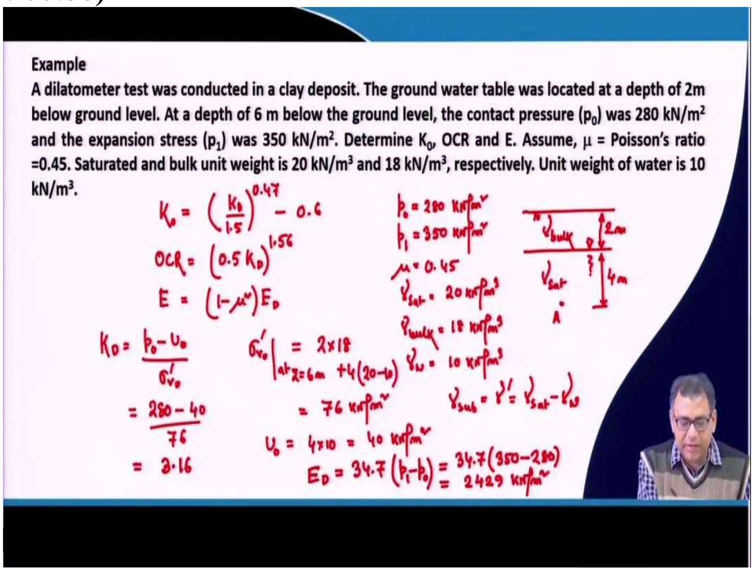
Advanced Foundation Engineering
Prof. Kousik Deb
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture - 04
Soil Exploration - IV

So, last class I have discussed about the pressure meter test and dilatometer test. Now, this class first I will solve one example problem related to dilatometer then I will discuss the other incisive test.

(Refer Slide Time: 00:50)



Now, the first thing that the problem is dilatometer tests was conducted in a clay deposit the groundwater table was located at a depth of 2 meters below the ground. So, let me draw the figure. So, this is the ground surface and this is the water table. Now, the water table is at 2 meter below the ground surface and at a depth 6 meter, we have to determine the soil properties. So, that soil property determines a point this point A and which is say 2 meter below the water and 4 meter below the water totally 6 meter depth from the ground surface.

Now, here given the p_0 is given as 280 kN/m^2 and p_1 is given 350 kN/m^2 Poisson's ratio of the soil is given 0.45 and saturated unit weight γ_{sat} is 20 kN/m^3 and γ_{bulk} which is 18 kN/m^3. So that means below the water is γ_{sat} and above the water is γ_{bulk}. Now, unit weight of water is taken as 10 kN/m^3. So, you have to calculate the K_0, OCR, E elastic modulus of the soil.

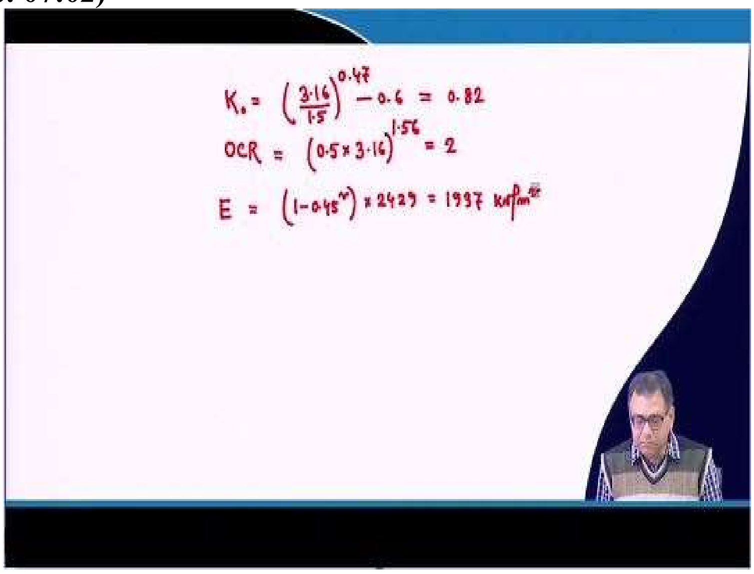
So, you know the K_0 expression is for the clay because this is what the clay K_0 expression is $\left(\frac{K_D}{1.5}\right)^{0.47} - 0.6$, OCR expression is $(0.5K_D)^{1.56}$ and E expression is $(1-\mu^2)E_D$ and K_D because we have to know the K_D expression is $\frac{p_0 - u_0}{\sigma'_{v0}}$, where, σ'_{v0} is effective overburden pressure.

Now, σ'_{v0} at z = 6 meter will be equal to for initial 2 meter it is above the water will be 2 × γ_{bulk} which is 18 + the 4 × (20 – 10) because here we have to take the γ_{sub} below the water table and this is the γ_{sub} or some time it is called γ' which is γ_{sat} - γ_w. So, above the water table is γ_{bulk} and below the water table γ_{sub} or γ' you have to use.

Sometimes in the problem you may find that above the water table and the saturated unit weight below the water table are same. So, you have to use according to that. So, this is 10 so, this value is coming out to be 76 kN/m^2 and the u_0 or water pressure at 6 m will be 4 × 10 so, that is 40 kN/m^2. So, now if I put this value here that p_0 is 280 - u_0 is 40 divided by 76. So, this value is 3.16. So, K_D value is 3.16.

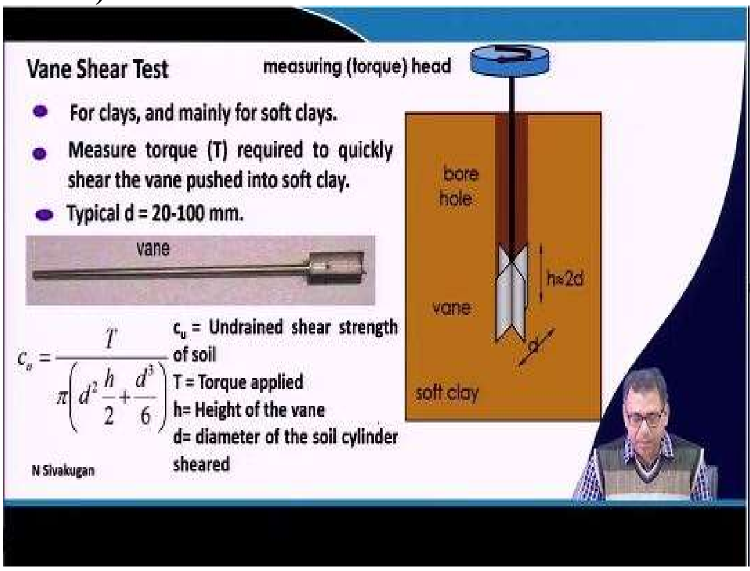
So, K_D value we will get 3.16 similarly, we will get the E_D value also. So, E_D value is equal to $34.7(p_1 - p_0)$ so, that is equal to 34.7 p_1 is 350 and p_0 is 280 so, that is equal to 2429 kN/m^2. So, we will get the K_D and the E_D now we will determine these properties K_0, OCR, E.

(Refer Slide Time: 07:02)



So, K_0 will be equal to $\left(\frac{3.16}{1.5}\right)^{0.47} - 0.6$ so, that is equal to 0.82 and OCR is equal to $(0.5 \times 3.16)^{1.56}$. So, that is equal to 2 so, OCR is 2 an elastic modulus E which is $(1 - 0.45^2) \times 2429$, so, that will be 1937 kN/m^2 so, in this way we can determine the required properties if I know the p_0, u_0, p_1 so, an effective overburden pressure so we will get the required properties for the soil. So, and this way we can determine the other properties also that I have discussed in my previous lecture.

(Refer Slide Time: 08:42)

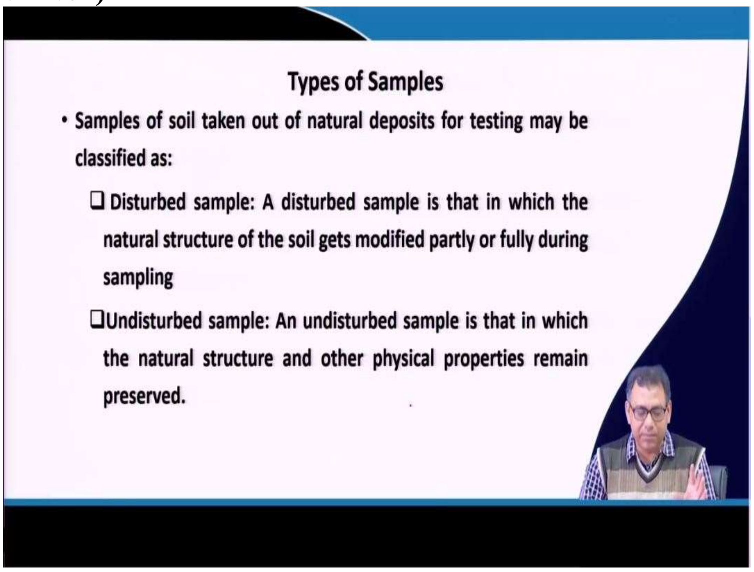


So, now I will go for the next test which is called the vane shear test. So, this vane shear test is suitable for very soft clay. So, these field vane shear where we basically apply a torque. So, we apply a torque and then we measure the torque required to quickly shear the vane pushed into the ground surface or into the soil. So, that means we measure that torque required to quickly shear the vane pushed into the soil that means the vane which is pushed into the soil we have to apply that torque and we measure the torque that required to quickly shear that soil.

So typical diameter of the vane is 100 millimeter and the height of the vane so this is the vane these vane heights are generally 2 times of diameter. Height of the vane is 2 times of diameter of the vane. So, once we apply this torque and then we measure this torque and if we know the diameter and height of the vane, then by using this correlation, we can determine the undrained cohesion of the soil and it is basically applicable for soft soil.

So, then cohesion of the soil, this is the torque applied height of the vane and diameter of the soil cylinder shear. So, diameter of the soil cylinder means basically diameter of this vane. So, this is the diameter means this total hole diameter so, that means, this is the one blade and this is another blade. So, these 2 blades that mean the total hole diameter is equal to d and that h is 2 times of that T. So, that is why it is written the diameter of the soil cylinder. So, this way we can determine the undrained cohesion of the clay.

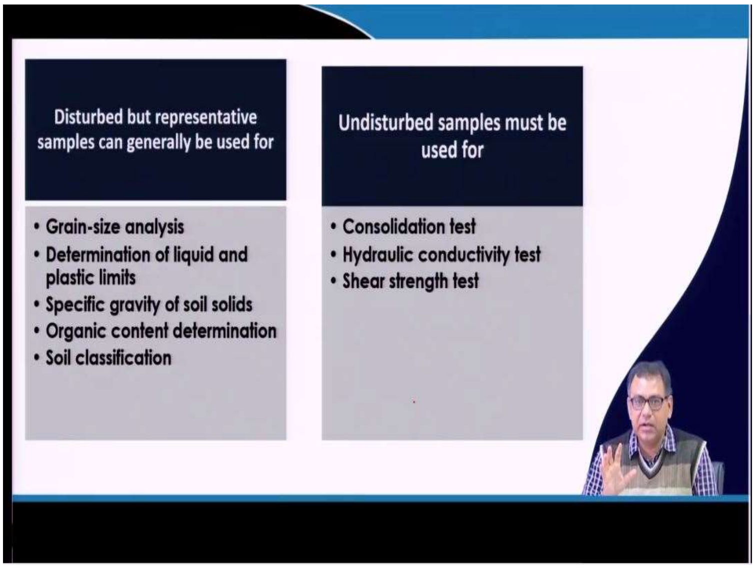
(Refer Slide Time: 11:02)



So, now, the next part so, these are the tests that I have discussed in-situ tests by which I can determine the soil sample few are directly and few are indirectly. Now, the next part and I have discussed that in several times that either we required to collect the soil sample then we have to use the sample at depth now, the question is how we have to collect the soil sample. Now, what are the different types of soil samples?

So, here the 2 types of soil samples are there one is disturbed and one is undisturbed. So, what is the definition of disturbed soil sample, the disturbed soil sample is that in which the natural structure of the soil gets modified either partly or fully during the sampling and the undisturbed is that, that means the natural structure of the soil will not be disturbed during the sampling. So, the undisturbed soil sample where the natural structure of the soil will not get disturbed and in the disturbed sample, the natural structure of the sample will be passed partly or fully disturbed during the sampling.

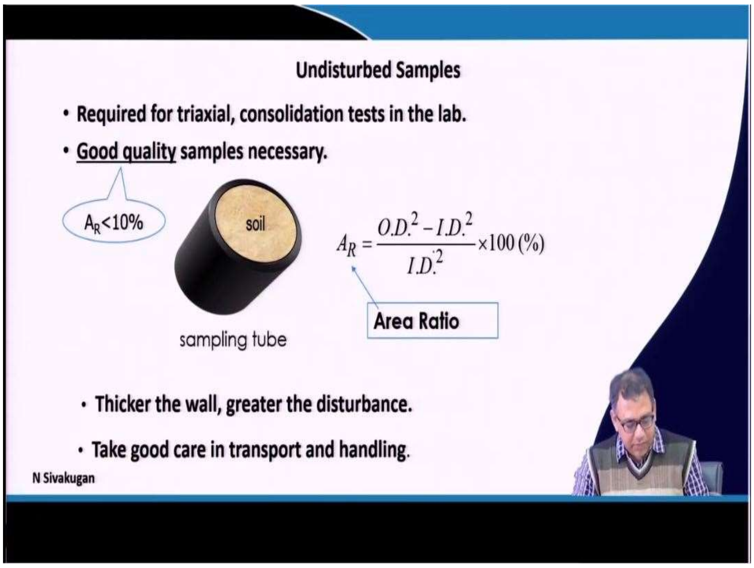
(Refer Slide Time: 12:19)



Now, again I have discussed that we have to use the disturbed soil samples also now, where we can use the disturbed soil sample the disturb, but the representative soil sample can be used for grain size analysis for determination of liquid and plastic limit, specific gravity of the soil, organic content determination and soil classification because in these cases where the soil is disturbed or undisturbed, it will not matter but the undisturbed soil sample must be used for the consolidation test, hydraulic conductivity test and shear strength test.

That means the triaxial or the direct shear or UCS. So, where we have to use the undisturbed soil sample because these results are required for design the foundation that means for bearing capacity calculation and settlement calculation and permeability, every hydraulic conductivity test or the permeability are also important parameters because the reconsolidation depends on the permeability of the soil that means the permeability, consolidation parameter and the strength parameters. So, these parameters you have to determine by using the undisturbed soil samples.

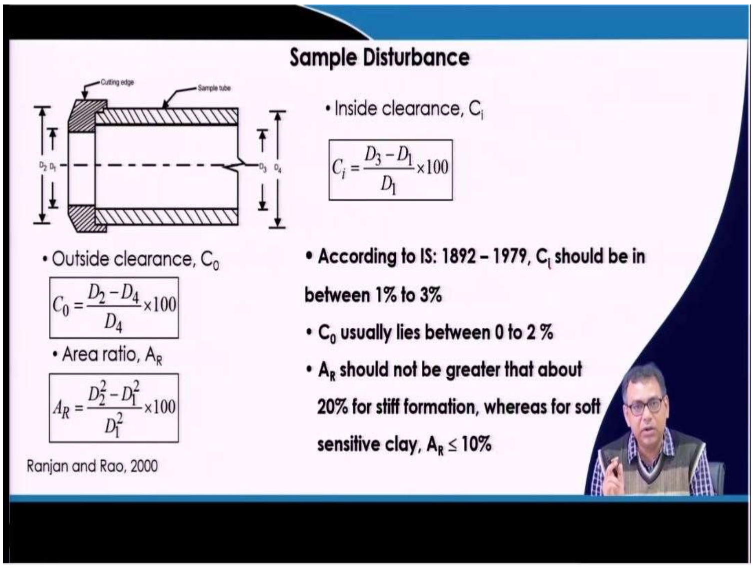
(Refer Slide Time: 13:46)



So, now the next one so, how we can collect the undisturbed soil sample what are the criteria. So, for the triaxial or consolidation test in the lab we have to collect the undisturbed samples. So, criteria that area ratio of the sample should be less than 10%. Now, what is area ratio, so, it is expected that if the thickness of the sampling tube is more than disturbed soil will also be more so, that in the sampling tube thickness will influence that disturbance.

So, that means we have to make the sampler tube thickness as small as possible to reduce the disturbance. So, now the sampler tube is the hollow tube. So, that sampler tube has the inside and outside diameter. So, the area ratio is outside diameter square minus inside diameter square divided by inside diameter square. It is expressed in percentage if it is less than 10% then the soil sample that will collect that will be disturbance free.

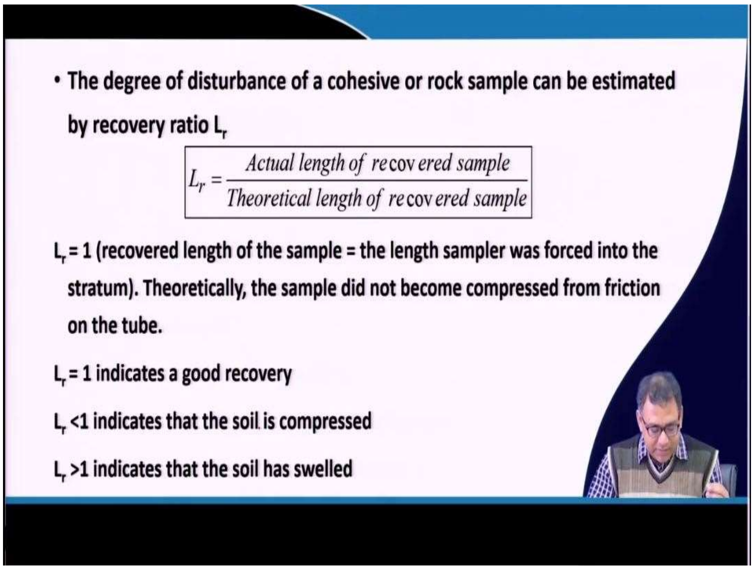
(Refer Slide Time: 15:04)



And we have to be very careful during the transportation of the sample also, only the collection is not sufficient we have to transport the soil sample from the site to the lab. So, that time also you have to be very careful, our outside also recommends few others criteria. So, this is our sampler tube and in the sampler tube there is a cutting edge attached at the front of the sampler tube. So, that means, if the sampler tube inside diameter is D_3 and tube outside diameter is D_4 and the cutting edge inside diameter is D_1 and outside diameter is D_2.

Then I can get these values also C_i is the inside clearance and these I can get by using these expressions C_i then I can get the C_0 and I can get the area ratio also. Now, according to IS code, for a good recovery the C_i should be in between 1% to 3% C_0 should be in between 0 to 2%, A_R area ratio should not be greater than 20% for stiff formation and for soft sensitive clay it should be less than equal to 10%.

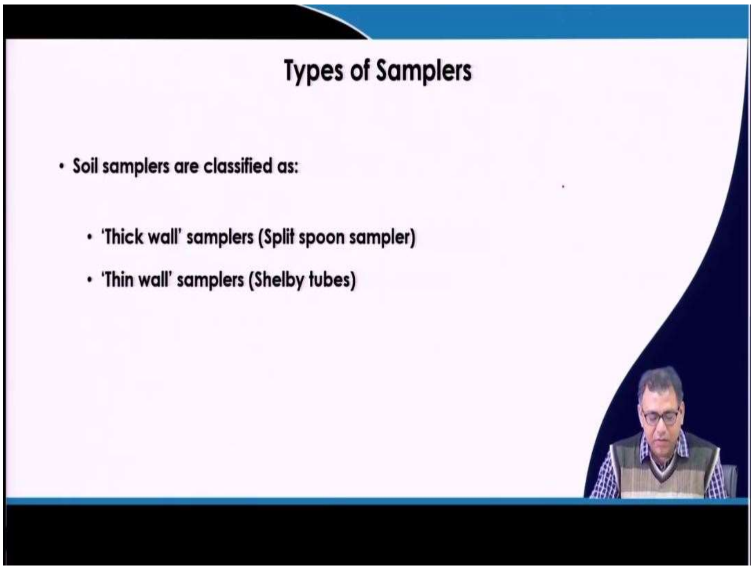
(Refer Slide Time: 16:33)



Then, by measuring the length of the soil sample also we can understand whether the sample is disturbed or undisturbed how we can identify that so, we can identify by a recovery ratio. So, this recovery ratio is equal to L_r, which is the actual length recovered sample and theoretical length recovered sample that means, if your actual length within a sampler tube is less than the length of the tube, then what will happen it indicates that the soil has been compressed.

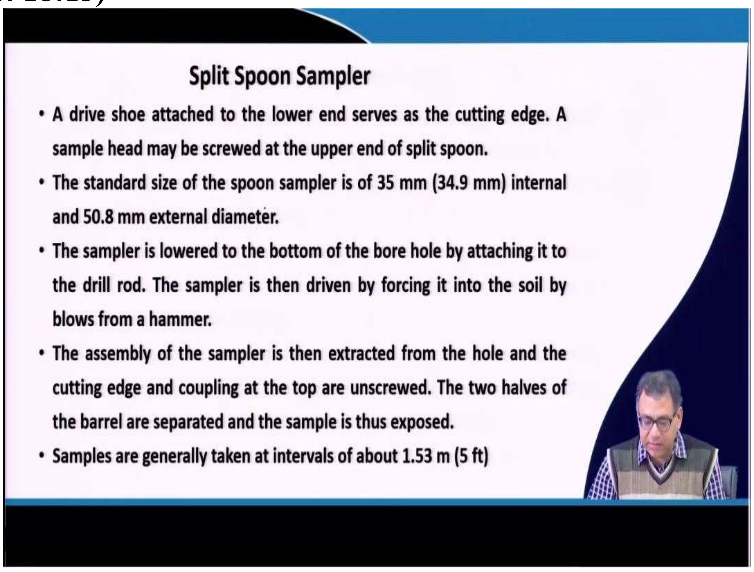
And if your actual length is equal to the theoretical length of the sample, then the soil is intact and if actual length is more then soil is been expanded. So, that means if L_r is 1 that indicates good recovery and less than 1 indicates that soil has been compressed that means your actual length is less than the theoretical recover length and if L_r greater than 1 it indicates the soil has been swelled. So, that means the actual recovered length is greater than theoretical recovered length.

(Refer Slide Time: 17:59)



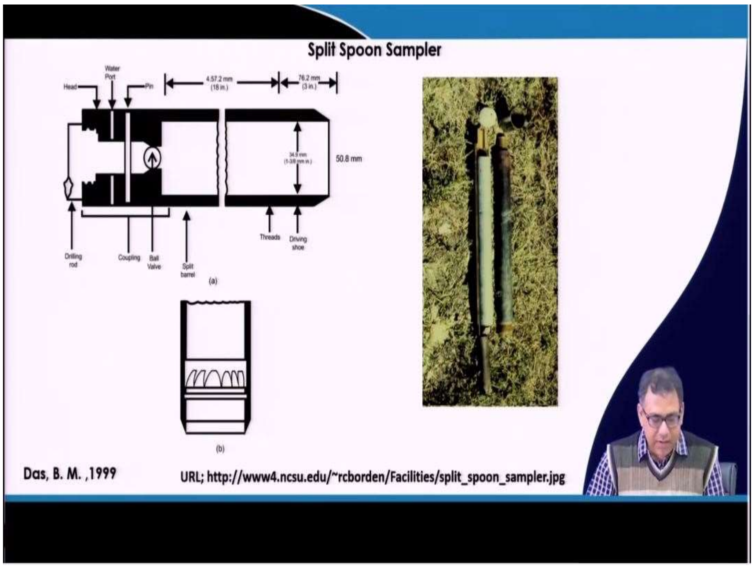
Then type of samplers so, that means, there are 2 types of sampler one is thick wall samplers, another is thin wall samplers, thick wall sampler is also known as split spoon samplers and thin wall sampler is also known as Shelby tubes.

(Refer Slide Time: 18:15)



And split spoon samplers. So, this is the description of the split spoon samplers. So, there is a cutting edge in front of the sampler tube and a split spoon sampler with inside diameter of 35 millimeter or 34.3 millimeter, an external diameter is 50.8 millimeter and then the sample is generally taken at an interval of 1.5 meter or 5 foot and these sampler tubes it has 2 halves.

(Refer Slide Time: 18:59)

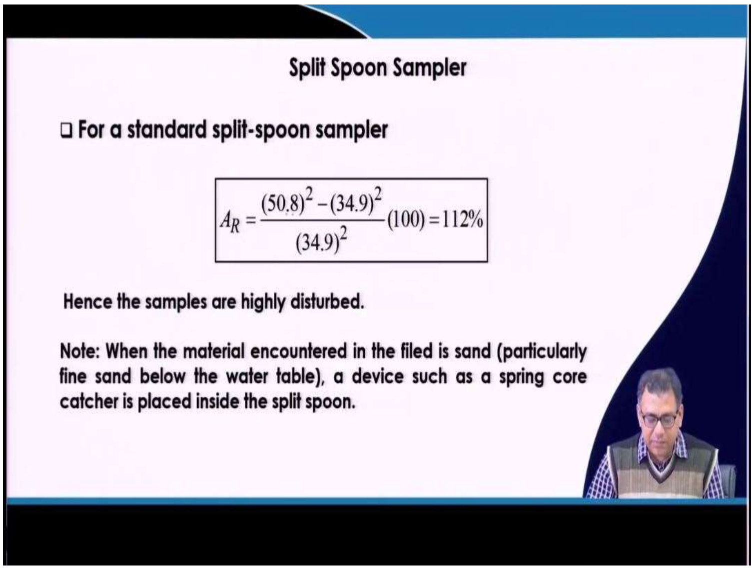


And this is the sampler tube which has 2 halves and this is the sample inside these 2 halves and these sampler tubes are pushed into the soil by hammer blow and the soil is collected from the site. So, these are the 2 couplings which are unscrewed during collection of the soil sample after taking form the site.

(Refer Slide Time: 19:36)

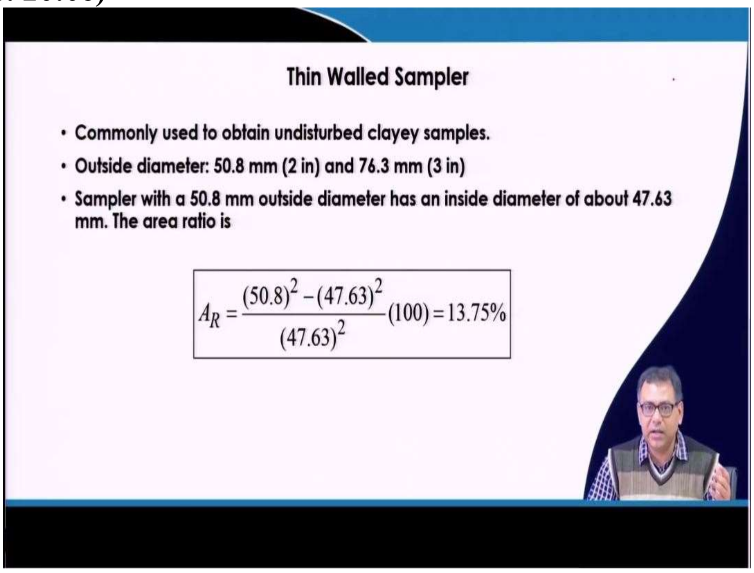
So, these are the samples and as I mentioned the inside diameter is 35 millimeter and outside is roughly 50 millimeter or 50.8 millimeter.

(Refer Slide Time: 19:44)



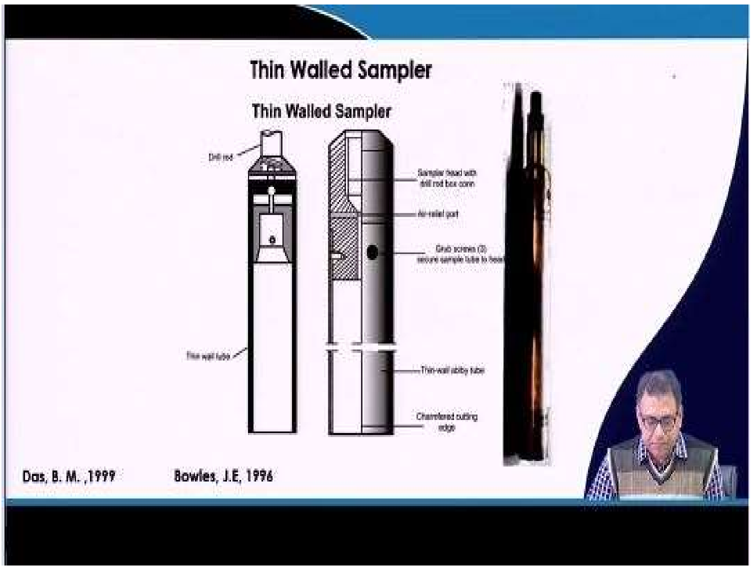
So, the area ratio will be $\frac{50.8^2 - 34.9^2}{34.9^2} \times 100 = 112\%$. So, that means the samples that we are collecting by using split spoon sampler are highly disturbed samples.

(Refer Slide Time: 20:06)



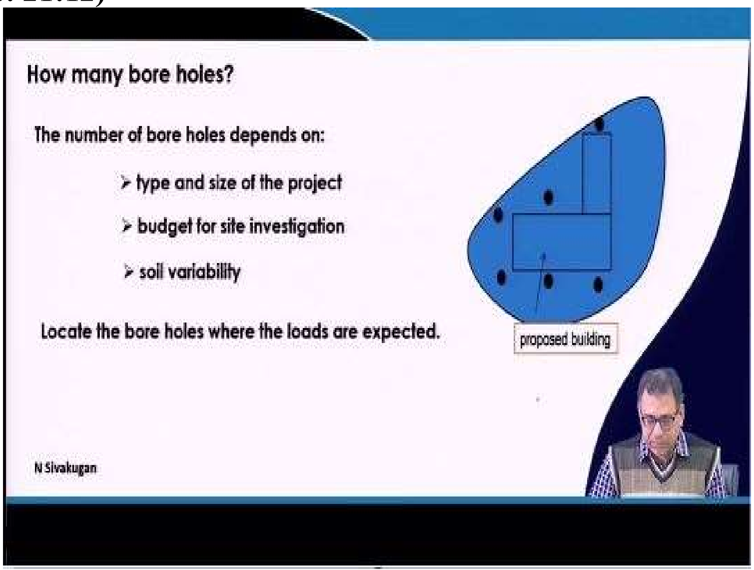
Now, for thin wall samples or the Shelby tubes, where the outside diameter is 50.8 mm and 76.2 mm. Sampler with 50.8 millimeter outside diameter and the inside diameter of the tube is 47.63 millimeter has an area ratio of 13.75%, which is close to the 10% which is the requirement. So, that means, if I use the thin wall sample or thin tube, the sample that I will get are disturbance free that means, it is a good sample or the undisturbed sample I can collect.

(Refer Slide Time: 20:56)



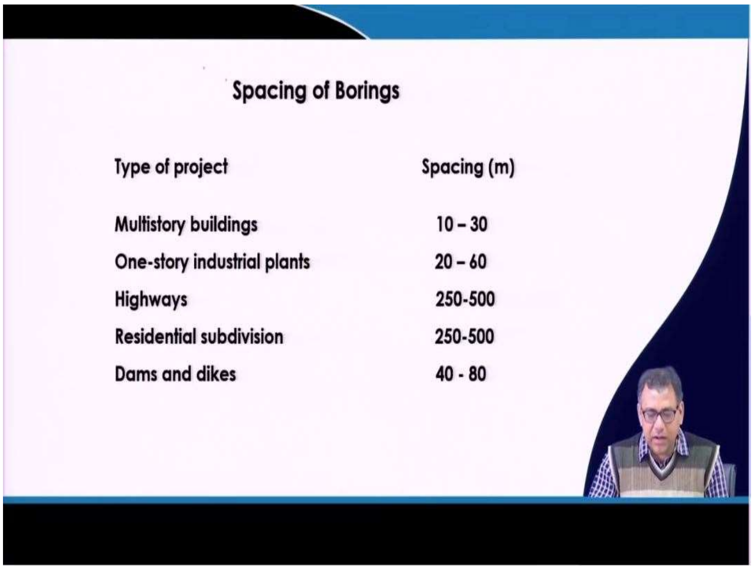
So, this is a particular sample a Shelby tube or the thin wall sample, this is the tube which is pushed into the soil to collect the soil sample.

(Refer Slide Time: 21:12)



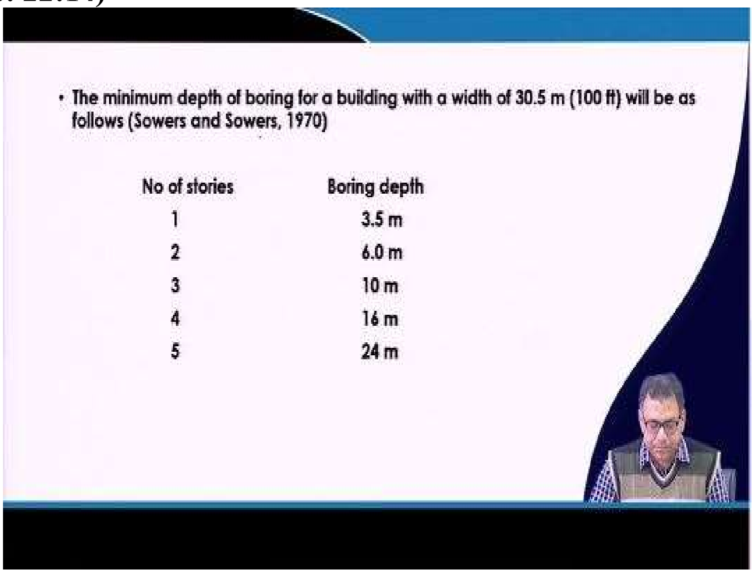
Now, how many boreholes we have to construct during the soil expedition. So, that depends on the type and the size of the project, the project of the site investigation and soil variability which is very important, if we have the large variation of the soils between 2 boreholes, then we have to definitely take more boreholes between these 2 boreholes. So, these are some guidelines.

(Refer Slide Time: 21:44)



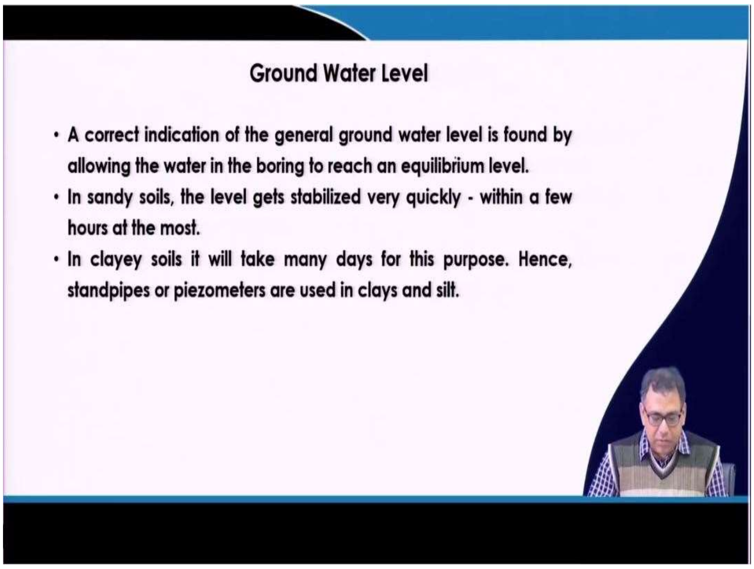
Then, the spacing of boreholes, that depends on the type of the projects also this have some guidelines are given. So, that means a multistory building 10 to 30 meter, one-story by industrial plants 20 to 60 meter, highways 250 to 500 meters, residential subdivision 250 to 500, dams and dikes 40 to 80 meter this is spacing between boreholes.

(Refer Slide Time: 22:14)



Then based on a number of stories also borehole depth can be determined for 1 story building 3.5 meter, for 2 stories 6 meters, similarly 5 stories 24 meters and so on with a width of 30.5 meters.

(Refer Slide Time: 22:32)



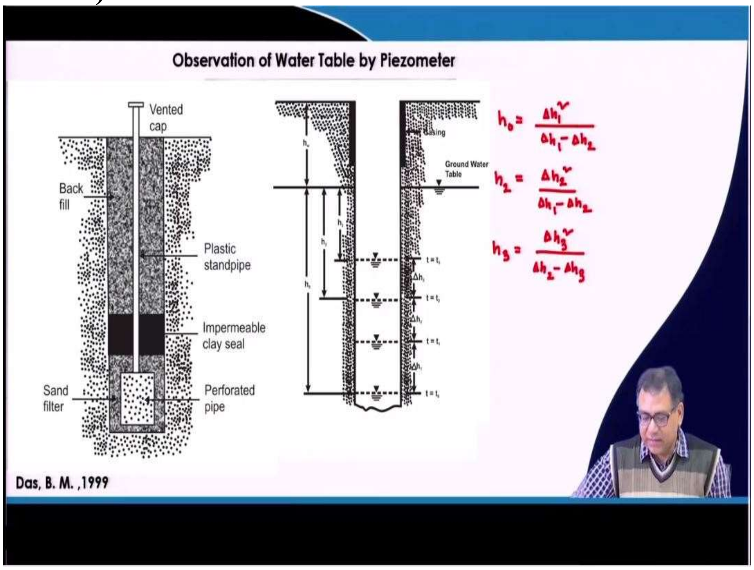
Now, in general case for determination of bearing capacity of shallow foundation, we go for up to width of the footing and for the settlement calculation purpose we can go up to 1.5 to 2 times the width of the footing. So, for shallow foundation we can go up to say 2 times from the base of the footing as my borehole depth, so, up to which we have to collect the soil sample.

So, next one is the groundwater table location. So, that the correct indication of the groundwater level is found by allowing the water in the boring to reach equilibrium level. So, that means we have to construct a borehole and then we see whether the water level is reaching equilibrium at what level. So, that means if the soil is sandy soil, then the water level will be quickly stabilized. So, you can within a few hours, we can identify the water levels.

I mean we construct a borehole put the water into the borehole and then that water will quickly reach or quickly stabilized and we reach the groundwater table level. So, for sandy soil, it will reach very quickly and within a few hours we can identify the location of the water table for sandy soil, but for the clayey soil, it will take several days to reach that equilibrium or the stabilization. So, for that purpose for clayey soil that we have to use the standpipes or the piezometers to identify the water table.

So, for the sandy soil by borehole we can identify the water table very quickly, for the clayey soil we have to use the piezometers. So, what is the methodology by which we can identify the water table for clayey soil?

(Refer Slide Time: 24:49)



So this is the observational water table by piezometer and this is for the clayey soil where the water table or if we put the water into the borehole it will not stabilize very quickly. Suppose, this is the standpipe or piezometer inserted into the borehole and then we measure the water level at different time intervals. So, this is your borehole and we put the piezometer or the standpipe into the soil and then we measure the position of the water of this borehole at certain time intervals.

First, we have to remove the water from this borehole when this water will come into the equilibrium condition. So, it will take time for water to come into the equilibrium condition. So, it will come at very slow intervals, I mean, it will take days and it will come at very slow rate, but that change in water level we can measure by piezometer. And then by using expressions, we can determine what would be the location of the groundwater table.

So, what is the location suppose, initially, I do not know what is the location of the groundwater table, but I know the position of the water level at $t = 0$ times so, that height that means the $h_0 + h_w$, h_w is the height of the water table from the ground, but initially, I do not know but I know $h_w + h_0$ initially because that is the water position at the borehole at $t = 0$ now at $t = t_1$ then the position will be at this level. So, I can measure what is the rise of the water table.

So, that will be Δh_1 at $t = t_2$ again further rise will be there that will be Δh_2 and $t = t_3$ then will be further rise of the water table that will be Δh_3. So, that Δh_1, Δh_2, Δh_3 I know I can measure. So, once I get these values, so, I will use these equations. So, from here I will calculate h_0 which is equal to $\frac{\Delta h_1^2}{\Delta h_1 - \Delta h_2}$ and I will get $h_2 = \frac{\Delta h_2^2}{\Delta h_1 - \Delta h_2}$ and $h_3 = \frac{\Delta h_3^2}{\Delta h_2 - \Delta h_3}$.

So, ideally all these values that means the h_0 h_2 h_3 that mean their endpoint will be on a particular line. understand what I am saying that means here if I know the h_0 as I mentioned that I can identify the this position of the water level at $t = 0$ from the ground that is possible now if I know the h_0 I can subtract this value from these total I can identify the groundwater table but these additional h_2 and h_3 will help me to get this data.

Because that will also confirm you that this is the position of the water table because that h_2 also from the water table h_3 also from the water table, so that these things I will discuss by example problems in the next class that how I can measure these data and then how I can use this data to identify water table. So, next class I will first solve one example problems on relative to observation of water table by piezometer for clay soil. Then I will go for the next type of soil exploration that is geophysical exploration. Thank you.