Geotechnical Measurements & Explorations

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Lecture No. # 25

Last class I have shown you this seismic piezocone test.

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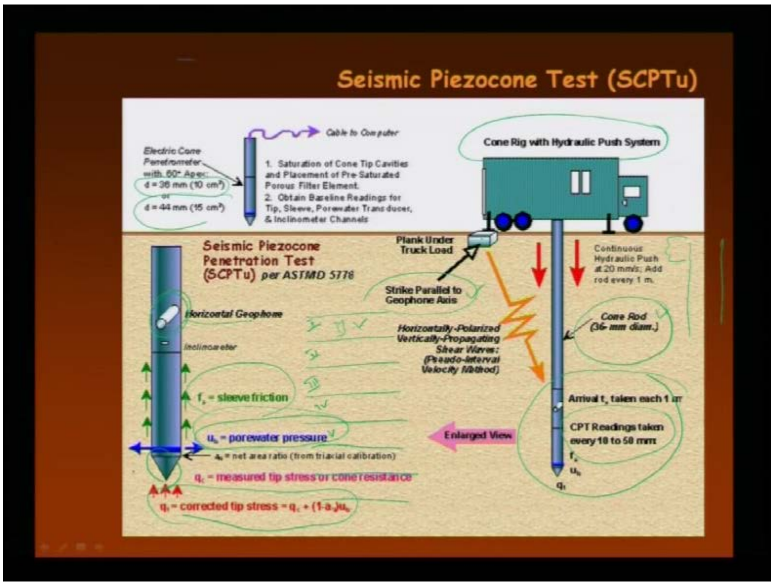

The detail procedure how it has been started by means of this reed just to repeat it once again. For layer of this all same slide layer 1, layer 2, layer 3, layer 4, layer 5. This method is a continues method and this has been this you look at here. If I take it with this enlarge view, this cone has a base cone and there is a measurement pore water pressure measurement above the base cone, then geophones are there to receive your 0 velocity. So, initially what happen this cone reed with hydraulic system, it puts this cone inside the ground then at each layer you can you just hammer it, this source from there this shear wave will be generated; it will be received by this geophones at each layer you can get it tip resistance, pore water pressure and sleeve friction, and also 0 velocity up to these we have gone.

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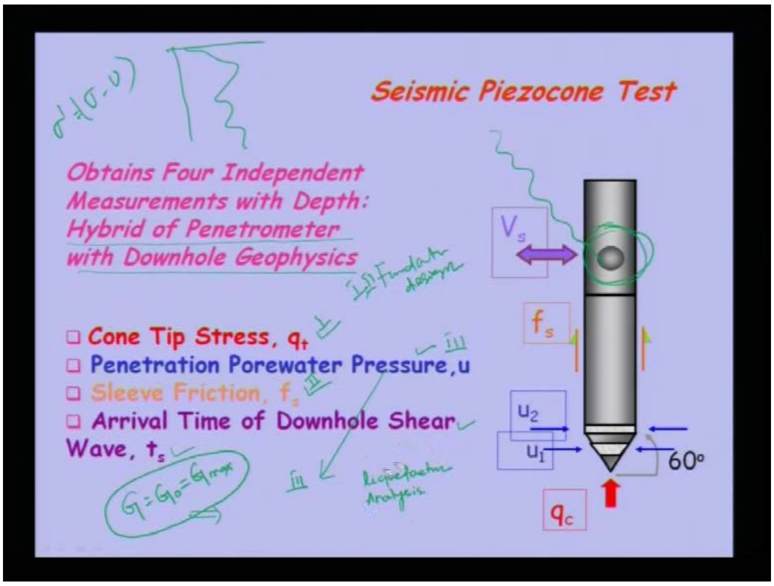

Now, there are four in one that means four independent measurements with depth; I can get it by seismic piezocone test. That is why this seismic piezocone is more versatile, four independent measurements you get means hybrid of penetrometer with downhole geophysics, hybrid of penetrometer it is a combination this has been developed means late eighties, this has been developed with this cone penetration test has been modified. This is a mixture or hybrid of penetrometer this is earlier it was a cone penetrometer with downhole technique arrangement has been made with this geophone has been then provided in this cone. So, if you look at here four independent measurement once again, first one is your cone tip resistance you can measure. Where this cone tip resistance is required? It is required particularly it is required if there is a pile foundation or pile has to be constructed. You should know what is the tip resistance of this pile for this purpose cone tip is required, cone or tip resistance is required. Now, second part is your frictional resistance, you see sleeve friction f s where again it is required suppose for a multi-storey building it has been decided you go for pile foundation.

Now, theoretically based on the soil classification you can calculate what is the side resistance or frictional resistance of pile. However, from here by means of seismic piezocone you can directly find it out, you can directly find it out what is that sleeve resistance so, that these resistance can be used for design of the foundations. Now, these two applications cone tip resistance as well as sleeve friction this is for foundation analysis and design of deep foundations. Then look at here penetration pore water pressure the moment you insert this piezocone inside the ground surface, suppose this is the ground surface, this is the ground surface at this ground surface then this is the soil layer. So, may be water table is lying at some distance say h, suppose may be water table is lying above the layer 3.

If I classify into layer 1, layer 2, layer 1, layer 2, layer 3, layer 4; water table is lying above layer 3 at an height h below the ground surface. Suppose this seismic piezocone has been inserted. Now, because of this water table how much the pore water pressure it is inside this soil in the layer 3 that from where you can get it? That you can get it from laboratory testing cyclic triaxial or static triaxial, but the advantage of this here is in initiative conditions particularly in initiative test it can give directly how much is your penetration pore water pressure generation. What is the pore water pressure at depth h? So, it has been in that cone if this is my total cone in this cone there are two pore water pressure transducers are there u 1 and u 2, from there you can find it out penetration pore water pressure u.

So, this is third one. Look at this is the where your geophones already there, this is where geophones has been there. So, from this from this geophone already it is there, with this geophone you can measure this shear wave velocity. Now, as I said four independent measurements, two measurements say one and two, cone tip resistance sleeve frictional resistance are f s, this is required for foundation design. Now, look at this pore water pressure. Pore water pressure measurement if I know the variation of pore water pressure are different depth I can easily find it out, what is that effective stress? Effective stress sigma prime is nothing, but total stress minus pore water pressure generate. Based on this effective stress calculation we can find it out what is that is there any liquefaction will occur or not. With this thought pore water pressure I can find it out this liquefaction analysis can be done or drained or undrained static condition can be done.

Then last is your arrival time of down hole shear wave t s. With this you can find it out how much time it requires to reach here arrival time once you get it by knowing the distance you can easily find it out 0 velocity. Once you get this 0 velocity I can get G or G 0 or G maximum at every depth below the ground surface I can find it out G 0, G maximum at G, this is required for seismic analysis. Instead of we taking this the advantage of this seismic piezocone instead of measuring by means of say let me erase this. What will happen this seismic down hole or seismic cross holes are there to measure only shear wave velocity.

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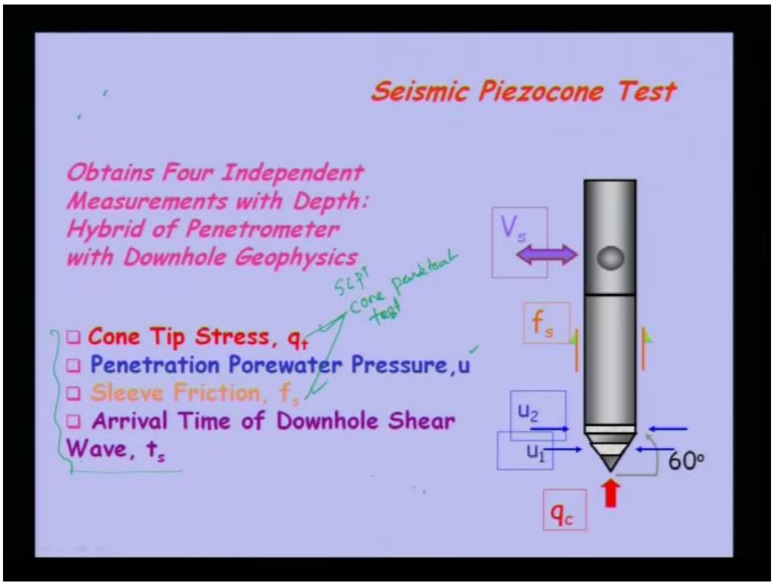

There are also arrangement only you can measure cone tip or frictional tip by means of cone penetration test. What I mean to get these four independent parameters, earlier you are suppose to do four different test or three different test like cone tip stress and sleeve friction. This you can get it from earlier cone penetration test or static cone penetration test or SCPT static cone penetration test. From there as I said earlier for measuring pore water pressure you can do another test in the laboratory. Each part of the soil you can take it how much pore water pressure built up you can get it, for measuring seismic down hole 0 velocity t s. Either you go by means of cross hole technique or down hole technique, that means for four different independent parameters earlier four different tests was conducted, to overcome this If you have this equipment at a time you can measure cone tip resistance, pore water pressure, sleeve resistance and shear wave velocity. It has a great advantage, it will allow you to save your time, save your money.

And at the same time you can getting parameters required for static as well as dynamic loading coming to this soil you can easily find it out, this has great advantage than your other methods, other techniques.

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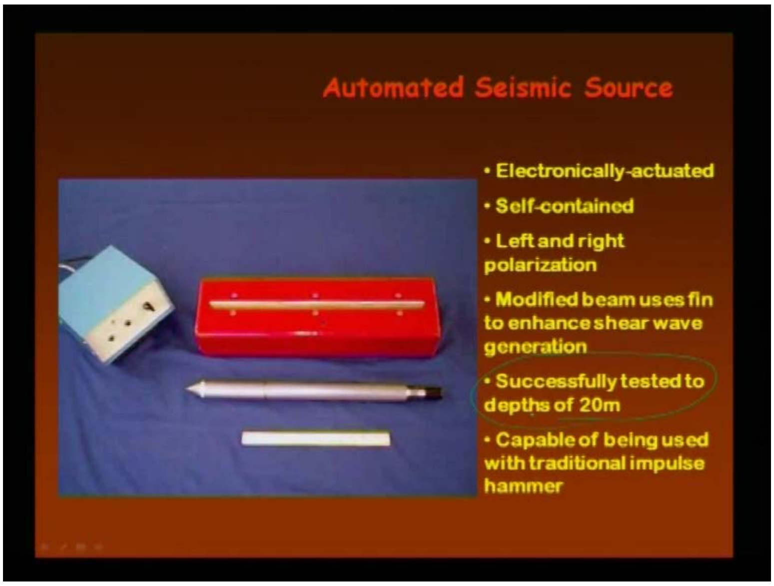

Now, there are different automated seismic source electronically actuated or self contained, left and right polarization, modified beam use fin, successful tested depth up to 20 meter, capable of being used with traditional impulse hammer. These are all seismic piezocone has been made it automatic seismic automated seismic source that can be automated instead of hammering you can start this automated source also.

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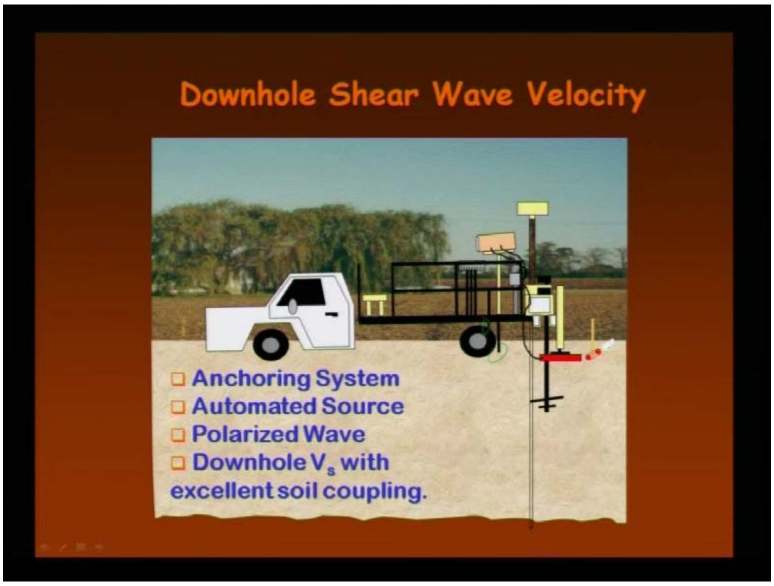

Now, look at this down hole shear wave velocity. I am just showing this animation then I will explain first look at this animation. Truck with this reed system hydraulic system is there then first anchoring has been done so that it cannot move here and there. This location has been fixed by means doing anchoring, then automated source you push it inside, then by hammering polarized wave should be there then downhole velocity v s with excellent soil coupling. Once again this I am showing, look at this animation anchoring system first it has been anchored so that this has been fixed. Then next step is seismic piezocone has been inserted up to that requisite depth then anchoring system automated sources third step polarized seismic piezocone down then polarise hammer it.

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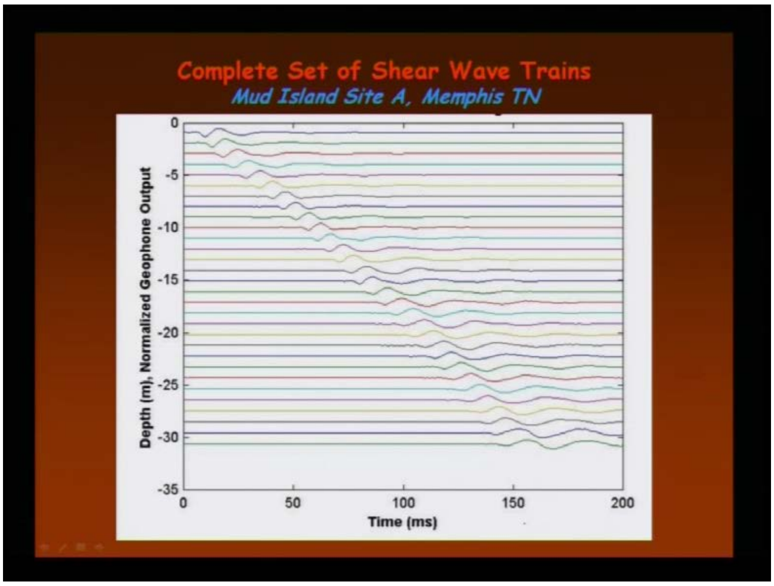

Then measure it, then you will can get, it is a one of the side you can get it complete set of shear wave times, shear wave train. That means depth versus time you can go to any depth, you can measure it with this depth, with this time complete set of how this shear wave velocity is varying that you can measure it.

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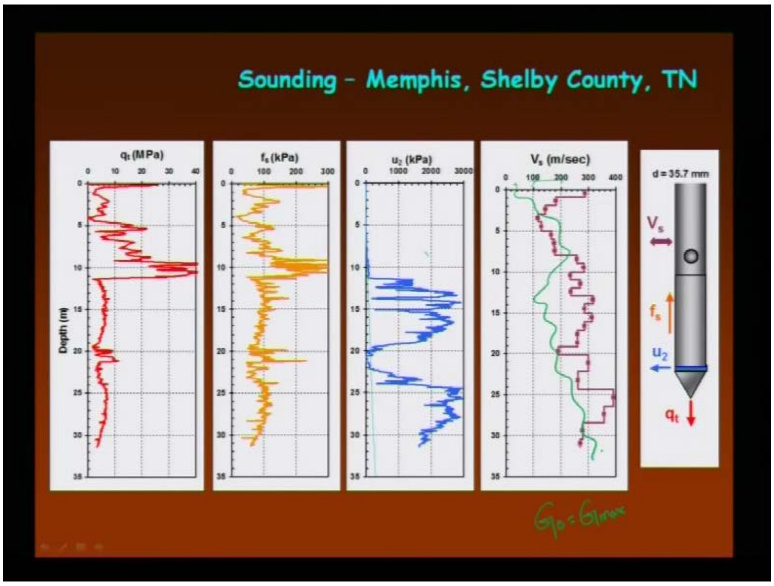

Then, what are the graphical form this once you get it, this is the profile I show you this measurement of shear wave train or time with this your depth. Then what are the parameters you are getting look at here, by this continuous profile of tip resistance how it is varying with this depth, you can say that 0 to 5 meters; the tip resistance is 0 to 10, say 5 to 10 meters in an average tip resistance is varying between 15 or 16 or may be 10 to 15 the tip resistance is 5, you can say 15 to 20 tip resistance 5. This is a continuous reading of tip resistance you can get it.

Similarly, look at this variation of frictional resistance. How this frictional resistance from depth one depth to other depth it is varying. More or less this frictional resistance if I remove this layer so, it is kind of a constant frictional resistance we are getting for this profile. Similarly, another most important parameter, variation of pore water pressure if you look at there up to 10 meter depth there is no pore water pressure that means it may be possible 10 meter water table is there so, below 10 meter there is a variation of pore water pressure. So, that means you can check your effective stress if you know this soil, if you know the over burden the pressure you can find it out the effective stress from these calculations you can say that you can calculate that may be this layer you will be prone to liquefaction or may be earth quake damage may be occur, this layer may be prone to liquefaction.

Similarly, you can measure also shear wave velocity. With this shear wave velocity there are two advantages. Once you get this shear wave velocity suppose 0 to 5 meters what is the shear wave velocity is varying 100 to 200, then based on this shear wave velocity variation you can say that this soil has been classified as sun shield or rock or may be that, 5 to 10 meter what is the shear wave velocity varying between 200 to 300, 10 to 15 meter how this shear wave velocity is varying between 200 to 300, 15 to 20 meter how it is varying 250. Now, if I look at this shear wave velocity profile I can say that these are my soils, this is soil but here you can say that very steep soil.

If you look at here shear wave velocity will be much higher. So, once you are getting shear wave velocity there are two advantages one is that what kind of soil layer is there that you can do it each and every depth we are finding out the shear wave velocity. Then another advantage is there you can plot with this shear wave velocity you can find it out G 0 or G maximum. You can directly find it out you can plot how G 0 G maximum is varying that means shear modulous. This shear modulous is required for seismic analysis, seismic analysis of soil or seismic analysis of soil or foundations that is required. So, this is all what is the output you are supposed to get and what kind of output, how graphically you can represent this you can get directly from there you can represent it there.

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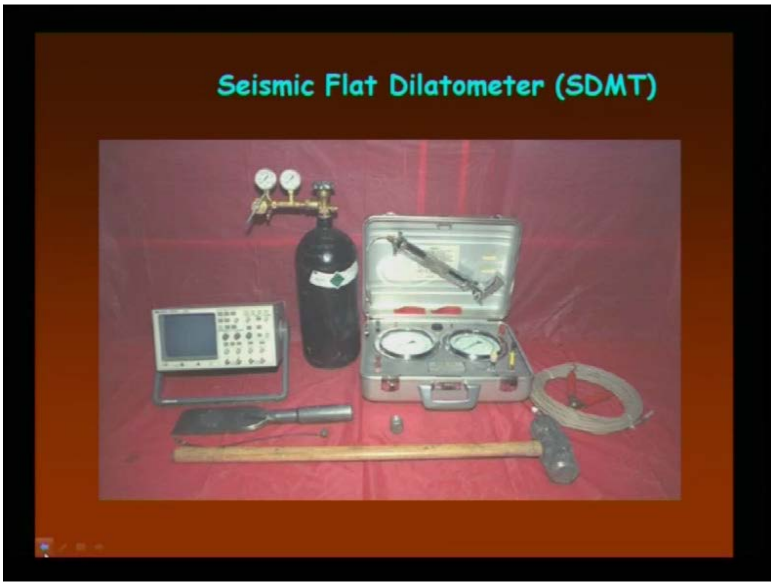

Then next is your, this I have discussed earlier seismic flat dilatometer from there you can find it out this expansion pressure and now, this earlier dilatometer, earlier I have explained only dilatometer. Earlier I have explained only static cone penetration. Now, the term seismic has come into picture, seismic cone resistance, seismic dilatometer.

That means in the seismic dilatometer you can measure shear wave velocity. So, that you can calculate G 0 or G maximum.

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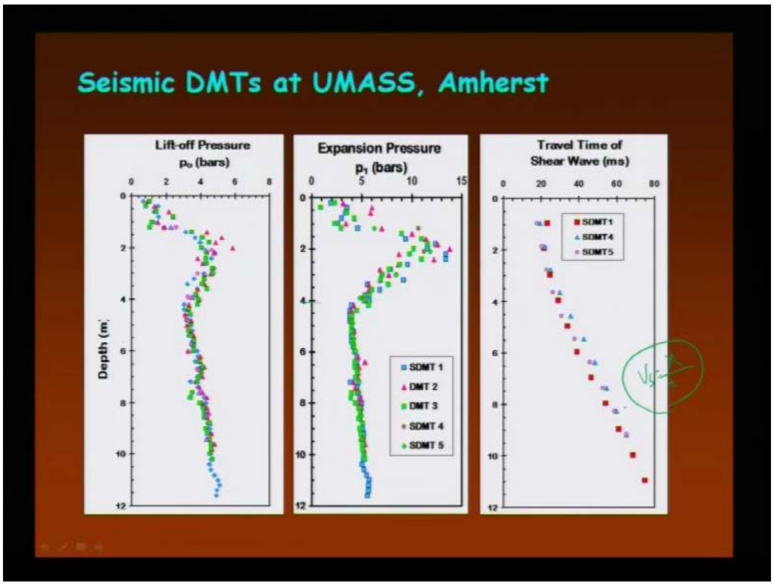

See from this, what you were suppose to get dilatometer tests earlier as I say from dilatometer test you are suppose to get k 0 earth pressure are traced e and other e also. But once I am saying seismic dilatometer what you are suppose to get you will suppose to get travel time of your shear wave velocity. Once you will get travel time with our shear wave velocity you can easily find it out. Here you are getting expansion pressure of every depth interval you are getting expansion pressure, with expansion pressure you can find it out change in volume, you can find it out sigma 3. So, sigma 3 by sigma 1, sigma 1 is your overburden at each depth and sigma 3 you can get it from flat dilatometer from there sigma 3 by sigma 1 is nothing, but your k 0 earth pressure are traced.

Now, with this once it has been seismic dilatometer test. It has been said this travel time of shear wave velocity you are measuring with each travel time you can find it out shear wave velocity v s is equal to distance travelled by time from there you can find it out shear wave velocity at each depth. With shear wave velocity at each depth once you find it out from there you can find it out G and G 0. So, out of this all seismic dilatometer cross hole or seismic downhole technique or only one test which is covering everything that is your seismic piezocone test this is covering all.

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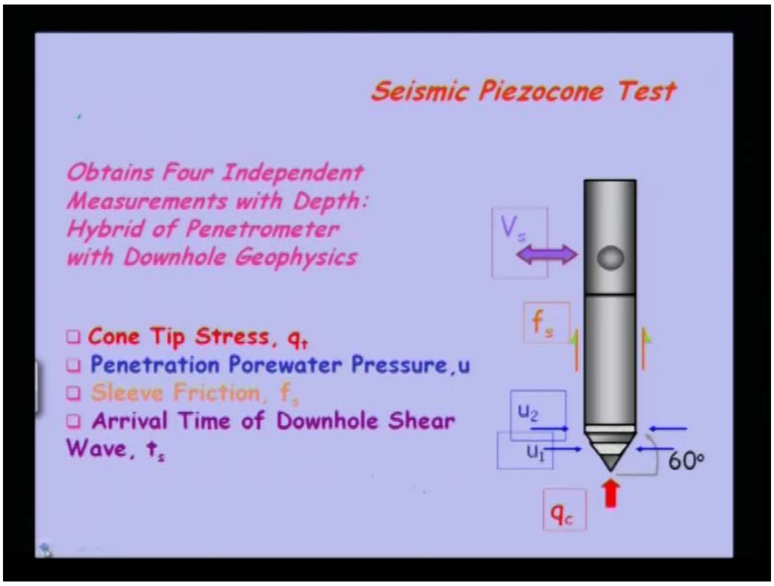

Now, come to next.

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More measurement is more better, in ground more you measure there is a chance of error you can nullify, so that more better.

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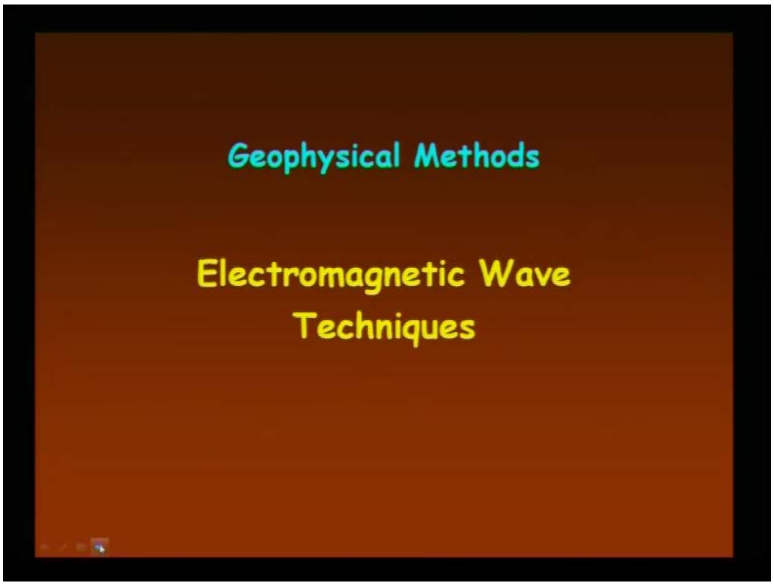

Now, next is your electromagnetic wave techniques, these are been used this is in geology as well as also geotechnical engineering.

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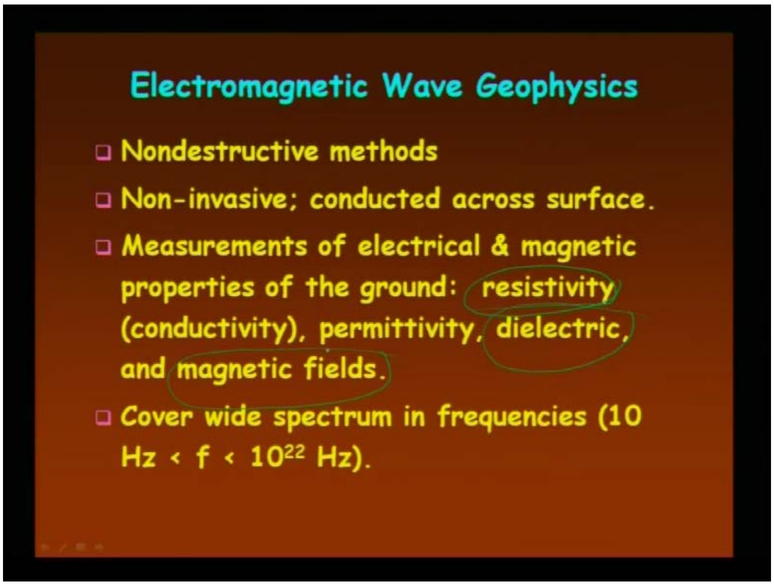

Electromagnetic wave geophysics, non-destructive methods, non-invasive or conducted cross across surface, measurement of electrical and magnetic properties of ground, electrical means with respect to resistivity or with respect to dielectric or magnetic field.

We can classify what is the soil profile also and cover wide spectrum in frequencies, it varies from 10 hertz to 10 to the power 22 hertz. All frequency it covers.

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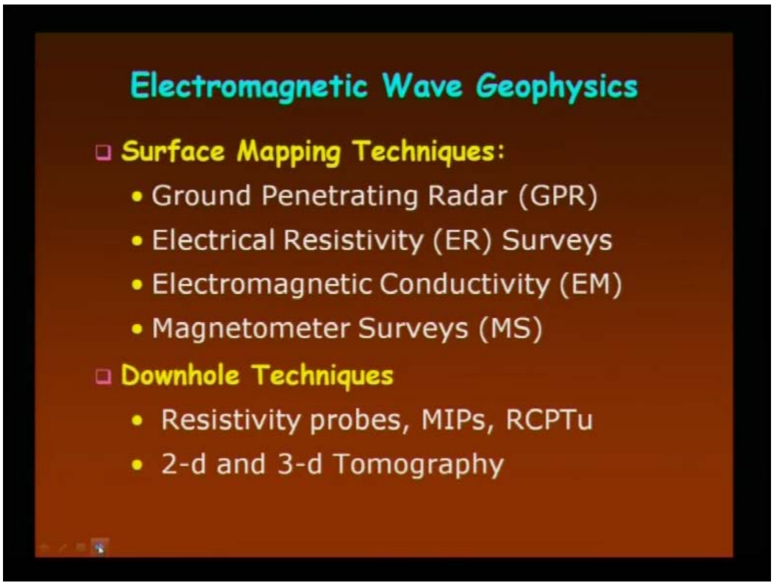

For surface mapping technique most advanced one is your ground penetration radar GPR then, second one is your electrical resistivity, third one is your electromagnetic conductivity, fourth one is your magnetometer surveys and downhole techniques resistivity probe or MIP s 2 d and 3 d tomography.

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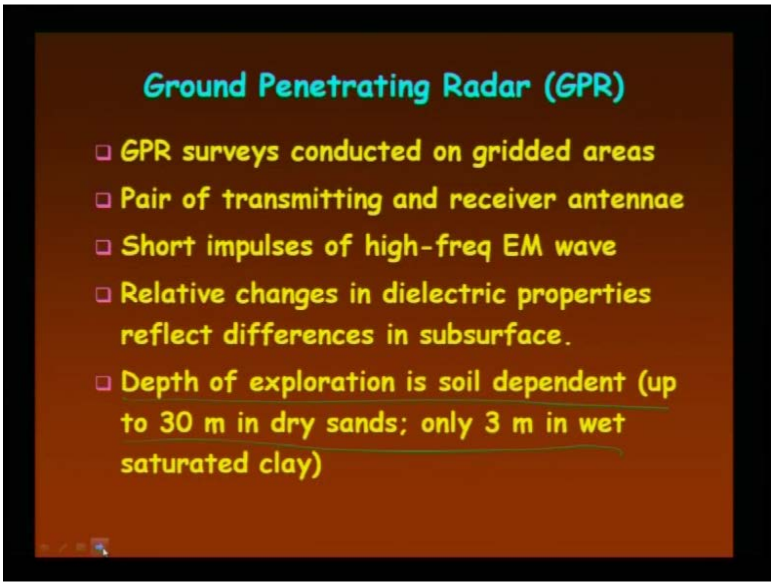

Now, ground penetration radar GPR on particularly, it has been conducted on gridded areas, pair of transmitting and receiver antennae, short impulses of high frequencies EM wave. Then you can measure depth of exploration, depth of exploration is soil dependent that means up to 30 meter in dry sand you can measure this, only 3 meter in wet saturated clay.

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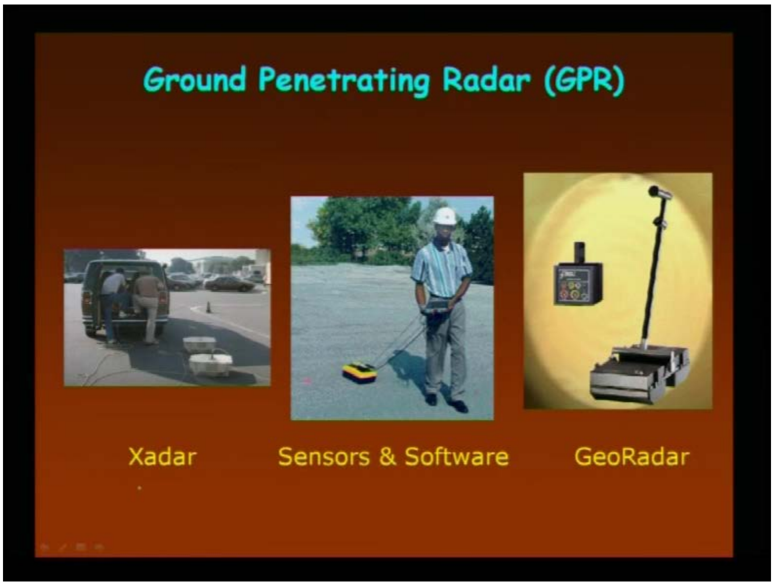

Ground penetration radar GPR, then sensor software and Geo radar,

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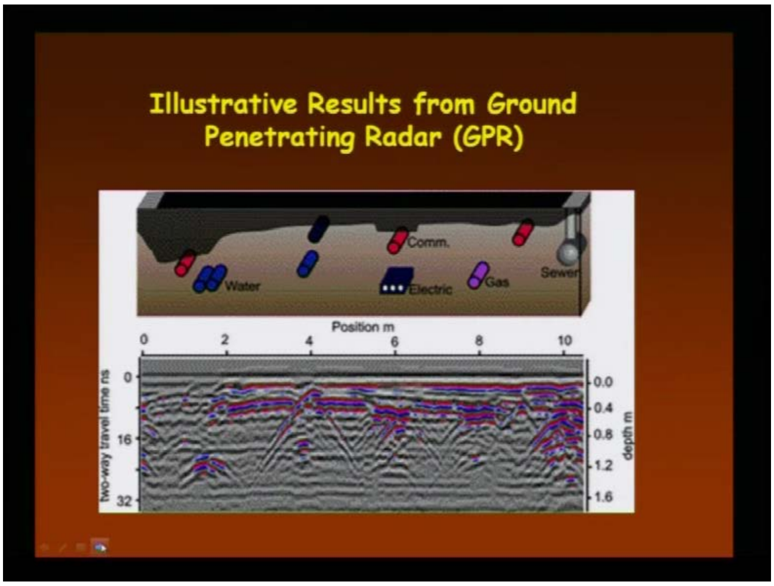

under ground utility corridor you can measure also with this GPR system.

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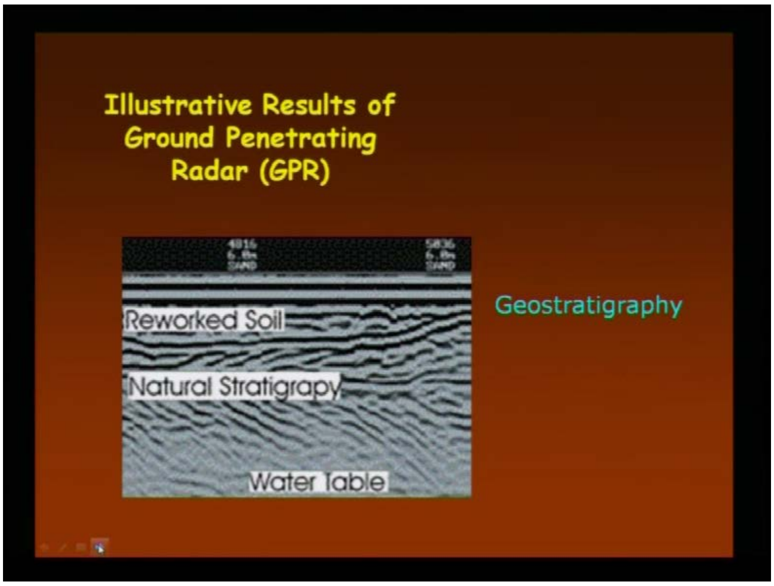

Water table natural stratigraphy, natural soil deposit, its stratigraphy.

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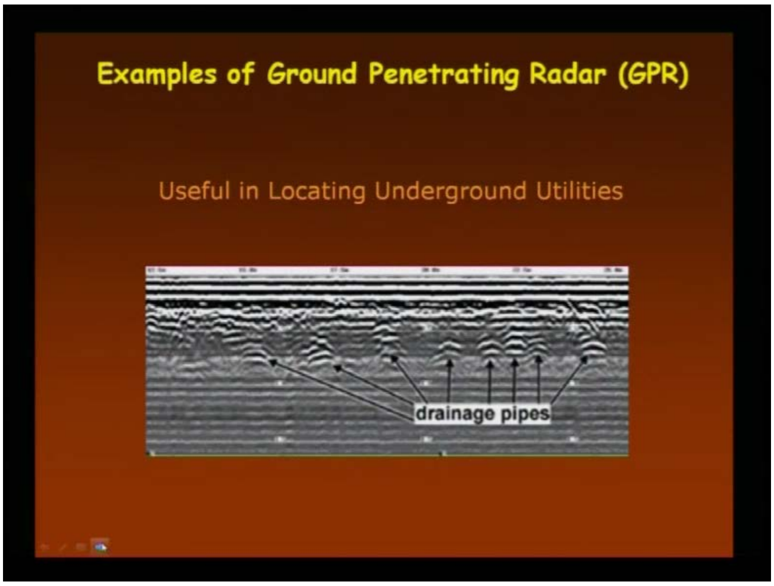

Locating underground utilities, is there any drainage pipe below the underground that you can easily locate it.

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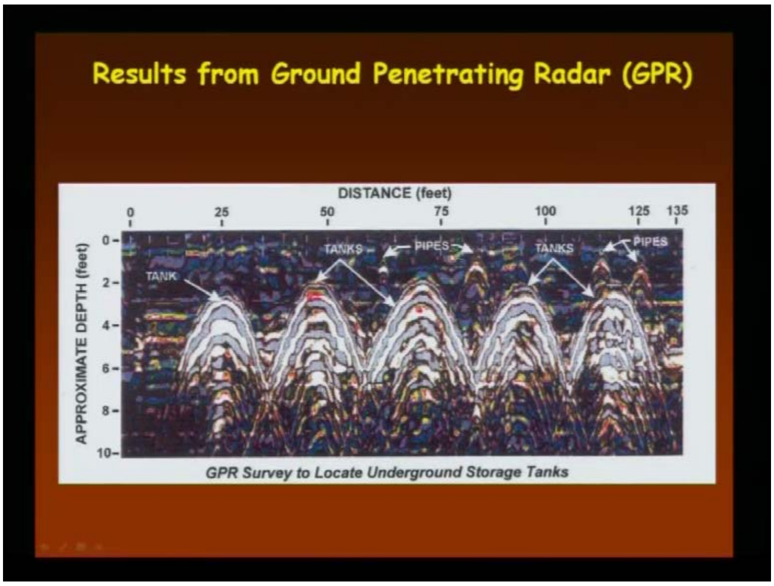

These are all examples of ground penetration radar. Typical results from ground penetrating radar GPR system, approximate versus distance these are pipes, tanks you can easily locate it where it is there exactly at what depth.

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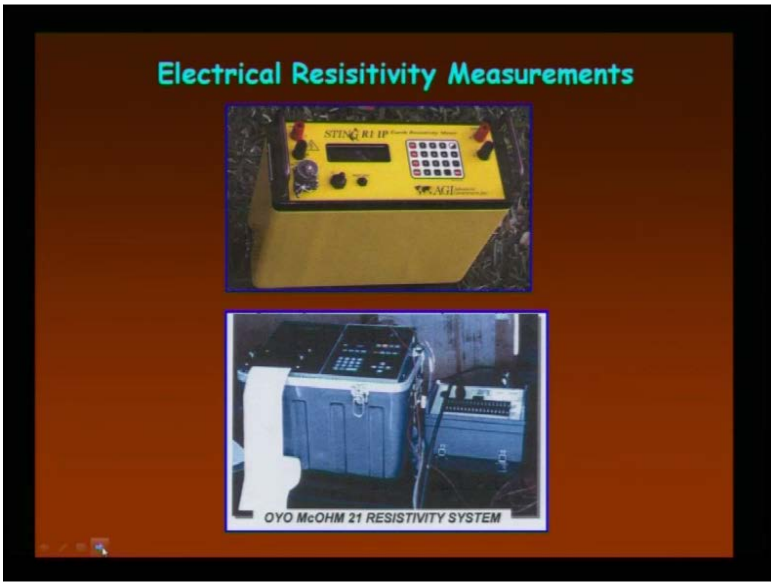

Electrical resistivity measurements these I have already earlier explained just showing this equipment, how it looks these are all your OYO 21 resistivity system.

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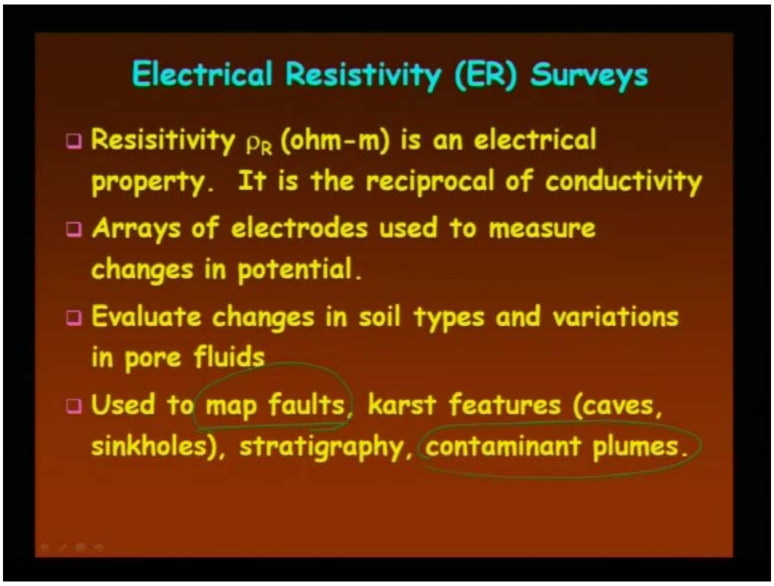

Resistivity unit is as I said earlier ohm meter is an electrical property. It is the reciprocal of conductivity, arrays of electrodes used to measure changes in potentials, evaluate changes in soil type and variation of pore fluids used to map fault, look at here what purpose it has to be used. It is used to map fault, any fault is there below ground you can find it out, caves, sinkholes stratification, contaminant plumes.

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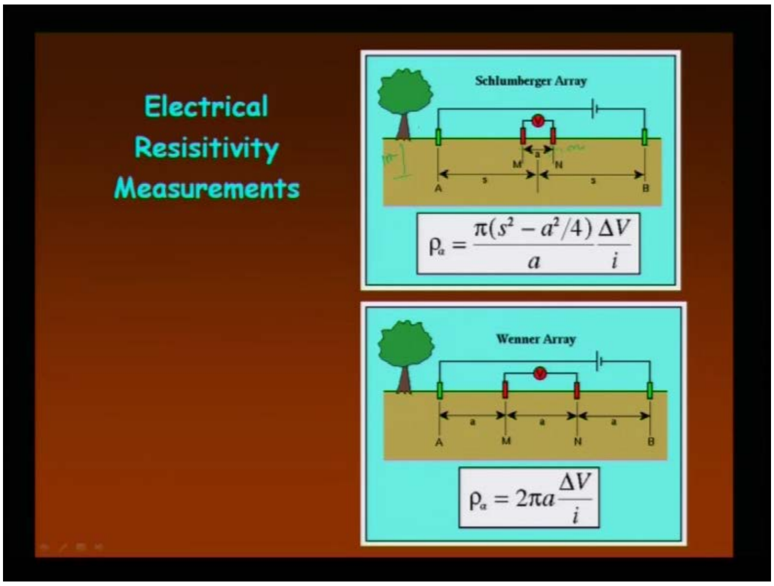

If you look at this electrical resistivity already it has, no need to explain again and again just show it. These are all electrodes so, this between is your potential drop.

Once again I am repeating, this is the current you apply current. So, voltage drop you can measure the inside electrodes and the distance a, based on the distance a, a is a distance between the electrodes. If this a is equal to 1 meter that means up to 1 meter you can go for this electrical resistivity measurement below the ground surface, that means varying you can decide what is that depth, if your depth you know this is the depth of exploration then accordingly you can vary a.

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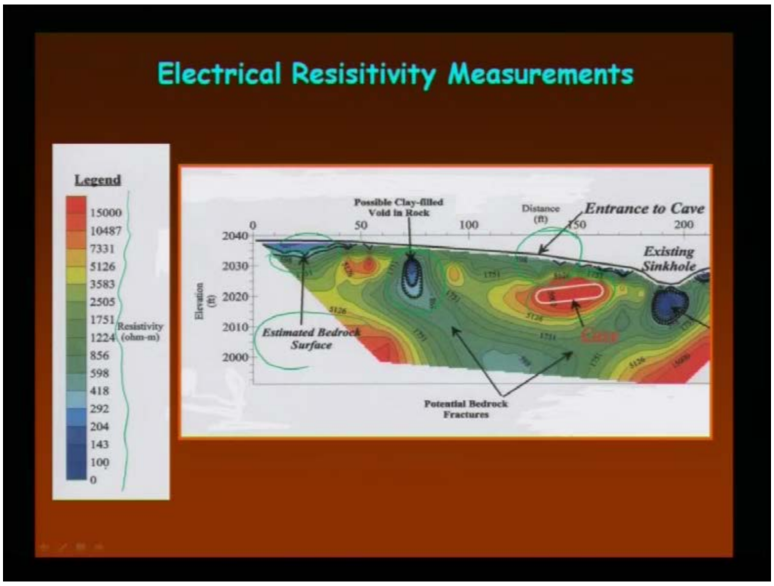

This is one of the typical result I am showing this from electrical resistivity. Where is the cave? This is the entrance of cave, where it is located exactly you can find it out. Is there any sinkholes below the ground? Yes, there is sinkholes. Where it exactly the sinkhole is existing. Then, is there any possible voids in soil or rock? Yes, we are getting possible voids and is there any bed rock where exactly bed rock? This is the surface where the bedrock is there.

So, basically variation of ground surface, below the ground surface and it has great advantage to find it out particularly bed rock. If any field, cave or sinkholes based on resistivity you see once we had doing this based on resistivity this has been classified. Whether it is a rock, soil, cold or gap or may be caves based on this resistivity you can measure it and you can show it.

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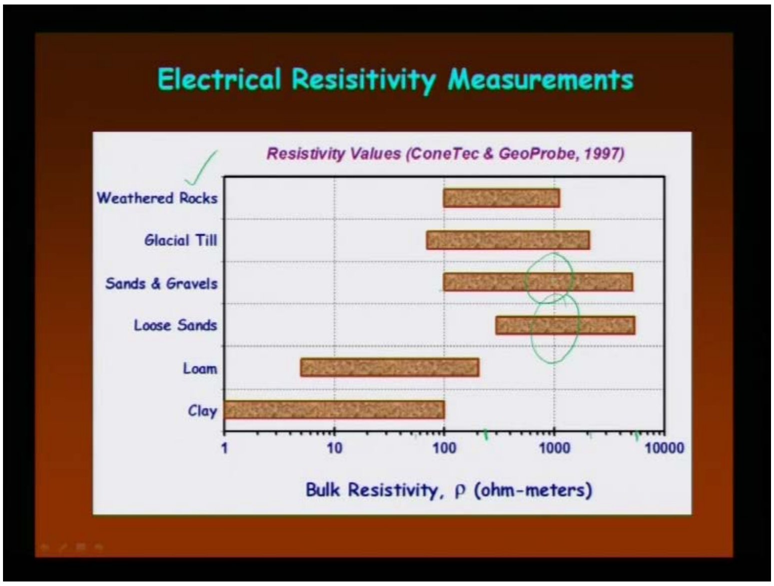

This I have already said even if I have written in that black board if resistivity value is between 100 to 1000, this is called rock. If it is between say 80 to 1200, this is glacial till. Sand and gravel it will 100 to 800, loose sand is you see 200 to 800, 900 means the range is given. It may possible that over lapping may occur because is as you say sand and gravel, it is between here to here.

Suppose you are getting a resistivity of this then how do you decide this and this? Of course, the basic soil classification is required, but you can get an idea what kind of soil it is there and basically we are not going for soil classification rather for the by this method we are looking for bed rock, we are looking for cave, we are looking for sinking hole. These are the possibility we are looking so, that we are we want to see.

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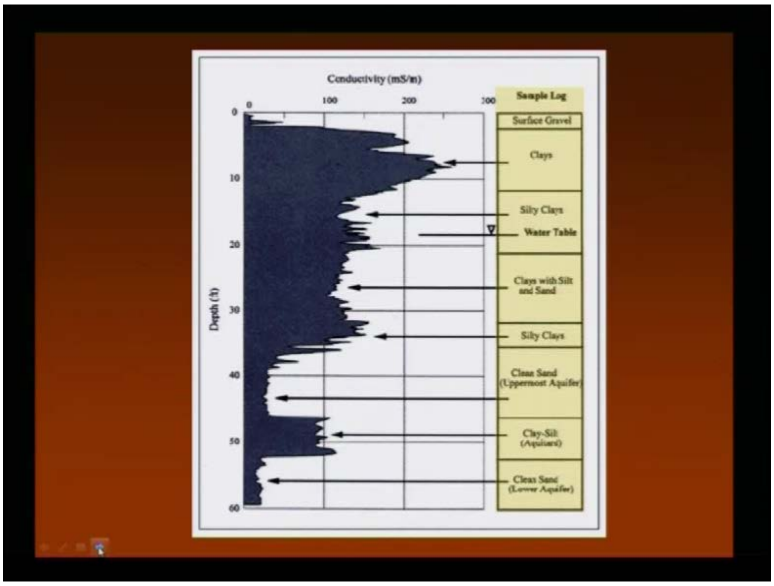

You see this with this sample log you can write it clay, silty clay, water table. Another thing is that you can locate this water table.

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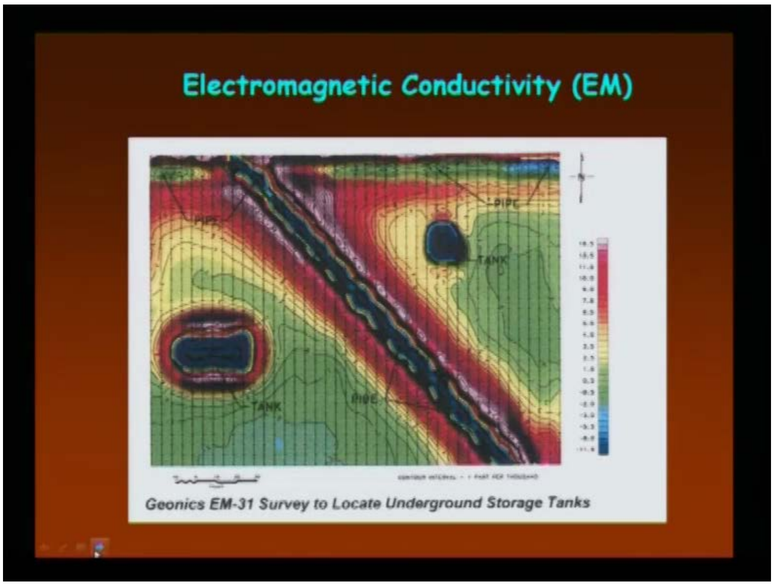

Then electromagnetic conductivity EM by means of varying magnetic field also you can classify. This is latest one this pipe, tank or anything you can find it out.

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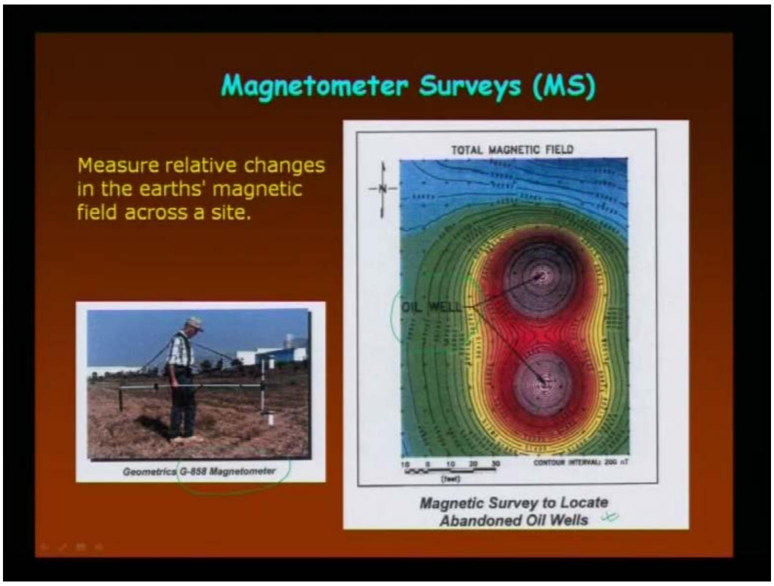

Electromagnetic magnetometer with this magnetometer earth magnetic field across a site you can change the magnetic field below the ground surface based on that, this is basically used to find it out is there any oil, is there any natural source, natural resources below the ground surface.

By means of electric earth magnetic field or electromagnetic I can locate any oil wells. How they are locating all of sudden they declare that below this coal is there or oil is there, huge amount of natural resources are there. This you can find it out by magneto meter surveys of course, there are other detail techniques are there I do not want to go because we are restricting only for geotechnical engineering related things you can find it out, just I am showing one of this magnetic surface to locate abandoned oil wells. Then in in-situ test.

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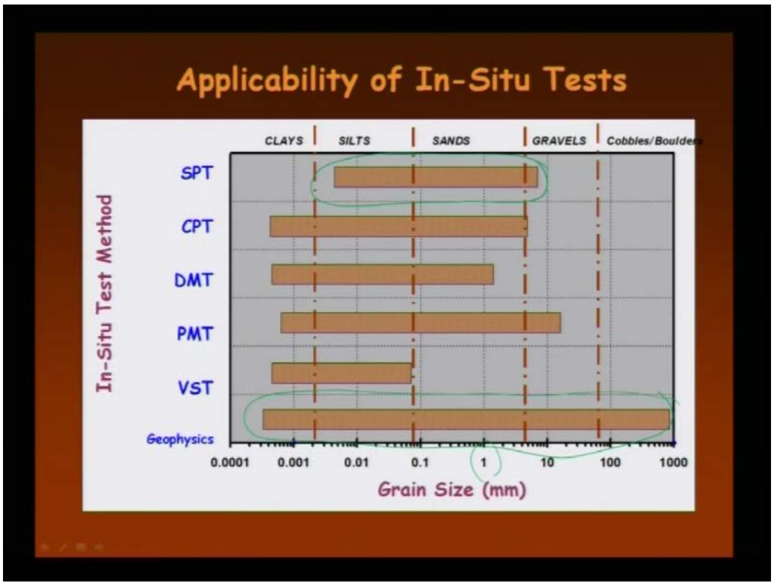

Now, how? This is most important. How do you decide what kind of test you are going to do and why? There are many tests applicability of a in-situ test SPT. I have explained earlier, standard penetration test, CPT cone penetration test, DMT dilatometer test, PMT pressure meter test, geophysics geophysical methods. You means, you see if soil is for example, silted sand then you go for standard penetration test, indirectly if soil is cohesion less then you can go for standard penetration test, silt and sand. Not for gravel not for clay. Similarly, CPT you can go for clay, silt, sand not gravel and other, DMT clay, silt, sand. Grain size also given, up to this grain size 1 mm PMT, but if you see this geophysics geophysical methods it can cover all clay, silt, sand, gravel and bolders everything it will cover.

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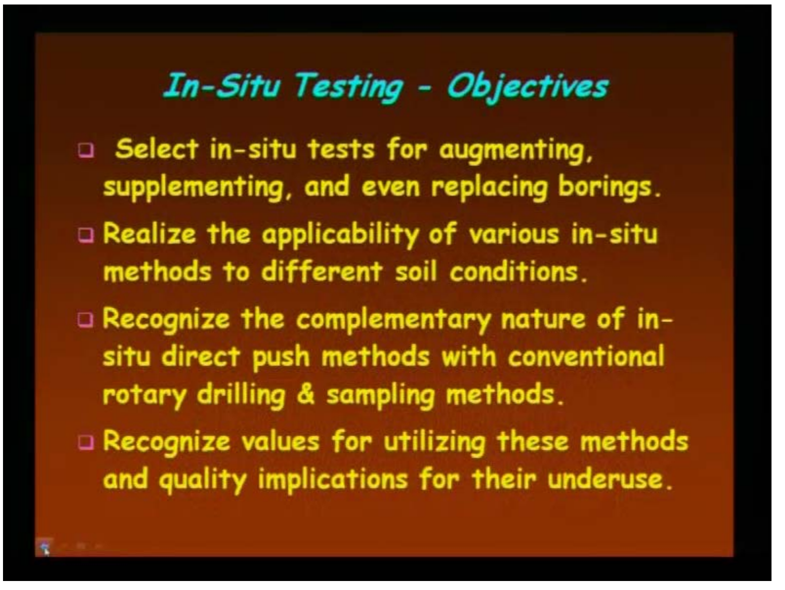

What is our objective in in-situ testing? Select in-situ test for augmenting, supplementing and even replacing boring as far as possible If you go for in-situ testing you can replace also boring, boring is a cost, cost is higher, realize the applicability of various in-situ methods to different soil conditions. As I said earlier different soil conditions what are the techniques you are going to use, recognise the complementary nature of in-situ direct push method with conventional rotary drilling and sampling methods.

You recognise instead of doing drilling and sampling what should be in-situ direct push method you can we use so, that it can replace, recognise value of values for utilizing these methods and quality implications for their underuse. This is all about in-situ testing, field testing corresponding to considering static as well as dynamic conditions coming to the soil. Now, next class I will start your dynamic parameters measuring dynamic properties of soil by means of laboratory testing. I have shown it earlier.

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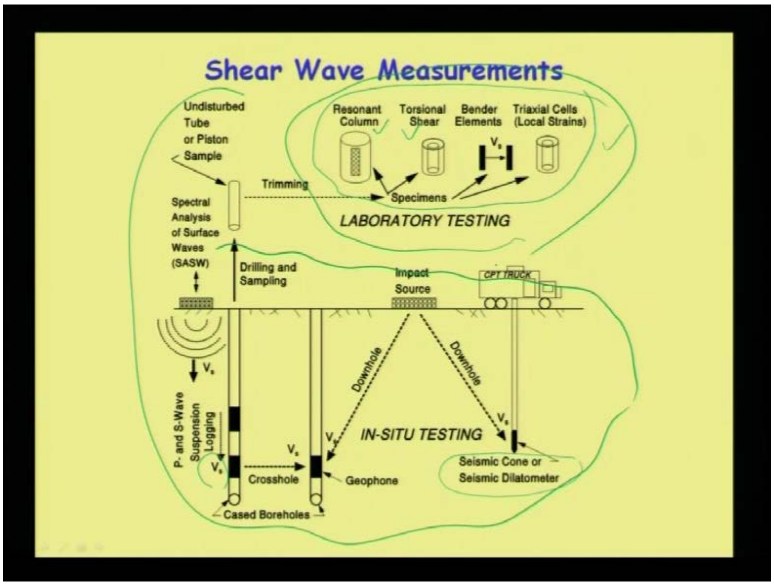

This part we cover in-situ, next class onwards I will start what are the different laboratory testing to get dynamic properties of soil reasonant column, torsional shear bender element and triaxial cell. This I will start from next class.