Foundation Design
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Lecture - 3B
Subsoil Investigation or Site Investigation
Part-6

So we have finished standard penetration test plate load test DCPT, now Cone Penetration Test.

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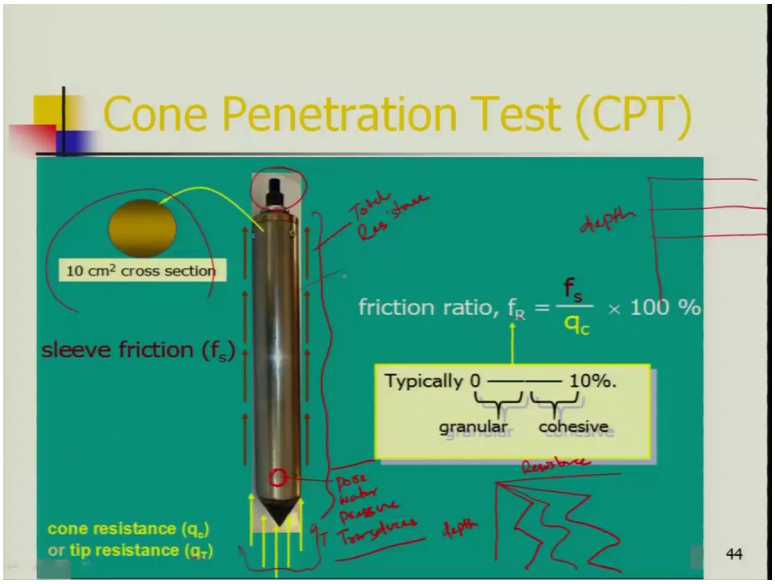

Cone penetration test to measure tip resistance as well as frictional resistance; generally, it has been used for design of your pile foundations. Now for cone penetration resistance test or cone penetration test CPT, it is called CPT. A cone having 20 centimeter square cross sections and this cross section is your 10 centimeter squares and there is a cone at the bottom. So, this has been arranging such a way that you can measure, if I go for a cone resistance measurement cone resistance versus your depth. If I say resistance versus your depth, I can get cone resistance I can get total resistance

So, total resistance minus cone resistance, I can get frictional resistance. What will happen once you insert it, there is a lock system here? If you lock it then what will happen this part will be locked, this part will be locked only, cone will be go inside. Once cone will be go inside at regular depth every 1.5 meter, 1 meter, 2 meter interval

depth wise depth wise you are going to measure tip resistance. Then what happen then you bring it back then you unlock then lock total yours entire cone pipe entire cone as well as sight pipe. So, it will move all together. Once it will move all together what your suppose to get, it you will get both cone resistance as well as side resistance; that means, it will give you total resistance if it moves all together it will give you total resistance total resistance.

So, depth wise you can measure cone resistance as well as total resistance once you get total resistance. So, from total resistance you deduct your cone resistance you will get side resistance; that means, sleeve friction or frictional resistance. That means, if it is a frictional pile design what is your frictional resistance particularly that site you can get it and here you can get it a n bearing resistance or it is a called tip resistance.

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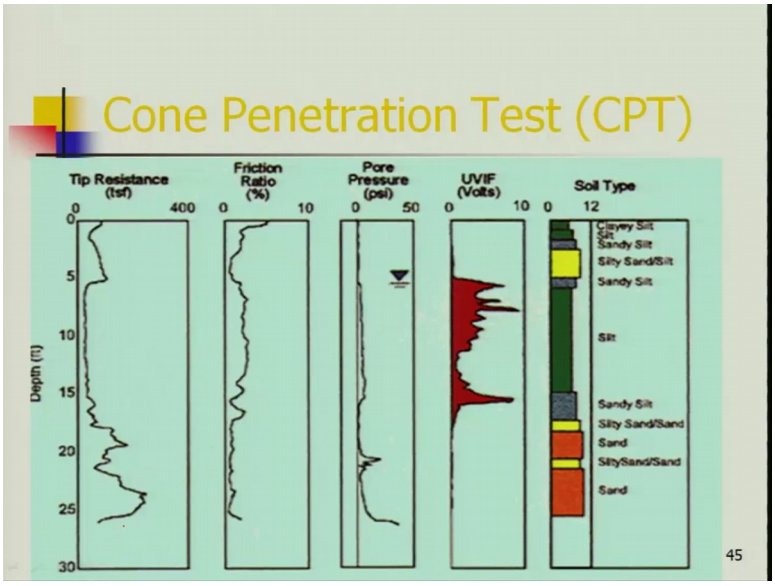

Now, you see another part I forget, friction ratio fr is equal to fs by q c. Fs by q c fs is your sleeve friction or frictional resistance, and q c is your cone resistance in to 100 percent. So, typically it is 0 for granular soil it barring from 0 to somewhere else here. And 10 percent is your cohesive soils. So, how you are going to get it? If you look at here I can get it tip resistance as well as frictional ratio or frictional resistance from cone penetration test. It is a continuous test sounding test will get various in after tip resistance as well as cone resistance over a depth, whatever the required depth you are going to find it out you will get it.

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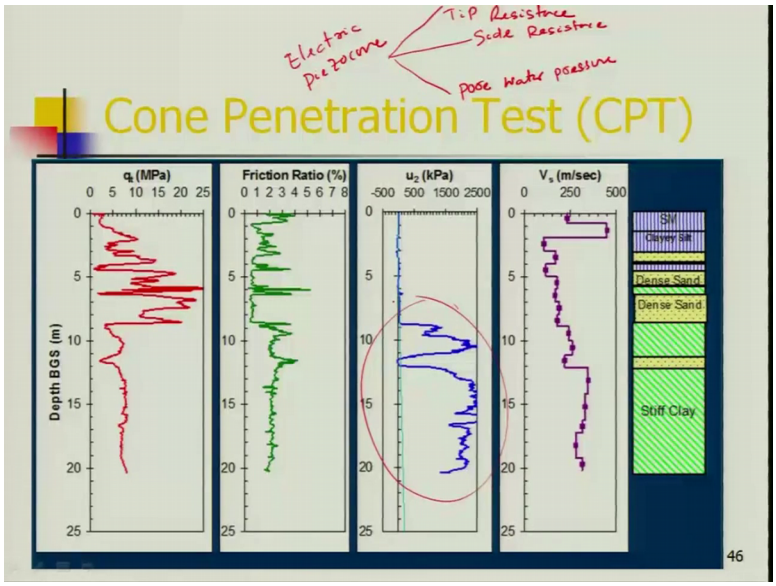

These are the different cases case store is different cases you see there are different types of soils sm clayey silt dense sand dense sand stiff clay; you can get it what is your tip resistance frictional resistance also. It has been modified cone resistance. Now you can get it cold water pressure also. You can get it cold water pressure this instrument has been modified.

So, that directly you can get liquefaction resistance or you can measure also cold water pressure. So, this case the cone penetration test has been changed. It has been now it has been said electric piezocone, electric piezocone, particularly in electric piezocone what you are suppose to get it. Earlier in cone resistance you are suppose to get tip resistance as well as side resistance. In electric piezocone what you are going to get it tip resistance side resistance, then your pore water pressure, or pore pressure. Once you are getting a pore water pressure, then once your excess pore water pressure is equal to your effective stress; that means, excess pore water pressure ratio at which is to 1; that means, and that state we say that soil may lose it is strength.

So, you can get it liquefaction potential liquefaction resistance of a soil. If you look at this is simple soil profile up to a depth of 25 meter of silt clay silt dense sand dense sand stiff clay. If you look at here pore water pressure here there is no change in pore water pressure all of certain between dense sand dense sand to up to stiff clay there is a change

in pore water pressure. So, that is a continuous process this is a continuous process you can get it.

Now, it has been change cone penetration test to electric piezocone. In electric piezocone and there is a there is pore water pressure transducer they put it here. So, that you can get it what is the change in pore water pressure in your soil, there is pore water pressure transducers. So, this is what you are supposed to get it.

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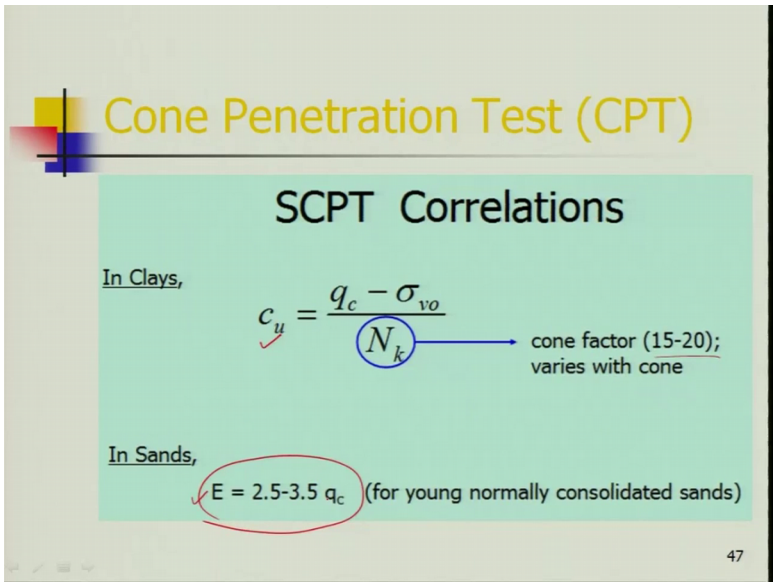

Then cone penetration test SCPT correlations, if you have a SCPT in clay how you are going to get, it in sand in clay what is the value of undrained shear strength you can get it directly from your cone penetration test and in sand you can get it E modulus of elasticity.

So, C u undrained shear strength is q c minus sigma v q c, cone resistance sigma v over burden pressure and nk your cone factor it varies is between 15 to 20. And from there directly you are getting strength and undrained coefficient value of in clay every layer wise you can get it. Similarly in sand you can also get E modulus of elasticity for normally consolidated sand it is barring between 2.5 to 3.5 q c, is your cone resistance q c is your cone resistance. If you look at here q c is your cone resistance; that means, this resistance this resistance is your cone resistance q c total q c cone resistance.

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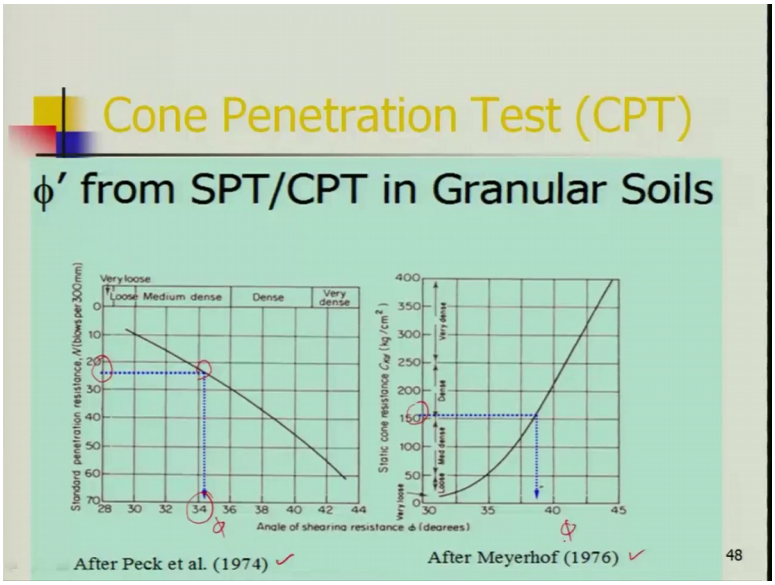

And tip resistance sorry I said wrong this is your tip resistance, this is your qt and q c is your cone resistance. From cone resistance from cone resistance you can get it C u as well as modulus of elasticity. Also from cone penetration test you can find it out 5, angle of friction or 5 prime. If you look at here I put it these are the 2 correlation has been given, one is your peck et al 1974 another one Meyerhof 1976. If you look at here past one is a standard penetration resistance, I have covered n blows per 30 centimeter or 300 mm and this is your angle of sharing resistance. This is a curve, there is a curve.

So, come here whatever in the field you are getting SPT value n, you take it and put it here, and varied cross you can get direct value of a phi angle of internal friction once you know the SPT n value. Similarly, static cone resistance if you know the cone resistance value here I put it very loose medium dense and very dense once you get your static cone resistance value you can extra pollute and you can get value of angle of internal friction phi; that means, I am getting many parameters from here from SPTN as well as cone resistance q u or q c I can get pi I can get E, I can also get C u value.

Then next takes is your dilatometer pressure meter test.

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So, I will have to go now in yours slightly first, where there are lots of course, content and syllabus main focus is your foundation design. So, these are all basic sight investigations.

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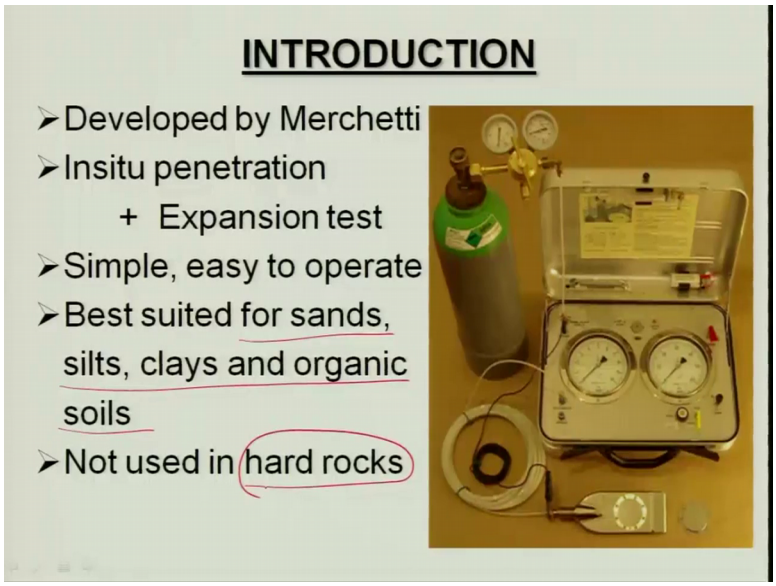

So, it has been developed by Merchetti, it is insitu penetration plus expansion test simple, easy to operate best suited for look at here best suited for sand silt clay and organic soils not used in hard rock.

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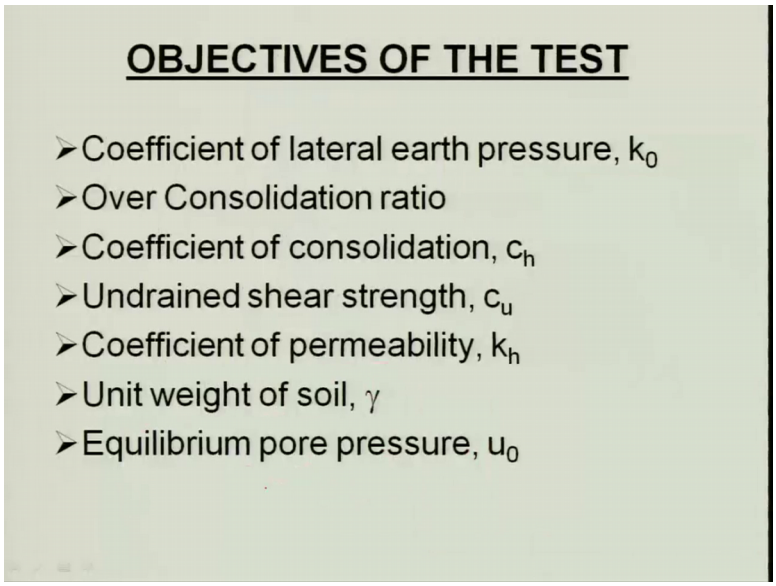

So, from these dilatometer, test what your suppose to get coefficient of lateral earth pressure K 0, this is particularly redaining walls structures or you have to find it out k, kp you need to have to have your K 0, over consolidation ratio coefficient of consolidation C h undrained shear strength C u coefficient of permeability K h unit weight of soil also you can get it equilibrium pore pressure are u 0 you can get it.

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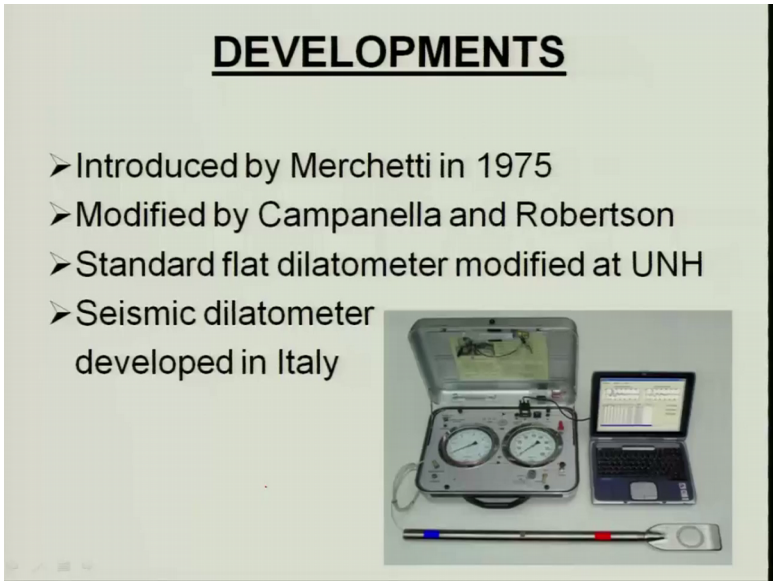

So, dilatometer right, now it has been modified to be seismic dilatometer or you can get it pore water pressure change in pore water pressure from there you can find it out also

from you can get also sharer of velocity also, you can measure also there are arrangements.

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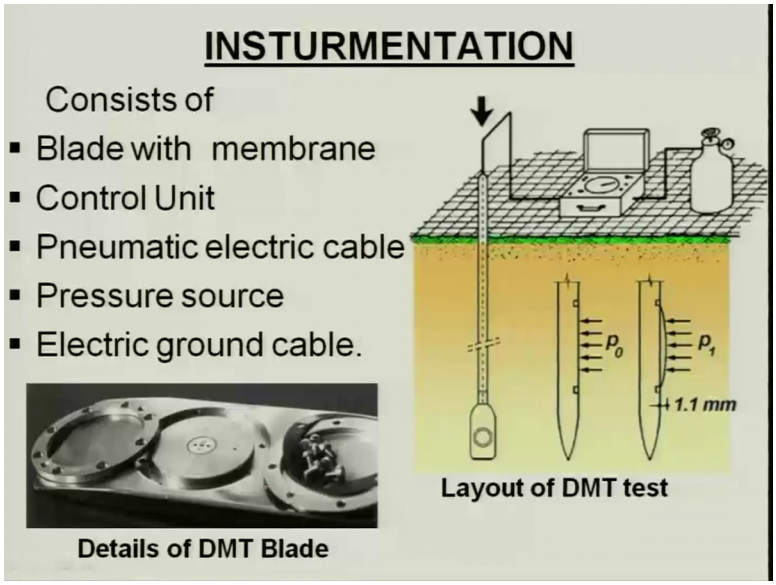

So, it consists of blade with membrane. So, control unit pneumatic electric cable pressure source electric ground cable, what are the working principles? It says stainless steel membrane.

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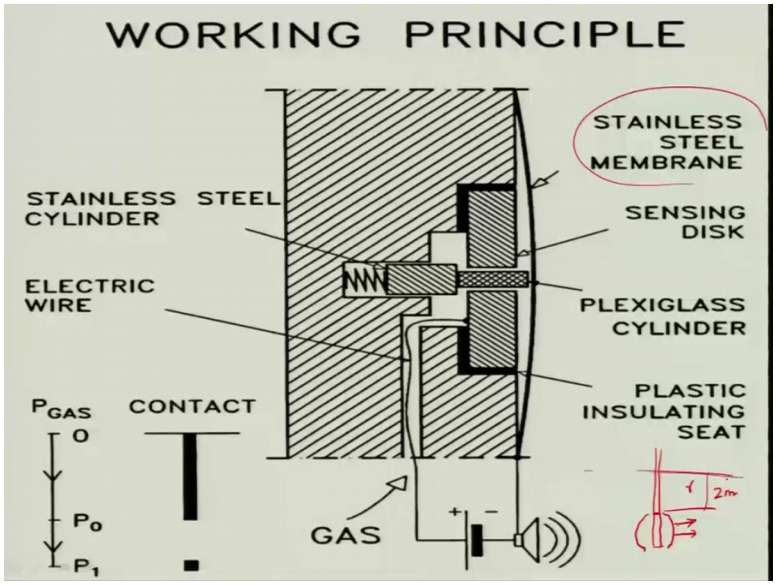

Look at here stainless steel membrane. And sensing disk it is sensor and there is Plexiglas cylinder. This is a Plexiglas cylinder plastic insulating seats and there is a

stainless steel cylinder electric wire. And it compacted here, basically what will happen? Once you push it inside, once you push it inside it will not expand vertically. Rather it will expand lateral. That means, if I want to get it earth pressure or stressed sigma 3 by sigma 1.

So, sigma b, sigma b is your over burden sigma 3 is your lateral. So, once it expands at the same time it tries to push these soils. So, laterally the soil fail or may be tends to fail will get sigma 3 value. And up to one depth this is a depth suppose a 2 meter. If will know the gamma in to edge you can find it out sigma b 0. So, sigma 3 by sigma b or sigma 1 you can get K 0 this is the basic principle.

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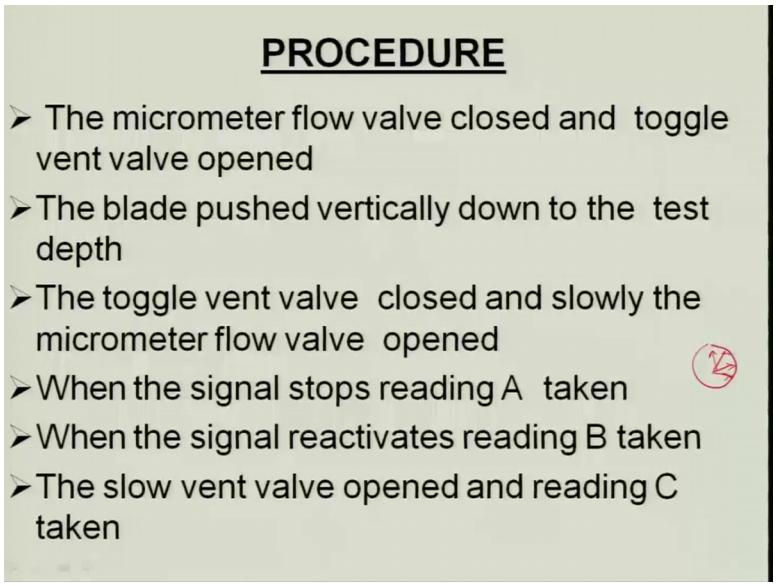

So, these are all procedures you pushed inside vertically down to the test depth, than the one vent value will be closed. Slowly lateral it will expand and it will give a signal. There are signals a outside you can very easily note it also there are outside also how much pressure it expand you can measure also outside.

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Symbol	Description	DMT Reduction Formulae	
P_0	Corrected First Reading	$P_0 = 1.05 (A - Z_M + \Delta A) - 0.05(B - Z_M - \Delta B)$	Z_M = Gauge reading when vented to atm.
P_1	Corrected Second Reading	$P_1 = B - Z_M - \Delta B$	
I_D	Material Index	$I_D = (p_1 - p_0) / (p_0 - u_0)$	u_0 = pre-insertion pore pressure
K_D	Horizontal stress index	$K_D = (p_0 - u_0) / \sigma'v_0$	$\sigma'v_0$ = pre-insertion overburden pressure
E_D	Dilatometer Modulus	$E_D = 34.7 (p_1 - p_0)$	
K_0	Coeff. Earth pressure insitu	$K_{0,DMT} = (K_D / 1.5)^{0.47} - 0.6$	for $I_D < 1.2$
OCR	Over-consolidation Ratio	$OCR_{DMT} = (0.5 K_D)^{1.56}$	for $I_D < 1.2$

So, there are different DMT reduction formulas corrected first reading P 0 corrected second reading material index horizontal stress index dilatometer modulus ed from P 1 and P 0, K 0 coefficient of earth pressure you can find it out over consolidated ratio.

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Symbol	Description	DMT Reduction Formulae	
C_u	Undrained Shear Strength	$C_{u,DMT} = 0.22\sigma'v_0(0.5K_D)^{1.25}$	for $I_D < 1.2$
Φ	Friction Angle	$\Phi_{safe,DMT} = 28° + 14.6° \log K_D - 2.1° \log^2 K_D$	for $I_D > 1.8$
C_h	Coefficient of consolidation	$C_{h,DMTA} = 7\ cm^2 / t_{flex}$	t_{flex} from A-log t DMT-A decay curve
K_h	Coefficient of Permeability	$K_h = C_h \gamma_w / M_h$ ($M_h = K_0 M_{DMT}$)	
γ	Unit Weight and Description	From chart	
u_0	Equilibrium Pore Pressure	$u_0 = p_2 = C - Z_M + \Delta A$	In free-draining soils

And C u you see; what are the parameters you are suppose to get it. K 0 over consolidated ratio C u undrained coefficient phi friction angle C h coefficient of consolidation K h coefficient of permeability gamma is equal to unit weight u 0, pore water pressure all parameters your suppose to get it.

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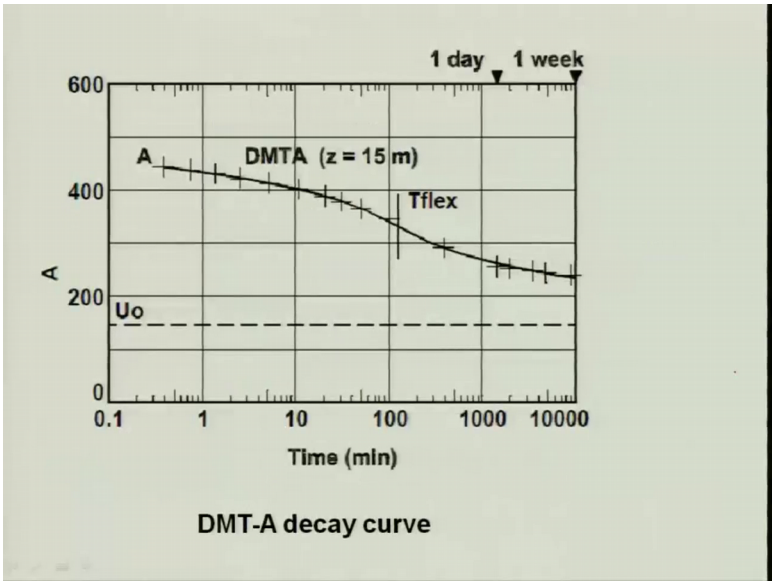

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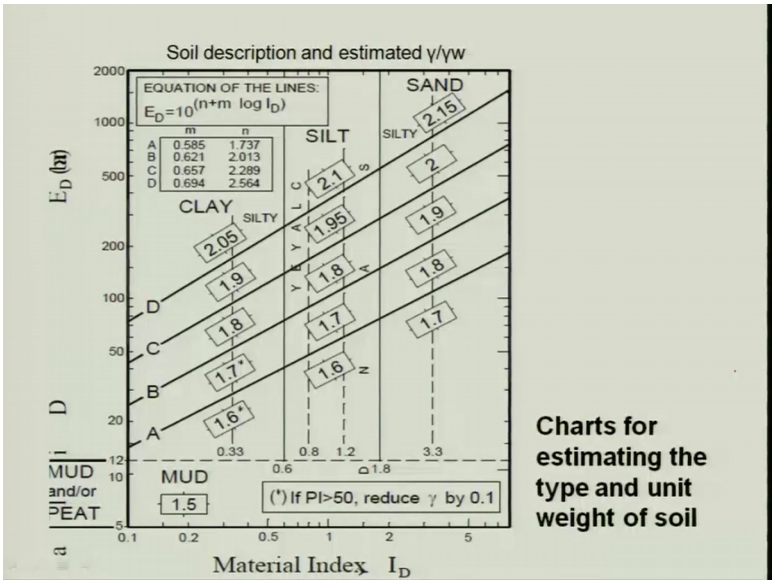

So, there are different charts available slightly it will be higher side.

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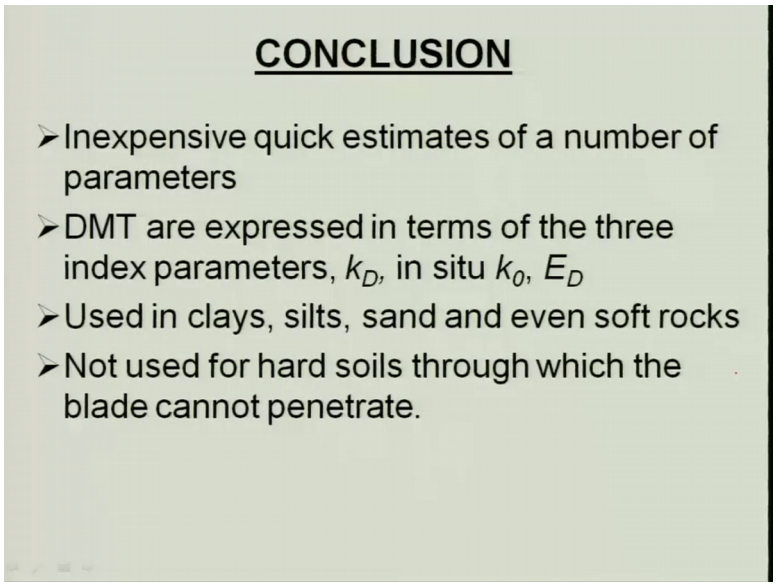

So, this is all about your flat dilatometer. It is inexpensive no need to go for bore hole quick estimate of a number of parameters you can very quickly you can get number of parameter. K 0 C u pi and your consolidation parameter permeability parameter DMT are expressed in terms of 3 index parameter Kd in situ K 0 and ed as I said earlier used in clays silt sand even soft rocks, not used for hard soil through which the blade cannot penetrate.

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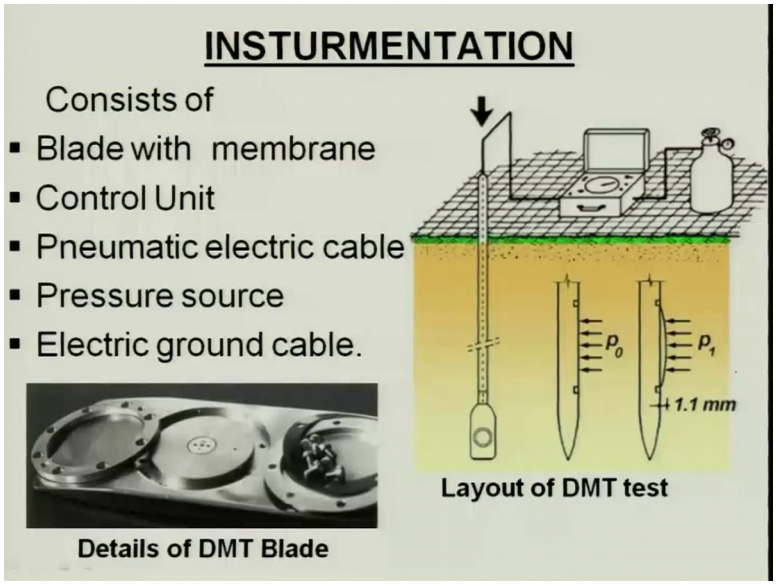

If you look at here, look this figure. There is a blade this is called flat dilatometer because it is in a flat set. This blade has to penetrate push to inside. So, there is a hard rock. It will be difficult to push very easily once you push it outside, you can very easily recorded all the parameters, you can very easily find it out c phi coefficient of permeability K 0, E all the parameter you can very easily got it. Pressure meter test also there pressure meter test all slightly discuss later part.

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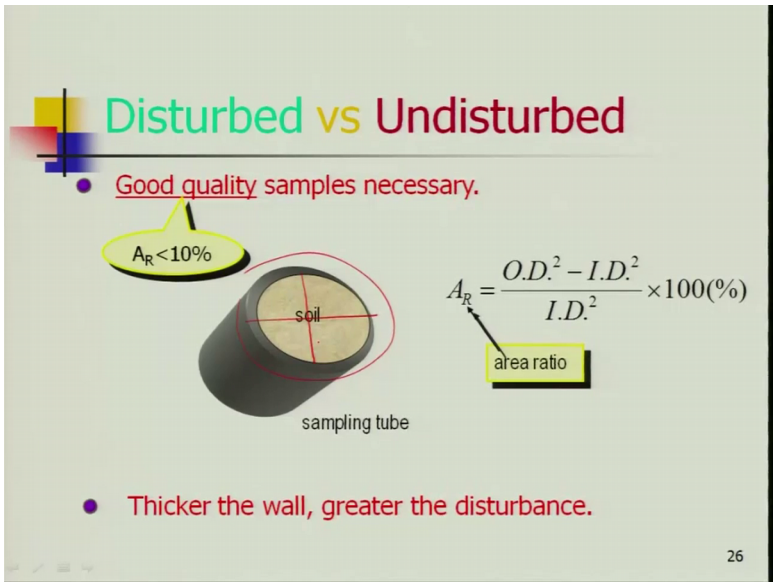

Now, come to go to the second half the part, I have let previously disturbed verses undisturbed. How to know that good quality sample necessary? If your area ratio is less than 10 percent; that means, if you this is your sampling tube, outside diameter this is our outside diameter, whole square outside diameter, then minus inside diameter whole square divided by inside diameter whole square into 100 percent. Whatever the sampling tube in your using you should be able to know whether you are getting a good quality of undisturbed soil sample. No soil sample is undisturbed once your collecting this soil sample below the ground surface it is partially disturbed.

So, in engineering particularly in civil engineering in geo technical engineering, if you say area ratio is less than 10 percent, then we can say that good quality of sample collected; that means, your undisturbed sample has been collected. Thicker the wall greater the disturbance, more thick walls your sample will be getting disturbed. If you

remember well I say earlier, for SPT test we push split spoon sampler split spoon sampler means I can split it longitudinally equal parts.

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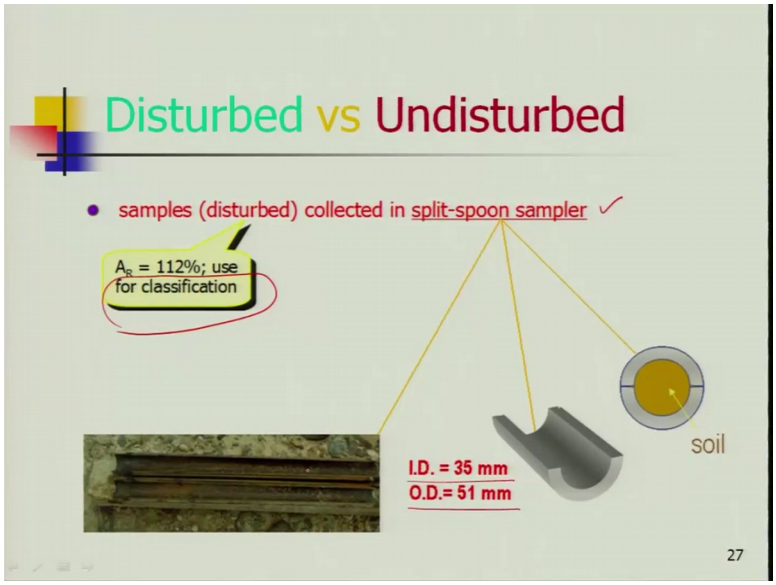

So, whatever samples you are getting from the SPT test, if you look at the area ratio outside diameter is 51 mm inside diameter is 35 mm. So, area ratio is 112 percent; that means, you are not getting undisturbed samples. Once you are not getting undisturbed sample; that means, it is disturbed you cannot use this sample for measurement of your engineering property particular phi and c in your laboratory like try it say I will consolidation no it will be done only for classifications.

Look at here, soil samples collected in split spoon sampler this is your split spoon samplers, it has been obtained you can connect it the area ratio is 112 percent and soil samples collected. So, it has been used for your classifications not for engineering properties.

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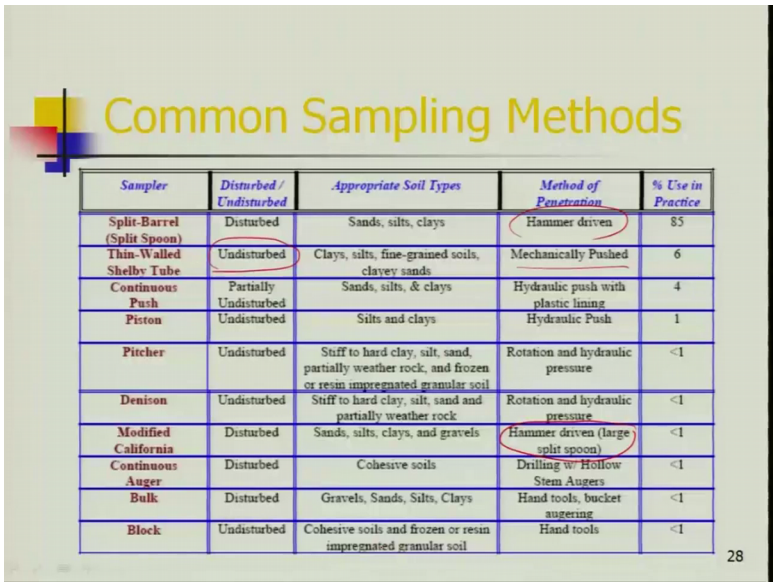

Sampler	Disturbed / Undisturbed	Appropriate Soil Types	Method of Penetration	% Use in Practice
Split-Barrel (Split Spoon)	Disturbed	Sands, silts, clays	Hammer driven	85
Thin-Walled Shelby Tube	Undisturbed	Clays, silts, fine-grained soils, clayey sands	Mechanically Pushed	6
Continuous Push	Partially Undisturbed	Sands, silts, & clays	Hydraulic push with plastic lining	4
Piston	Undisturbed	Silts and clays	Hydraulic Push	1
Pitcher	Undisturbed	Stiff to hard clay, silt, sand, partially weather rock, and frozen or resin impregnated granular soil	Rotation and hydraulic pressure	<1
Denison	Undisturbed	Stiff to hard clay, silt, sand and partially weather rock	Rotation and hydraulic pressure	<1
Modified California	Disturbed	Sands, silts, clays, and gravels	Hammer driven (large split spoon)	<1
Continuous Auger	Disturbed	Cohesive soils	Drilling w/ Hollow Stem Augers	<1
Bulk	Disturbed	Gravels, Sands, Silts, Clays	Hand tools, bucket augering	<1
Block	Undisturbed	Cohesive soils and frozen or resin impregnated granular soil	Hand tools	<1

Common sampling methods, we have details common sampling methods, split barrel split spoon, what your suppose to get it disturbed. Thin walled Shelby tube, generally in India everywhere else your using thin walled Shelby tube undisturbed samples. Appropriate soil types clays silt fine grained soils clayey sand. It has been mechanically pushed and split is spoon if you remember, hammer.

Once you hammer your suppose get disturbed sample your not suppose get undisturbed sample. Continuous push partially undisturbed sand silt and clay hydraulic push with plastic lining piston samplers undisturbed your suppose to get it, piston samplers used for silts and clays, and it has been pushed by means of hydraulically or hydraulic pushed pitcher undisturbed stiff to hard clay why I am saying it these are different sampler tubes and it has been particularly classified quick sampler tube you are going to use for what kind of soil. If it is a stiff to hard clay you cannot use your thin walled Shelby tube.

So, in that case pitcher undisturbed, it has been collected by means of rotation, means by means of rotating you push it inside. Denison undisturbed sample your suppose to get it stiff to hard clay silt sand and partially weather rock and also how you penetrate it rotation and hydraulic pressure. Modified California modified California sampler tubes it has been used in United States. So, this is a disturbed you are suppose get disturbed samples sands silt clays and gravels.

Look at here method of penetration your hammering it hammer it driven, hamma and drive it, continuous auger continuous auger disturbed particularly cohesive soils, and drilling by means of hollow stem augers bulk disturbed gravels sand silt and clay hand tools bucket augering, block, undisturbed, cohesive soils frozen or resin impregnated granular soils. This table is for a kind of comparative study. Once you go after graduating once you go in any of your construction company or design where these are all your set of sample sampler tubes. You will recommend as geo technical engineer.

If you are going to collect a undisturbed sample go this, go this this is your soil type.

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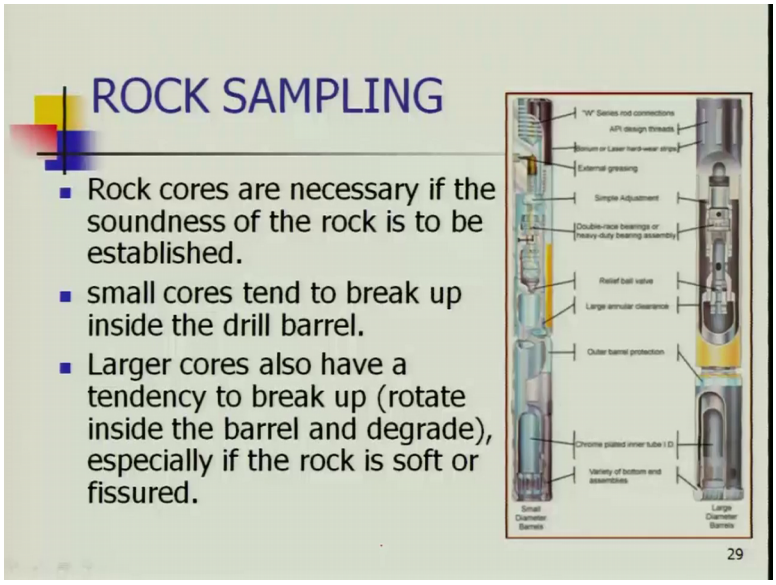

And this type of sampling tube you have to use to collect your undisturbed soil samples. Rock sampling in brief I do not want to go in rock because it is beyond our scope. I have covered this pit sampling trial pit just I am showing the figure trial pit or pit sampling is possibly only in case of place you can open a pit.

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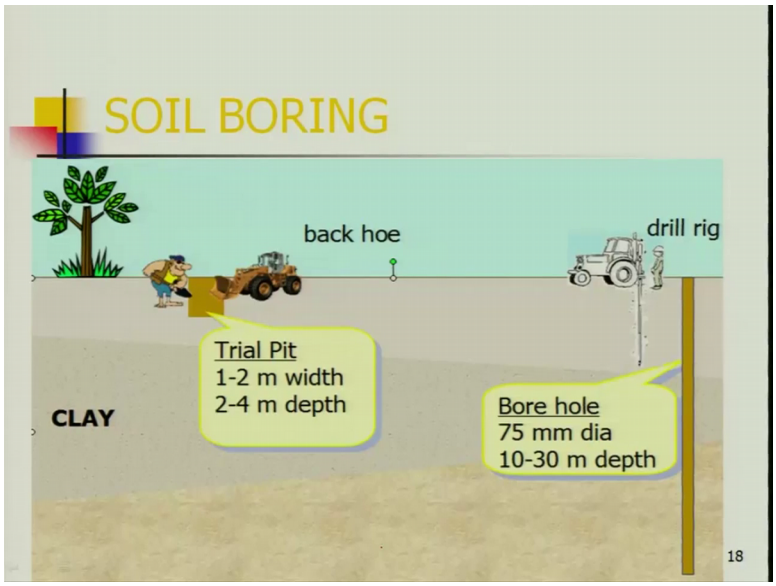

And very easily you can push these sampling tubes. Bore holes 75 mm dia and 10 to 30 meter you can push it by means of drilling rig, boring tools as I said auger boring power drill.

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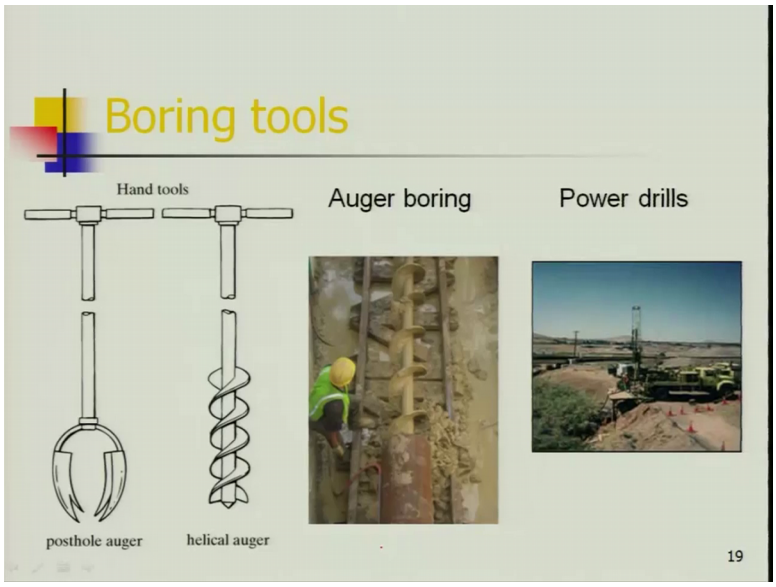

Look at here I have earlier draw need, but I am showing it manually helical auger post hole auger. What happen these are for boring to make manually boring, or power drills by using power drills also you can bore it. These are manually you can use it also wash boring I have discussed your wash boring.

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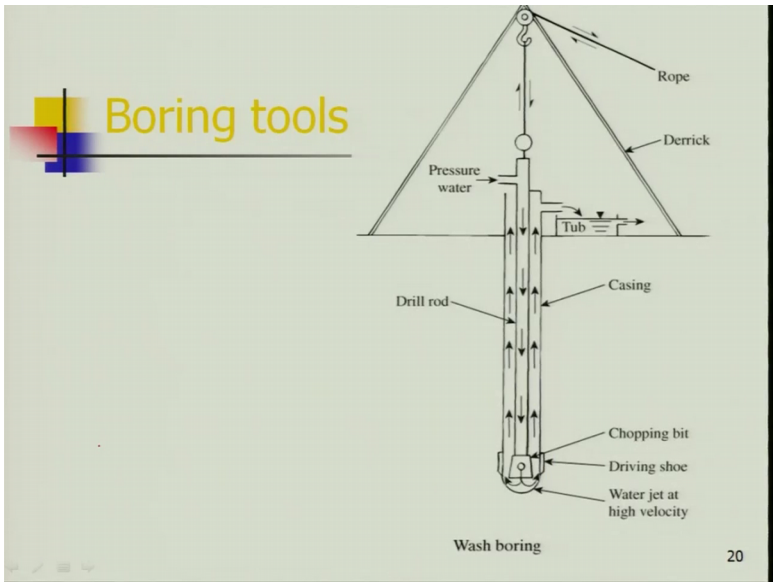

Now, will boring tool if you look at here, this is your scraper bucket by means of rotation your, it has to be pushed drill rod this is scraper bucket.

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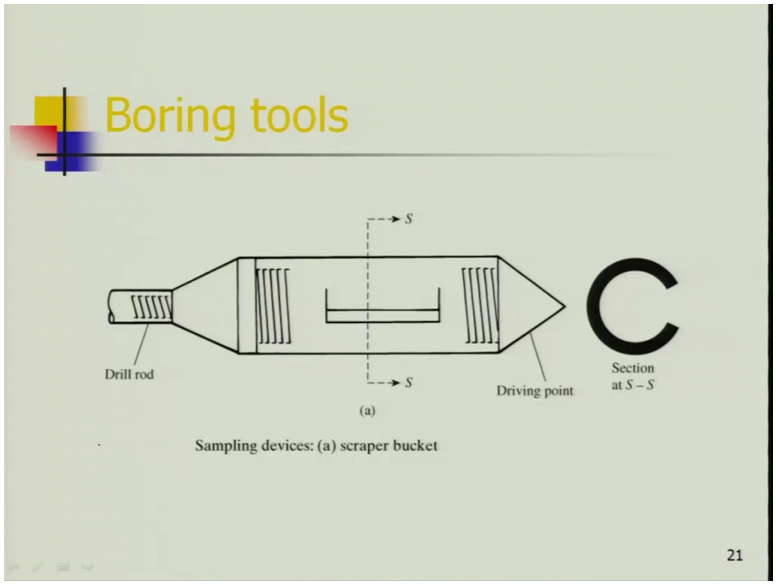

Now look at here Shelby tube thin walled Shelby tube. Once bore hole has been made in the drill rod this thin walled tube has been connected.

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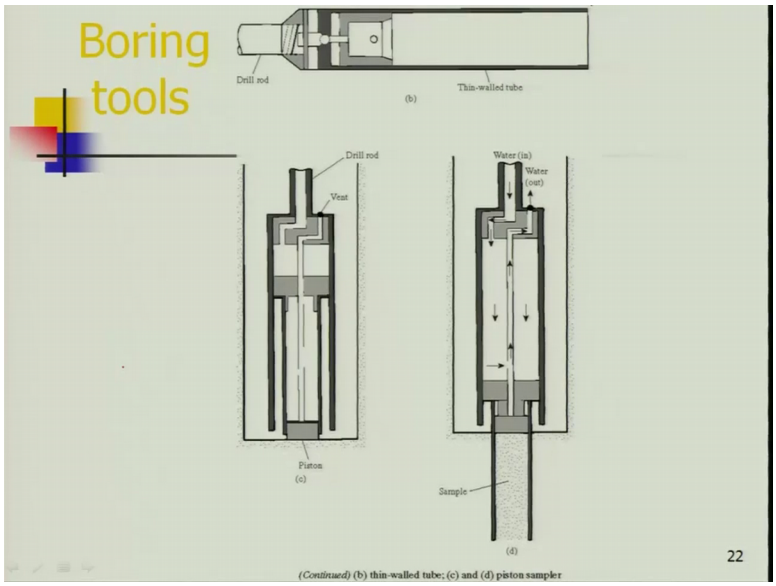

And it has been look at here in the drill rod it has been connected, either you can use manually or you can use piston also. Piston sampler here, it can be use manually you can push it inside. So, soil sample will be collected undisturbed soil sample or there is a double or single piston by means of piston action you can push it inside you can collect undisturbed soil sample. This is what the boring tools and I will take one more class after wards how to prepare your bore log data bore log charts, what information you want to give.

This is all about a brief description not in details about your subsoil investigations once you get your subsoil investigation, you prepare a report. That report has to go for a design sections. Based on that report they will take a call what kind of foundation there going to construct.

Thank you.