Foundation Engineering

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Module - 03
Lecture - 03

Hello viewers, welcome back to the course on Foundation Engineering. Last time we had just started discussing about the geotechnical engineering tests, there are two categories of the tests which I discussed last time.

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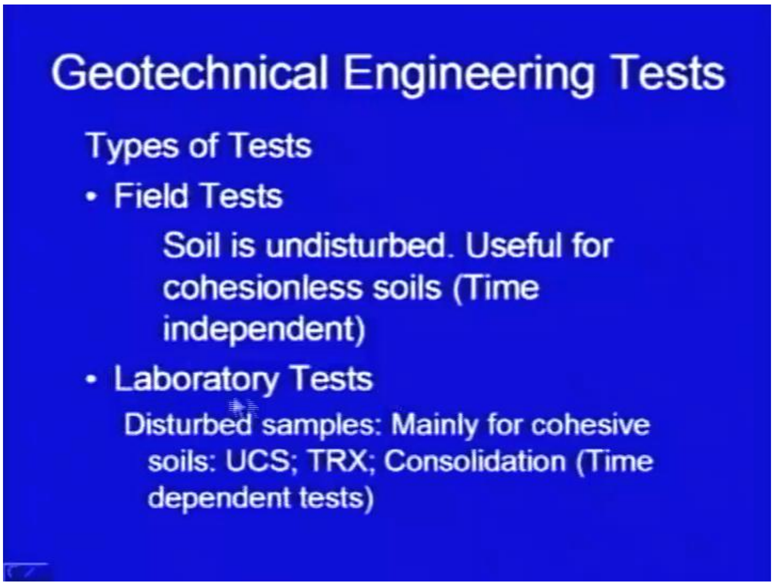

Field test and laboratory test, laboratory test are conducted on the samples which are relatively undisturbed and the test for UCS, triaxial, consolidation, etcetera. The field test are conducted mainly for the cohesionless soils, because we have no other alternative, in the field this soil is undisturbed, but when you if you try to bring to the lab it becomes undisturbed. That is why in the field the test is conducted on undisturbed sample and we get the representative values.

Most of the times these tests are very of short duration time independent test, time independent test, for example for clays are conducted in the laboratory.

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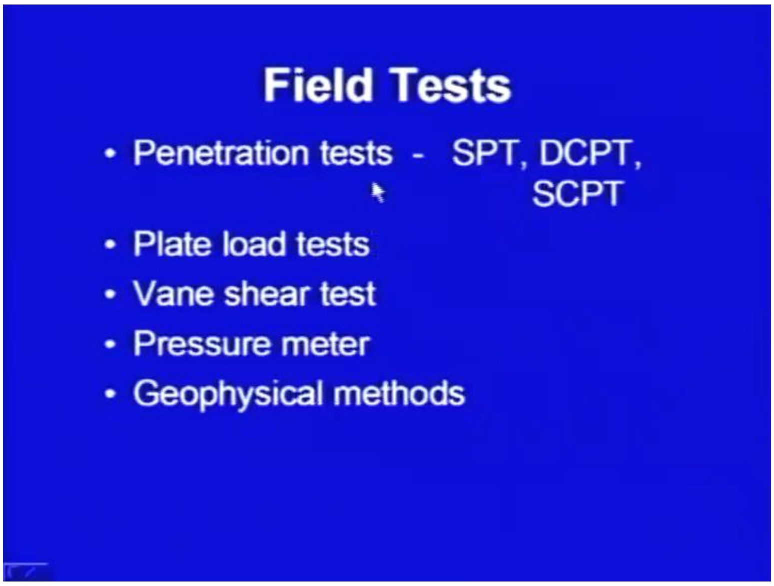

Let me start with the field tests, we shall be discussing the penetration test, plate load test, vane shear test, pressure meter test and geophysical methods.

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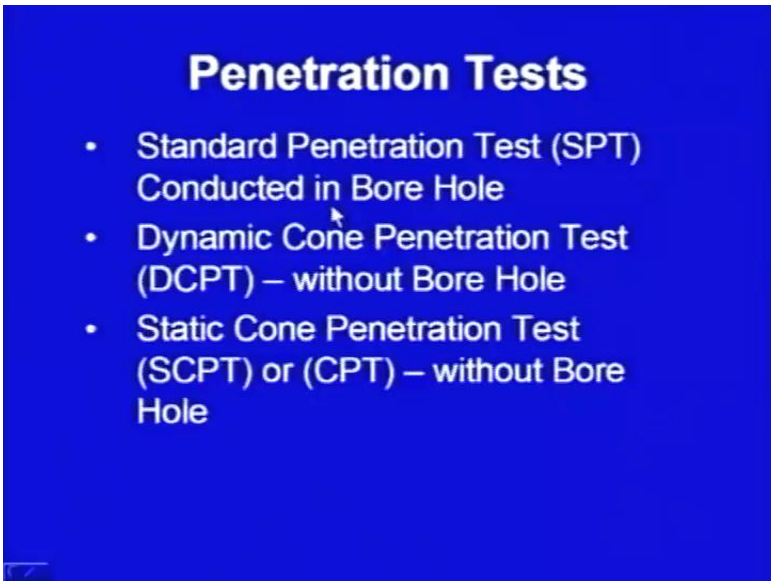

The penetration test will include three types of the test, Standard Penetration Test, SPT which is conducted in a bore hole, bore hole is required for this test. Second type of the test we shall discuss is Dynamic Cone Penetration Test, in short it is called as DCPT it is a quick test and no bore hole is required to conduct this test. Third one is a another test which is becoming quite popular now a days is Static Cone Penetration Test, SCPT or simply Cone Penetration Test or CPT this also does not need bore hole.

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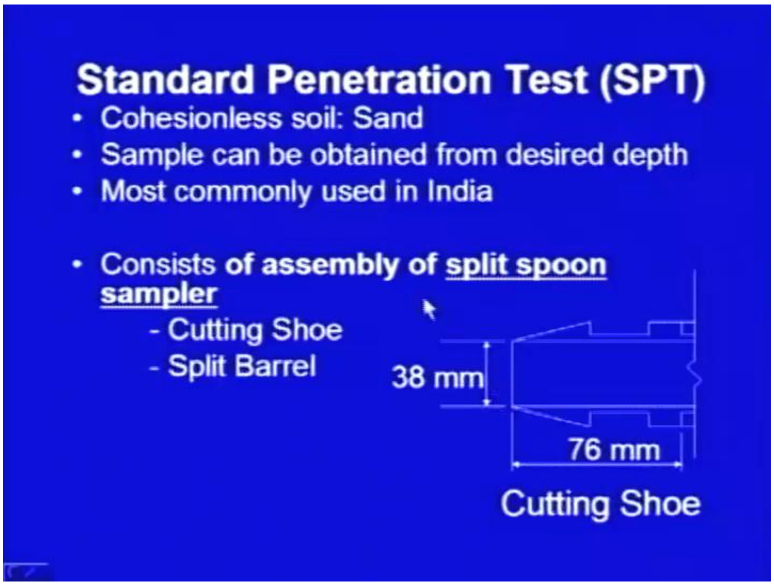

Let me start with the first one Standard Penetration Test SPT, this test is a basically or it is applicable mainly for the cohesionless soils, for example sands and as I discussed it is conducted in the bore hole. The samples can be obtained from the desired depth and probably this is the most commonly used test for sands in India, the most important part of this test is assembly of split spoon sampler, this is the assembly.

Here I have shown only the cutting shoe, this is having some internal diameter, standard dimensions are there and it is pressed, this cutting shoe is pressed into the soil at the bottom of the bore hole. And on this side the split barrel is there, so the soil sample will enter from this side and it will go into the split barrel and that sample can be taken out.

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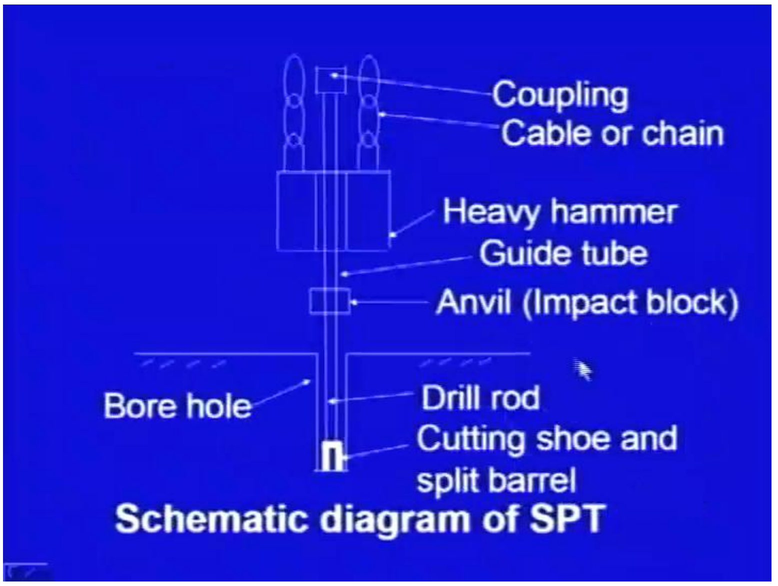

This is the schematic diagram of the standard penetration test, here this is the ground level and there is a bore hole, the bore hole has been advanced to certain depth, normally we do it at certain intervals. For example we start with let us say 0.75 meter depth below the ground, next test we take at 1.5 meter, then at the interval of 0.75 meter or as the depth increases we can increase the interval.

Here it is the bottom of the bore hole and this is the cutting shoe and split barrel which I discussed few seconds up just now and here it is the drill rod, this cutting shoe is attached to this drill rod, here is an anvil or the impact block. And above that this is the guide tube and here is a heavy hammer of standard weight we shall discuss it later on and this hammer is can be lifted up using some cables or chains and here is a coupling and on these sides the tripod will be there.

So, this heavy hammer can be lifted up it is lifted up and then, it is allowed to fall freely for a certain distance it will impact against this anvil and it will impart energy, because of this cutting shoe will penetrate the soil.

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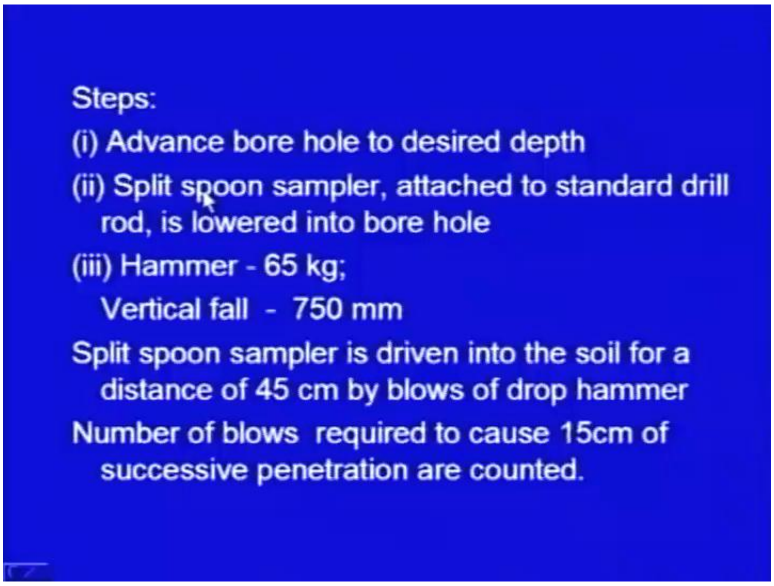

These are the steps involved in the SPT, first step is advance bore hole to the desired depth as I told you we can select the interval depending on the field requirement, we can conduct at 0.75 interval or 1.5 interval whatever is the requirement in the field. Then at that particular depth split spoon sampler attached to standard drill rod is lowered into the bore hole, then there is a hammer which I discussed just now, the weight of the hammer is 65 kg, this is the standard weight as per the highest specification.

And it is allowed to fall freely for a distance of 750 mm this is also a standard fall as per the iso specification. Now, this hammer is allowed to fall freely, because of that the split spoon sampler is driven into the soil for a distance of 45 centimeter, because of this blows of the hammer. And while doing this we keep counting the number of blows, so number of blows required to cause 15 centimeter of successive penetration, this is counted, this is recorded, so for every 15 centimeter we keep on recording the number of blows required.

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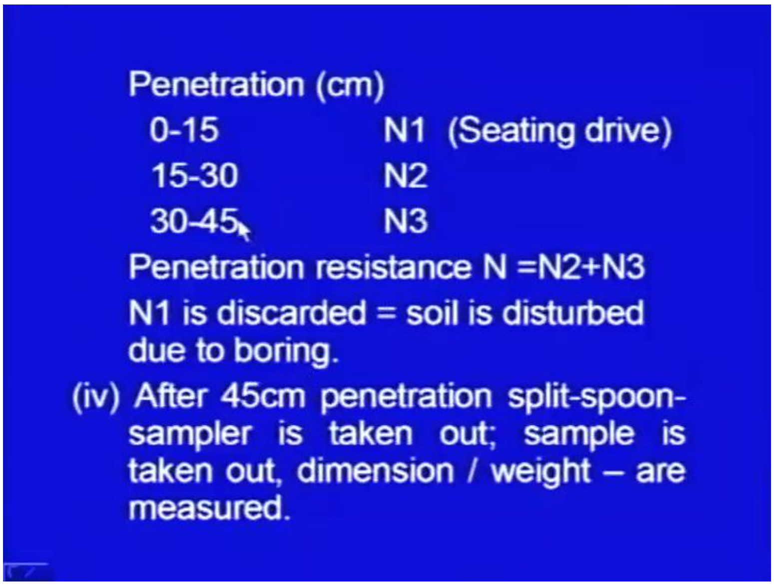

Let us say for first 15 centimeter N 1 are the number of blows, second 15 centimeter N 2 are the number of blows and for last third 15 centimeter N 3 is the number of blows. Now, this first value N 1 it is called as seating drive, we discard it because we assume that the soil might have been disturbed due to boring, so this value is not considered and only these two values are taken into account.

And the penetration resistance is defined as N equal to N 2 plus N 3, so first one is discarded, N 2 is the number of blows required to cause penetration between 15 centimeter to 30 centimeter and N 3 is the number of blows required to cause penetration between 30 centimeter to 45 centimeter. Now, after the 45 centimeter penetration the split spoon sampler is taken out and then, the sample can be taken out it is dimensions can be measured, it is weight can also be measured.

If it is a purely cohesionless soil you will not be getting the shape, you will not be getting the exact shape, but you will be getting the weight. And also from the dimensions of the split spoon sampler you can find out it is volume and then, you can find out its unit weight.

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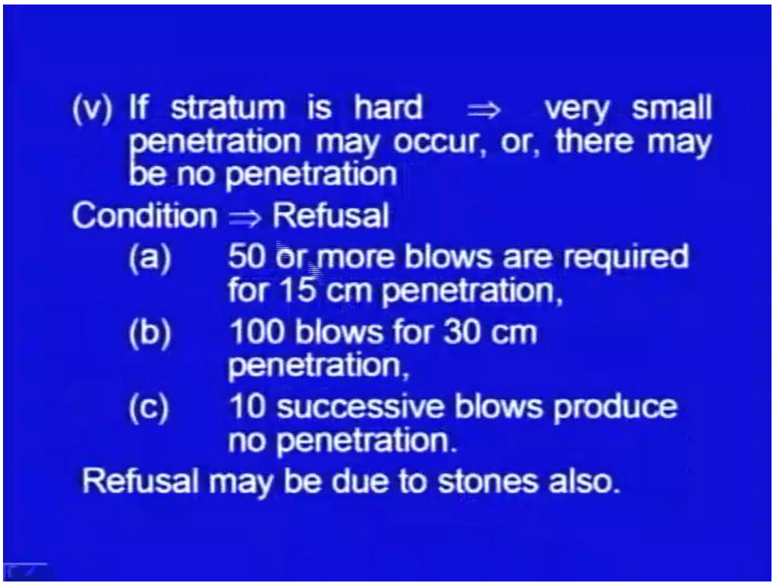

Now, if the stratum where we are conducting the test, if it is hard very small penetration may occur or there may be no penetration at all, this condition is called as refusal. There are standard number of blows, there are standard, there are specifications for the conditions for which we say that refusal has occurred. The conditions are if 50 or more than 50 blows are required to cause 15 centimeter penetration.

That means, first 15 centimeter, second 15 centimeter and third 15 centimeter penetration anywhere, if you observe more than 50 equal to 50 or more than 50, then you say the refusal as occurred, then we stop the test. Second condition is 100 centimeter of blows are required for 30 centimeter penetration and the third condition is if 10 successive blows produce no penetration, then also we must stop the test.

And we should say, we should record that refusal has occurred, the refusal may be it is not necessary that it is always because of the hard stratum, it may be because of the stones also, boulders also and it may give us a false impression of hard stratum, so we have to be careful while analyzing this data.

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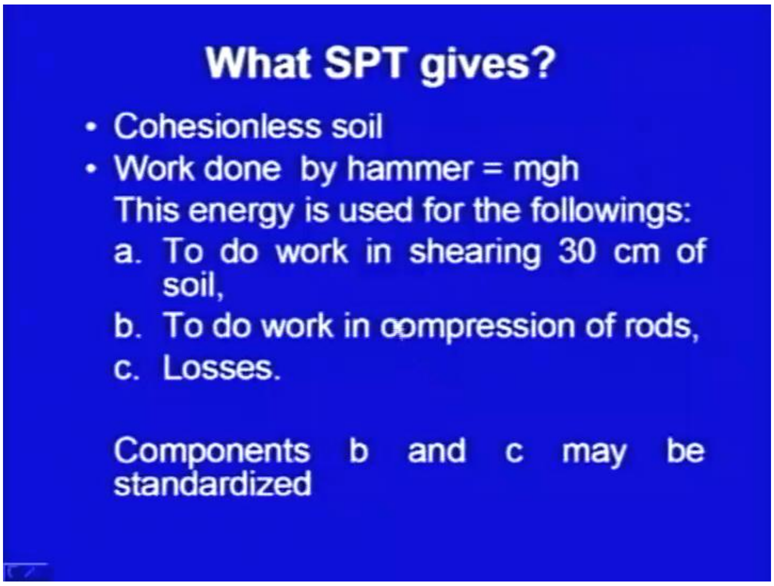

Now, what SPT gives us, as I told you it is mainly for cohesionless soil, as far as design is concerned we shall be using these values for cohesion less soil. Now, if you recall the basics you studied for energy you can find out what is the work done by the hammer, you know it is mass, you know acceleration due to gravity and you know the height for which the hammer is falling freely.

So, you can find out what is the energy it is possessing at the time when impact takes place and this energy is then used for the following components, these are the components in which this energy is utilized. First component goes to the work in shearing 30 centimeter of soil, see we have recorded total N for 30 centimeters and for shearing 30 centimeter of soil there must having some energy, so there must having some work, so that component comes from here.

And not only that second component is to do work in compression of rods, the rods are made up of steel and it will be having some modulus of young’s modulus, modulus of velocity it will be having some compression, you can find out what is the compression. You can find out what is the work done in compressing these rods and third component with there will be some losses, because of the friction or because of the impact, there will be some losses.

Now, these components may be standardized based on the experience and based on the material used, these components may be standardized and then finally, one can have a relation between this energy and this energy, what is required to cause shearing of 30centimeter of the soil.

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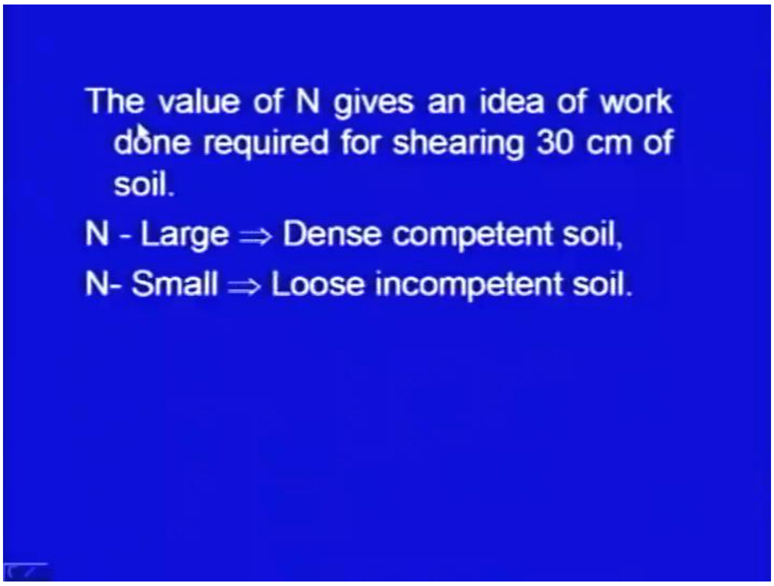

Basically the value of N gives us an idea of work done required for shearing 30 centimeter of soil if we correct it for the components other components, if N is large it is obvious, we can expect a dense competent soil provided there are no stones etcetera. We have to be careful while analyzing this data, and if the value of the N is small, then we should expect loose incompetent soil.

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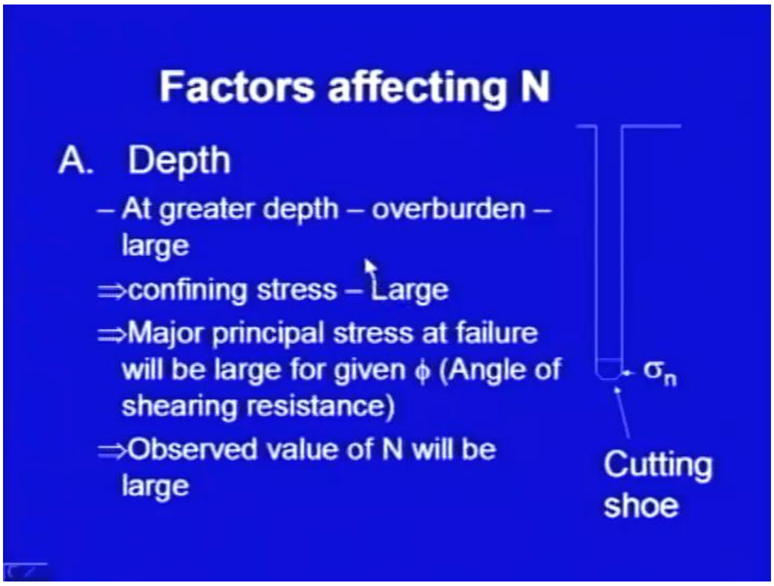

Let me discuss some factors which affect and because, we are going to use, we are going to correct this n for those factors, the first factor is the depth at which we have conducted the test. Now, here I have shown a bore hole and here there is a cutting shoe, cutting shoe is cutting this soil the soil is failing here and let us say there is some depth here, this is the depth at which the test is being conducted.

If this depth is large at greater depth this overburden, this soil will be imparting an overburden pressure and because of that overburden, the confining stresses on the soil will be large. So, at greater overburden confining stress will be large, that means sigma 3 will be large and if you remember when I discussed Mohr-Coulomb failure criterion, the major principle stress at failure sigma 1 is a function of sigma 3 and is a function of angle of shearing resistance phi.

So, if sigma 3 is large, if the confining pressure is large you should expect higher strength, so if the higher strength, this particular soil is giving higher strength, so it is obvious the observed value of N which is nothing but, a measure of the strength of this particular soil here it will also be large. So, if the overburden is large the observed end will be large.

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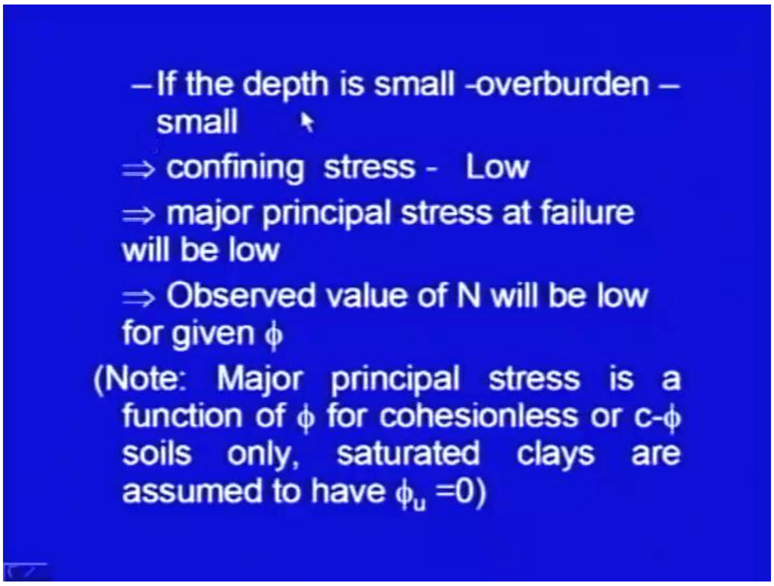

What happens if the depth is small, the overburden will be small that means, the confining stresses will be low, major principle stresses at failure will also be lower in this case and then, observed value of N will also be low. You can note down that for the same phi value, for same phi value if I conduct a test here or if I conduct a test here or if

I conduct a test at this place, the strength will be different. And that strength is not different, because the soil is different, soil is same soil is same here, here here.

What is changing is the confining pressure, so we will be getting lower strength here somewhat higher value here and maximum value here, so correspondingly N value will be minimum here, somewhat larger here and maximum at more depth. So, for small overburden the observed value of N will obviously be low despite the fact that phi is same for the soil. Here I am putting a note, the major principal stress is a function of phi as I told you it is only for the cohesionless soil or c phi soil.

Please note down, if you are working in saturated clays then we assume the phi value undrained phi value equal to 0, so the strength of clay, saturated clay should not depend on sigma 3. So, this particular factor is not going to affect the behavior of the clay.

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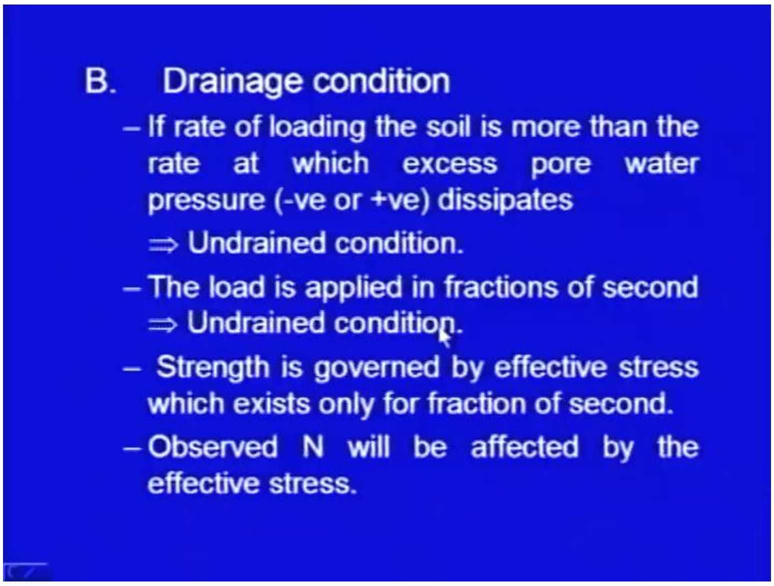

So, first condition was the pressure, because of the over burden, second factor which affect the value of N is drainage condition how it affects, if the rate of loading the soil is more than the rate at which the excess pore water pressure dissipates, then undrained condition will occur. You are familiar with this phenomena, that if water is present there in the pores and if you apply a stress, then that stress initially is taken by water, pore water pressure will develop and it depends on the permeability of the soil.

It depends on the rate of the dissipation of excess pore water pressure, so if the rate of dissipation of excess pore water pressure is very high, the condition will be drained condition. But, if the rate of dissipation of excess pore water pressure is low undrained condition will occur here, now here in this case, in the standard penetration test we are doing the test using a hammer and the hammer drops. And it imparts energy within fraction of seconds, so the load is applied within fraction of second it is very fast, it is very rapid.

So, if the situation is such that, this soil is not drained the rate of dissipation of pore water pressure is low, then undrained condition will develop there and the strength as you know is governed by the effective stress, not at dot total stress. And that effective stress in this case will be occurring only for fraction of seconds, so observed N value will not be the true value, it will be some apparent value and it will be affected by the effective stress.

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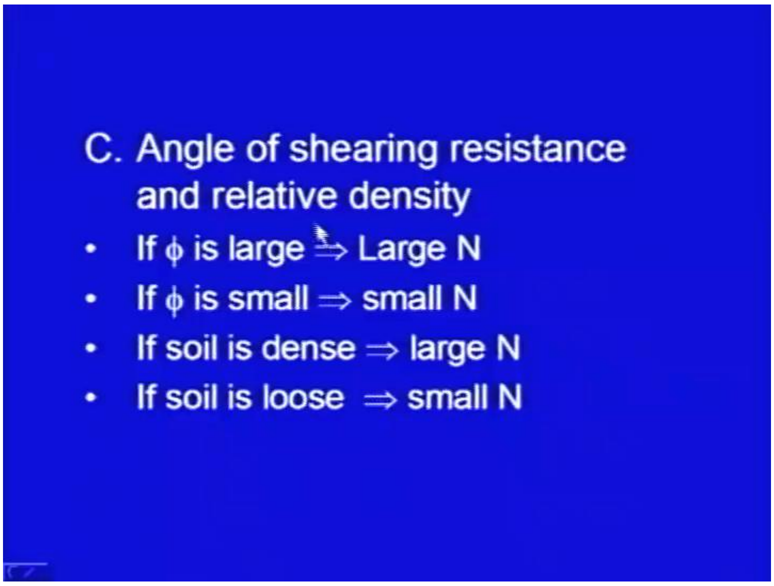

The third factor which affects the N value is obviously the parameters of the soil, if phi value is large you are expected to that large N, because it will be having higher strength, again we are talking about the cohesionless soils not the clay soils. If phi value is small you are going to observe, you are going to get smaller N, if soil is dense it will be highly compacted soil then you will be getting larger N. If soil is loose then it is strength will be smaller you are expected to get small value of N.

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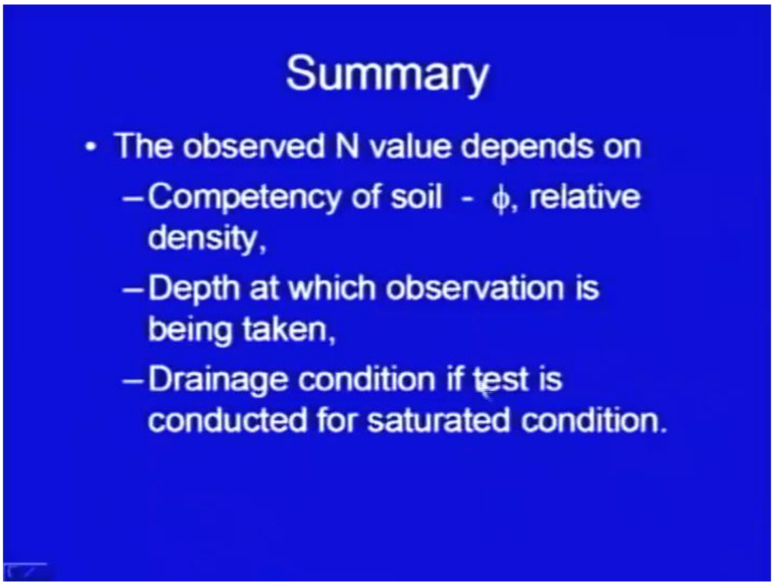

Let me summarize now what are the factors, the observed N value is affected by these parameters, competency of soil that means, phi and relative density. In fact these are the parameters which we are trying to find out from these tests. Second factor is depth at which observation is being taken, so it is through the confining stress at higher overburden, the confining stresses will be larger.

At low confining stress at low overburden the confining stresses will be low, the third condition is drainage condition that depends what kind of the soil is there is it fine sand, is it coarse sand, is it silt, is it clay something like that. So, drainage condition if the test is conducted for saturated condition, so obviously this will be applicable only when it is completely when the soil is completely saturated.

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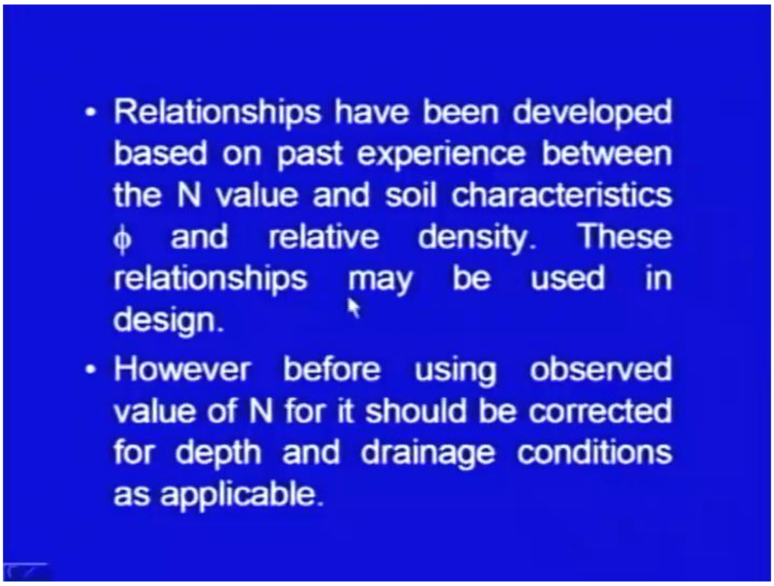

Now, based on the past experience, relationships have been developed between the N value and soil characteristics phi and relative density, these relationships may be used for design purposes. Before using the observed N value, we must correct the N value for the depth and drainage conditions as applicable.

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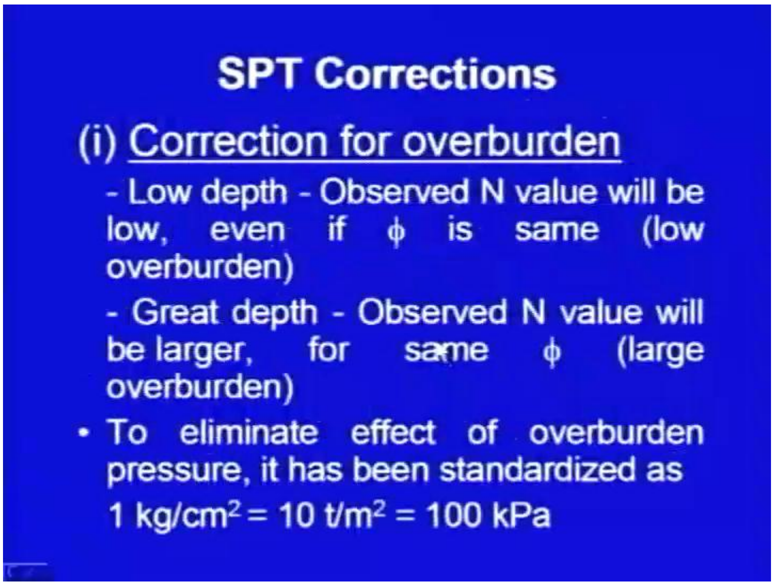

Let me now discuss what are the different corrections, I have already discussed the factors, so first correction is correction for overburden. As I discussed earlier when the test is conducted at lower depth observed N value will be low, even if phi is same because of the low overburden pressure. Because of if the depth is great observed N value will be larger for the same phi because of higher overburden, now to eliminate when we use this because phi is same, same phi is there, so the soil is the same there.

So, we should have the idea we should know how these parameters, how this depth parameter is affecting the N value or phi value, so to eliminate this effect of overburden, the one standard overburden has been taken. It has been standardized as per the code and the standard value is taken as 1 kg per centimeter square, this is the effective overburden which is taken as the standard overburden. So, we will be getting phi values for this particular standard overburden, in other units 1 kg per centimeter square will be equal to 10 ton meter square or 100 kPa.

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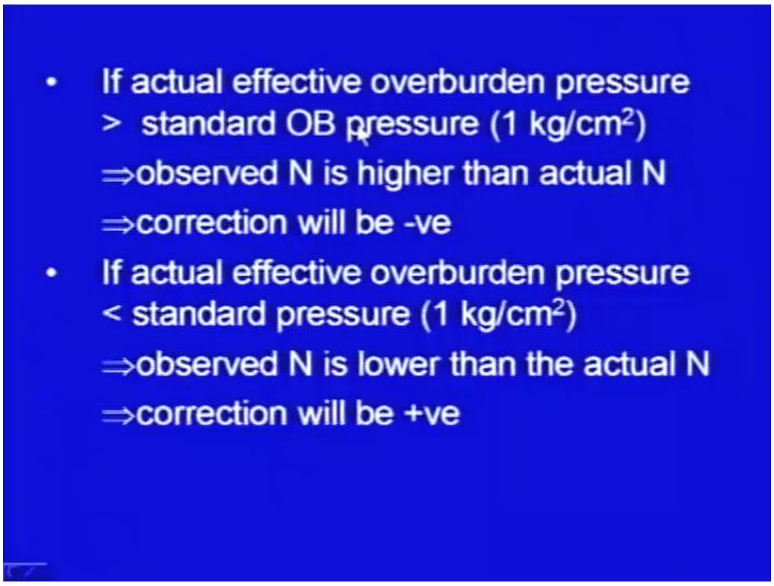

Now, if the actual effective overburden pressure is more than this, this will happen at higher depth, observed N value will be higher than the actual N, this I have already discussed. At higher depth observed strength will be more, so observed N will be higher than the actual N. So, the correction in this case will be negative, so at higher depths where the effective overburden is more than this standard value, the correction will be negative.

If actual effective overburden pressure is less than the standard pressure that is 1 kg per centimeter square, then it happens at lower depth, observed N value is lower than the actual N and therefore, you have to apply correction which will be positive in nature.

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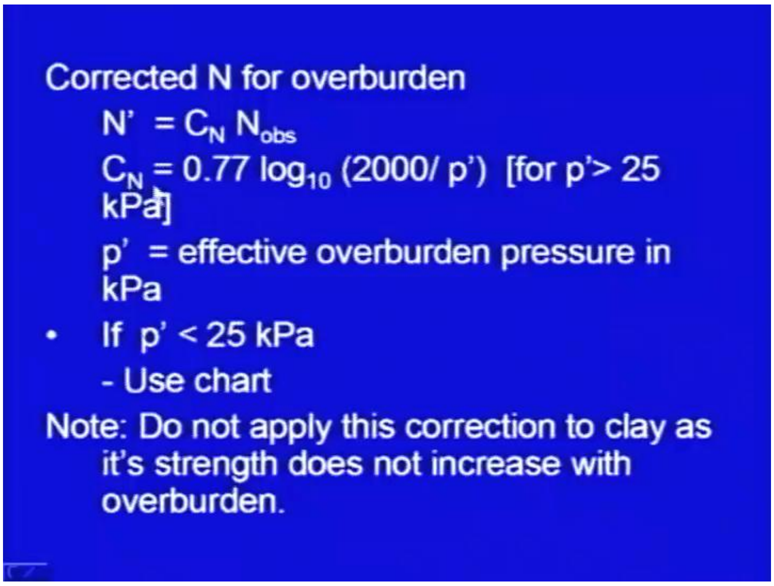

Here are the methods based on experience, this is one of the methods by which the values of N can be corrected, so corrections for overburden N dash is equal to C N, this is a coefficient into N observed, this is the observed value in the field. And C N is the correction factor, it is given as 0.77 log to the base 10 inside bracket 2000 divided by p dash bracket closed and this equation is applicable, when p dash is more than 25 kPa.

P dash is the effective overburden pressure in kPa and if p dash is less than this value less than 25 kPa, this equation include introduces some small amount of error, then it is recommended that you use chart, there is a standard chart available in standard books, so those charts can be used. Again do not apply this correction to clay as it is strength does not increase with overburden, this I have already discussed. This correction is applicable for the sandy soils, in which case the strength increases, because of the confining stresses.

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Here is that chart, you can get this chart in any of the standard book, on x axis the correction factor is there, it is varying here from 0.4 to 2.0, on y axis it is the effective vertical overburden pressure in kPa. And you can note down that when the pressure is between 0 to 100 kPa this is the standard value and at 100 this value correction is exactly 1.0, so no correction is applied for effective overburden pressure equal to 100 kPa.

But, if it is more than 100, for example if it is around 50 you can see somewhere here the correction factor is C N as 1.2, so actual value will be 1.2 times the observed values and you can see at almost theoretical 0, 0 confining 0 overburden it is almost 2 times. So, this chart has to be used for getting C N values, when the effective overburden pressure is more than 100 when it is in this range 100, 50, 200, 250 and so on, you can see these values are less than 1.

So, this is the one value and beyond this in this range the values are less than 1, so if the depth is more than that which gives you effective overburden pressure more than this, then the correction factor is negative. So, one has to remember this thing above standard if the effective overburden pressure is less than standard pressure, then the correction is more than 1 and if the pressure is more than 100, more than standard, then the correction factor is less than 1.

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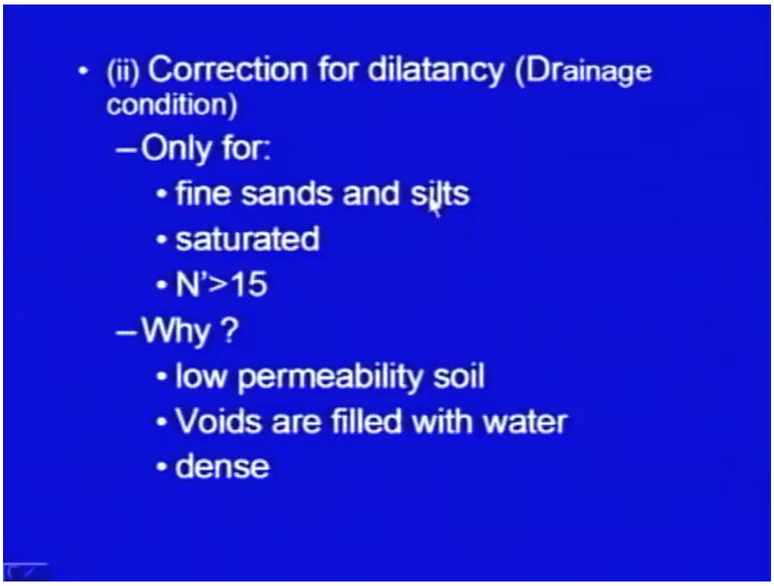

Now, let me come to the next correction that is called drainage condition, popularly this correction is known as correction for dilatancy and remember it will be applicable only for fine sands and silts not for coarse sand, it will be applicable when the soil is saturated. See we are talking about the drainage conditions, so water has to be there, so we apply this correction when it is saturated, thirdly the N dash value should be more than 15, Please note down here we have already corrected the observed N and we got N dash because of the overburden.

The sequence of correction will be same, first is the observed value of N and then, you get the overburden corrected value of N that is N dash, now why we apply this correction for this condition only. The first point is we apply it for fine sands and silts, because they are low permeability soil, I discussed the undrained condition will occur when the permeability is relatively low it depends on the rate of application of the load and the rate of dissipation of excess pore water pressure.

So, if the permeability is low rate of dissipation of excess pore water pressure will be low and undrained condition will occur, so this is why it is applied only for fine sands and silts not for coarse sand. Secondly it has to be saturated, voids should be filled with water if the drainage conditions have to be accounted for and thirdly we will be applying this correction only for the dense soils.

Means when N dash is large and this is the value which has been taken from past experience that if N dash is more than 15 it will be dense, so for dense is soils only we will be applying this correction.

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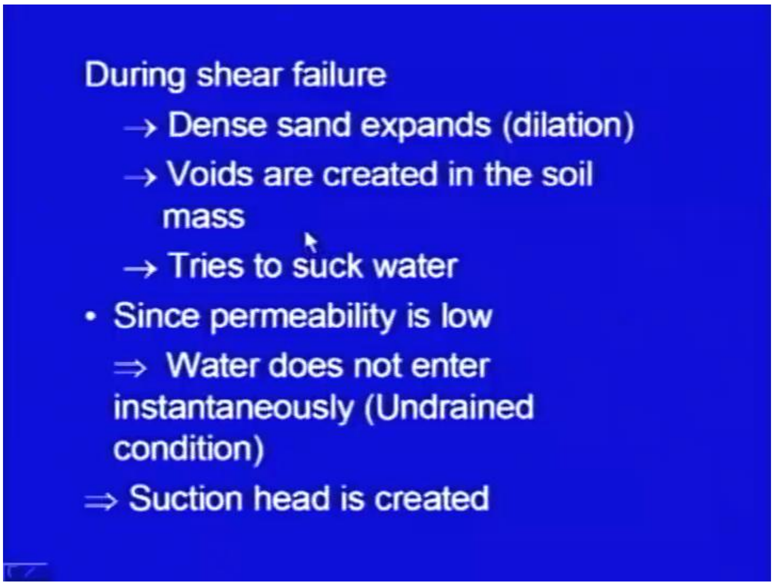

Let me explain why this correction is applied what is the phenomena, what is the basic concept behind this, now we have already discussed that it is dense sand or silt fine sand. Now, during shear failures what happens is as you remember the soil is failing, because of the cutting shoe the soil is failing at the time of failure, if it is a dense sand then it will dilate. If you remember your fundamentals from the soil mechanics course, if it is a dense sand at the time of failure it should dilate, if it is a loose sand then it should contract.

So, if it is dense sand it dilates, it increase it is volume increases it expands, so when it expands the voids are created in the soil mass, because soil grains are there, these soil grains they change their position they are all over each other, they slide over each other and voids are generated. So, voids are created in the soil mass, now again this is filled with water, so what happens when the void is created in the soil mass the soil mass tries to suck water, it will tries to suck water.

And since permeability is low water does not enter instantaneously and undrained condition is achieved, it occurs it the undrained condition will prevail in the soil mass. So, because of this when the soil mass is trying to suck water, but water is not very easily coming into it suction head is created, undrained condition is there.

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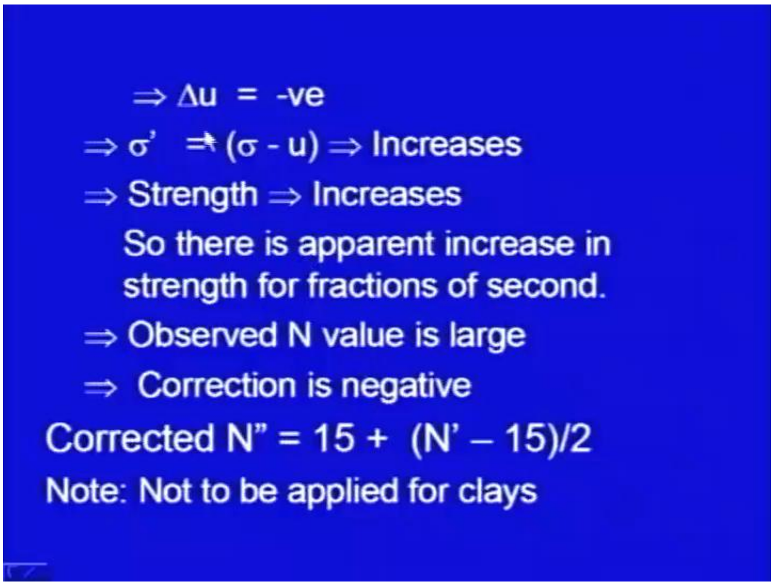

And because of this suction head there is negative pore water pressure which will be generated inside the soil mass. So, there is a negative head which is created in the soil mass and effective stress as is given as total stress minus pore water pressure and this pore water pressure, the incremental effective stress if I use here delta sigma dash that will be delta sigma minus delta u and this delta u will be negative, so negative negative it will become positive.

So, effective stress will increase, so effective stress increases and strength will also increase because the strength depends on the effective stress. So, there is an apparent increase in the strength for only few fractions of seconds, it is not the actual strength, but we are getting some apparent value some false value and because the effective stress is higher the observed N value will be large, because the strength is large.

So, we have to apply the correction which is negative in nature and the correction is applied in this way, this is the equation, the corrected value it is represented as N double prime equal to 15 is the arbitrary value which has been taken based on past experience plus N dash this was the corrected value for overburden minus 15 divided by 2. So, in case of the dilatancy correction what happens is that, the soil is saturated and it is a relatively impermeable kind of the soil, sand, fine silt.

And when the load acts on it when the soil fails it is in dense condition, so when it fails it expands, it is expanding, but it is relatively impermeable, so undrained condition will prevail. Because of the undrained condition when it is trying to expand, it is trying to suck water the negative head is created inside this, negative pore water pressure develops because of that effective stress will increase and the strength will increase.

So, this phenomenon when it fails at fails because of the shearing stress, it is dense and it expands that is called as dilation, so because of this dilational nature of the soil, there is increase in strength. This will not happen in case of clays and because of this apparent increase in strength for fraction of second N value will be larger, so we have to reduce that value and this is the equation.

And this correction should not be applied for clays, because the clay will not be showing this dilational characteristics.

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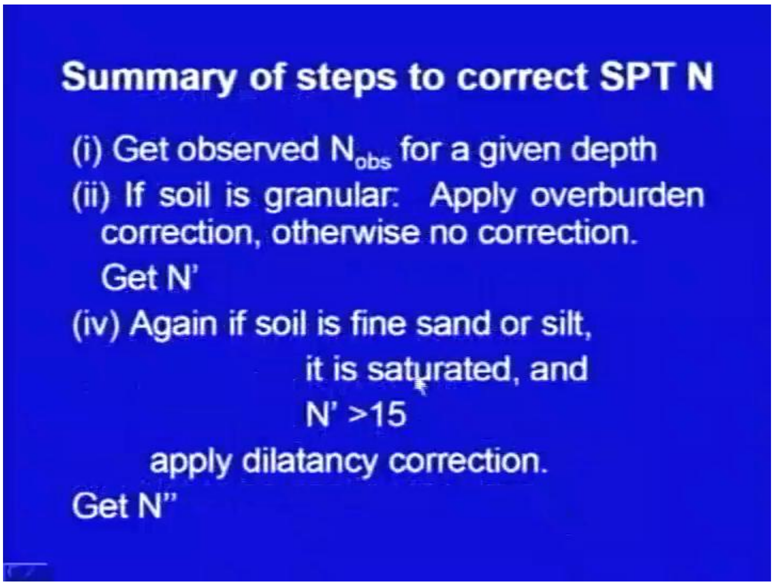

Let me now give the summary of the steps, get first step is get observed N value for a given depth, in fact when we plan a program as I discussed earlier we take the N value, we observed N values at different intervals. So, let us say for any depth N observed is available, if soil is granular apply overburden correction, otherwise no correction, so by applying overburden correction get N dash. Again check if the soil is fine sand or silt and it is saturated and it is dense, dense means N dash is 15 then apply dilatancy correction and then finally, get N double prime that is the corrected N value.

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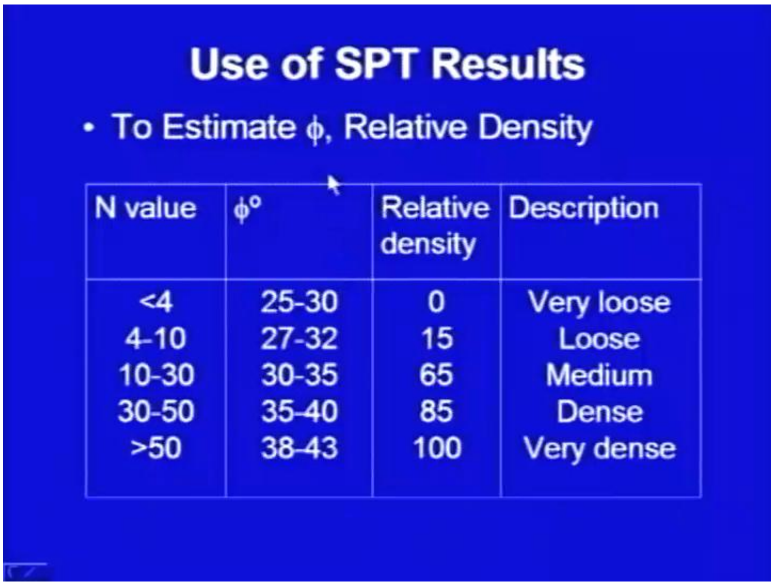

How to use these results, SPT results are very important for sandy soils, in case of sandy soils probably we have no other choice, you cannot take an undisturbed sample from a sandy start stratum and test it in the laboratory. So, we rely on this test, so this test is very very useful and it is used in design, so you can estimate phi value and also the relative density from the corrected, this is the corrected N value. If it is less than 4 the phi value will be varying somewhere between 25 to 30 degree, relative density is taken as 0 and it is described as very loose soil.

If the corrected value is between 4 and 10 from the experience people have obtained these values that phi values are expected to vary between 27 and 32 degree, relative density will be on the order of 15 and the soil can be described as loose soil. If the corrected N value is between 10 to 30 phi values for the sandy stratum can be taken between 30 to 35 relative density of the order of 65 and the soil can be described to be having medium type of the relative density.

If the N value is 30 to 50, then phi value will be between 35 and 40 relative density is 85 and the is sandy stratum is termed as dense, if it is refusal please you have to be careful while deciding it. It should not be because of some stones, because of some boulders and if it is only sandy stratum and it is more than 50, then the phi values will be somewhere between 38 and 43 the relative density will be taken as almost 100 and the soil will be very very dense.

So, these are the phi values and you can find that the first range is 35 to 30, second one is 27 to 32, so there is some overlapping in between two. So, you have to use your own experience may be you have to use some supplementary tests also when deciding the exact value. So, this gives the range or you can at an approximation, if suppose your value is 7, you can make an a linear interpolation also between these two values for using in design.

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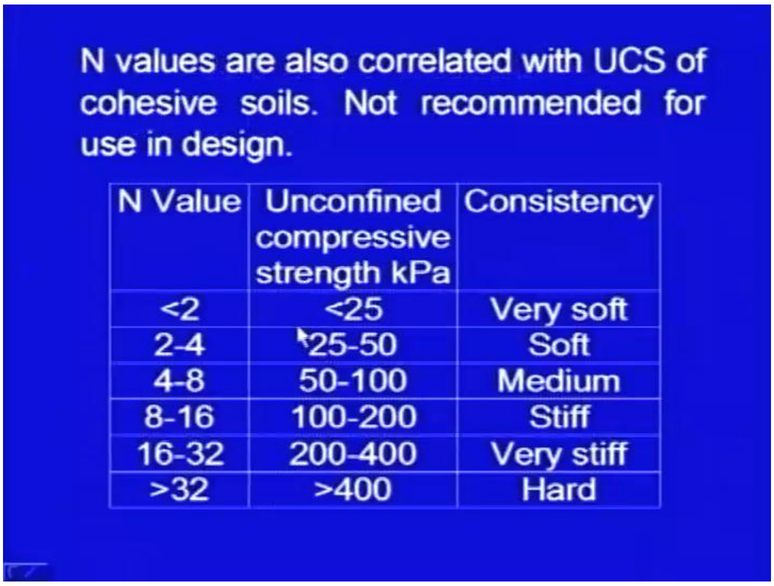
N values are also correlated with UCS of cohesive soils. Not recommended for use in design.

N Value	Unconfined compressive strength kPa	Consistency
<2	<25	Very soft
2-4	25-50	Soft
4-8	50-100	Medium
8-16	100-200	Stiff
16-32	200-400	Very stiff
>32	>400	Hard

Now, these some people have used the N values for cohesive soils also and they have found correlation between the UCS and N values, in fact UCS means unconfined compressive strength test. The UCS value UCS test is also done in a short duration, so it is also time independent, so some people have tried to find out the correlation between the N value and unconfined compressive strength values and also the consistency.

But, as a philosophy these values are not recommended for design, unless there is nothing is available these values are not recommended for design, for designing purposes in fact, for the cohesive soils one has to go in time dependent analysis. So, those parameters will be more important, but these values can be used for comparison purpose, so if N value is less than 2 the unconfined compressive strength of the cohesive soil is of the order of less than 25 and it is termed as very soft soil.

If the N value is between 2 to 4 then compressive strength will be between 25 to 50 kPa the units are kilo Pascal's and the soil is termed to be soft, if N value is between 4 to 8 the strength will be in the range of 50 to 100 kPa and the consistency of the soil is termed to be medium. If the N value is between 8 and 16 the strength values will be between 100 and 200 kPa the soil is termed to be stiff; if N value is between 16 and 32, the strength values will be between 200 and 400 kPa the consistency of the soil will be very stiff.

If the N value is more than 32 the unconfined compressive strength may be expected to be higher than 400 and the consistency of the soil is termed to be hard. So, again these values should be used for comparison purpose in general they should not be used for designing the structures.

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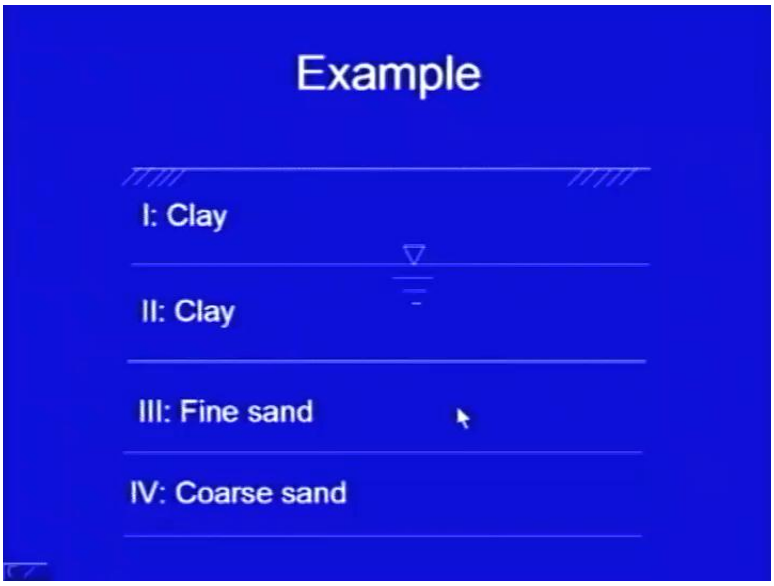

Let me now take an example how to use, how to apply these corrections and how to do the analysis I have taken an example here this is the soil, this is the is ground level and we have taken 1, 2, 3, 4, 4 layers. The first layer is of clay and water table is observed in the first layer, so we have divided the first layer itself into two parts it is clay it is also clay, but for the sake of solving this problem we are taking it second layer, so first layer second layer is saturated clay; the third layer is fine sand and fourth layer is coarse sand.

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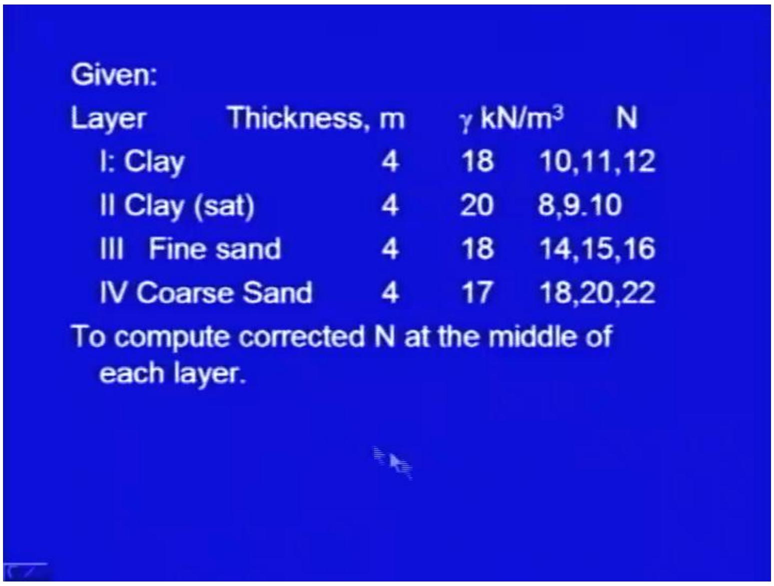

From the field observations this is the data available, for the first layer thickness is 4 in fact, to make the things simple I have taken all the layers to be here in same thickness of 4 meter and this is the unit rate, in the first layer it is 18, these are the N values observed. These are N values representing these are the representative values I am taking at the mid of these layers, you have to decide see when you conduct an experimental, an a field investigation program, you will be doing tests at some intervals or may be at some pre-determined depths.

And I have assumed that these N values are available at mid of the layer, for example here at first layer, second layer, third layer, fourth layer, at mid of the layer these are the representative N values. So, here I have shown three values 10, 11 and 12, the first one is for first 15 centimeter penetration, second one is for second 15 centimeter penetration, and third is for third 15 centimeter penetration. Similarly, seconds layer is a saturated clay having same thickness gamma is little bit more now, because it is saturated this is gamma saturated.

N values are little bit on lower side now, these this is for first 15 centimeter, second 15 centimeter and third 15 centimeter 8, 9 and 10. Then there is a layer of fine sand of 4 meter thickness the unit rate is 18 again it is saturated unit rate and observed N values are 14, 15 and 16 respectively, the last layer is a coarse sand layer of 4 meter thickness and it has been found gamma is 17.

Gamma you can find out from the samples which you take during the SPT, so from there you can find out the gamma. So, here it is the values of the blows for successive 15 centimeter penetrations are 18, 20, 20 respectively and the problem is we want to compute the corrected N value at the middle of the each of the layer.

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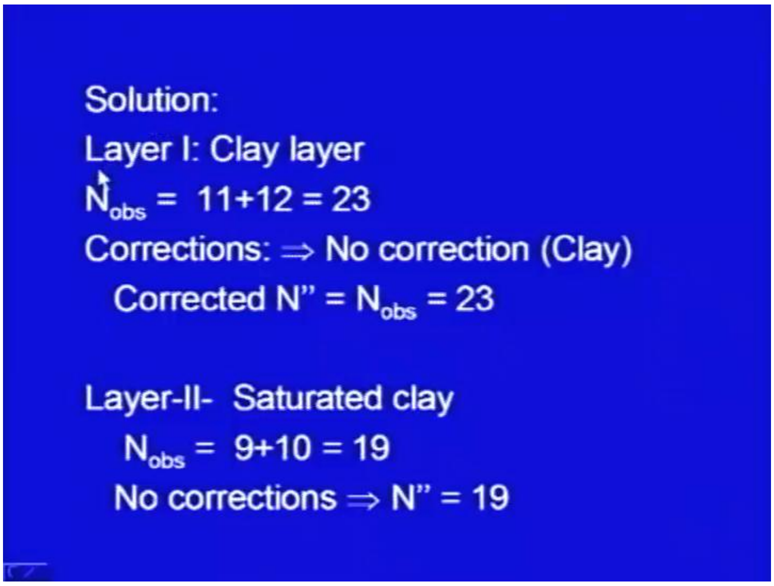

Let us start with the first layer it is a clay layer, now N observed this as I discussed there are three values available, the first value normally we will not take into account. We consider that when we were repairing for the bore hole, when we were advancing the bore hole there should have been some disturbances, because of that this value may not be representative value. So, we consider only these two values 15 centimeter plus 15 centimeter, so for 30 centimeter penetration we take this an 11 plus 12.

So, N observed is termed as 11 plus 12 that is 23, now what are the corrections we have to apply, there is no overburden correction, there is no dilatancy correction because it is clay. So, corrected N double prime is equal to 23, so if it is a clay soil then there is no correction which has to be applied same value, observed value should be taken as the corrected values.

Second layer is a saturated clay again here the values of the blows were 8, 9, 10, we have to discard this, so for 30 centimeter penetration the N observed will be 9 plus 10 and that comes out to be 19 and we take this 19 as the corrected value.

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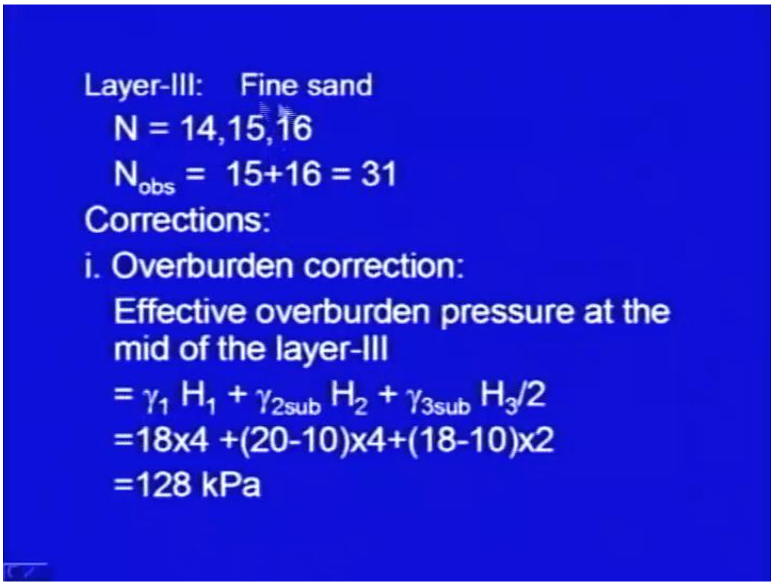

Come to the layer number 3 it is find sand and the observed number of blows were 14, 15, 16, so observed N will be discard this 15 plus 16 that becomes 31, let us now apply the corrections. First is overburden correction to apply the overburden correction, first we calculate the effective overburden pressure at that particular depth were we are doing the analysis. So, in this particular case the effective overburden pressure at the mid of the layer third has to be calculated.

And this will be equal to gamma 1 H 1 for this gamma 2 into H 2 for this remember gamma 2 here has to be taken effective total minus gamma w and then, this is the third layer. So, here you have to take gamma 3 H 3 and gamma 3 again will have to be taken effective, because it is under water, so effective overburden pressure at the mid of this layer will be gamma 1 H 1 plus gamma 2, we have to take submerged.

Because, we are talking in terms of effective stresses into H 2 is the depth the thickness of the second layer plus gamma 3 submerged is the third layer submerged unit weight of the third layer into H 3 upon 2 half of the thickness of the third layer. So, 18 into 4 I am assuming here gamma w is equal to 10, so 20 minus into 4 plus 18 minus 10 into 2, 128 kPa is the value of the effective overburden pressure at the mid of the layer number 3.

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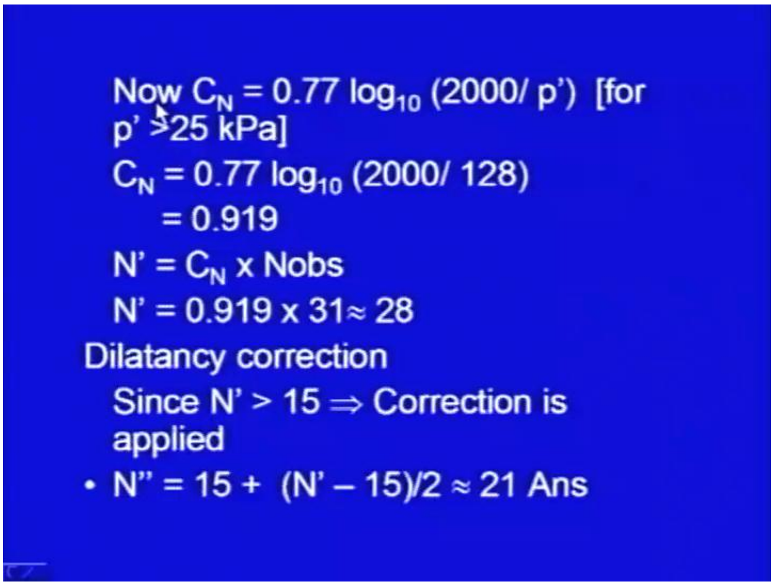

Now, C N is given as 0.77 log 10 2000 upon p dash, for p dash more than 25 kPa, so by putting p dash value here C N value comes to ought to be 0.919, that means the corrected value will be little bit lower than the observed value. Now, N dash is equal to C N into N observed, so that becomes 0.919, 31 was the observed value, so N dash N prime will be equal to 28, so this was the first correction.

Let us now apply the second correction dilatancy correction, now dilatancy correction you remember those three conditions it should have N dash more than 15, it should be saturated, it should be fine sand or silt. Because, it is fine sand it will be having low permeability N dash is more than 15, so correction has to be applied, N double dash this was the equation, N double dash equal to 15 plus N dash minus 15 divided by 2.

So, when I put N dash from here the final value is 21, so for this layer the final N value, N corrected value will be 21.

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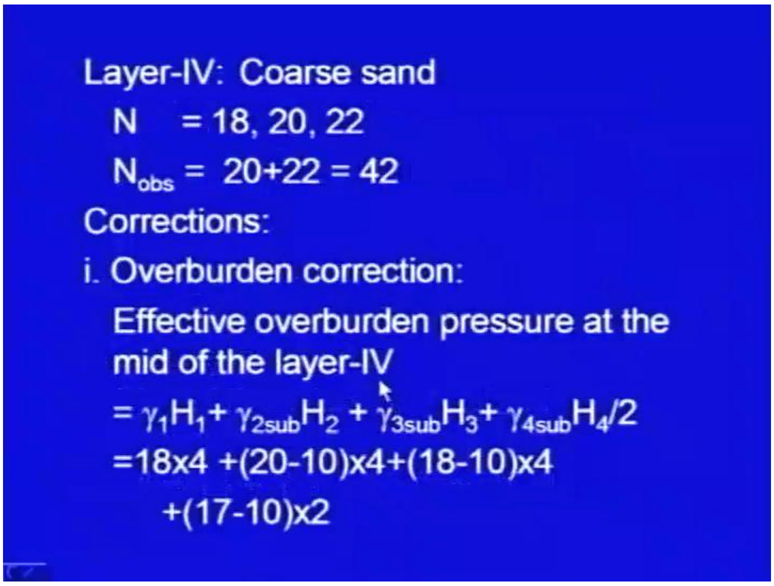

Let us now go to the layer number 4 it is a coarse sand layer, the number of blows observed in the field were 18, 20 and 22, we discard the first value, so N observed for 30 centimeter penetration is 20 plus 22 that is 42. Apply the corrections, overburden correction again we calculate effective overburden pressure at the mid of the layer 4, it will be gamma 1 of first layer into H 1 plus gamma 2 submerged into H 2 plus gamma 3 submerged into H 3.

And now fourth layer it will be gamma 4 submerged into H 4 upon 2 only and when you put these values gamma submerged is calculated by taking unit rate of water as 10 kilo Newton per meter cube. And when you put these values ((Refer Time: 52:24)) you will be getting the effective overburden pressure as 158 kPa.

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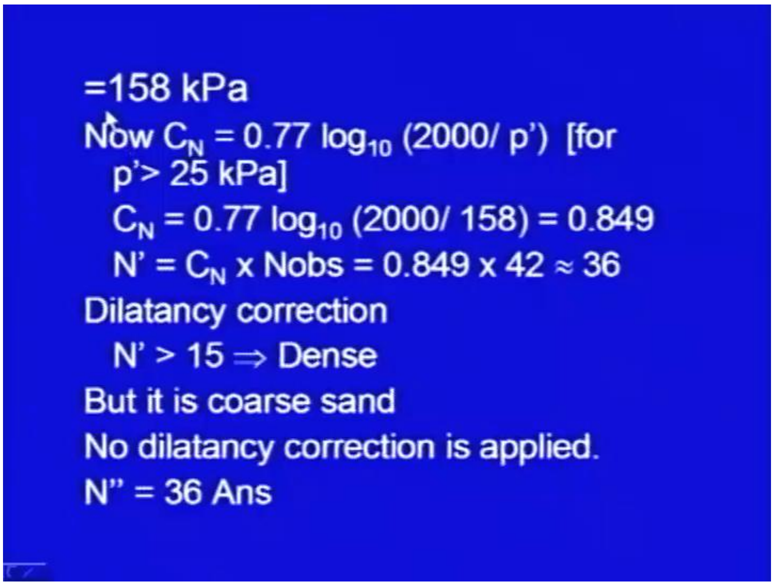

Again the equation for finding the overburden correction is C N is equal to 0.77 log 10 bracket 2000 upon p dash bracket closed, here p dash is 158 which is more than 25, so we are using this equation. In case you get this value let us say had this value been 20, 15 something like that, less than 25 you would have used those charts, standard charts which I discussed earlier.

So, C N will be equal 0.77 log 10 inside bracket 2000 upon 158 and value is 0.849, so I get corrected N for overburden equal to 0.849 into 42 was the N observed, so this value comes out to be 36. Now, let us go to the last correction dilatancy correction, let us check whether it is dense sand yes, N dash is more than 15, is it saturated yes it is saturated, but it does not satisfy the condition of low permeability.

It is a coarse sand, so for coarse sand this correction will not be apply, so no dilatancy correction is applied. So, N dash will be equal to same, N double dash will be same as N dash, so this will be 36.

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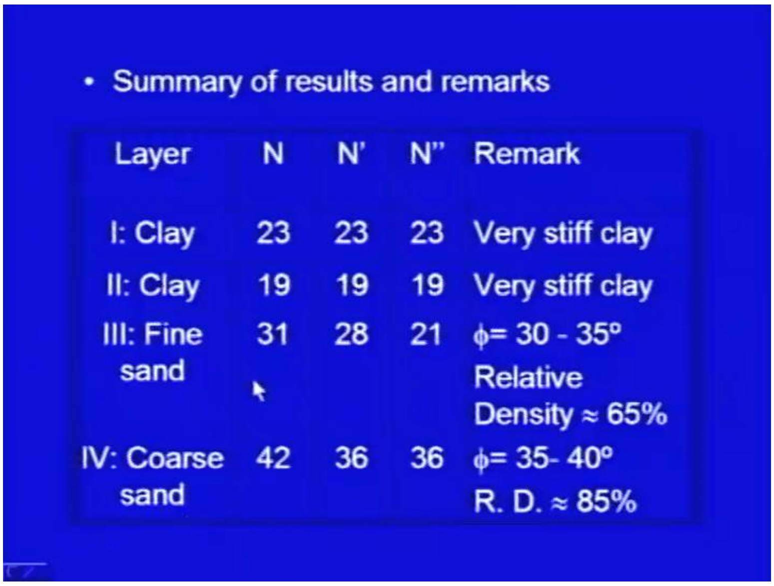

- Summary of results and remarks

Layer	N	N'	N"	Remark
I: Clay	23	23	23	Very stiff clay
II: Clay	19	19	19	Very stiff clay
III: Fine sand	31	28	21	ϕ= 30 - 35° Relative Density ≈ 65%
IV: Coarse sand	42	36	36	ϕ= 35- 40° R. D. ≈ 85%

So finally, these are the results for the different layers, first layer, second layer, third layer, fourth layer, these were the observed N values 23, 19, 31, 42, the values corrected for overburden 23, 19, 28, 36. These are the finally, corrected values this remains 23, this remains 29, it becomes 21 and this becomes 26, now remarks this is very stiff clay as per the values are available very stiff clay and phi value here it varies from 30 to 35.

One can interpolate it for the value of 21 and the relative density of this particular soil is on the order of 65 percent, the fourth layer is having phi value between 35 and 40 degree and the relative density is on the order of 85 percent. So, these informations this data, this information can be used for designing the structures, so friends today we have discussed one of the most important field test that is standard penetration test.

The test is conducted at desired depth, you can get the samples also and the value which you get is an, it is called as standard penetration resistance N and that represents the soil resistance for a penetration of 30 centimeter. This N value is then corrected for overburden as well as for dilatancy depending on whether it is a granular soil and also whether it is a fine sand, silt or it is under water or not depending on those conditions these N values are corrected.

And these corrected N values for sandy soils then can be used for designs, for cohesive soils we do not generally recommend use of these values for design purposes. So, this was all for today, then in the next lecture we shall be starting the next field test dynamic cone penetration test.

Thank you.