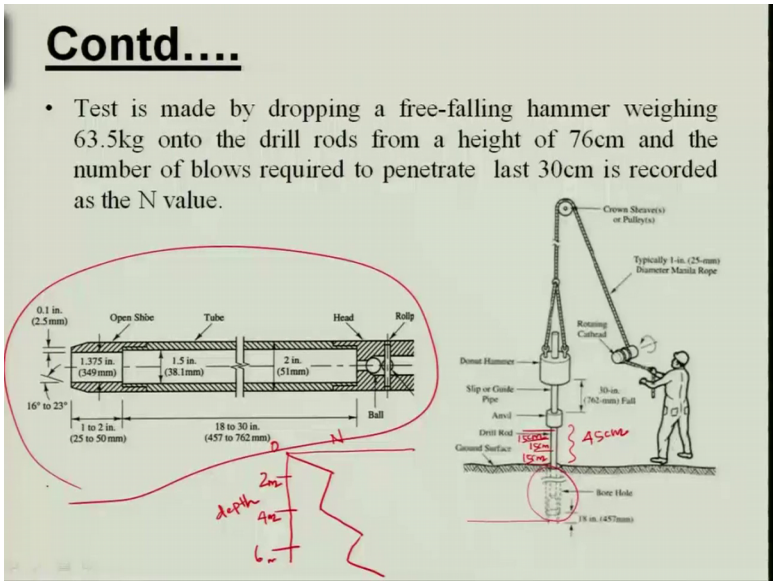

So, the test is made by dropping a free falling hammer. If you look at here there is a first you have to do a borehole, up to that depth you do a borehole. Then insert the bore hole with the help of drill rod, you insert split spoon sampler inside. Then there is a drill rod and there is a anvil and there is a drop hammer.

Generally, what happened? Free falling hammer of weight 63.5 kg, weight is 63.5 kg is code says 65 kg onto a drill rods upto a height of 76 or 75 centimeter and number of blows required to penetrate last 30 centimeter is recorded as N values. Suppose this is your drilling rod or drill rod. Now you allow by means of a respite, you raise this hammer and drop it, and you mark this scale here 15 centimeter then another 15 centimeter then another 15 centimeter.

Total you are going to do 15, 15 30 plus 15 45 centimeter of your penetration. Generally, first 15 centimeter of penetration has been left; why because, it is carrying up about your any kind of sitting load unevenness of the soil or if this because you are making a borehole here. So, it is not possible to give the exact value of your N value properly.

So, that is why first 15 centimeter has been discarded. So, that is why last 30 centimeter recorded as the N values. So, what you are supposed to get it? This is the N SPT n, this is your depth. So, if I say this is my 0, 2 metre, 4 meter, 6 meter, then I am supposed to get this kind of this diagram SPTN values for last 30 centimeter of your penetrations. And

this is about your split spoon samplers detail dimension has been given. Here it is a split spoon sampler.

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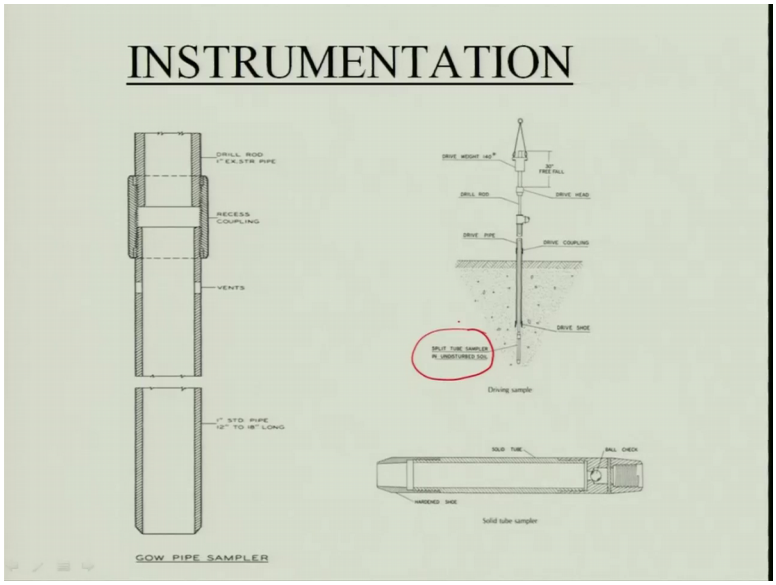

So, it will penetrate inside. This is about your how this split spoon sampler details, you can see it pipe sampler tube and split spoon samplers. Split tube sampler it has been retained here then. So, hammer comprise of hammer mechanism that lift.

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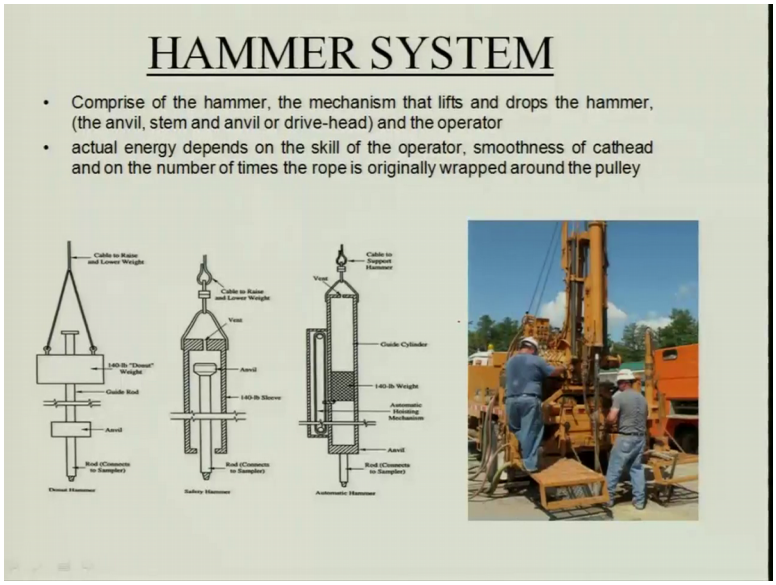

And drop the hammer it consists of anvil system and anvil or drive head. Actually energy depends on the skill of the operator's smoothness.

This is your visual inspection you can visualize a means. Last few lectures I am showing it by drawing the diagrams. Here are your photographs; you can see how it is a continuous process. One side borehole has been made and same side same process one bore hole has been made you can do the SPT also you can collect your on dist of soil samples.

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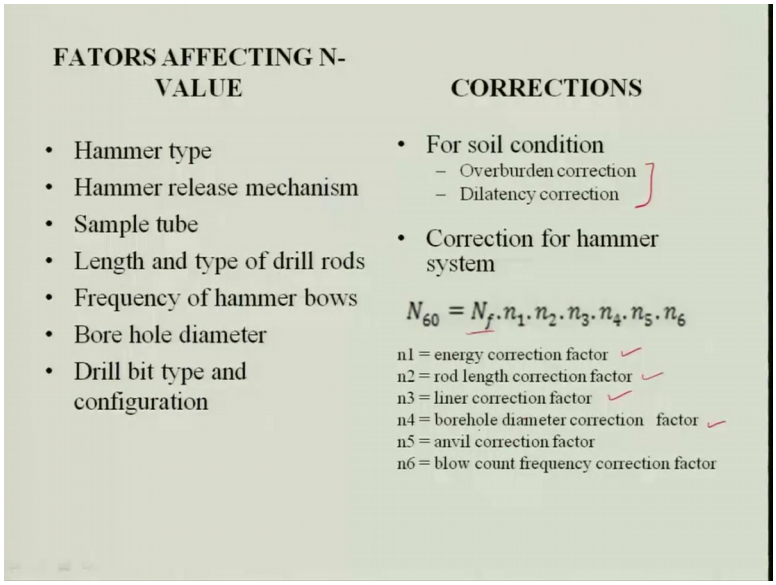

So, there are 2 core corrections, basically 2 corrections required. One is your overburden correction and second is your dilatancy corrections.

This I am going to discuss in detail. Correction for your hammer system what you are doing hammer it will look at generally this is called N 60. It is your N f means whatever your penetration resistance n 1, n 2, n 3, n 4, n 5 and n 6: n 1 is your energy correction factor, and n 2 is your rod length correction factor, n 3 is your liner correction factor, n 4 is your borehole diameter correction factor, n 5 is your anvil correction factor, n 6 blow count frequency correction factor. These all corrections have to be added before reporting your N value it should be N corrected.

Now, let me start with this. So, far as per (Refer Time: 05:52) 1967. So, why we are measuring the penetration resistance, for particular granular soil, if I take it granular soil; that means, version less soils.

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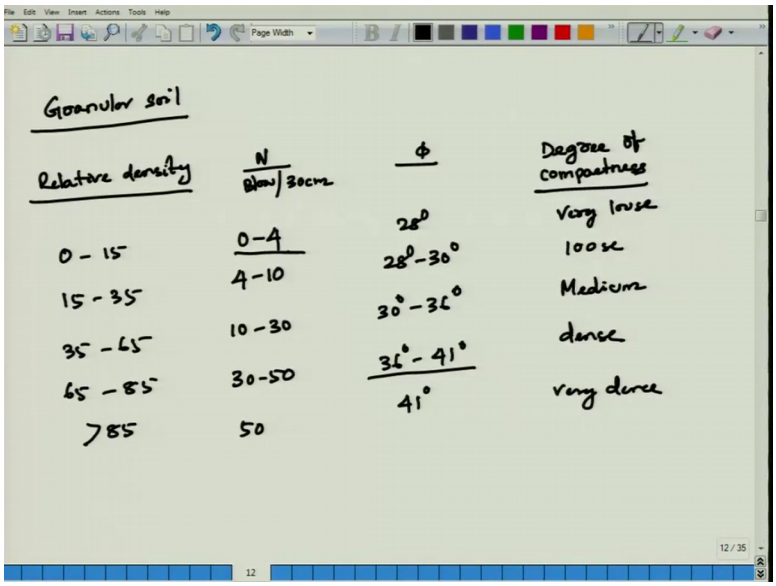

So, one hand I am putting it relative density. Then N, n is your blow per 30 centimeter then angle of sharing resistance, phi then degree of compactness.

So, 0 to 15, 15 to 35, 35 to 65, 65 to 85 greater than 85 and blow supposed to, you are supposed to get 0 to 4, 4 to 10, 10 to 30, and 30 to 50. And here you are supposed to get 50. Phi value is varying 28 degree. 28 degree to 30 degree and 30 degree to 36 degree and 36 degree to 41 degree and here it is your 41 degree.

Now, very loose, then is your loose, then medium, then dense then very dense. This is for your granular soil.

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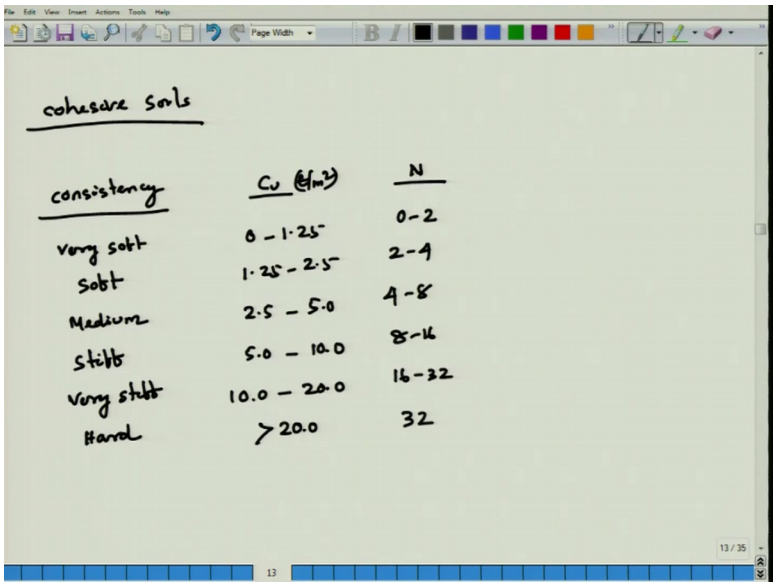

Now if I come to your cohesive soils, then I can put it consistency one hand. Then on densior string Cu then N, very soft, soft, medium, stiff, very stiff, hard. Cu is your generally it will be ton per meter square.

Generally, it will be 0 to 1.25, 1.25 to 2.5. Then 2.5 to 5.0. 5.0 to 10.0 then 10.0 to 20.0 then greater than 20.0. Then blow supposed to be your supposed to get 0 to 2, then 2 to 4, then 4 to 8, then 8 to 16 then 16 to 32 and it is 32.

Standard penetration test is basically for cohesively soils or granular soils. And it has been extended for c phi as well as cohesive soils. If you look at here what parameter, I am supposed to get it? If blow count is in my SPTN after first second and third block count 30 centimeter is 0 to 4, what does it indicate? It indicate it is a very soft, very loose soil and it is high value will be 28 degree or less than 28 degree.

If it is within 30 to 50; that means, it is very dense soil. Phi value is 36 degree to 41 degree. Once I am getting the N value I am supposed to get phi, I am supposed to get it is relative density or the compactness. Similarly, for cohesive soils, once you get the N value from N value, you can say that average soft very soft medium stiff very stiff or hard soils and depending upon your on dent share strength you can range is given in ton per metre square.

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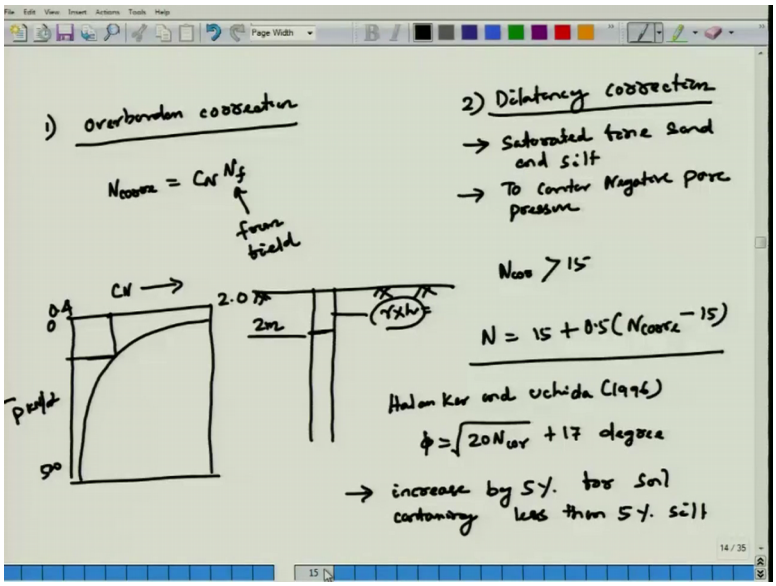

Now, come back to I just said after hammer correction is over there are 2 corrections. One is your overburden corrections, second is your dilatancy corrections. If overburden correction, first is your overburden correction. Generally N corrected, Cn into N f. So, N corrected based on your overburden pressure, and Cn is your correction factor. N f is your N value obtained from the field, it is from the field. And Cn is your correction factors.

So, you can follow the as per your bureau of Indian standards. They have given you can download it, bureau of Indian standard. They have given a chart or particularly Cn corrections here it is varying from 0.4 to 2.0, and p effective overburden pressure kilo newton per metre square it varies from 0 to 500. The correction is coming about to be in this range.

So, once you know a particular depth, suppose you are making a bore hole, why overburden corrections any logic, because what happened. Initially the ground is a level surface. What happened? You do a borehole; that means; you are taking out the soil samples, and then measuring penetration at this depth. While measuring penetration at this depth the entire overburden has lost, that is why this overburden correction is required.

For particularly this depth at 2 metre, gamma into h which is equal to what is density into h. Find it out effective overburden once you know the effective overburden from there

from the chart you can get correction factors Cn. There are many connections available. There are many correlations available given by pace, and others that you can see, but best way you follow the chart from your bureau of Indian standard from there you can find it out your overburden corrections.

Second is your dilatancy correction. dilatancy correction is recommended saturated fine sand and silt. It is recommended for saturated fine sand and silt. To counter particularly to counter, to counter negative pore pressure; once there is a water table, if there is fine sand. So, what will happen there will be a kind of negative pore water pressure? To counter that this correction is required or dilatancy; if it is a saturated fine sand and silt, then only your dilatancy corrections required.

Remember dilatancy correction followed after your overburden correction. You cannot do dilatancy correction first then overburden. First overburden correction then is your dilatancy corrections. So, it is only possible after overburden corrections, if N corrected is greater than 15 after overburden corrections. Then finally, after your dilatancy correction 15 plus 0.5 into N corrected minus 15.

This is your dilatancy corrections provided look at the 2 conditions. dilatancy corrections will be followed after your overburden corrections. And if after overburden correction if N corrective from overburden is greater than 15, then only your dilatancy corrections it is N is equal to 15 plus 0.5 N corrected minus 15. So, there are many correlations are available directly you can get it phi value from your N corrected.

Now, one of these has been given by Halankar and Uchida 1996. So, phi is equal to 20 N corrected Cr root over plus 17 degrees. It is in terms of degree. Also you can find it out E value. Let us discuss this phi you can get correlations from this correlationship, we can get the phi. So, generally recommended you increase by 5 percent phi value for soils, for soil containing less than 5 percent silt.

Whatever phi you are getting you increase 5 percent for soil containing less than 5 percent silt.

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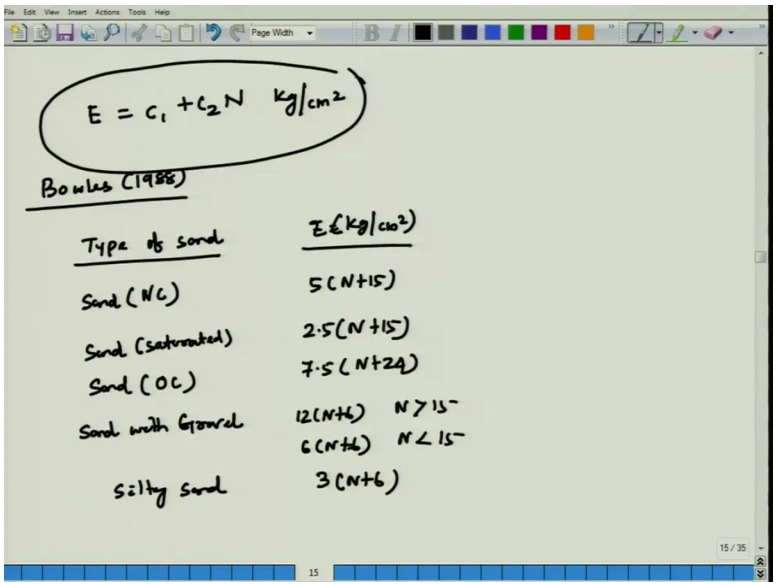

Now, what else, I can get it? I can get the modulus of elasticity E from the N value. E is equal to c 1 plus c 2 into N. Unit is your kg per centimeter square. So, now, how the value of your c 1 and c 2, how these things are going on. So, c 1 c 2 values are depending upon this this c 1 c 2 values I will give it to you c 1, c 2 are functions of typical type of sand c 1 c 2 are typical type of this sand. So, Bowles 1988, he has given some kind of correlation. So, type of sand, then E kg per centimeter square. Sand NC, NC is your normally consolidated soil. So, in this case E is equal to 5 into N plus 15. Then sand saturated in this case it will be 2.5 N plus 15. Then sand over consolidated it is your 7.55 into N plus 24.

Then sand with gravel. So, this will be 12 N plus 6, for N greater than 15. And 6 N plus 6 N less than 15, then silty sand it is your 3 N plus 6. So, these are the correlation has been given buy them, particularly to get the value of your E. You can get this c 1 and c 2 values from the bowels book I will give you next class. What are the generally c 1 c 2? So, c 1 plus c 2 N this is widely used and bowels 1988 also given typical type of type of sand for that what is the value of a e.

Once you get N, N corrected once you get it then from there you can find it out what is the value of your E, E is your modulus of elasticity. Then there is another test that is called DCPT. It is full form is your dynamic cone penetration test it is called DCPT

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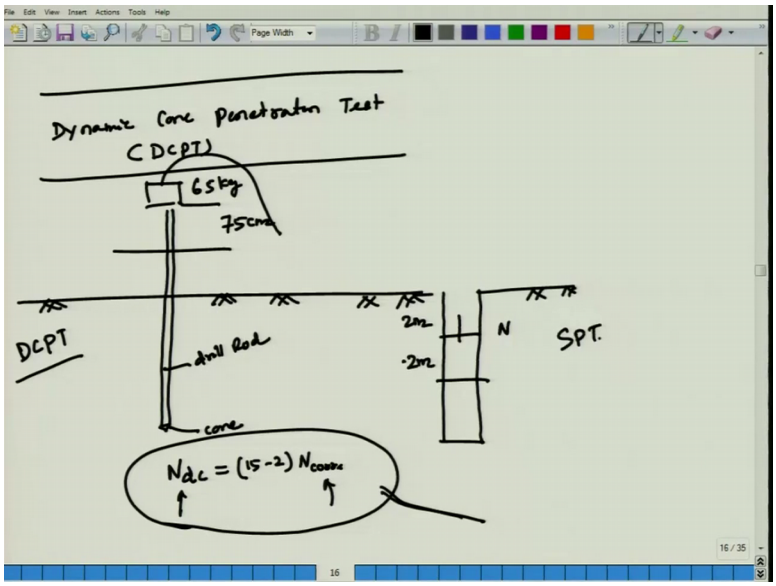

It is a quick test. What happened? There is a rod at the end there is a cone. So, drill rod this is called drilled rod there is a cone.

Generally, 65 kg of your hammer at a height of 75 centimeter, you can say that this is your 75 centimeter. And this size is 65 kg; a, we will do it for SPT. So, 65 kg of hammer free fall at a height of 75 centimeter. So, you can measure every 30 centimeter what is your penetration. So, what is the advantage of DCPT rather than SPT?

In SPT what you are doing there are advantage as well as disadvantages. If you look SPT in SPT, what you are supposed to do you. First in SPT first make a bore hole. Suppose upto 2 meter to make a bore hole measure your penetration resistance N, collect on dist of soil sample in the same bore hole. Then again you make the bore hole. It is your 2 metre, this is your 2 meter up, 4 meter then do the SPTN collect on dist of soil sample.

So, in this case advantage in SPT advantage is this is your SPT; this is your DCPT dynamic cone penetration test. SPT advantages you are doing 2 things. One thing is your measuring penetration value from there you can get a phi right, at the same depth also you can collect on dist of soil samples, from on dist of soil sample you can get engineering properties of these soils this is the advantage.

Disadvantage is in this case you are making a bore hole; you are making a bore hole the cost will be slightly higher side. In DCPT what you are supposed to do? This is your

ground surface. In this ground surface advantages is you are not doing any bore hole. You are only putting in the drill rod putting a cone at the base and doing the penetrations. Away 65 kg of your hammer free fall of your 75 centimeter or 750 mm you are measuring every 30 centimeter what is the penetration value.

So, basically at the end the cone will be there once you are going you are you can go down. So, here you are saving a price kind of your not doing any bore holes. And you can go up to any depth in this case it is very difficult. Going for a bore hole at a deeper depth in deeper depth it will be very difficult to bore hole because what will come into picture and loose soil will be there it will be very difficult.

So, both has merit as well as demerit once you get DCPT what is the correlation between DCPT and SPT, if I write it N dynamic cone DCPT, dynamic cone penetration what is the value of the N every 30 centimeter is equal to 15 minus 2 into N corrected. This is your DCPT and this is your value SPT. So, once you know it then you will be knowing; what is the value of N corrected, N corrected that is from the SPT I check this correlation there are other correlations also available I will check the correct one, I will put it.

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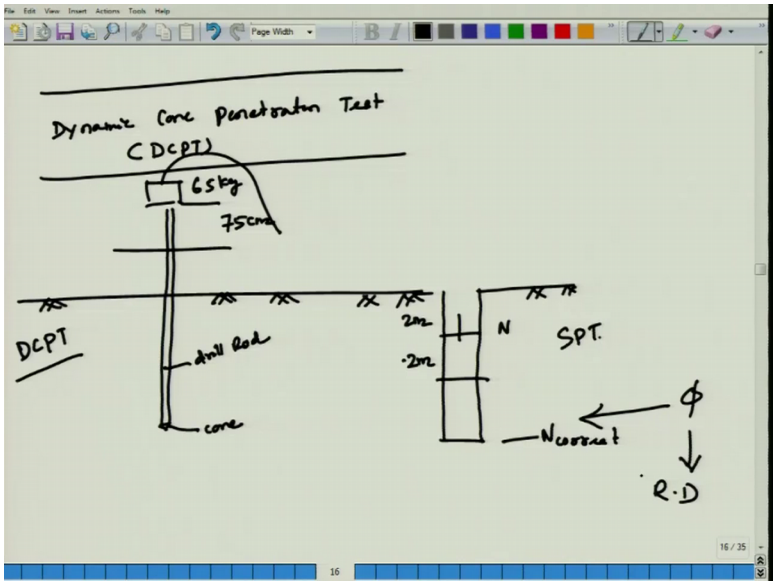

So, basically once you are getting a DCPT, you can from the correlations from the correlations you can find it out SPTN value. Once you get the SPTN value corrected from SPTN value corrected, you can find it out your value of phi. Once you get the phi value from there you can find it out your relative density. Once you get the phi value

then this will taken care, this will be helpful for your foundation design. This is most popular this is most popular in India particularly SPT NCPT CPT (Refer Time: 25:07) cone penetration as well as DCPT.

So, I will show you some of the ppt form I left it earlier. So, overburden corrections and dilatancy corrections. As I said- so dilatancy correction will be followed by your overburden correction; that means, first you have to do your overburden correction; you cannot do your dilatancy corrections. Again after overburden correction if N is greater than 15 then only you can go for dilatancy corrections. These are all your rod length corrections.

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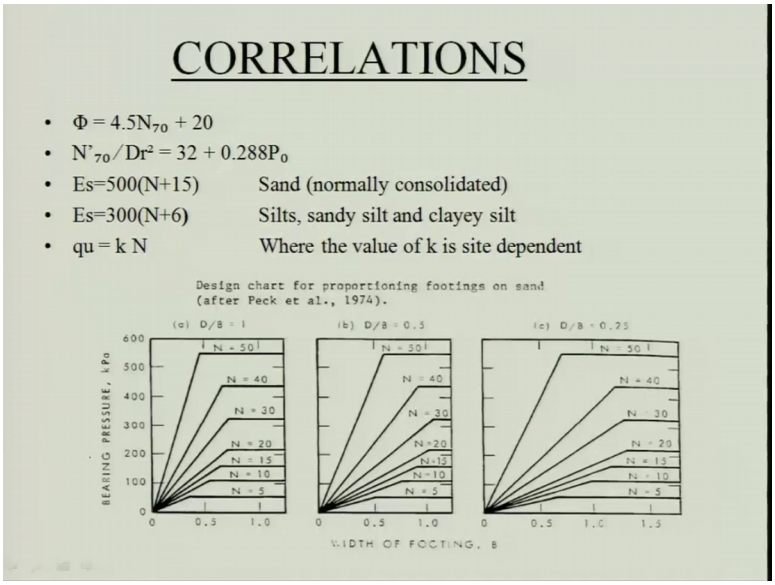

The many correlations are available you see now here it is there. Sand normally consolidated all the value correlations are available you can get it by means of pake 1974 if footing is there N values is there you can directly find it out your bearing capacity.

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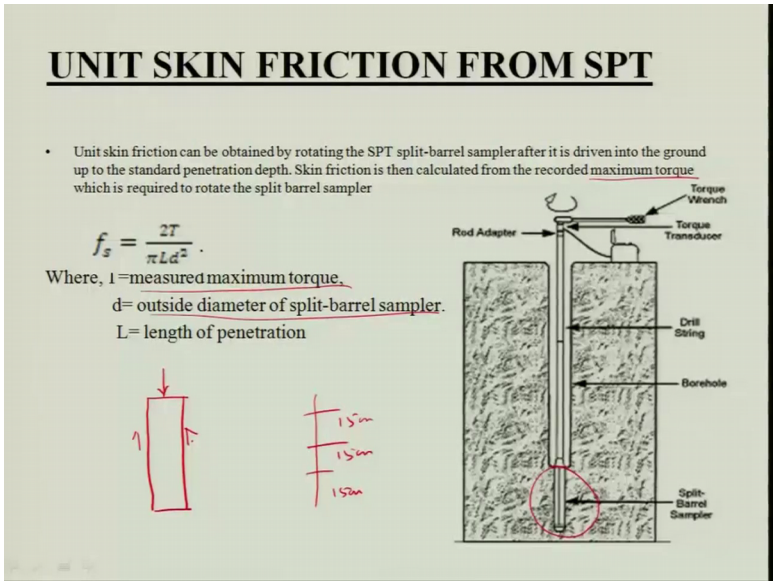

Now another advantage of these SPT another new thing has come into picture that is your unit skin friction from SPT. Unit skin friction can be obtained by rotating the SPT split barrel sampler after it is driven into the ground up to the standard penetration test.

Once it has been inserted once you are done these standard penetration tests, then it can be rotated. See here you are rotated by apply the torque, then calculated recorded maximum torque, then from the torque you can find it out your frictional resistance or unit skin friction fs is equal to 2 t pi L d square, is your measured maximum torque. These your outside diameter of split barrel sampler or split spoon sampler, outside diameter of these then length of the penetrations, total length of your penetrations.

So, length of the penetration will be we are measuring last 230 centimeters last 215 centimeter; that means, it will be penetrated first 15 centimeter, then 15 centimeter, then 15 seconds. So, length of penetration will be 45 centimeter. From there you can get unit skin friction. Once you get unit skin friction where it will be utilized. If you go for pile foundations, there are 3 types.

Frictions pile end bearing pile friction as well as end baring pile in friction piles it will be resisted by means of your frictional resistance. Once you get this skin friction you can directly go for a pile foundation design.

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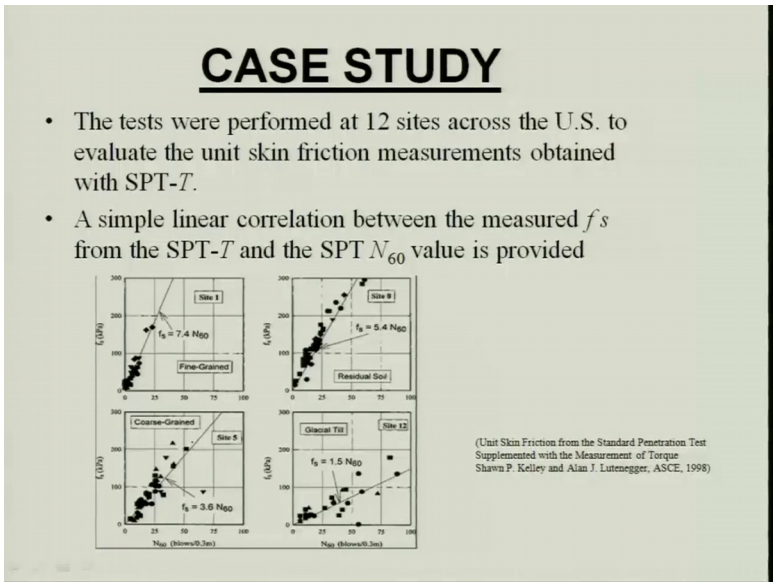

Of these there are different case studies unit skin friction has been observed by 12 sites across the; us to evaluate unit skin friction measurement of 10 from SPTN values.

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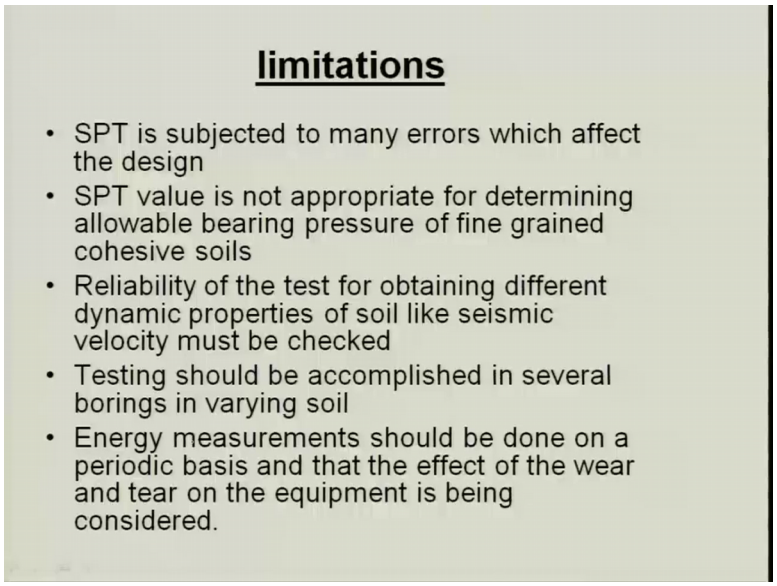

So, what are the limitations? SPT is subjected to many errors which affect your design. SPT value is not appropriate for determining or to find it out allowable bearing pressure of fine grained cohesive soil. It is not appropriate. Reliability of the test for obtaining different dynamic properties of soil like seismic velocity Sarah velocity must be checked. Testing should be accomplished in several borings in bearing soil. Energy measurement

should be done on a periodic basis and that the effect of wear and tear on the equipment is being considered.

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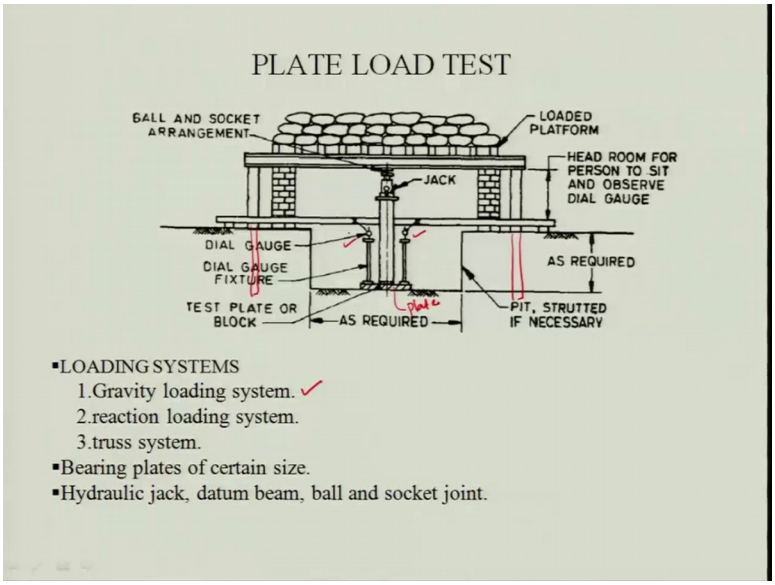

Now, last class, I have finished the plate load test by showing your diagram by plotting the diagram. Now it is a visual if you see this how it has been done. Look at here this is your test feet. This is a plate. This is a plate, 300 mm to 700 mm. This is hydraulic jack and this is your reaction beam wave of the reaction beam load has been applied. So, that it should not be uplifted, and now you apply by means of pressures.

So, loading system may be 3 types. Gravity loading system, gravity loading system means you apply by means of sand back. So, that load has been applied to the reaction beam by means of your gravity load only gravity load. Reaction loading system; that means, this reaction frame will be anchored here by means of piles. So, then this loading system will not be there. Then there is a truss system, by applying truss system we can apply.

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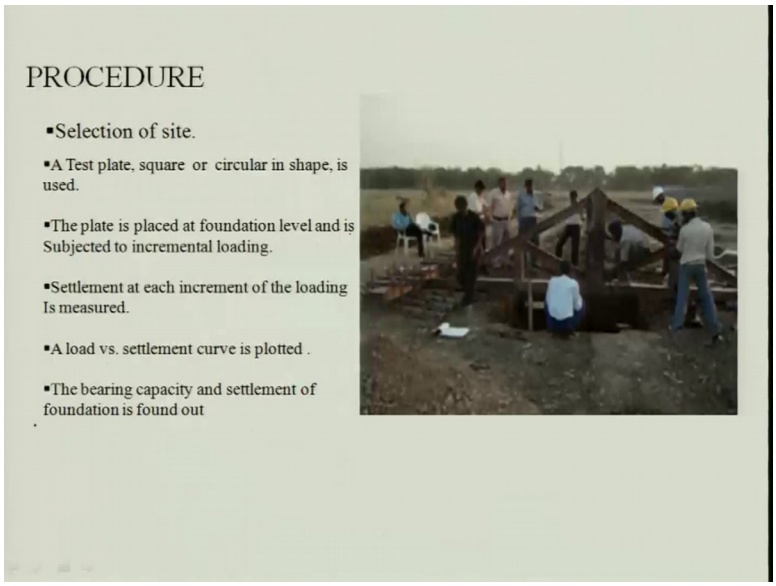

Then look at here, as I said here dial gauge here dial gauge here, I can show a photograph to you.

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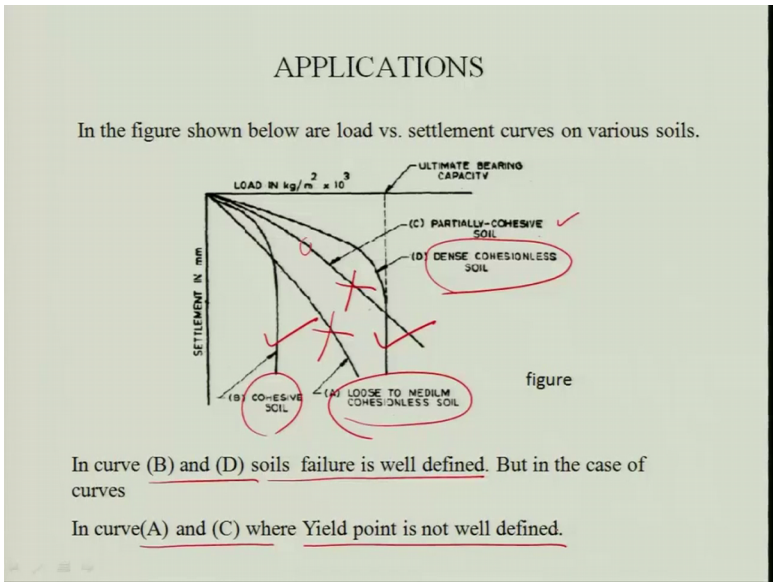

This you can see it. This is a truss system here we carried out. At IIT Kanpur, truss system loading system and there is a feet inside your feet plate hold test has been carried out. C different types of cause you are supposed to get it yesterday I said. From nature of the curves you can slightly say that what kind of soil it is.

Look at here if it is moving this way then change linear up to hear linear non-linear again here asymptotic. So, this case it is a dense cohesionless soil; that means, it is a kind of general share failure. I will come back what are the different types of failure. Then look at it slightly non-linear, then it goes again linear partially cohesive soil. Another one is after linear all of sudden it become asymptotic it is a cohesive soil.

Then there is a straight line loose to medium dense cohesive soils. This, whatever you are getting load versus or pressure versus settlement from plate load test on from this graphs it gives an indication, what kind of soil possibility of what kind of soils are there. Look at curve BD curve B put a tick mark D here. Curve BD soils failure is well defined yes it is well defined.

I can plot a single tangent or double tangent from there I can find it out ultimate bearing capacity, but in case of curve A and C, this is your A this is your C, yield point is not well defined. Where yield point is not well defined, where you are getting a kind of a straight line, in that case you plot it logarithm scale, log scales. Then will get approximate value of intersections here and here.

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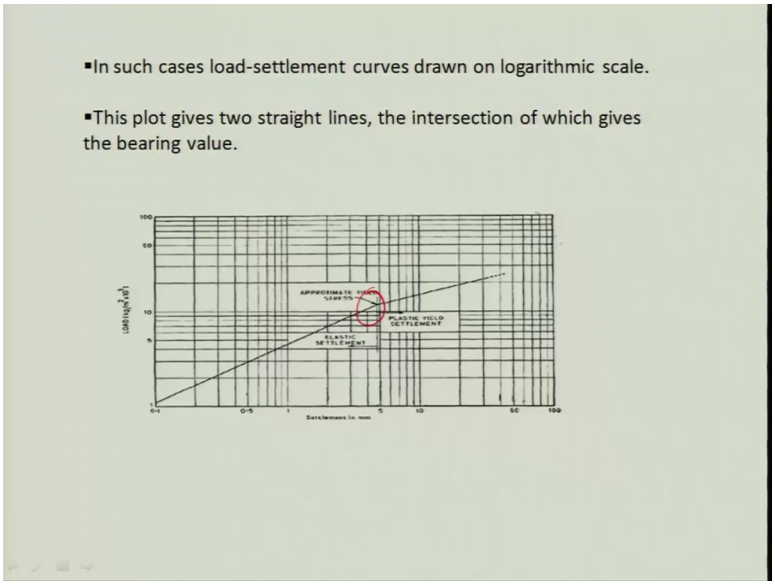

In such cases load settlement cards drawn on logarithmic scale, the plot gives 2 straight line and the intersection of which gives the bearing value the intersection of the which this this giving your bearing values.

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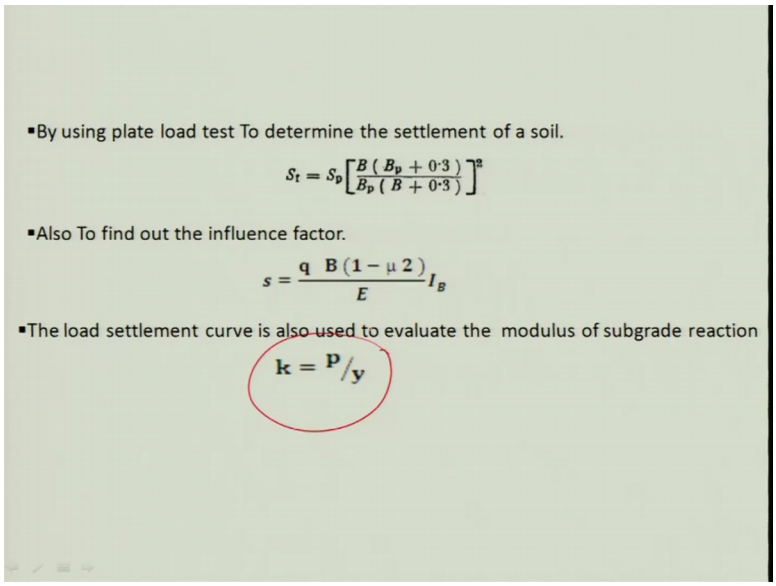

This I have already discussed. This part subgrade modulus I am not discussing once I will start the foundation design, how it is coming there is in detail I am going to discuss it.

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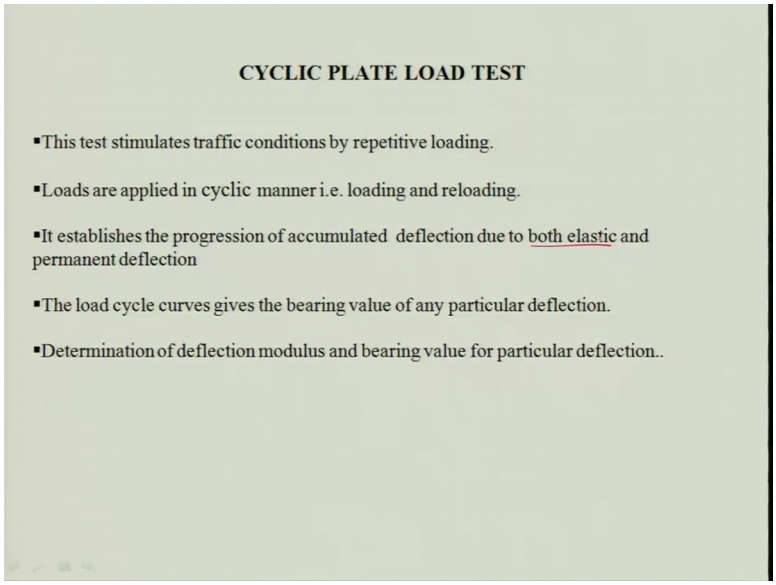

There are also plate load test there are also cyclic plate load test. Cyclic plate load test loading and unloading why you are doing it the test simulates traffic conditions by repetitive loading loads are applied in cyclic manner; that means, loading and reloading it establishes the progression of accumulated deflection due to both elastic and

permanent deflections. Cyclic loading you are doing it you find it out what is your elastic settlement as well as permanent.

Basically elasto plastic behavior of the soil you can get it permanent deflections. Load cycle curves gives bearing value of any particular deflections; determination of deflection modulus and bearing value for particular deflections. How you are supposed to get it.

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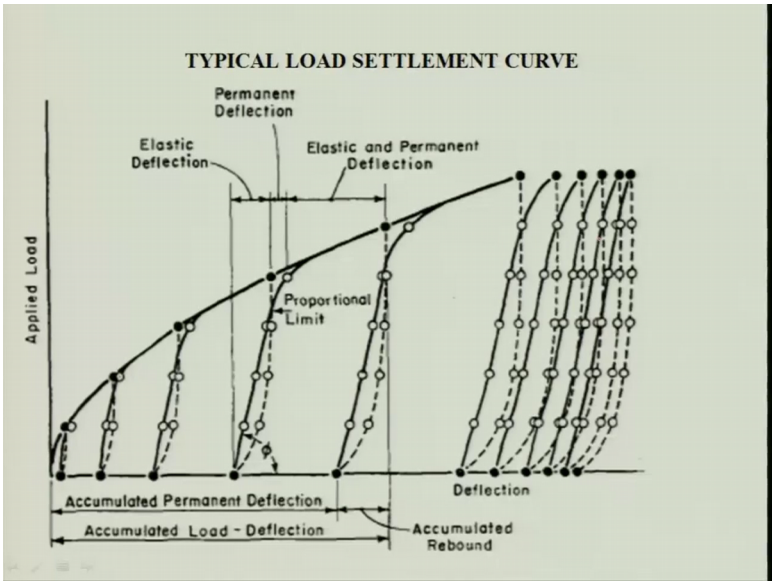

How the graph looks like typical load settlement curve cycling, loading, unloading, look at here. Suppose you are giving a 20 ton per metre square or 10 ton per metre square by means of your hydraulic jack, loading bring it back to 0 then reloaded then again loading unloading reload cycle 1, cycle 2, cycle 3, cycle 4, cycle 5, it will continue.

Now, if you look at here this is the value of your phi you can get it. Now from there you can find it out what is your, if this is my things last week and permanent deflections, I can find it out what is elastic deformation as well as permanent deflections or deformations that I can get it from here. This is what where I want to stop it.

Next class I will start it cone penetration test as well as permeability, I will go slightly faster because this course basically a foundation design this part as a preliminary, what are the test then we will go to your go to our real foundations, how it has been designed.

Thank you.