Soil Dynamics
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Module - 4
Dynamic Soil Properties
Lecture - 19
Seismic Refraction Test, SASW Test,
Laboratory & Model Tests

Let us start today's lecture of Soil Dynamics. In the previous lecture let us quickly do a recap, we are continuing with our module 4; that is Dynamic Soil Properties.

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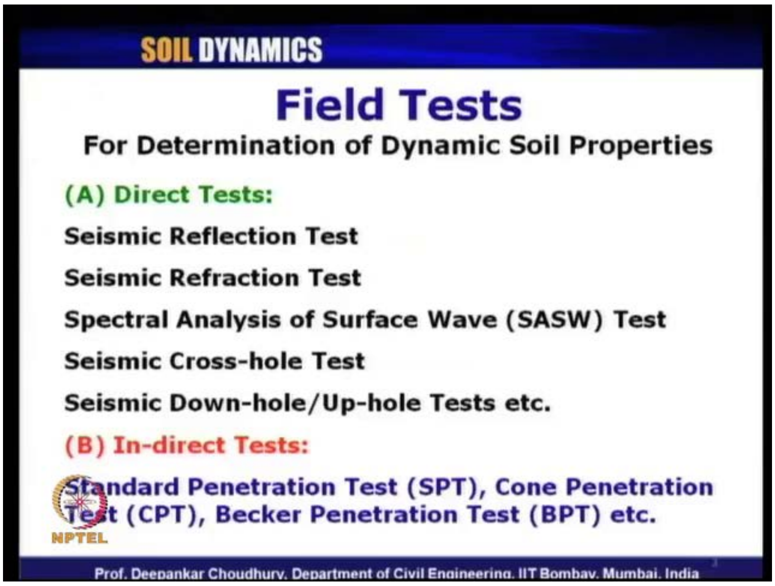

We had learned in the previous lecture like for determination of the soil properties, similar to the static case for dynamic case also. It can be classified in two major categories field test and laboratory test, within field test we have sub classified mainly into two broad categories, one is called direct test, another is indirect test. Within direct test we have seen seismic reflection test, seismic refraction test, SASW or MASW test, seismic cross hole test, seismic down hole, up hole test, etcetera.

And indirect tester, which are common for static test - field test like SPT, CPT, BPT pressure meter test, dilator meter test. All these are test for static property determination for the soil which can be also used for determination of dynamic soil properties using some empirical relations.

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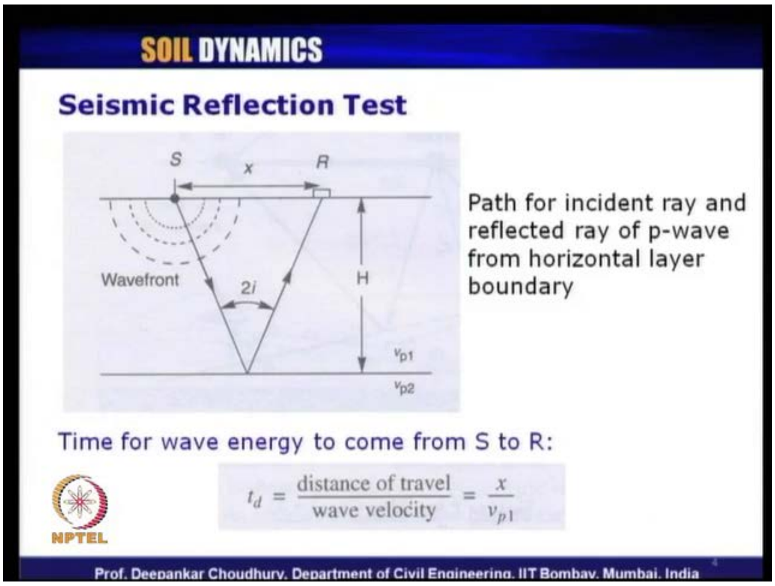

Then seismic reflection test we have seen, what are the basis of the seismic reflection test?

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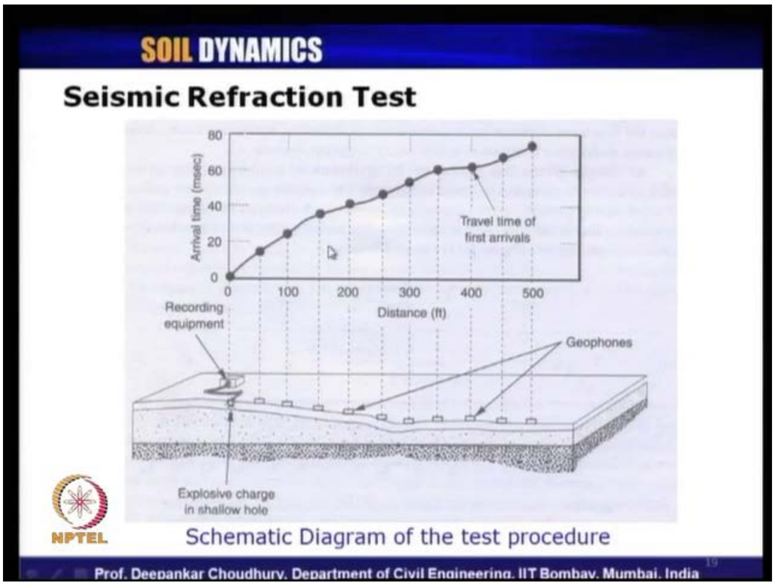

Coming to the next type of test, which is seismic refraction test these are common geophysical test you must have studied in your under graduate soil mechanics course also, so just to brush up a memories. Suppose, we have recording equipment here were the explosive charge at a shallow hole or by using vertical impact or horizontal impact we are providing the vibration in the soil system. And we are using several receivers which we call as geophones at different distances, then through refraction we can find out the travel time versus distance curve for the first arrivals.

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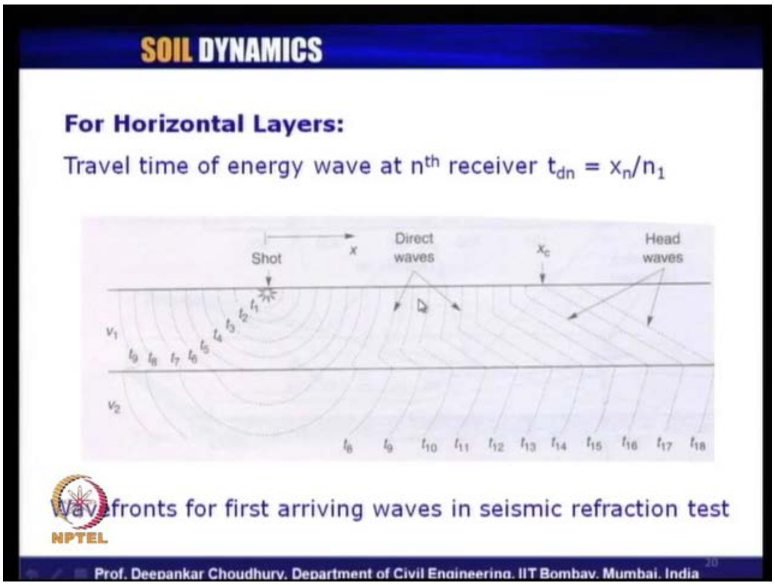

And if we have the horizontal layers this is the source point and various receivers can be here. So, direct waves can reach here directly, whereas the refracted waves can get refracted at the boundary and come back there.

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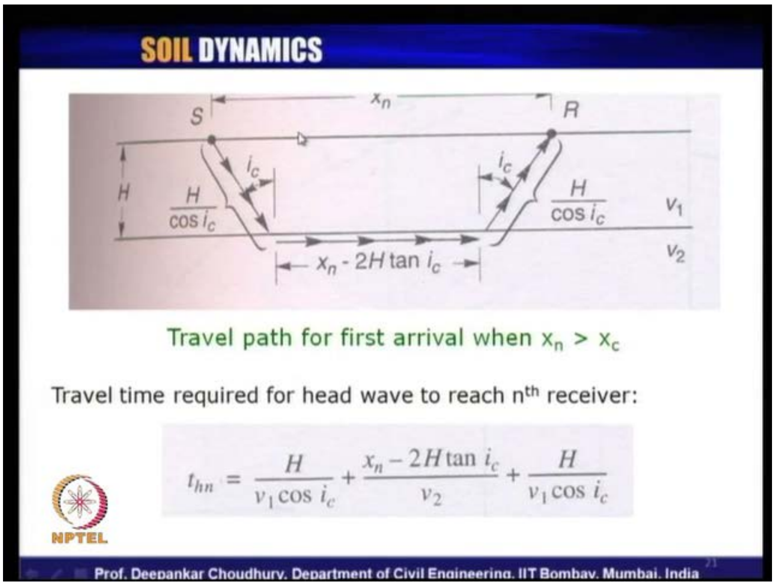

So, this is the way the waves can travel at the boundary they are travelling in this direction and refracted back and going to the receiver. So, there is a difference between the previous method of reflected test and this is refracted test, so this is the major difference. So, from the difference of the time you should identify, which one is my reflected wave arrival time, which one is my direct wave arrival time and which one is my refracted wave arrival time.

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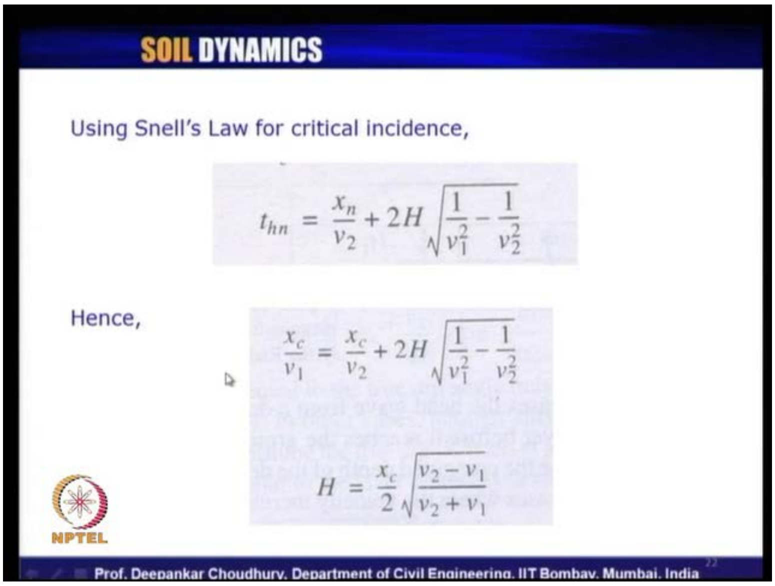

And using the simple Snell's law for critical angle of incidence and simplifying the different expressions the thickness of a layer can be obtained.

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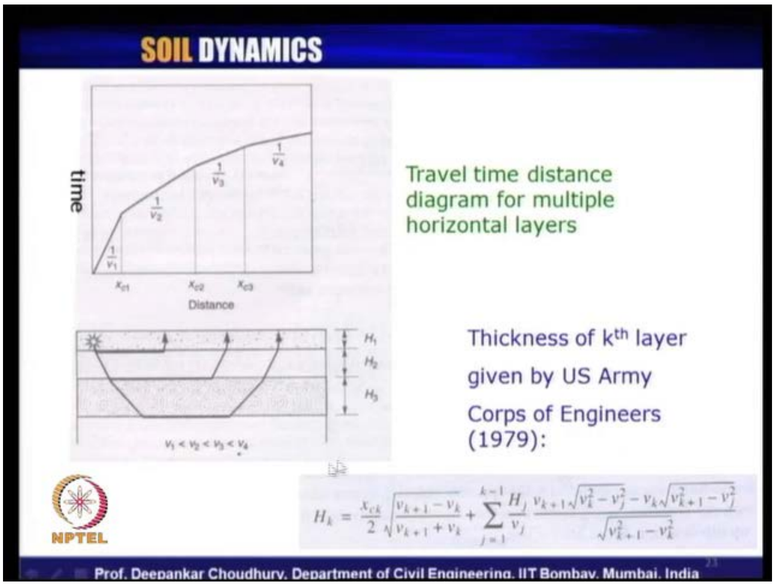

So, if we use multiple number of geophones to receive the data from a particular source and then plot the time versus distance. We will see that after a certain distance there will be a kink in the graph. So, that point of discontinuity is nothing but showing the changing of a layer, that is from those layer interfaces the waves are getting refracted. And slope of each of the line linear segments will give us the value of the wave velocity in that particular layer.

So, this is the pictorial representation of how from source to the refraction is getting place between the first layer and second layer boundary giving us the value of v 1, then second one v 2, third one v 3, next one v 4 and so on. There is one assumption that the v 1 is less than v 2 is less than v 3 is less than v 4, so if it is not, so our test will give some erroneous result. So, these are the few drawbacks we should remember about this particular test.

And also thickness of any k th layer as expressed by US army corps of engineers, this is the expression used to obtain the thickness of any of the layer k th layer, first layer, second layer. You can use corresponding lower layer velocity and upper layer velocity to find out the thickness of the upper layer velocity.

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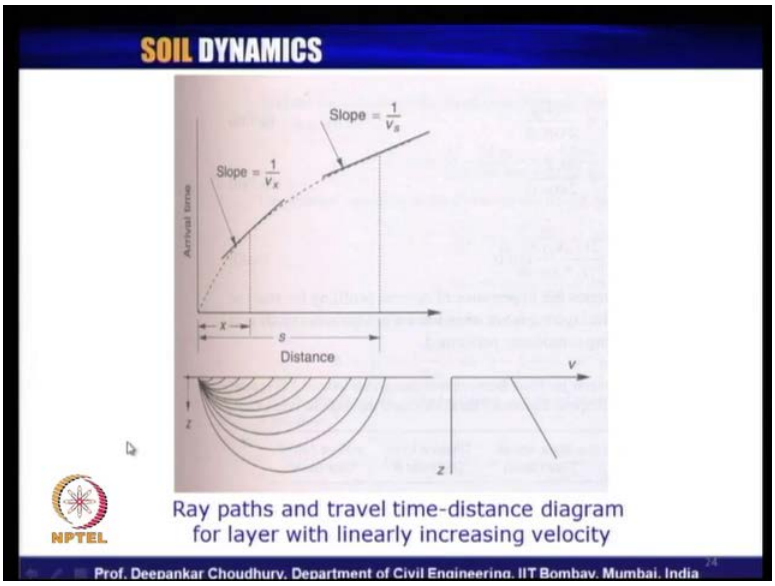

This is again representation what I have mentioned just now, slope of this will give us the velocity in that particular media, velocity of wave in that particular media.

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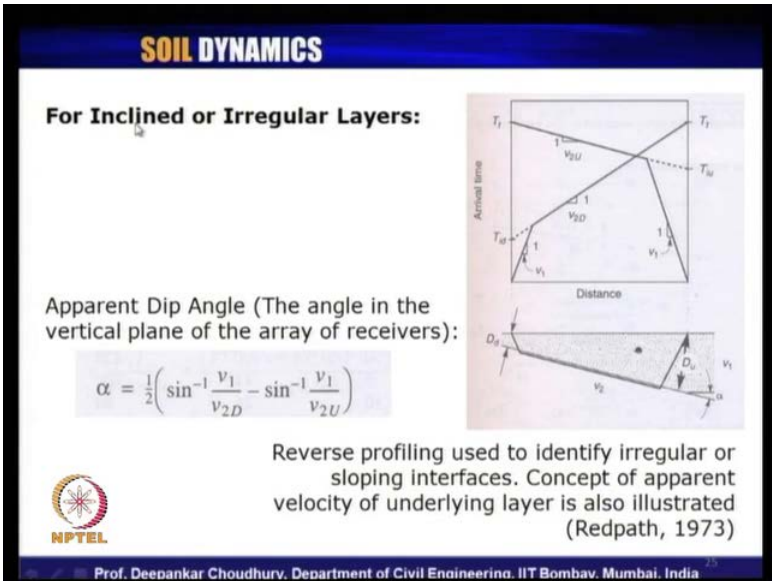

Now, what happens if instead of horizontal layer, we come across with an inclined layer like this. So, below ground we have an inclined layer the top layer is like this, with thickness of D, D here whereas, D u at this place, so alpha is the inclination of that layer with respect to horizontal. So, what is aid in these type of cases of inclined or irregular layer you use source at this point and at two other ends you use the geophones or receiver stations.

So, arrival time and distance you plot for both the sides of the different geophones from both left hand side of y axis and right hand side of y axis and they will meet at some point. And which will help us to obtain the inclination alpha using the relationship obtained for the velocities for two directions or two thickness of the soil from two sides.

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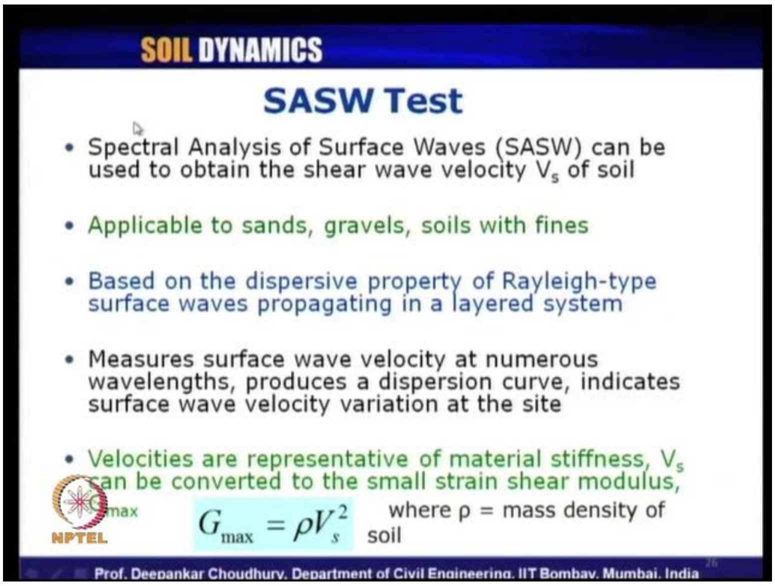

Now, coming to the spectral analysis of surface waves which is very commonly used even nowadays also for determination of shear wave velocity of the soil. So, some of the characteristics let me mention first spectral analysis of surface waves, can be used to obtain the shear wave velocity V s of the soil. This test is applicable to sands, gravels and soils with fine, that is for most of the types of soil it is applicable, which is a advantage of this test.

Now, based on the dispersive property of Rayleigh wave Rayleigh type surface wave propagating in a layered media we obtain the V s. What is the basic physics behind the test that is as the name suggest, spectral analysis of surface wave by using that vibration at a very shallow depth of the soil, what we are creating? We are creating the vibration and waves getting generated and they are travelling through the media; now it can produce both body wave and surface wave.

Now, surface wave will arrive; obviously, first like a direct wave kind of thing, now what are the surface wave, most of the energy is taken care of by Rayleigh wave as I have already mentioned in the theory of wave propagation. So, those Rayleigh wave when it reaches at the receiver stations, so we record the arrival time of those Rayleigh wave and the corresponding distances from that charge point to those receiving stations.

Now, this Rayleigh wave will help us finally, to obtain the shear wave of the soil how, because we know from the relationship between Rayleigh wave and shear wave depending on the partial stress of the material. We can compute the shear wave velocity of the material right, so that expression actually use to obtain the shear wave velocity. So, it is kind of we are using first surface wave of Rayleigh wave then through which we are finally, getting a value of shear wave velocity, so remember this.

Now, measures it measures surface wave velocity at numerous wavelength produces a dispersion curve, which indicate that surface wave velocity variation at that site. Obviously, depending on your (( )) technique at different time, it will create different wavelength of the waves travelling through the media. And you will get a set of curves which will help you to obtain the surface wave velocity or Rayleigh wave velocity that finally, will be used to obtain V s. And these velocities are representative of material stiffness, because as we know the shear wave velocity actually represent how stiff the material is, if the V s value is lower than the other material. Then it automatically means that the stiffness of that material is lower than the other material.

And it can be converted to obtain the small strain shear modulus, what is small strain shear modulus I will explain these things in subsequent lectures that is expressed by G max, G is the expression for shear modulus. So, G max is nothing but called maximum shear modulus or small strain shear modulus. So, that g max is given by row times V s square, V s is shear wave velocity of the soil and row is mass density of the soil material, so this is the expression used to obtain the shear modulus.

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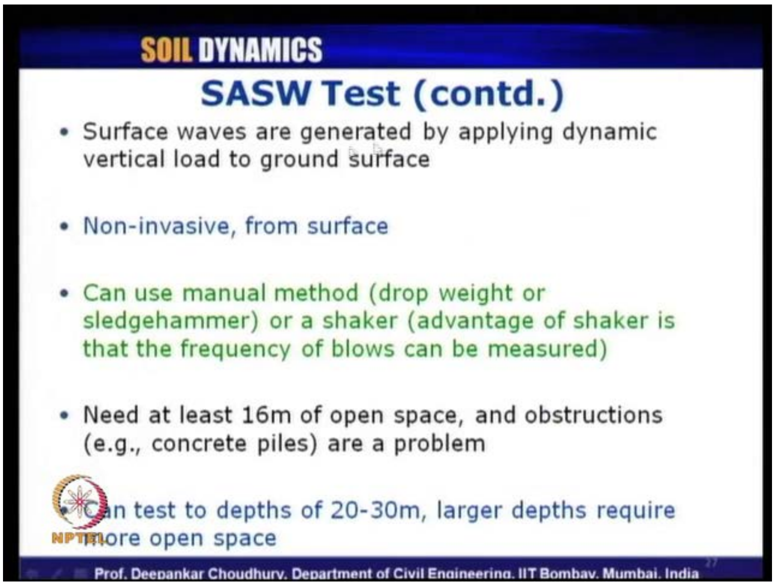

Now, the surface wave are generated by applying dynamic vertical load to the ground surface, as we have already seen how the agitation or vibration is getting created. These test are non invasive from surface and can use manual method that is not necessarily you need to use the hydraulic jack or hydraulic machine to create the vibration. You can use a manual method by using the drop weight or sledge hammer type of method to create the vibration or a shaker.

Shaker is of course, a instrumented vibration you are getting created in the soil media and advantage is of the shaker that frequency of the blows also you can measure. So, you know want more input whereas, in your manual method you cannot find out what is the frequency of your the vibration you are getting generated in the test procedure. What are the other major characteristics for SASW test we need at least 16 meter of open space in the direction of where from source to receiver is placed.

So, otherwise what will happen the waves will not get sufficient distance to travel to generate as both surface wave and other body wave, so you cannot differentiate the time arrival and etcetera. So, we need at least 16 meter of open space, so remember this point because many times in field you will find that contractors or field engineers they are not following this criteria. In that case you are not sure whether they are measuring Rayleigh wave or you are measuring some other wave like even body wave, because the time overlapping may occur. So, that is why be sure to provide a minimum of 16 meter.

If you are providing more than 16 meter open space that is well and good and it helps you to identify the some of the kind of obstructions, if they are present because then changes of wave characteristics will occur. Because, material changing means the V s or Rayleigh in that particular media will completely change instead of soil, if we have say concrete materials. Some very old pile or very old piles are already hidden below the soil which is not known say some historical construction was done, and then it was damaged and nobody knows that below the ground what exists many times it happens mainly in the urban areas.

That when you are going for a new construction you will find that when you are doing the SASW test suddenly at one particular point or one particular layer you are getting very high value of V s which is not commensurate with your other recording stations values of V s for that same region. What does it mean, definitely at that region you have some very hidden stiff material below the ground, which is creating the recorded value of very high V s value. So, be aware of this points, that is how to identify the very high value of a V s or very, sometimes even very low value of V s also will help you to identify some sandwich of thin layers, what does it mean.

If you have a continuous pretty large thick layer of some stiffness and soon after that below that you have another similar stiff material, which is following the criteria, which we are mentioning that the upper layer stiffness is lower than the lower layer stiffness. But, in between them suppose if some very small thick material, that is sandwich material we call, which is very weak in nature because of the geological formation of the soil.

Some sandwich layer or hidden layer lies between these two major layers, what will happens suddenly will see that there is a jump or means jumping down the values of V s at some interfaces or at some recording stations that will indicate the presence of a very soft layer or sandwich layer. And many times if the sandwich layer thickness is pretty small compared to your major layer for which you are obtaining the V s value you may not even identify that the change in V s value.

You may sometimes ignore also because the changing of the values in that two layers will be, so certain and time arrival and things like that will be, so abrupt you will not able to find out. And what are the other major characteristics they can test up to a depth of about 20 to 30 meter that is it can identify the properties of a soil of thickness of about up to 30 meter depth beyond that it requires more open space as it is mentioned. So, as more deeper shaker you want to identify their dynamic shear wave velocity value you need a more open space to conduct this test and as I have mentioned.

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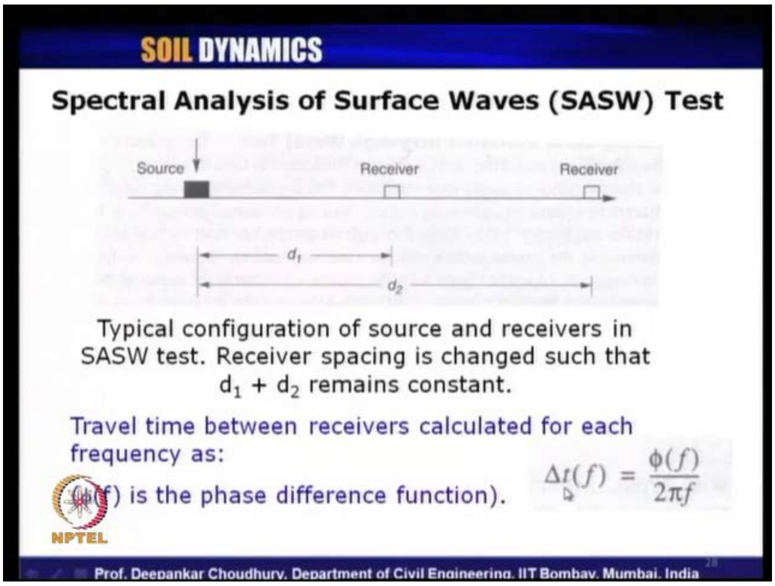

MASW test is also the similar test only thing you use multichannel, multi sources and multi receivers. So, this is the pictorial representation or configuration of a SASW test we have a source, different receivers at different distances suppose distance d 1 at first receiver d 2 for the second receiver. And receiver spacing is changed in such a way that this summation of d 1 plus d 2 they remains constant. And travel time between receivers calculated for each of the frequency in this way, so this is the phase difference function and this is the frequency, this is the travel time.

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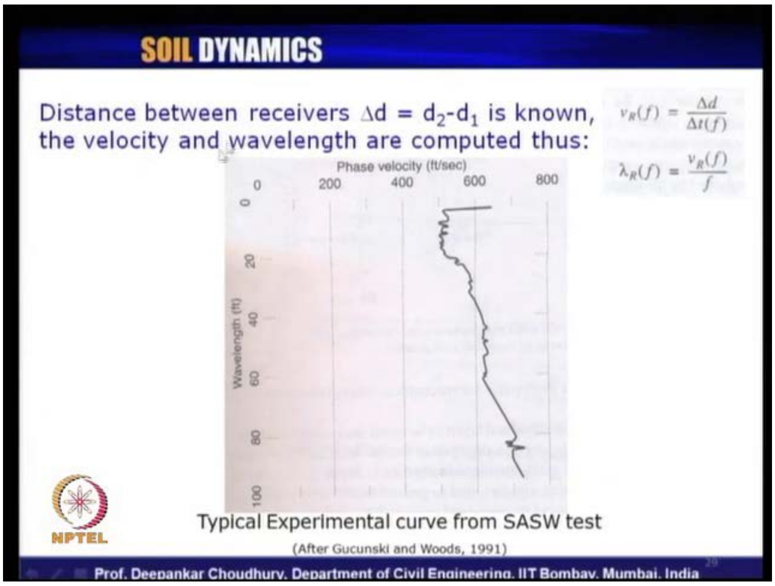

And the distance between the two receivers that delta d which is nothing but d 2 minus d 1 that is known to us, because that is how we have kept on our ground surface the receivers. Then the velocity and wavelength they can be computed, so this is the typical way how the phase velocity and wavelength they are plotted.

So, this is after this researchers typical experimental curve you can plot it like this, which will give you the value of V R and lambda. These are nothing but your Rayleigh wave velocity from which now you have to use a relationship between Rayleigh wave and shear wave velocity and you will get the expression for V s.

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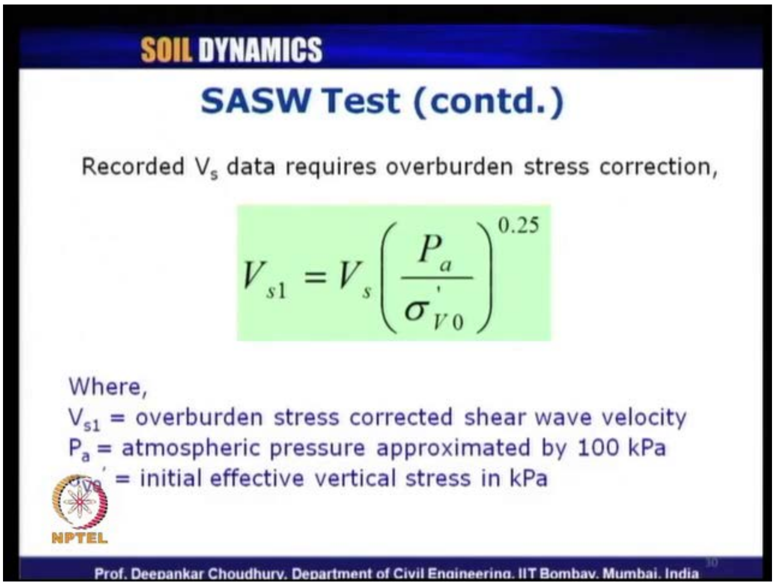

Now, after obtaining the value of V s through this V s SASW test we need to do some correction of the raw measured value of the V s. So, raw data V s measured at the site need some correction that major correction is known as overburden stress correction. Why this correction is necessary, because as you know if we go deeper and deeper in a soil media even though it is a homogeneous or same media if we continuously move down from the ground surface what will happen, because of the overburden stress the stiffness will keep on increasing right.

So obviously, you are recorded V s value as you deeper and deeper will be higher and higher, but that is not the basic property of that soil media it is just, because of the overburden clear. So, we need to do the overburden stress correction factor we need to apply to this recorded V s data. So, that the effect of this depth the effect of overburden is not present in our reported soil data, how we do that to do that, we need to identify a reference value that is with respect to what stress condition what overburden stress condition we can say that this is our standard value of V s.

So, that referencing of the overburden test is used here let us look at the slide here. So, that reference value of the pressure or the overburden stress is nothing but one atmospheric pressure which is equal to about 96 point something k P a which for all practical purposes we take approximately equal to 100 k P a. So, 100 k P a is the standardized or reference value of overburden stress, which will give us the correct V s value that is with respect to the standard value of V s standard value of overburden stress we report our V s value.

Because otherwise as we go deeper and deeper V s value for the same soil will keep on increasing that will not give us the correct idea of what is the exact V s value for the soil we should use in our design. So, to avoid that we are doing this referencing at a particular pressure or at a particular stress, which is the one atmospheric pressure? And this is the formula used for applying the overburden stress correction factor this V s is the field recorded data raw data value we have which we have recorded from the SASW test.

P a is one atmospheric pressure or 100 k P a sigma V naught dash is nothing but effective vertical stress at the point where you are measuring this V s. So, suppose your raw V s data you have measured at 25 meter depth below the ground then the effective vertical stress at the 25 meter below the ground you need to compute and the unit of that must be k P a if you use the unit for P a as hundred k P a. So, remember that do not forget, that if you use this as 1, that is one atmospheric pressure then convert the unit of effective vertical stress also to atmospheric pressure you need.

That is unit of them must be same, so that the dimensional things are maintain that is whatever the unit of this raw V s in meter per second you have recorded the same unit will carry forward to your corrected value of shear wave velocity. To the power 0.25 this coefficient is used to apply the correction or to apply the reference standardization and that serve the correct value of V s is calculated from this test.

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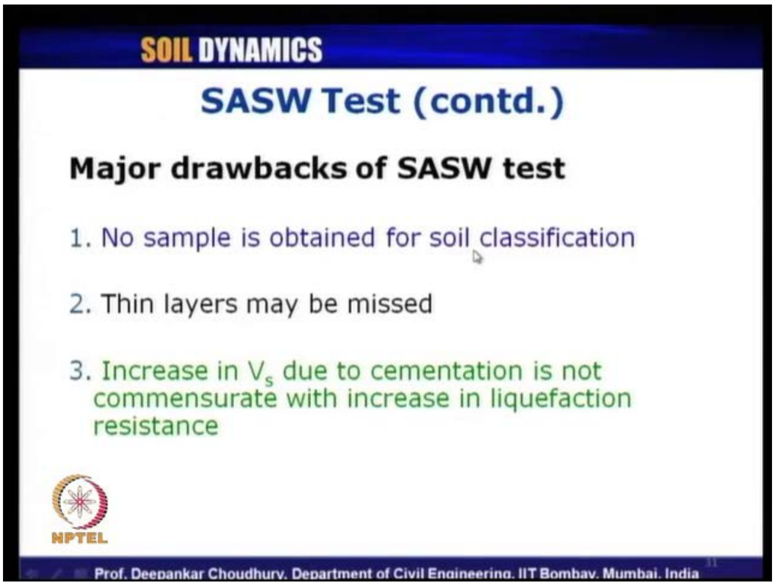

Now, when we are study any test we must know what is the major drawback of the test, because the major limitation of our any particular test unless we know we will blindly follow the results. So, that is why it is very, very important along with the characteristics of test methodologies and values we must know the limitation of the test which will help us to put our proper engineering judgment for a kind of values, which we are getting recorded.

So, let us look at it what are the major drawbacks in this test no sample is obtained for soil classification. Because, as the test methodology we have described there is no scope that we can get a soil sample for this test. So, to avoid this limitation or to avoid this drawbacks what one should do when we doing the field test, simultaneously we should take out some sample from some bore hole to cross check. Whether yes the same soil material is existing at that particular layer where we have obtain the SASW that V s value or not if it is not a same soil here.

Then obviously, we can suspect some drastic change in the V s value recorded, so this is kind of a cross verification. Now, the second point is thin layers may be missed what I have told just few minutes back, if there is a sandwich layer between two major layers that thin layer may be missed and we may not get V s value for that thin layer. But, remember in case of damages due to dynamic load for example, say due to earthquake load may occur because of the presence of this thin layer, which we are not able to identify in this test.

So, how to overcome this drawback once again this taking a sample is a good option to identify if really there is some thin layer or not. Third limitation of this test is suppose we are getting continuous increase or sudden increase in V s value from our record of this SASW test it need not necessarily mean that it is providing as a very stiff or good soil material which in turns mean that their liquefaction resistance. We will discuss this soon in the course of our study, what a liquefactions and how they are related to V s and so on.

So, at this point just note it down that increase in the shear wave velocity need not necessarily be due to the original soil property or stiffness of the soil it may be due to some cementation effect, external cementation effect. What is that as I have mentioned presence of some buried structure in the long back or in history, which we are not able to identify or which we do not know long, long back. Suppose some buried structure where there are some buried pipeline, buried utility lines, buried concrete piles, which are not in use and on ground surface which are not visible also.

So, sudden rise in V s value should not give you an idea that oh I got a very nice or very stiff soil layer and easily we can put and we easily we can recommend that this soil is not going to liquefy it may not be so. That sudden rise in V s value may be because of this some cementation effect due to the external material presence of external material not because of the parent soil material. So, remember this major drawbacks and then whenever you are using the value of V s for further interpretation of design or construction we have to be very, very careful.

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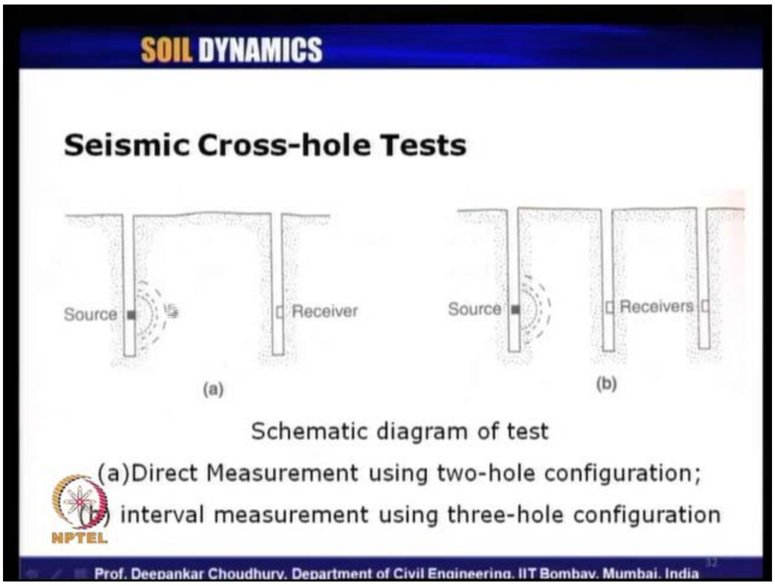

Some other types of direct test for determination of dynamic soil properties are seismic cross hole tests. So, seismic cross hole tests this is the schematic diagram how the direct measurement using two these are nothing but cross holes are nothing but similar to you create a bore hole. And within the bore hole you apply your source that is create the vibration and in another bore hole adjacent to it you put your receiver and record that travel of the waves. So, that is the direct measurement using two bore hole configuration.

And instead of two bore hole you can utilize multiple bore holes also interval measurement using three bore hole configuration. So, these are referred to as seismic cross hole test. Here, also the same principle of travelling the wave the direct wave, reflected wave etcetera can be adopted, because there will be clear time gap between the waves arriving at the receiver point.

And also this is a quite useful test, because whenever you go for field investigation or site investigation many a times we will have to do or we must do a bore hole. So, after doing the static test when the bore holes are means free you can utilize them for your dynamic test also by using this cross hole test.

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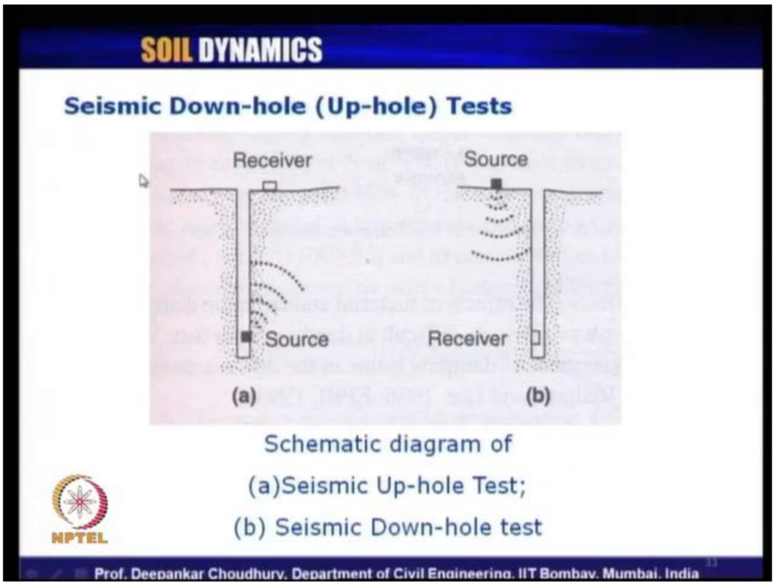

Another type of common test is seismic down hole test or seismic up hole test. So, what is up hole test look at figure a, when in that bore hole if you put the source of vibration inside the bore hole and keep your receiver on the ground surface that is called up hole test. And if it is the positions of source and receivers are vice versa that is look at figure b, in that case source is located that is where the vibration is created that is located on the ground surface. Whereas, your recording station or receiver point is located inside the bore hole then it is called seismic down hole test; and then all the methodology are like similar to travel time method.

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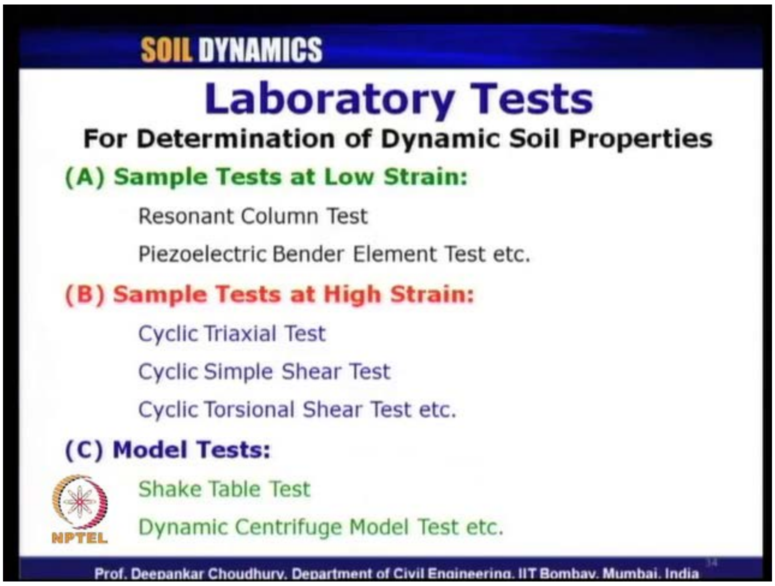

Now, coming to another major category of test which are laboratory test for determination of dynamic soil properties. So, common laboratory test for determination of dynamic soil properties some of them are can be classified in three major sub categories. One is sample tests at low strain condition that you apply your cyclic or dynamic strain at low strain level you conduct the test and you measure the strength of the soil.

So, within that category we have test like resonant column test piezoelectric bender element test, so these are sample test at low strain level. Then another category can be sample test at high strain level and within that sub classification we have different test like cyclic triaxial test, cyclic simple shear test, cyclic torsional shear test etcetera. And another category is model test, in model test the sub classification we can have shaking table test or shake table test and dynamic centrifuge model test. So, these are the common model test can be used to obtain the dynamic soil properties.

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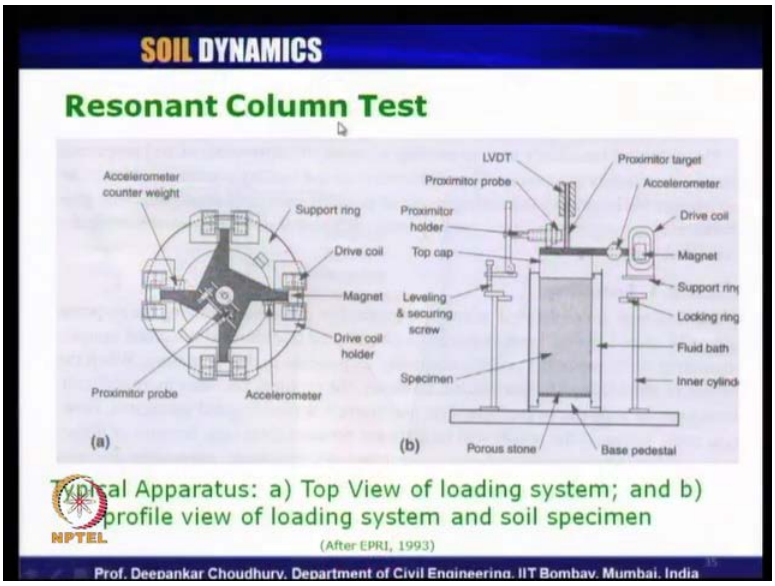

Now, coming to a small description of each of these test in the sample test where we are using the concept of small strain label test they are, the first one is resonant column test. This is the pictorial representation of the apparatus, which are used accelerometer counter weight supporting ring drive coil a magnet these are the accelerometer's here. So, this is the top view of the loading system and this is the cross sectional profile you can see LVDT proximitor probe, proximitor holder this is the top cap, then your soil sample or soil specimen, then fluid bath supporting ring, drive coil and here you provide the accelerometer.

So, the boundary condition for this resonant column test you can provide different boundary conditions, it can be fixed end here, free end here, fixed free you can provide fixed, fixed depending on the boundary condition of your soil specimen you need to use different equation to obtain the shear wave velocity from this test. So, from this test we can obtain the shear wave velocity from the length of the soil sample and from the resonant frequency. As the name suggest resonant column test what we apply we apply different frequency of vibration through this sample and we want it to resonant.

So, you plot that forced vibration of dynamic displacement versus different frequency input, you remember that half power bandwidth meter we have seen. So, the same concept is used here in resonant column test, you can resonant the soil specimen at you apply different frequency find out the resonant frequency and use that to obtain your shear wave velocity expression based on the boundary condition. Boundary condition is very important whether it is fixed, fixed or fixed free depending on that the fixed length of your soil column depends on.

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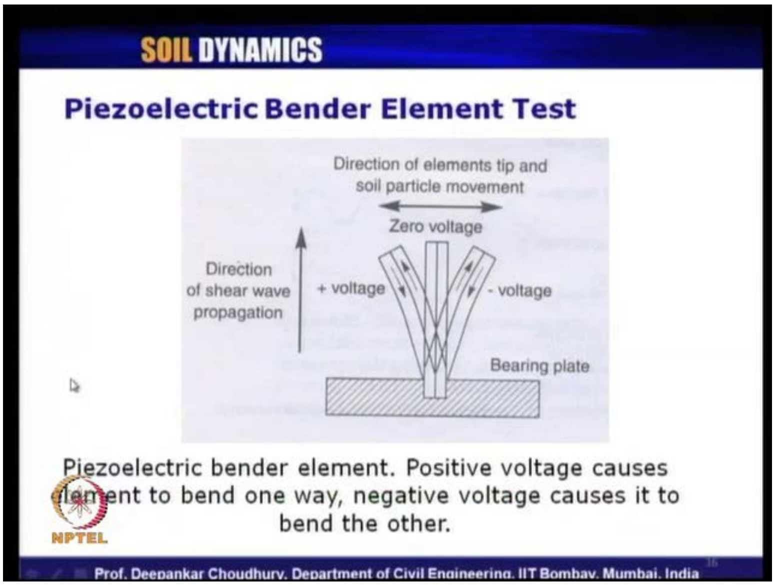

Coming to the another type of small strain level sample test is piezoelectric bender element test. Piezoelectric bender element test in this case this is the direction of shear wave propagation, one bearing plate here and if it is a zero voltage then it will be standing like this, if you change and apply voltage that is from positive to negative due to the propagation of the wire through the sample it will bend in this. So, like this using the bended elements the direction of elements tip and particle moves in this perpendicular direction to the direction of shear wave propagation. So, this way also it can give us the value of shear wave velocity and remember this is again at the small strain level. So, I will come in the application of this measurements for liquefaction. And other studies of dynamic soil properties in those cases I will mention the advantages and disadvantages of this test

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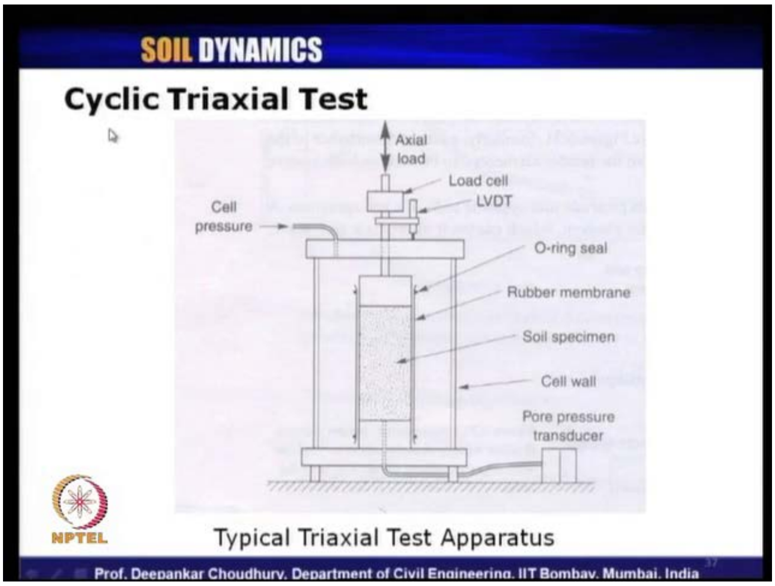

Coming to large strain dynamic test for soil cyclic triaxial test. So, this is a typical triaxial test apparatus, which all of you know we apply cell pressure this is o ring rubber membrane here we have the soil specimen cell wall, this is the load cell and then LVDT. What is the major difference from the standard static triaxial test and cyclic triaxial test, the major difference is the deviatric stress what will apply in static test that is in one direction only of course, but in cyclic test it will be cyclic in nature like this. So, that is the major difference from our static triaxial test to cyclic triaxial test. And obviously, with respect to time you should record this application of your deviatric stress to the soil sample and then you can get the development of bore pressures and so on.

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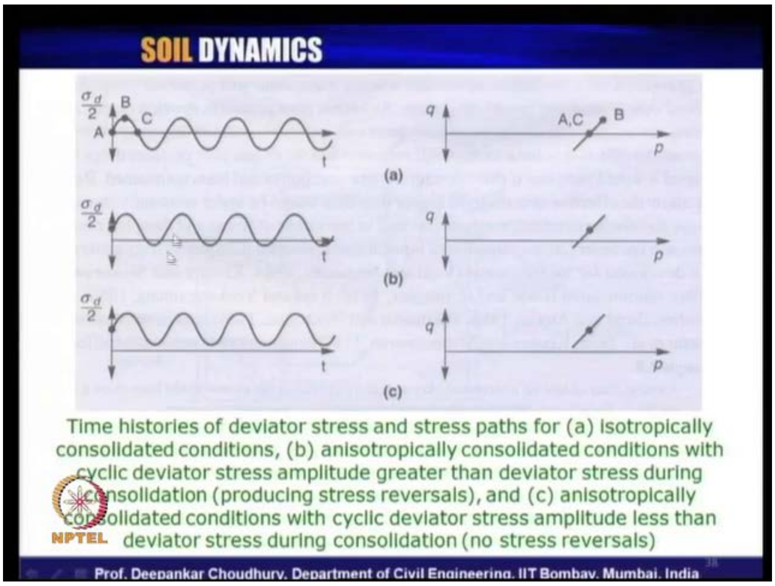

So, a kind of representation of the deviatric stress with respect to time, which where you are applying the cyclic load can follow this kind of pattern. Suppose if you are providing some harmonic load in this cyclic load, so this is the typical pattern how you can provide. So, what it says time histories of deviator stress and these are corresponding stress path. So, these are the input deviator stress and these are the stress path in the q p plot.

So, the first one this a it shows the test for isotropically consolidated condition, the second one shows anisotropically consolidated condition with cyclic deviator stress. Amplitude greater than deviator stress during the consolidation producing a stress reversal. So, that is why this case this applied deviatric stress is not with respect to your zero line, but it is with respect to some other positive line about this axis. Why because air after applying the deviatric stress for your consolidation then you are applying additional cyclic deviatric stress.

So, that is why it automatically gives give that representation of deviatric stress with respect to time like this and the corresponding stress path will be like this. And the third one the k c shows the case of an isotropically consolidated conditions with cyclic deviator stress amplitude less than deviator stress during consolidation. But, there is no stress reversal, there is no stress reversal that is why the entire thing is in this one side of the axis and corresponding stress path here.

I assume though this is not within the scope of this course you understand what is meant by isotropically consolidated test for a triaxial, under static condition. What is an isotropically consolidated and for static triaxial test we have three categories we know U U test C U test and C D test.

Now, within C U test and C D test we can have again two more sub classification I assume that all of you are aware of it. Those two sub classification are Isotropically Consolidated Undrain, that is ICU test, another is called Anisotropically Consolidated Undrain, so ACU test. Again C D test can be sub classified as isotropically consolidated drain test and another sub classification will be Anisotropically Consolidated ACD test. So, what are the major differences let me just give you the major principle or background of the study.

When we are doing the consolidation the first term is showing the consolidation as you know in the triaxial test whether you have consolidated the material and then applying the deviatric stress or not. So, during the consolidation process isotropic means you apply a cell pressure uniformly from all the directions, what is anisotropic then. Anisotropic in any particular direction you provide a larger or smaller cell pressure how you can generate that.

So, in one particular direction in your soil sample you provide another element that is another weight through using a kind of balance. You provide another extra load in the soil sample in horizontal direction by providing and anisotropy in a particular direction, that will give you the anisotropic condition, when you are doing the consolidation. So, those cases will arise or will give us the condition of anisotropically consolidated undrain test and anisotropically consolidated drain test.

These tests are not, so common, but in the case of dynamic soil test we should do this kind of test also that is anisotropic cyclic triaxial test. Because, unless we do the anisotropic test in one particular direction due to the anisotropy or the changes in the stresses or property, we are not able to identify how the behavior of soil sample is going to happen. Because, it is not necessary that earthquake or any dynamic load with it is arising it will uniformly act around the periphery of your soil sample it can be in any particular direction. So, that may create the condition of anisotropic, so remember these things it is not. So, common in your static test, but in dynamic or cyclic triaxial test, an isotropic test should be conducted.

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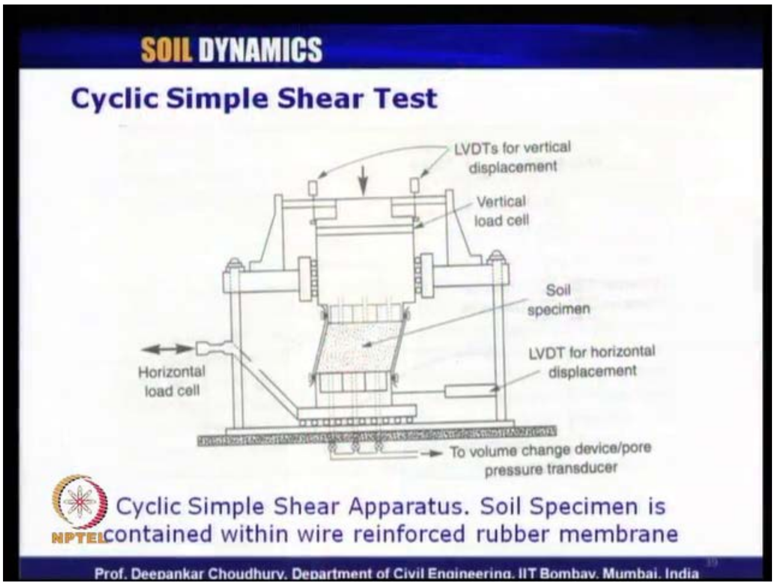

Now, coming to another type of large strain test cyclic simple shear test, in this case the same direct shear test in static test whatever we use the same concept and same apparatus is used. The major difference is this one, when we apply the shearing load in the static test for a constant value of normal load we apply it in one direction only. So, that the soil plate that get sheared right the soil sample for a under a constant normal load in this case under that same constant normal load we apply a cyclic horizontal load or cyclic shearing load. So, that is the major difference between a static simple shear test and cyclic simple shear test.

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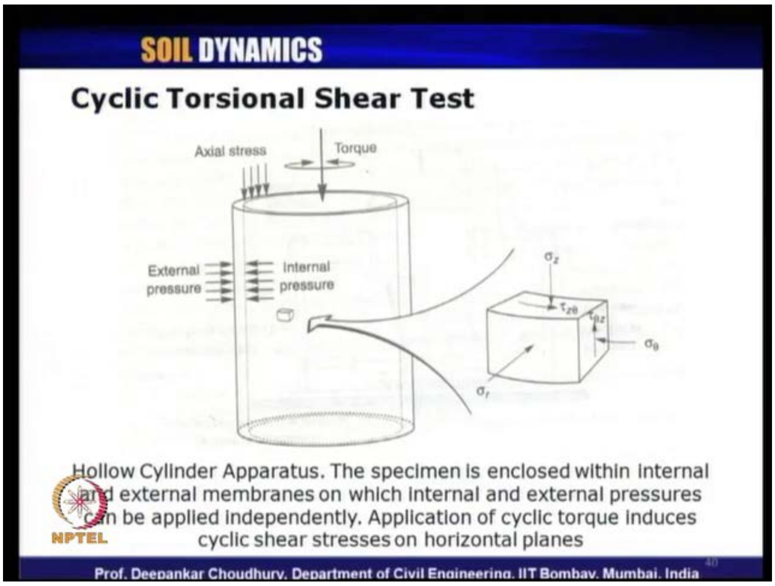

Then another type of large strain test is cyclic torsional shear test what we do in this case suppose if we have a angular cylindrical or hollow cylindrical apparatus like this. So, we apply the axial stresses provide a torque in the soil specimen, then internal pressure and external pressure that get generated within the soil sample and torque is applied. So, these are the stress conditions from which we can find out the dynamic soil properties.

So, this test whatever the shear versus normal stress or shear stress versus shear strain profile, what we are getting from this test we will see soon in our lecture. Coming to another major category of test in laboratory or model test now within model test as I have already mention two commonly used model tests are shake table test and dynamic centrifuge test.

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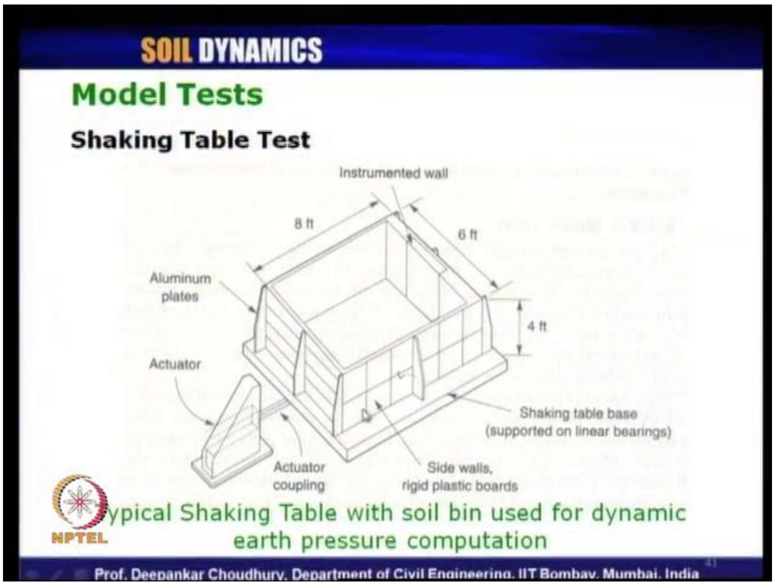

So, let us look at here shaking table test this is a typical diagram of a shaking table test it is nothing but as the name suggests we have a table on top of it you have a peripheral boundary instrumented wall. Or whatever test you are going to do depending on that you create this boundary at different distances and suppose this picture is showing for a dynamic earth pressure computation test. So, there will be a retaining wall you field up soil at one side another side there will be a dredge level of the soil, you instrument that wall and what you do you then start shaking this table. So, as the name suggest there will be actuator it will be coupled to this it will start shaking this table.

And of course, this shaking table test can be of different directional that is one directional shake table test. Suppose if you have the actuator only in this direction then you are creating the shaking or vibration in this one direction only, if you are able to create in this direction also along with this, if you have an actuator in this direction as well you have bidirectional shaking table test. If you have another one to give the vertical one then you have three directional shaking table test.

Now, if you have the actuator to provide a rotational shaking also to your table in that case you can get torsional or rotational directional degrees of freedom also. So, the best shaking table test will be of the 3 dimensional in 6 degrees of freedom right, that is all three linear shaking you can provide that is 2 horizontal 1 vertical and all three rotational shaking also you can provide.

So, now in India we have several such advanced or very high equipped shaking table test for example, one at CPRI Bangalore, that is Central Power Research Institute these all under CSIR labs all are research institute. That CPRI Bangalore is having 6 degrees of freedom that what I have mentioned 3 horizontal and 3 rotational vibration you can create in that that type of shake table is available one can do experiment in that.

The other one is at SCRC Chennai, so S C R C Chennai along with collaboration with BARC they also got a 6 directional. They actually got two such shaking table test one a big size, another is small size with collaboration with BARC Mumbai they have created this testing facility. Other than that from several years there are several shaking table test have a level in various research institute as well as academic institute like IIT (( )) also having shaking table test IIC Bangalore is also having shaking table test. But, those are limited to only either unidirectional shaking horizontal only or bidirectional at most checking, so other directions are not available.

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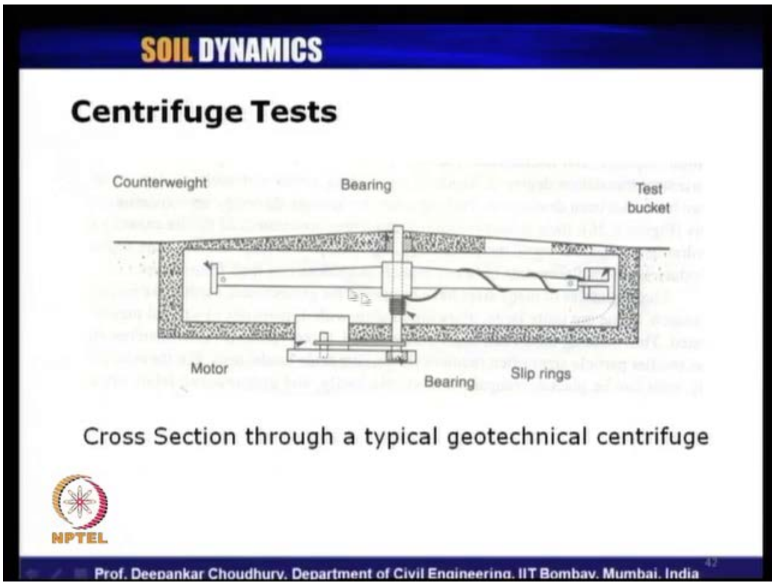

Now, another model test is centrifuge test for obtaining the dynamic soil properties. So, in centrifuge test this is the cross section of a typical geotechnical centrifuge we have bearing, slip rings, we have bucket test bucket here counter weights are provided above this point this keeps on rotating. And the centrifugal force is getting generated and that is how the principle is used to scale up the model dimension, which we use in our geotechnical engineering to a prototype or actual field dimensions. So, you remember or those of you were aware of the centrifuge testing facility.

Then know the drawbacks of 1 gravity 1 g test model test for our geotechnical engineering problems. Why because in structural engineering it is pretty common to do 1 gravity or 1 g model test that is you scale down your 10 storied actual building to a small model ten story building and do the test. You will get fairly accurate value of stresses displacement and so on, from the model test you apply the scaling loss etcetera.

Whereas, if you apply to do the same thing for geotechnical problems that is where you are handling with soil samples or problems, where suppose you have a soil slope you are earthen dam. What happens the concept of that scaling down from the actual prototype or field problem to a small model dimension is not giving you always the correct value of the stresses and displacement getting generated in model two prototype. Why because in this case the scaling loss are not that simple not that linear, scaling loss.

In this case many times we have the concept of pressure bulb generated. In case of suppose we want to find out the bearing capacity or settlement of footings. So, if we do the test of a actual foundation say raft foundation of 10 meter by 15 meter of raft size that if you scale down in the model say 1 meter by 1.5 meter to maintain the ratio and do the test with the soil media also you have change. Suppose in actual case we have below just below the raft about 20 meter depth one particular soil then below that another ten meter depth of another particular soil.

And if you scale it down with respect to prototyped model what you will do you will foot the 2 meter depth of that particular soil below the footing then again another one meter of next layer of soil, but when you are doing the test doing the bearing capacity failure test or finding out the settlement of the footing under some particular load. A pressure bulb getting generated in this small 1 gravity 1 g test in laboratory for the model test, the pressure bulb it may go through the other layers also in model test.

Whereas, it may need not be necessary for your actual prototype case, where you are getting sufficient 20 meter depth. So, these are the major cases also suppose if you want to test a pile, now scaling down a weak actual pile say of twenty meter length in prototype, you are scaling it down in the laboratory. Say to 1 meter depth and doing the test in a soil profile, again the same theory of scaling loss are not accurately used for geotechnical problems, because for piles also the zone of influence will come into picture which will not be commensurate with your model and prototype.

So, these are the basic disadvantages of using 1 gravity model test in geotechnical problems compared to other areas like structure engineering or other areas. So, that is why using this shaking table test for a dynamic soil properties or the behavior of dynamic say earth pressure or dynamic bearing capacity things like that are not always correct or not always giving us the true result. So, we have to be very, very careful to understand what are the limitations of the shaking table test for geotechnical engineering problems.

Though people worldwide they use it, but it is not giving us accurate result. And when we will get more accurate obviously, as bigger the size as we can use. So, if we can use actual prototype sizes for our testing in shaking table test, then obviously, yes it will give you the correct result. So, to avoid that kind of scaling effect for the geotechnical problem the best solution is to apply the geotechnical centrifuge facility where the stress conditions are first maintained.

Then all other dimensions are getting obtained, so that your small model can be scaled up to your actual prototype by using at high gravity level. So, it is something like you are doing the testing of your material in some other planet where you have say high value of g level. So, with this we have come to the end of today’s lecture, we will continue our lecture in the next class.