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ADVANCED GEOTECHNICAL ENGINEERING

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Lecture No. 58

Module – 7

Lecture – 9 on Geotechnical Physical Modelling

Welcome to lecture on advanced geotechnical engineering course in module 7 lecture 9 geotechnical physical modeling, so this is module 7 and lecture9 on geotechnical physical modeling.

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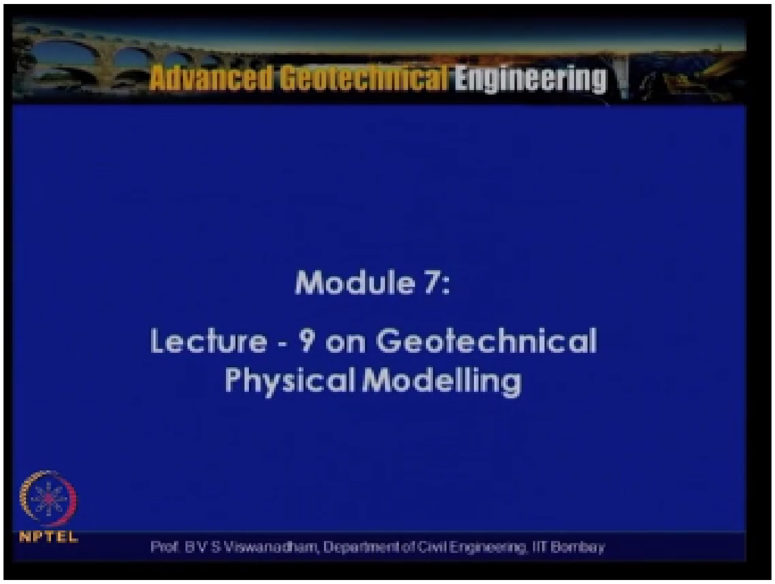

So in the previous lecture we have introduced ourselves to different types of shaking systems and then different types of containers which are required for you know the earthquake based experiments.

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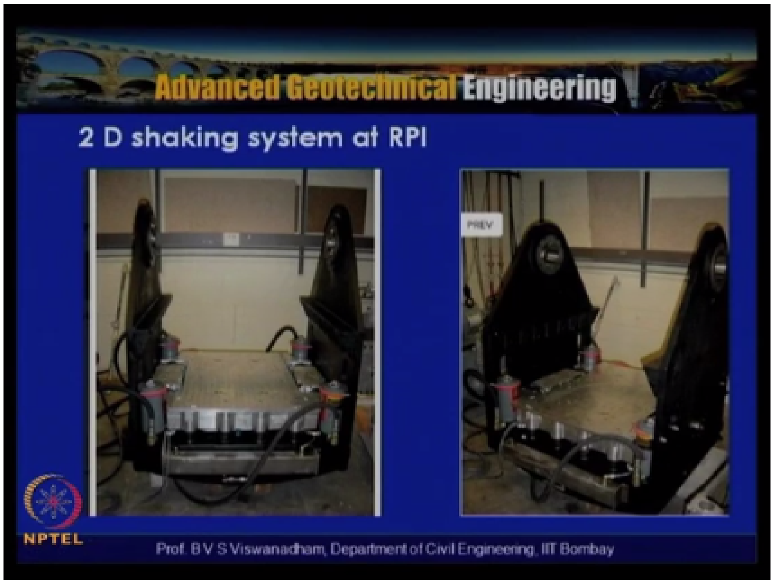

So this is the typical two-dimensional shaking system available at RPI and you art and wherein you can see that the swing basket package will come out of the chamber along with the earthquake actuator that means the earthquake actuator fitted in a soul basket and they use this for performing earthquake experiments and for the rest of the experiments they will use a different basket, so this particular slide shows the use of a you know earthquake actuator mounted on the swing basket.

You can see that this is the portion which is actually subjected to shaking in this direction and in this direction, so this is actually a typical two-dimensional shaking systems there are also some three dimensional shaking systems which are available in Japan and other countries wherein they can actually have shaking in X Direction y direction and Z direction.

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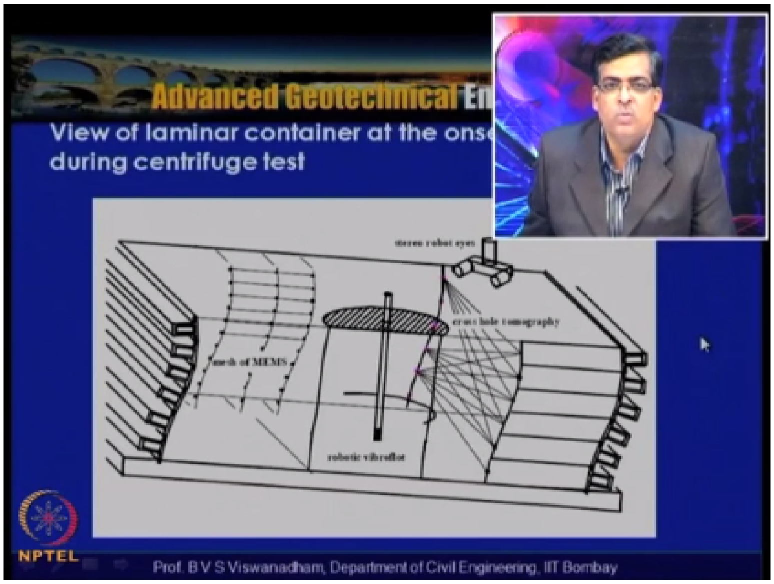

So this is the view of a laminar container which we have seen earlier and wherein the dynamic stiffness of the soil will be identical as that in the you know at the along the edges as well as within the soil, so in this way what will happen is there and the event of shaking the soil actually takes the form of the shape which is exerted by the you know by the body subjected to this motion, so here for example a pile subjected to you know the earthquake shaking is being studied so you can see that you know different types of instrumentations are actually place to monitor during the earthquake.

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So this is a typical laminar box at the schofield centrifuge Center wherein you can see that you have what different types of aluminum discs which are actually placed and contained in this direction as well as the, so for shaking in this direction and also they contained in this direction so this is you know said the distance is said depending upon the whatever the amplitude is allowed, so this is atypical model container in National University of Singapore.

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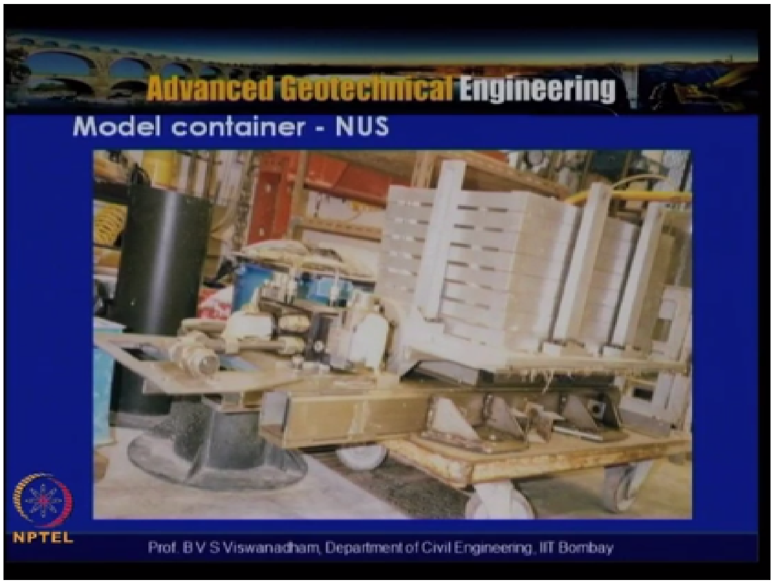

Small one dimensional shaking system and wherein we have the earthquake actuator.

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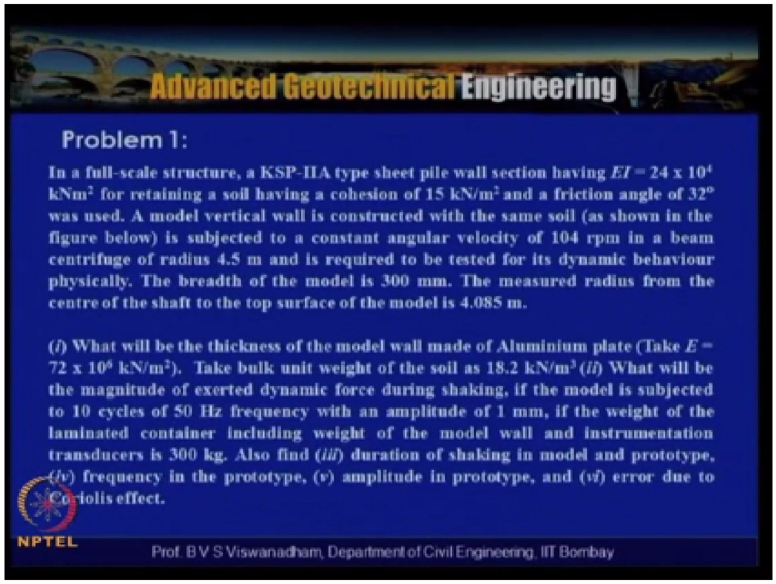

So after having seen you know the you know different avenues for inducing earthquake and then scaling considerations by using the knowledge which we have gained let us try to look into this problem, so in a full-scale structure a KSP to a type sheet pile wall section having II I that is the flexural rigidity EI = 24 into 10^4 KN/m2 returning a soil having a cohesion of 15KP and a friction angle of 30^0 was used a model vertical wall is constructed with the same soil and is subjected to constant angular velocity of one not for revolution per minute.

In a beams interviews of radius 4.5 meter and is required to be tested for it's dynamic behavior physically the breadth of the model is 300 mm and the measured radius from the center of the shaft to the top surface of the model is 4.0 85metres, now we are required to find out what will be the thickness of the model wall made of aluminum plate that is take E = 72 into 10^6 KN/m2 that means that 72 mega Pascal's and take unit weight of bulk unit weight of soil as18.2 km per meter cube.

And what will be the magnitude of Exeter dynamic force during shaking if the model is subjected to ten cycles of 50 cycles per second frequency with an amplitude of 1 mm if the weight of the laminated container including the weight of the model wall and instrumentation transducers in stress a 305 during of the shaking in the model and free property in the end duration of the shaking in the model and prototype and frequency in the prototype and also amplitude in prototype and errors you to coral is effect.

So here we have been asked a number of things so this is basically a sheet pile wall retaining wall problem, so what we have is that a model retaining wall is required to be selected so for that based on the scaling considerations which we have reduced earlier so EI in model / EA in prototype is equal to 1 by n 2 o 4, so by where n is equal to the scale factor n or gravity level in order to get that we know as we know the model rate model height and model height then what we can do is that we can actually calculate what is the radius up to the you know a point where the stresses in modern prototype are identical.

That is effective radius rg is equal to RT + hm by 3 and after having obtained that by using ng is equal to r you make a square what we can do is that you can calculate what is the RPM you know the RPM then you can calculate the N and by using the 10 value we can calculate what is the you know thickness of the plate because here ye of aluminum is not equivalent to a of you know this you know material which is actually used, so here the e is not specified but what we can do is that but that is the prototype a value was given.

So what we can do is that we can take this ei value and divide by N^4 2 and you will be able to get by knowing the e value of the model sheet pile wall you get the I value and based on that we can actually calculate by using BT^3 / 12 and by knowing the breadth of the model you can actually calculate what is the thickness of the aluminum sheet which is actually required for modeling you know a is equal to 24 into10^4 KN $m/^2$ after having obtained now determining the weight so by knowing the dimension by knowing the weight we can actually calculate what is the you know the model weight and based on that one can calculate.

What is the you know by knowing the acceleration by taking by picking up from the acceleration magnitude and once we assume that this is subjected to a sinusoidal motion and by multiplying with the mass and then acceleration you will get the dynamic force and then you know by taking the 10 cycles of 50 Hayes frequency, so in the model what is the duration and amplitude has to be you know n times that of you know in the model so that you the details can be obtained and by picking from the velocity magnitude by calculating from the velocity magnitude and by knowing the V is equal to R ω R is known to us that is r is equal to rg ω is you know the RPM converted into radians per second.

We can actually calculate what is the model velocity so to view by V we can actually calculate the error due to you know Coriolis effect, so this is the problem basically it is a combination of you know the problem which is required combined with the you know even in static experiments also you know in order to model the sheet pile wall we have to follow these considerations and the problem.

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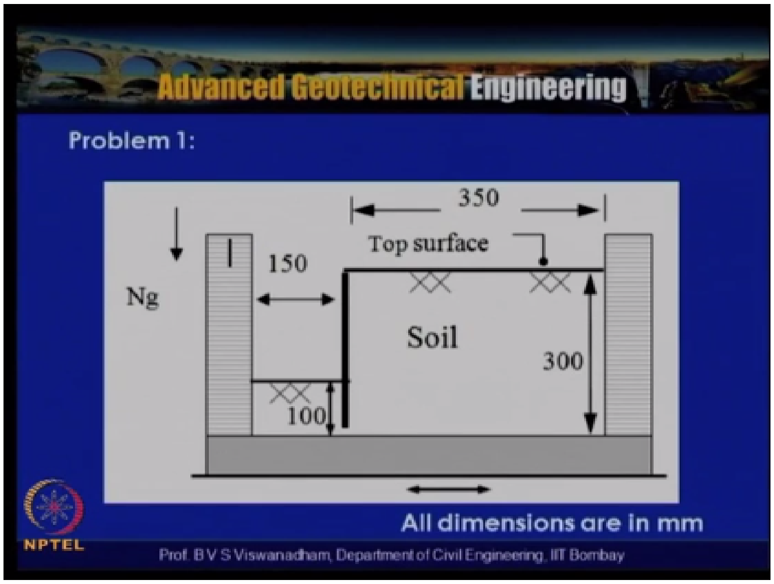

And the you know the problem for the figure for the problem one is actually shown here where you know the dimensions are all are in millimeters and this is a typical laminar container and this is 150 mm distance a murder depth is hundred mm and this height is 300 mm and breadth of the model is 3 and among and this length is 350 mm, so by knowing this the bulk unit weight of the soil we can actually calculate what is the gamma value and the container and other assets value is given so entire mass is actually placed on the swing basket so we can calculate what is the this dynamic force component so our another important aspect which you know we required to learn is that for any static cement or dynamic experiments instrumentation is very vital.

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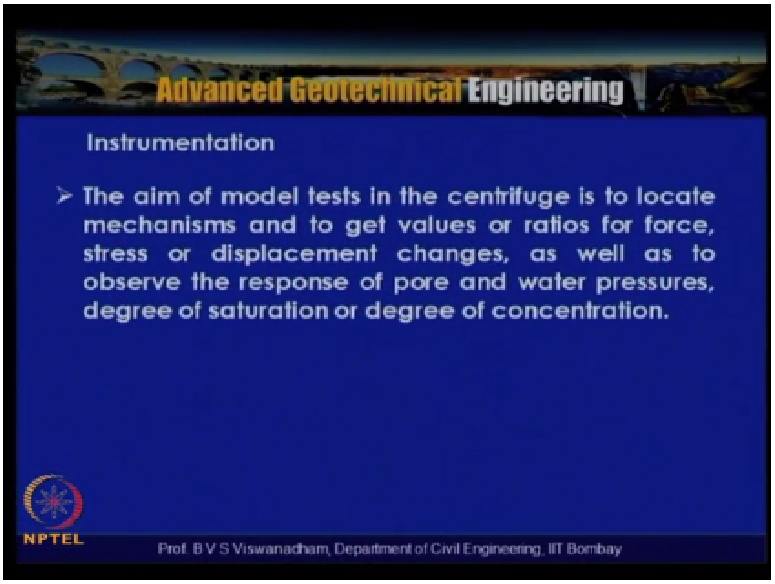

So the aim of any set a fuse model test basically to get the data like displacements water pressures or pore water pressures are accelerations and you know force changes and forces which are actually applied and stresses in the soil, so in order to get that we have to learn about the instrumentation, so the aim of the modern tests in this interview is used to locate mechanisms and to get values are ratios for force or stress or displacement changes as well as to observe the response of pore and water pressures degree of saturation degree of concentration.

So you know there are a number of types of transducers which are actually available for the center fewest domain wherein you know we have to use them to basically to get the displacements of loads and stresses and you know the accelerations etc. So with a name to you know retrieve the information and also you know capture the exact mechanism of failure before failure and a trade you and also to get the you know values or ratios for stress and or displacement changes and you know these you know instrumentation is vital.

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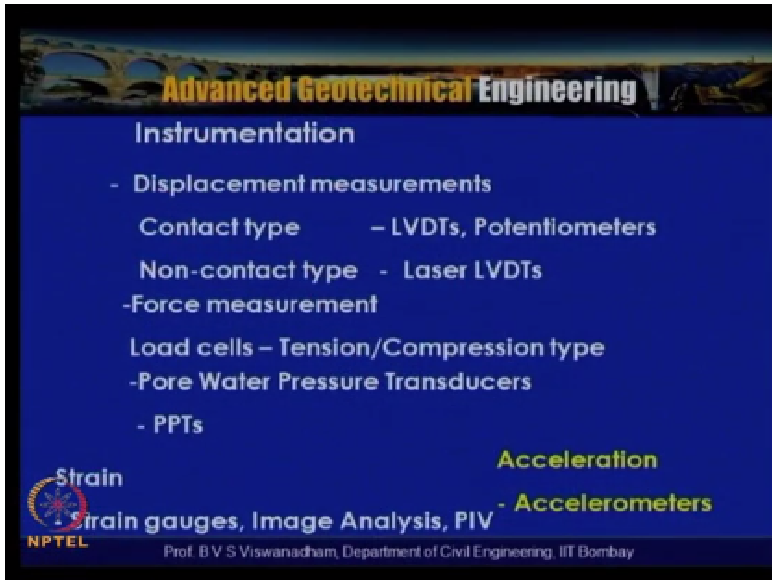

So in the instrumentation what we have primarily first is that contact type basically there are two types one is called a you know linearly variable linearly variable differential transformer the other one is called potentiometers these are contact types and their contact with the model there are also some non contact type you know displacement measurement transistors are there they are called as lesser LEDs and they work on the principle of triangulation and the closer the small is the distance range then you know the resolution.

Will be very high and there are also some force pressure it is like if you are applying a load on the pile our load on the retaining wall then you know if you wanted to measure what is the force which is actually applied then you know we need to know measure through a load cell, so there are basically compression right load cells and tension compression type load cells wherein they can take both tension and compression and suppose if you are pulling a pile out of the soil then you know you have to measure the tensile force.

And if you are trying to apply the axial load on the pile then you have to apply the compressive force on the pipe and, so in between the load application actuator and the object this particular load cell has to be fitted and to be connected to a detection system for retrieval of the data and mostly and most widely used transducers are pore water pressure transducers PPTs we are in now if you wanted to measure the, so-called water pressures within the soil pore water pressures then these done through miniature type pore water pressure transducers and one important thing we have to notice is that incentive-based physical experiments because of you know the you know these a the transducers which are actually embedded in the soil.

Have to be miniature in size that means that they have to be as small as possible, so that they will not actually have influence on the and they will not actually act like a some reinforcement inclusion in the soil, in addition to that if you are actually trying to measure the stresses on the soil then there are also now the pressure sensors are available and they are all so now you know some pressure sensors that actually can be available now they are called as you know some foil type disposable pressure.

Sensors suppose if you are actually keeping below the base of the footing then you can actually measure the distribution of the base pressures on the soil at the onset of loading and then for measuring strains we have the string gauging technique and with advent of the optical data equation systems image analysis and very recently the particle image velocimetry which is you know being widely used in a centrifuge base modeling then we also have the accelerometers like there are two basic types one is called piezo electric accelerometer switch are widely used.

And the other ones are now very recently how come they are called mems-based you know accelerometers, so we will look into the details of you know different units in a in a brief way so here in this particular slide.

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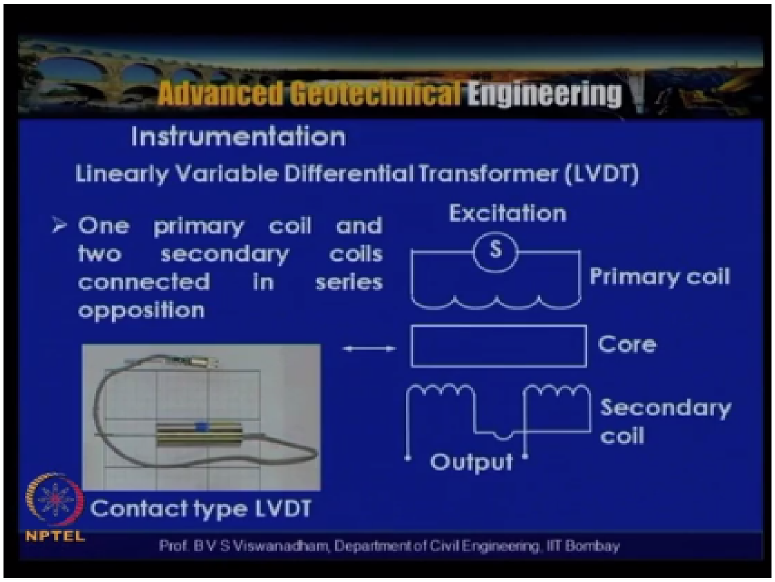

What you see is a linearly variable differential transformer LVDT and wherein you have a core and a primary coil and secondary coils, so one primary coil and two secondary coils are connected in series opposition so whenever the core moves here and that actually resistors as a change in voltage and that is actually measured as you know the voltage and this is a typical photograph of atypical already T and which actually has got contact type you know there is a this is the casein and this is called a core and to reduce the stresses.

And there will be you know small pads will be attached to this one so that the stresses on the soil will be reduced, so that they will not Pierce into the soil so this is a contact type LVDT and the important requirement to calibrate is that you know we need to calibrate for a given millimeter what is the you know all the all the you know the transducer which are actually you know you know placed on the in the model required to be calibrated.

So the abilities are calibrated by subjecting two different millimeters like 05 mm 10 mm 15mm and for each displacement you measure what is the voltage and by plotting you know the displacement induced versus the measured output you can actually get you know a linear line and within that range what we get is that linear distribution, so sometimes you actually have - 252 + 25 mm - 52 + 50 mm, so this is different depending upon the requirement of the travel the transducers can be selected and potentiometers are you know the which are nothing but to a spring which is you know subjected to the movement of the core J induces a change in voltage.

And so that is also used for some you know non accurate measurements, and laser Alou DT which is a non-contact type basically.

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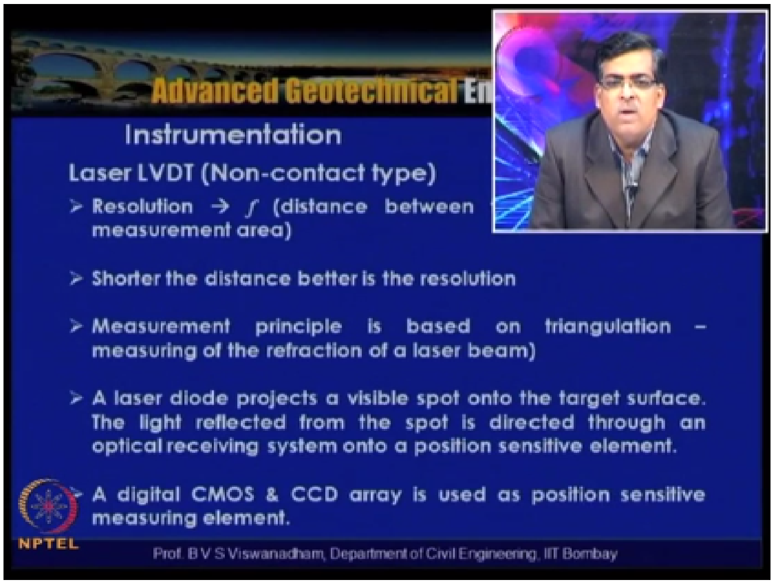

And the resolution is the function of distance between the transducer and measure measurement area and the shorter the distance better the resolution and the measurement principle is based on the triangulation and the measuring of the refraction of a large supreme, so what will happen is that you have a you know this razor transducer and which actually throws a you know a light on the subject or object, so what will happen is that the refraction is actually received in a same transition.

So with that what will happen is that the laser diode which is actually projects a visible spot on to the target space and the light reflected from this part is actually directed through an optical receiving system on to a position sensitive element, so with that what it does is that it measures the distance for example this laser due DT is fixed to a moving you know object then there is a possibility that you will be able to get you know the profile of the system during the test and the digital CMOS and ccd array is used to as a position sensitive measurement elements.

So the laser authorities are you know depending upon the resolution they actually have the accuracies which may be required for usage in the centrifuge model tests so this is atypical lesser distance sensor.

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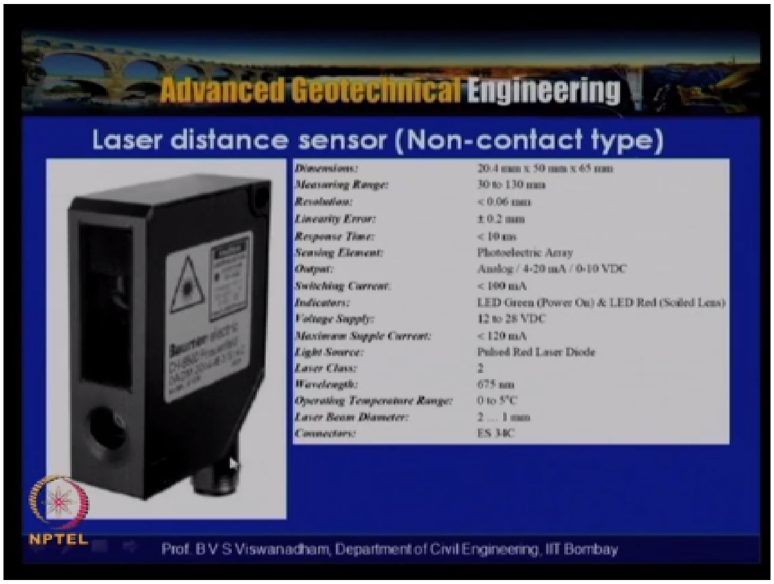

Non-contact type and so this is what actually is being shown at the through this actually the light is actually shown then this is a connected to the data acquisition system.

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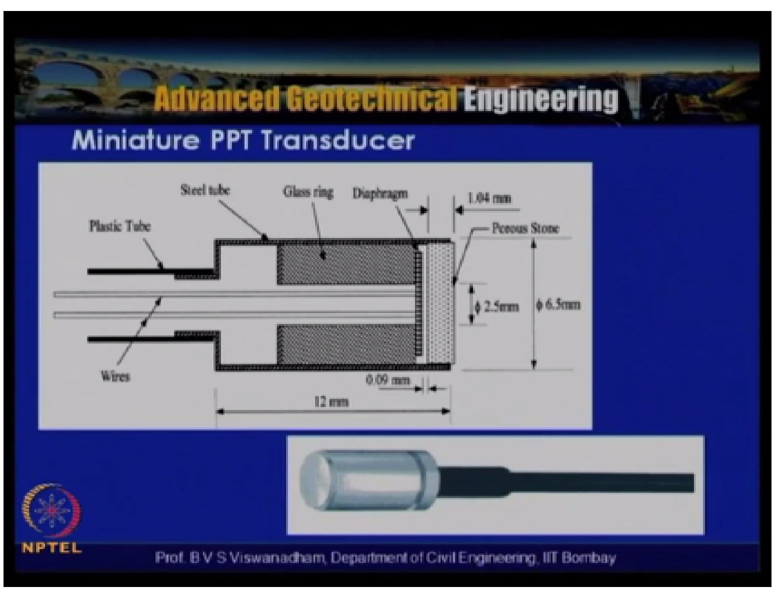

Now after having seen the displacement transducers then the miniature PPT transmitter which is called pore water pressure transmitters, so this is a typical pore water pressure transducer you can see that the dia meter is about 6.5 mm and length is about 12mm, so one can see that you know it has actually has got a diaphragm and onto this diaphragm there will be small miniature strain gauges will be pasted in a full scale of the full bridge of the winter beach still full bridge and so here the filter stone that is porous stone a ceramic stone has to be remained saturated always.

And so what happens is that in order to measure the positive pore water pressure water has to enter into this chamber between this diaphragm and you know the poorest on so through porous stone the water enters into it, so it measures the head of water or the height of pressure above its mid height, so this is actually taken as so as the water enters into this it exerts pressure on this diaphragm and this deflection of deflection of a diaphragm results in a change in the strain and that is recorded as a change in voltage.

So the pressure is this is calibrated again its induced pressure with change in voltage so when we plot the induced pressure without put in words we can actually get a line which is a straight line passing through horizon and with that what we can get is that you know pressure by volts that is a calibration factor for a particular transducers.

So these pore water pressure transducer available from 0 .5 / 2 up to 35 bar wherein they can actually measure that is about 3500 kilo Newton per meter square of pressure so this is the typical pore water pressure transducer is shown here and this is the you know protection for the sleeve here and then there is a cable which is actually running for the to the connector to the detection system.

So this is the casing of a stainless steel casing of a ppt which is actually shown here, and these are the typical load cells and which are used for tension compression these are after hpm.

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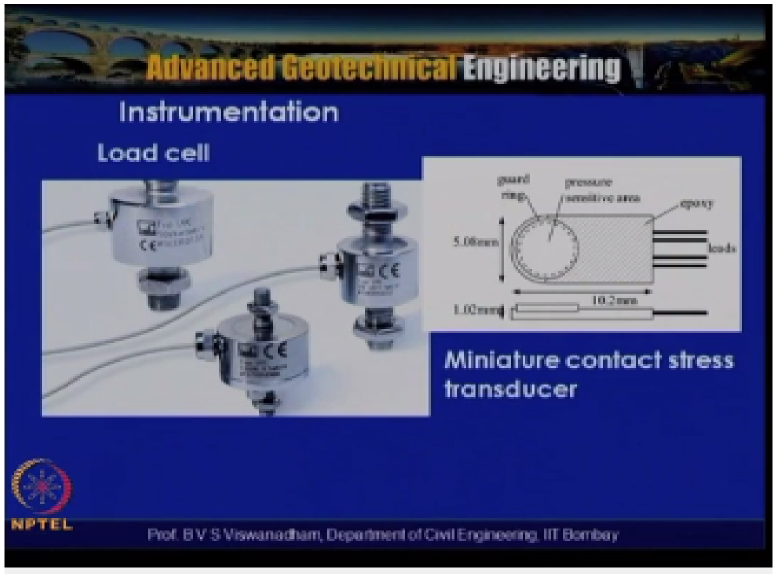

And these load cells are actually used for you know for measuring tension as well as compression, and we also have miniature contact stress transducers and they are of the size of a button basically when the load is applied on the pressure sensitive area. So the it measures in the results in a change in voltage, so this actually also leads to the development of a pressure versus you know pressure versus change in voltage. So in order to measures let us say later when you are actually trying to do a retaining wall problem we wanted to measure the pressure on the wall and done and this connect this concept can be used.

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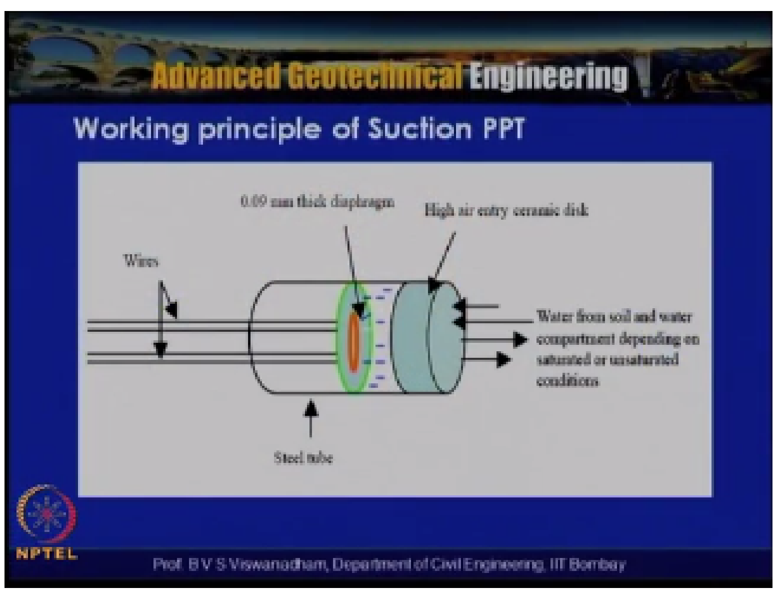

So then in sometimes when we were actually have doing the partially saturated soils we need to measure the suction pore water pressure, so in order to measure the suction power water pressure as the soil is not completely saturated. So here what will happen is then in the working principle of the suction pore water pressure is that here the diaphragm is actually filled with water and the ceramic disc is will be placed in position so here the difference is that water is actually thrown into the into the soil basically in when it is being thrown into the soil surrounding soil it is actually relieved of the deflection.

So that actually results in you know change in pressure, so water from the soil and water compartment depending upon the saturated unsettles will be considered. So this type of transistors can actually measure up to -100 to -200kilo Pascal's of suction pressure.

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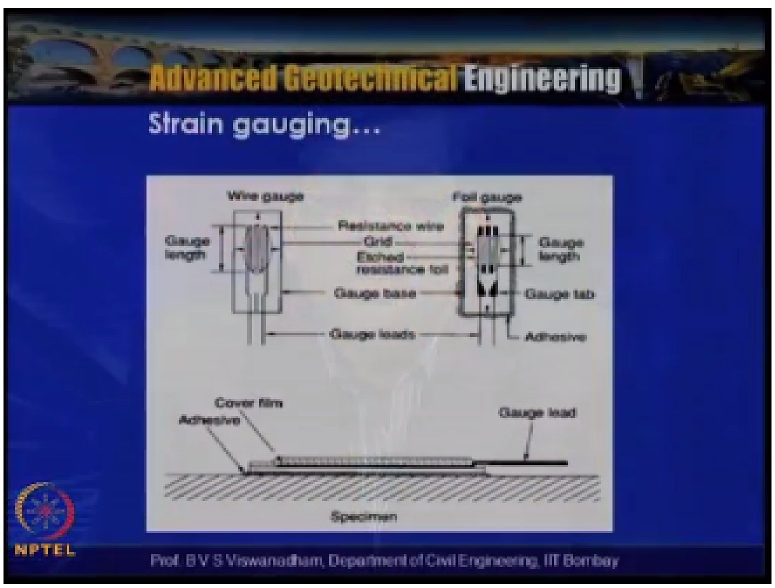

And these are the typical string is in strain gauges soil type strain gauges are shown and the gauge length is actually shown here and which is actually having you know they backing what is called as a very important when you are actually trying to do on the particular say you know stiff material or nonstick material depending upon that you have to have a backing and then you know you have what the copper micron connected to a lead cables and that any change in the length is actually given as the change in strain.

So that is actually calculated as you know these you know the strains in particularly for example in model sheet pile wall or any geo grid layer if you wanted to measure you know then you have to have a suitable strain gauges which should be pasted along with a suitable backing material.

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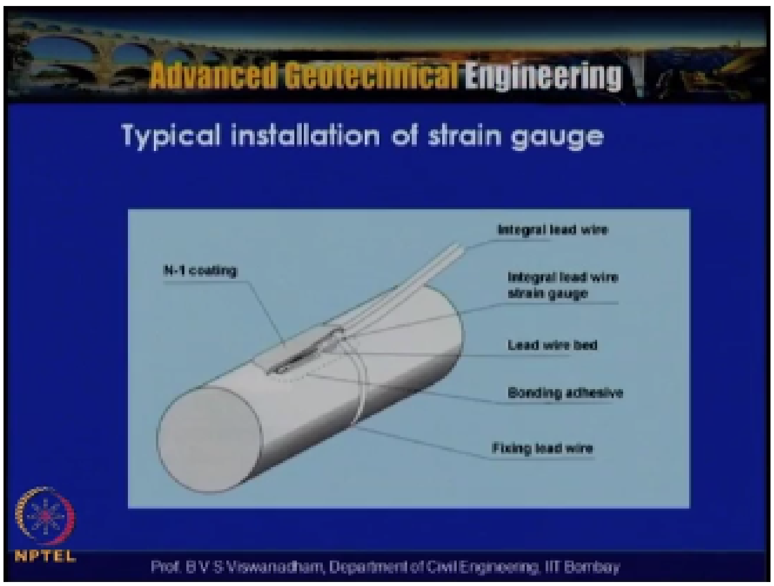

So this is the typical installation of a strain gauge on a pile and for some convenience to avoid some roughness one can actually also take the leads through the pipe is actually hollow can be taken through the through the pipe.

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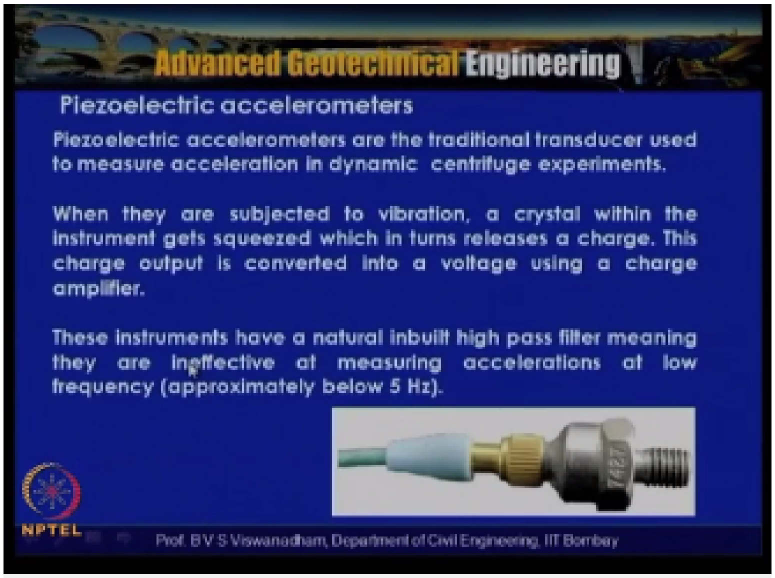

So these are the typical piezoelectric accelerometers, so piezoelectric accelerometers are the traditional transducers used to measure the acceleration to in dynamics centrifuge achievements, so when they are subjected to vibration a crystal within the instrument gets squeezed which in turn religious a charge, so this charger output is converted into voltage using a charge amplifier so these instruments have a natural inbuilt high-pass filter meaning that they are ineffective at measuring accelerations at low frequency is approximately below 5Hz.

So this piezoelectric accelerometers are the traditional transmitters used to measure acceleration dynamics and defense experiments and basically when they are used when they are subject to vibration a crystal within the instrument gets squeezed within it which in turn religious a charge. So this charger output is converted into a voltage using a charge amplifier, so this is also calibrated by a system wherein can induce - 1 g to + 1 g and within that we have what a linear you know variation.

So generally these accelerometers how calibration factors of the order of say some 7 g per volt 28g per volt then as I said earlier the MEMS based accelerometers that is micro electro mechanical system accelerometers.

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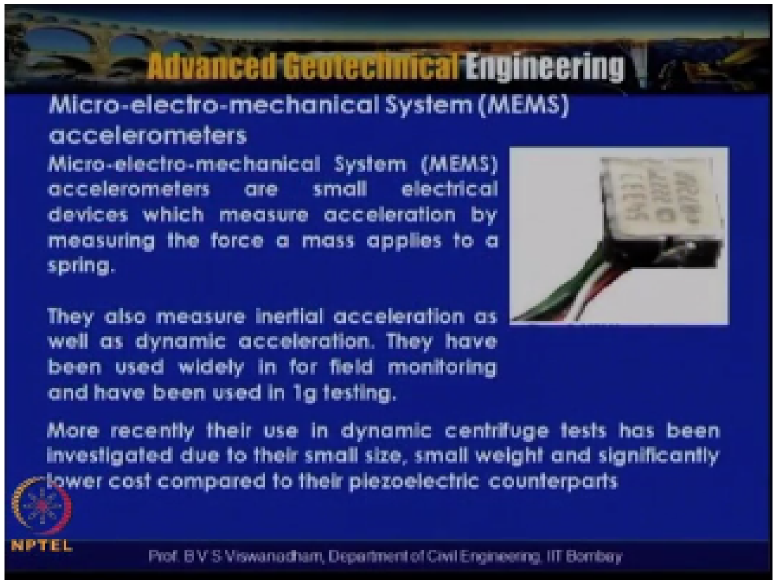

So these are you know MEMS accelerometers are small electrical devices they are basically useful for measuring acceleration by measuring the force a mass applies to your spring, so the MEMS-based accelerometers now they are there small electrical devices and they are actually used to measure the acceleration by measuring a force amass applies to a spring. So they also measure the inertial acceleration as well as the dynamic acceleration so they have been used widely for field monitoring and have been used for 1g testing.

So more recently they use in dynamics and few stress has been investigated due to their small size and the small weight and significantly low cost compared to their piezoelectric counterparts, so these dynamic in the dynamic self you stress the piezoelectric these MEMS-based accelerometers are being used because of their small size and small weight and significantly low cost compared to their piezoelectric counterparts, so this is a typical you know MEMS spacer accelerometer which is actually shown the principle is actually explained in the next slide.

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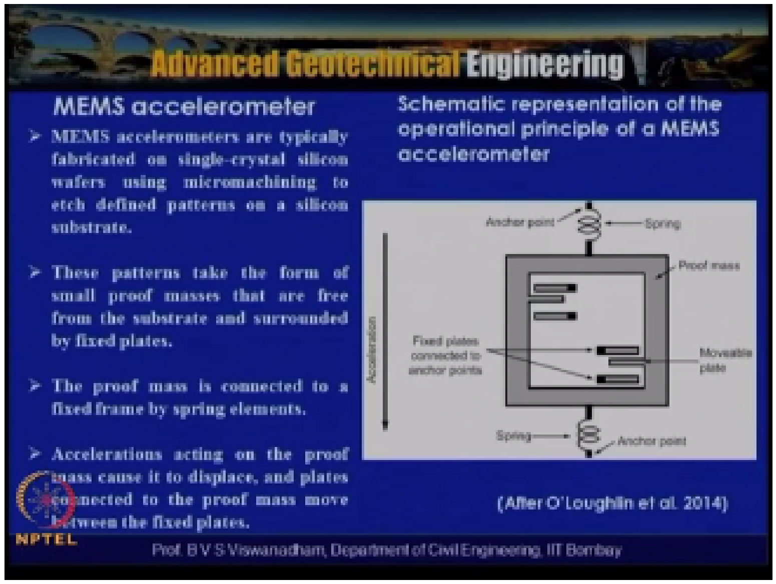

So here what we see is the schematic representation of the operating principle of a MEMS accelerometer and we can see that and this is the proof mass and there is a one anchor point where the spring is attached and another anchor point one spring is attached and there are fixed plates and then there is another moving plate, so these plates are attached it to you know the there they are the pixel plates and this plate is actually subjected to movement depending upon the application of the load so the MEMS accelerometers are typically fabricated with a on single crystal silicon wafers using micromachining 2h that defined patterns on a silicon substrate.

And these patterns take the form of a small proof mass which is actually shown here and that are free from the substrate and surrounded by fixed plates so these are the fixed plates and the proof mass is connected to fixed frame by spring elements, so acceleration acting, so this is the direction of acceleration acting on the proof mass is to dissipate and plates connected to the proof mass move between the fixed plates and this actually enables to measure the you know inertial as well as the dynamic acceleration.

So the in this particular slide working principle of MEMS- based accelerometers is actually given, so here the MEMS-based accelerometers actually have you know the mobile plates and pixel plates and when the proof mass is actually connected to a fix would bomb by spring elements and acceleration acting on the proof mass causes it to displace and the mobile plots plates will be subjected to you know vibration and the plates connect to the proof mass move between the fix will place and that results in the you know the you know lead for the change in voltages and which we actually measure as you know the accelerations.

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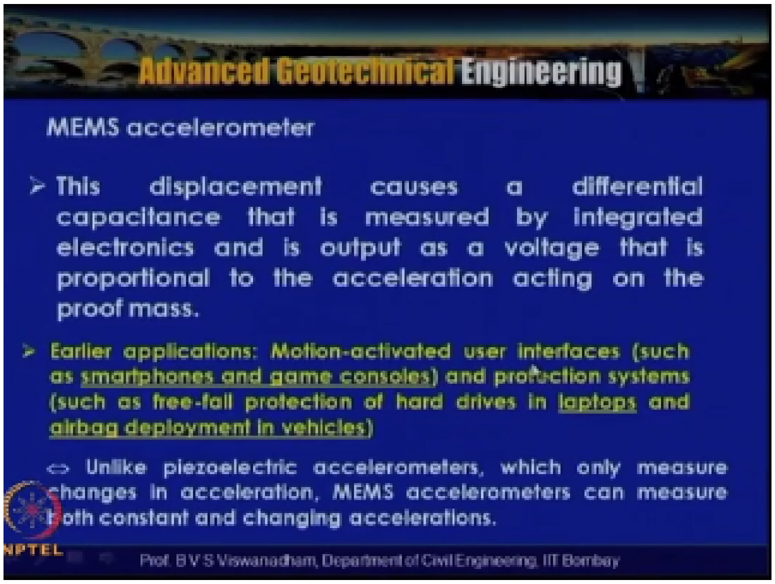

So the displacement causes a differential capacitance that is measured by the integrated electronics and is output as voltage that is proportional to acceleration acting on the proof mass so you know this is you know the basic you know principal and the applications earlier applications include motion activated user interface such as in smart phones and enter game consoles and protection systems such as free fall production of hard drives in laptops and airbag deployment in vehicles.

So motion activated user interfaces such as smart phones and game consoles and protection systems basically for you know of the hard drives in laptops and airbag deployments and vehicles, so these are fitted with nowadays with MEMS-based accelerometers unlike piezoelectric accelerometers which are only measure the changes in acceleration MEMS accelerometers can measure both constant and changing acceleration. So these MEMS accelerometers noted to have you know lot of potential and you know the usage of this can lead to measure either constant and changing accelerations and are at the onset of the seismic perk turbines particularly for dynamic centrifuge experiments.

So after having seen different sets of you know the required you know the instrumentation so then you know we can actually look into a different you know construction processes which are actually there, so before that let us look into we question ourselves after having discussed what is the requirement of physical model tests the you know we can answer this by considering the complex and non-linear stress and behavior of the soil.

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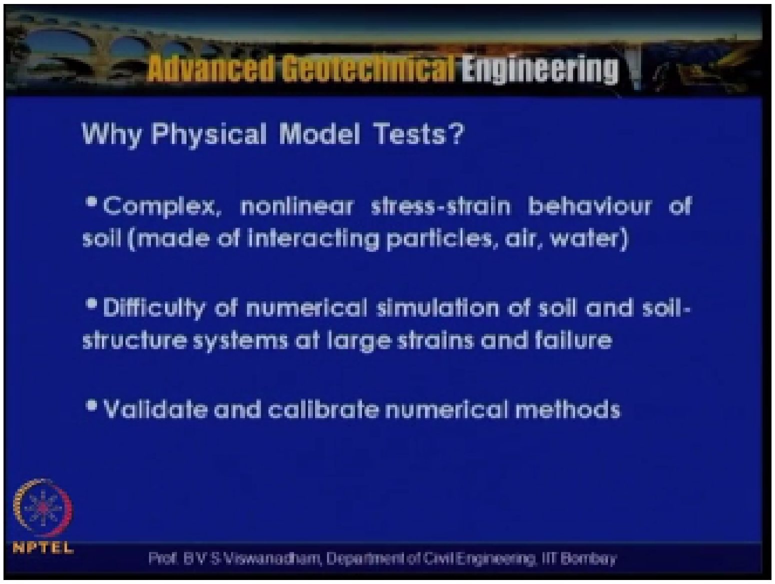

And made of interacting particles a water and different surfaces so this is one particular first reason that you know you require physical model tests a difficulty of numerical simulation of soil and soil structure systems at large strains and failure, so this is one thing where the numerical simulations have limitations and to be late and calibrate numerical methods like number of numerical methods which are actually available they are required to be very dated and it and also have the once we calibrate these numerical methods just there is a possibility that we will be able to you know use them with contents.

And then after having seen physical model tests we said that physical model tests can be that 1: 1 and 1: n and small scale then we also have said that this interview smarter tests are definitely superior to the you know the small-scale model test performed at 1g, so definitely by centrifuge model test in the sense that since small-scale model or models are cost effective.

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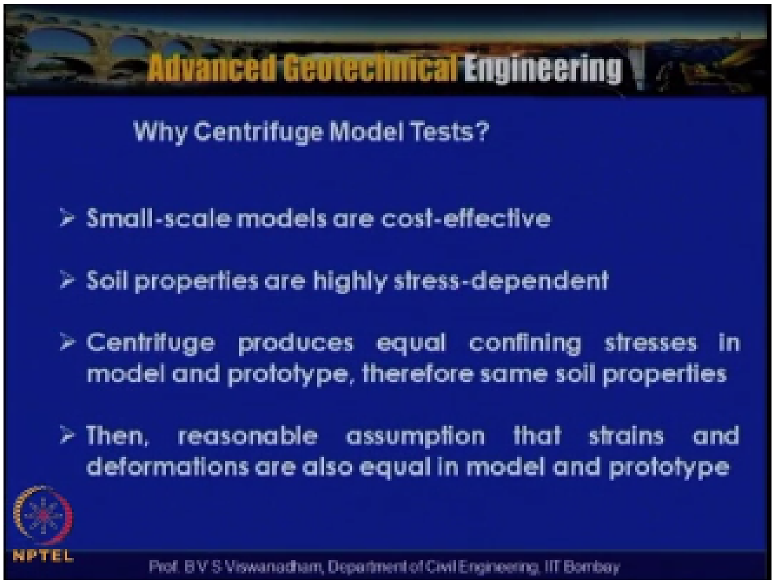

And the cost of centrifuge basically model tests are is very small compared to the cost of construction, so if you are able to do this in a before and then construct, so in this is the reason why the many countries actually adopt ATM that is called analyze test and construct ATC policy analyze test and construct policy, so the small scale models are cost effective and soil properties are highly stressed dependent so because of that you know this interface model is the one of the obvious reason and centrifuge produces equal confining stresses in model and prototype therefore same soil properties.

So we also have said that you know because of the simulation of the stresses σ V and σ H and because of that there is a same soil properties are there and so that is one advantage and then reasonable assumption that strains and deformations are also equal in model prototype and we also have seen that from the seepage and consolidation point of view the time required for completion of the particular event of this thing is $1 / n^2$ times smaller.

So that means that you know they can also give you know rapid results particularly when we are actually having some contaminated migration or polluted migration studies where they actually take years to that but you know this infuse more test studies will be possible for you to do it in a short time. Now let us look into is this particular example of you know effect of pile installation.

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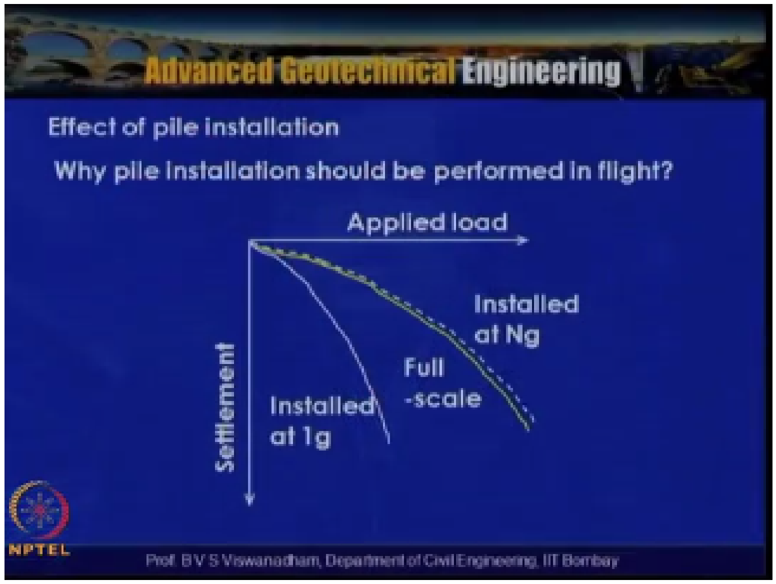

We actually have got different types of pile foundations like what we have is that precast driven piles and vodka sensitive files then what we do in the you know in the installing these piles in the field is that a precast driven pile is actually driven into the ground by driving the pipes into the soil. Now once we look into that that is the construction process we're in a pre cast one pile is the length of the embedment or cut off of a pile is actually selected based on the soil stratum which actually has been obtained from this whole investigation.

And if you are actually going for board cast in-situ pile so what has been done is that the width by auguring technique the hole is actually drilled and then the reinforcement case is actually placed and by using if it is under water by using the term a method the concreting is done. So that is so if you look into this when we have got pipe installation through precast pile the surrounding soil is actually subjected to additional confinement or compression and that results in a different behavior and the surrounding soil is pre loaded and then you know it actually has better k value.

But in case of bored cast in-situ pile because of the removal of the soil from the surrounding soil there is a possibility of release of the relief of the stresses which actually takes place. So because of that the k value or coefficient of x pressure will be less in case of barbed cast in-situ points. So if you are actually having you know a typical pile installed let us say through a driving into the soil then if you are actually having a case where in the field if you are actually measuring a if pile which is actually driven into the soil and measure the applied load versus settlement by using say pay pile load test.

So in that case we may get the profile what we get like this, so where virtually if you are actually installing the pile at normal gravity if you are installing the pilot normal gravity and you know test the pile at n gravities then you may get actually something like a applied load settlement behavior will be like this and which is drastically different from the one in the field, but if you are actually having a system where you have got a soil body and into which the pile is actually driven into the soil body by using certain type of a robotic actuator and once the pile is actually driven and if you actually test the pile then you know the applied load settlement behavior was found to be very close to that in the full scale.

So the reasons actually need to be understood between the soil stresses which are actually going to happen when the pile is actually installed at 1g and when it is actually taken to ng what will happen particularly in the form of a stress spots we can actually explain what is the you know the effect of piling installation and why you know pile installation should be performed in flight and that question cannot be answered by applying our you know knowledge of soil mechanics with the the stress spots.
So now let us say that if you have got a model pile installed at1g, so when you actually have a model pine installed at 1g so you actually have σ that is the stress.

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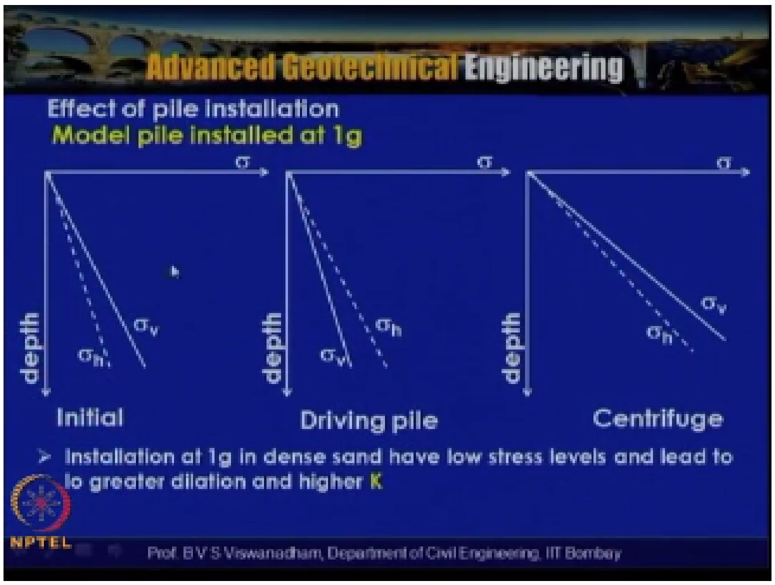

And the σ mean σ H or the you know if you take an element very close to the pile then σ V is the vertical stress and σ H is ours and stress, so because of the low stresses the stresses are low there is a σ v and then there is a σ h which is actually low stress which is actually acting on the pile surface. By driving pile at 1gmomentarilythe horizontal stresses are more than vertical stresses and thereafter by you know subjecting to high gravities and centrifuge the vertical stresses are more than horizontal stresses.

But when you take this into these centrifuges then what will happen is that the vertical stresses increases and pile is actually driven at 1g so the stress will remain same and it actually has picked up the Rays to the value whatever the σ V raises and corresponding to that it actually mobilizes. So installation at 1gin dense and because have the low stress levels in normal gravity and lead to the greater dilation and higher k value and so this actually lead to basically the soil surrounding the pile actually experiences the greater dilation which is actually different from what actually happens in you know in real practice.

When let us say that we have got a model pile installed at energy that is that you have soil mass which is initial at1g and when we take into these centrifuge the you know the soil is σ V that is vertical stress and the σ H the stresses have been magnified because of the NGO Norman and now when you are actually driving the pile then what will happen is that σ H will be more than σ V and then this results in because this is because of the increase in the increase in the you know the horizontal confinement because of the driver driving of the pile during flight.

So installation 10g increases the urgent distress and higher k value, so here and this particular process was found to be very close to you know if you are able to test the pile which is driven in the normal gravity test the pile driven at ng gravities then there is a possibility that the load settlement behavior will be close to that observed in the in the field. So from the stress path diagrams we can actually plot.

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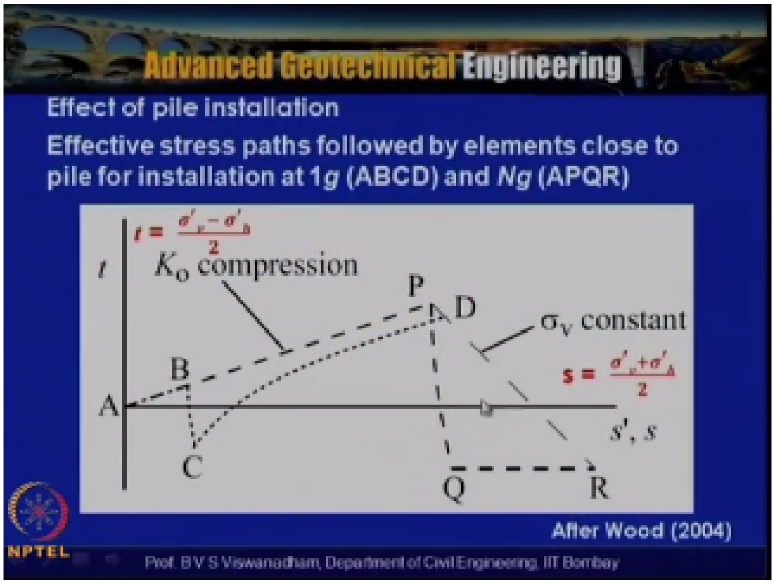

So here on the x-axis the S which is σ v' + σ h' / 2 is plotted sand t which is nothing but σ v' – σ h'/2 is plotted. So and here is actually shown and this is the k0 compression line and effective stress parts followed by elements close to the pile for installation at 1g we are in that it follows that a b c and d.

So the it follows this path like ABCD this is actually pile installed at 1g which is actually you know the different from the one actually happens in the field incase if you are actually having a pile installation at it actually goes like follows this compression light AP and then you know PQ and then QR okay so this a PQ R is the you know stress path which actually taken or obtained for a pile installed at NG.

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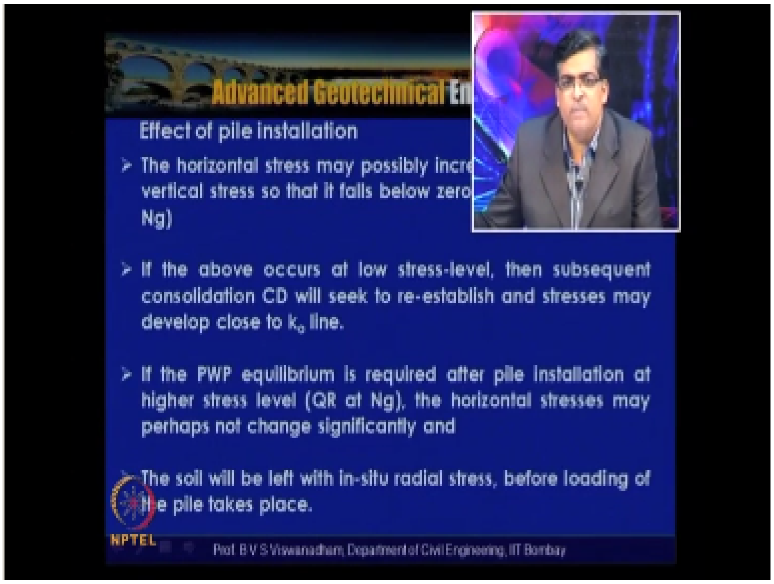

So let us explain this the horizontal stress may possibly increase even above the vertical stress so that it falls below zero bc at NG+ PQ at NQ that is that this horizontal stress increases because of the pile ride so it falls below zero and bc incase of 1NG installation and then PQ in case of NG installation if the above you know the variation occurs at low stress level then subsequent consolidation CD will seek to reestablish.

And stresses develop close to cannot line so the pore water pressure equilibrium is required after pipe installation at higher stress levels that is Q R at NG then the original stress may perhaps not change significantly and the soil will be left with Institute radial stress before loading of the pile takes place so here if the above variation occurs at low stress levels the subsequent consolidation CD will seek to reestablish.

And you know the stresses may develop close to k0 line that is a you know the stresses may develop close to the cannot land that is actually this is actually being shown here if the pore water pressure equilibrium is required after pile installation at higher stress level q at NG then horizontal stress mistresses may perhaps not change significantly and the soil will be left in the Institute registers before loading of the pile takes place.

So that means that here there might not be much change and you know and then you know the loading of the pile takes place in this direction so here once you look into this you know the if you are actually adopting you know this ABCD stress path and a peak you are you know the process if you look into this is actually distinctly different from at pile install it 1g and pile installed at energy they are different.

So because of that and this particular stress path is actually also analogous to the one is actually happens in the field so in away what actually understands is that in order to get the two results and the it is actually required now pi installation actually has to happen at NG and then subsequently load testing has to happen in order to have the results which are actually as close as to that in the field.

So the now let us after having looked into a particular problem wherein we have seen you know the typical problem wherein you have got installation of pile and then we said that installation of pilot NG and subsequent testing at NG is beneficial now let us also look we have the you know problem of construction process where it involves excavation in front of the wall.

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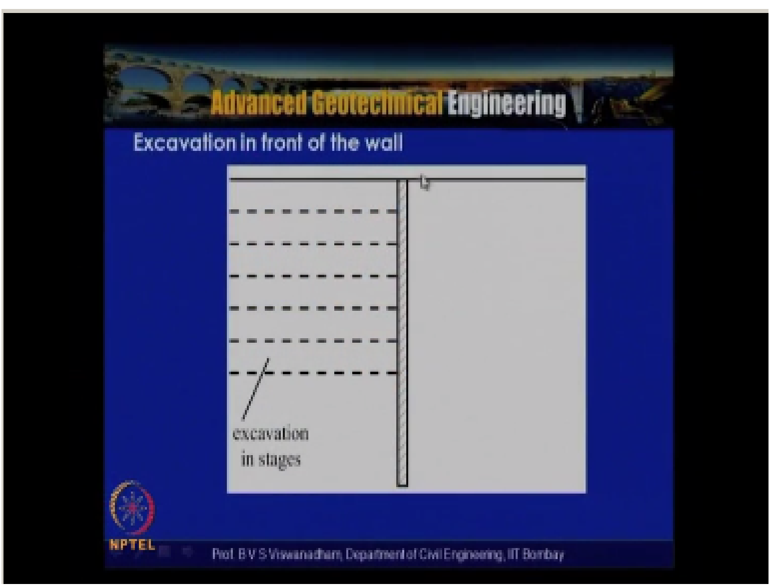

Suppose consider here you have a retaining wall and this is the soil which is actually backfilled nowadays you know large amounts of works are actually happening and wherein you know if you are having a particular foundation and objected to certain load what is the influence of excavation on the you know the building foundations that can be investigated and you know can lead to very interesting results.

So if you assume that this actuation actually takes place in stages like stage 1 stage 2 stage 3 stage 4 Stage 5 statistics excavations and this is the you can say that you know the dredge level are the bed level which is actually inspected so nowadays increase in you know urban structures particularly in urban areas these are actually becoming quite common and so it many times many situations which is something very difficult to model numerically.

So these are actually tackled very well by using this interface based physical experiments so in this particular sequence in the field sequence what will happen is that excavation actually happens in stages and so that the soil support is actually moved to the wall and the wall is actually subjected to a la you know ultimately subsequently the wall becomes unsupported.

So this can be modeled by using number of techniques many people are many investigators actually have used different types of earthquake different types of excavation simulators like some of the simulators the include is that we have a blade which actually gets punctured into the soil and then the bail the blade actually drives a takes away the soil mass and then drops into the certain area so that is one process.

And now there is also another method which is actually called is that they replace this area so the wall is actually placed and then they replace this area with a heavy fluid like zinc chloride and you know the Jing chloride concentration selected such a way that you know you actually have identical you know stresses in both sides of the wall.

So that the K not conditions can be simulated now but here this is jean-Claude being you know the being actually having a fluid the $K0=1$to one and particularly where our gentle stresses and vertical stresses will be equal and that leads to you know when you actually take a normal element soil element here the σV and σ H the σ H actually less than σV and this actually leads to you know you know σX and σ V they are not equal but in case if you are actually simulating excavation by using you know the heavy fluid.

Then you know the $\sigma H = \sigma B$ that actually can lead to some you know difference so to address this many investigator actually have used and to as an alternative to this actually there is also some plate support system will be put and then you know once you know reaching of certain gravity the plate support can move away and that also can lead to any differential movement so this is a you know the excavation inter of the fry excavation in front of the wall by using heavy fluid in back drained in stages.

So here also what will actually happen is that there will be a pore water pressure transition and you connect it to a wall and with a solid wall so once we wanted to decide to so many centimeters of fluid to be drain the solid wall will be on remotely and drained into some other compartment then so it they actually 1rasked by switching on and off we will be able to construct you know the excavation.

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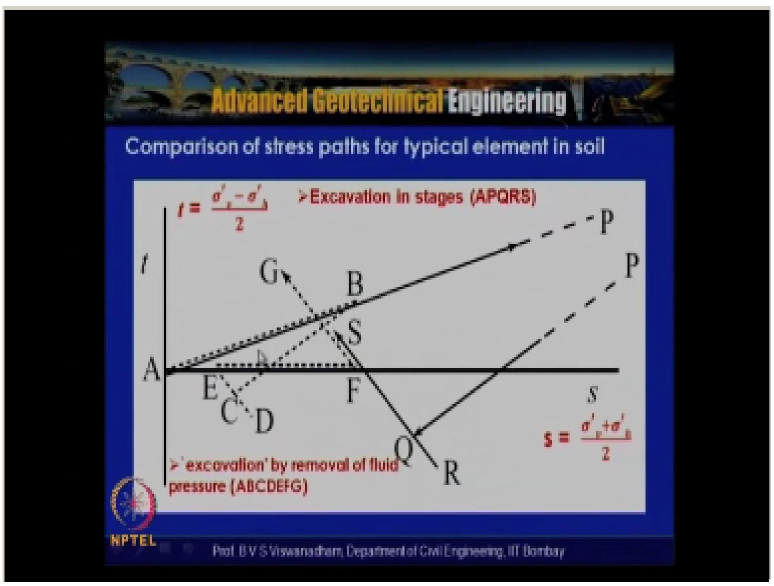

So this let us explain in terms of the stress paths again wherein we have got again s which is a you know Sigma V+ σ H / 2 and T it is σV - σ H / 2 so here excavation stages is a PQRS excavation by removal of the fluid pressure is that abcdefg so here excavation in stages if you are actually doing then which is actually close to the prototype what you can say is that a p and q a p q so these are actually you know they meet at a point here at a certain point here AP q and q r and r s.

So that is the you know the stress path which actually takes in the field but if you are actually removing the fluid then it actually takes like a B and then C D and E and FG that is this direction FG okay so you know if you look into this because of the stress dissimilarity this actually leads to the difference between the excavation through fluid as well as excavation stages the stress spots are actually different one need to note down.

That the excretion stages in a PQRS what is actually if you has done through a proper excavation simulator and that stimulates you know a system which is close to that in the field but if we are simulating equation variable of the heavy fluid then you know the stress path is distinctly different that we have to make a note in this particular slide so let us dissect this excavation stages a PQRS excavation.

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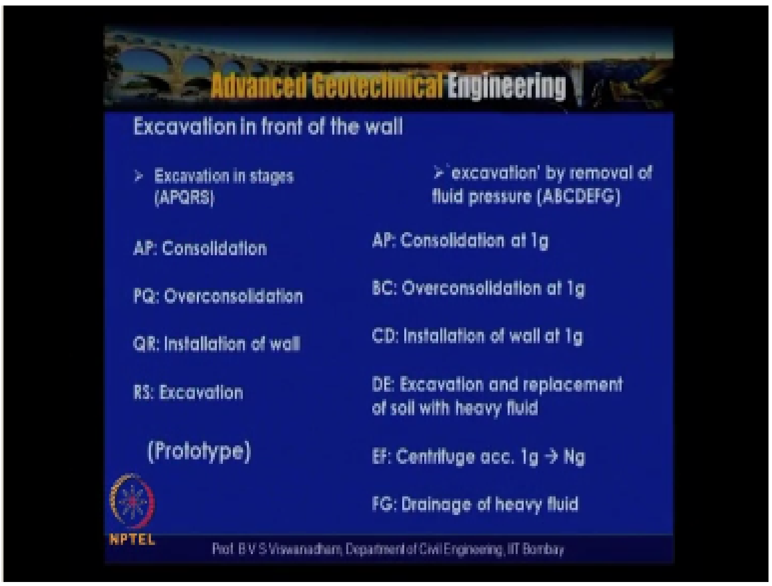

By removal of fluid pressure ABCD EFG so AP which is actually consolidation and PQ is war consolidation that is the removal of the load and QR installation of wall and RS is the excavation so if you look into this AP is consolidation that is along the compression line and then we have seen that PQ war consolidation so PQ is or consolidation release and a QR is what we said is that installation that is the driving of the wall and RS is the excavation that is the RS is the excavation.

So if you are actually pre installing the wall then they actually meet at same point okay and so this is a stress path which is you know obtained by using excavation stages and excavation by removal of the fluid fraction so AP the consolidation 1G and B C or consolidation at one G and C D is the Anna installation of wall atone G that means that here CD the wall is actually driven into the soil mass atone G say in a clay when it is driven at one G.

So at low stress levels kindly note here then de is the excavation replaced with the soil with heavy fluid that is de is nothing but excavation you know and replacement within heavy fluid and then subsequently where you have what EF the centrifugal acceleration changes from 1 g 2 NG that is seduced acceleration changes from 1 g 2 NG so there is an increase in the stress okay then FGM is the excavation.

The draining of the fluid so here the stress paths are actually distinctly different and the excavation stages if you are actually properly doing through a proper excavation simulator then we get very close to the what actually happens in the field is a PQRS in the excavation by the removal of the fluid pressure that is actually ABCDEFG this is actually is obtained by you know in the field in the in the model by draining the fluid pressure.

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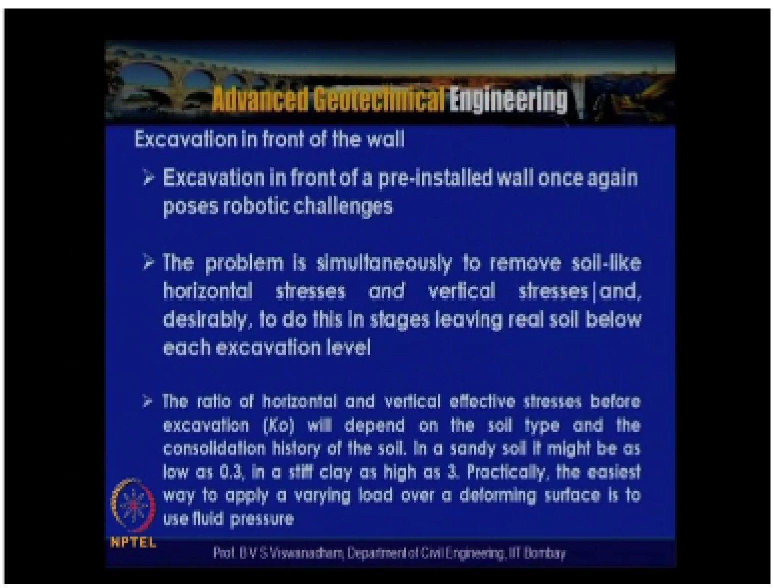

So for the excavation in front of the wall basically you for a preinstalled wall once again this actually poses robotic challenges and the problem is some it you know the simultaneous removal of soil like horizontal stresses and vertical stresses and desirably to do this in stages leaving real soil below each excavation level that is actually the requirement.

And the ratio of the Argentine vertical effective stresses before excavation will depend upon the soil type and the consolidation history of the soil and basically in sandy soil it me it might be as low as point 3 in a stiff clay it can be as high as 3 that horizontal stress so practically the easiest way to applying varying load or a determining surface used to use the fluid pressure.

So this is you know particularly the you know the application which was actually used for applying the pressures initially and then withdrawing the pleasures by draining the plate.

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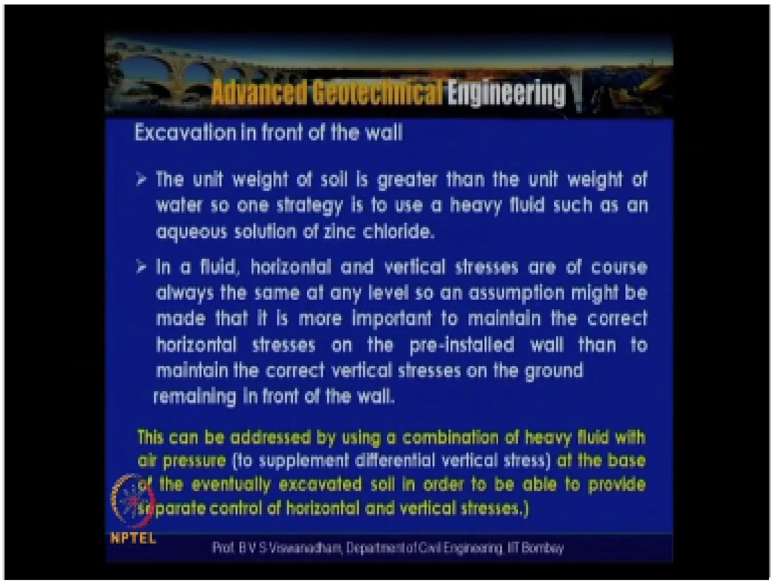

So the unit weight of the soil is actually greater than the unit weight of water so this strategy is to use a heavy fluid such a ways that aqueous solution of zinc chloride can be used so in a fluid if the horizontal and vertical stresses are of course always same in any level so an assumption might be made is more important to maintain the correct horizontal stresses on the preinstalled wall then to maintain the correct vertical stresses on the ground remaining in front of the wall.

So this problem has actually has been described because of the Pascal's law the stresses in horizontal material direction are same so this can be addressed by using a combination of heavy fluid with the air pressure this can be addressed by you seeing a combination of heavy fluid with a air pressure to supplement differential vertical stress at the base eventually excavated soil in order to able to provide the separate control of horizontal material stresses.

So what actually you know people have done particularly McNamara at all they have done is that they used the you know the heavy fluid but at the bottom you know there is actually you know they actually added you know the so-called air pressures very recently you know the work actually has been done at IIT Bombay is that combination of zinc chloride and you know the water draining has actual interrupted.

And this is actually also found to produce the identical stresses as that in the you know vertical stresses are actually stimulated to as the identical that in the model that means that here what actually has been explained is that by using a combination of heavy fluid and you know water by draining heavy fluid and water seriously.

So the weight of heavy fluid and weight of water such that you actually simulate σv like in the field and σ h like in the field say for example for a normally consolidated my h = 0 point five as copy and that those conditions can be simulated by usually by using this combination then there is no requirement of giving air pressure at the base of the container so one example which can be taken is that you know.

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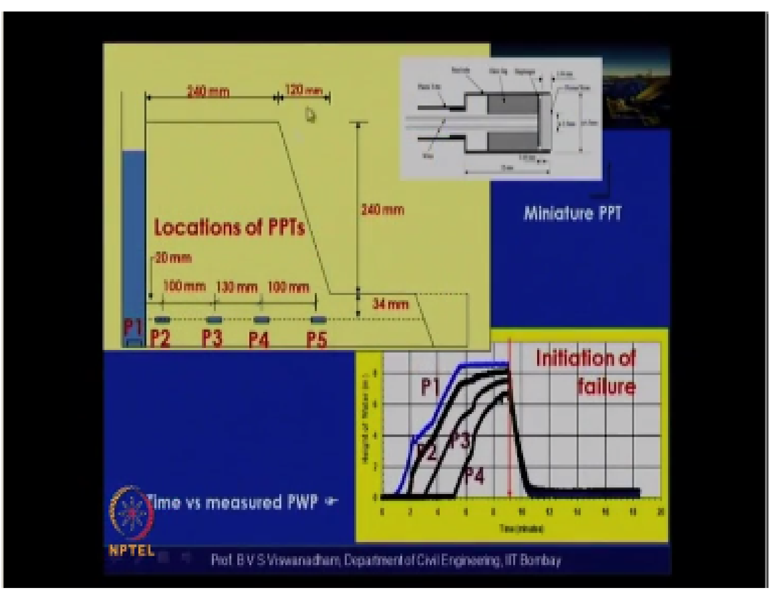

Suppose if you are actually having a particular slope and if you are having a pore water pressure transducers at five locations and if you measure the pore water pressure then you will get the reading like time versus pore water pressure like here this test was actually carried out at this data this figure which is actually shown is a test was carried out with 30 gravities.

So you can see that they you know 24centimeters of model you know 25centimeters of model actually has got this much height of water okay and these are the pore water pressure transmitters within this slope and this is at the toe you can see that the pore water pressure is low here.

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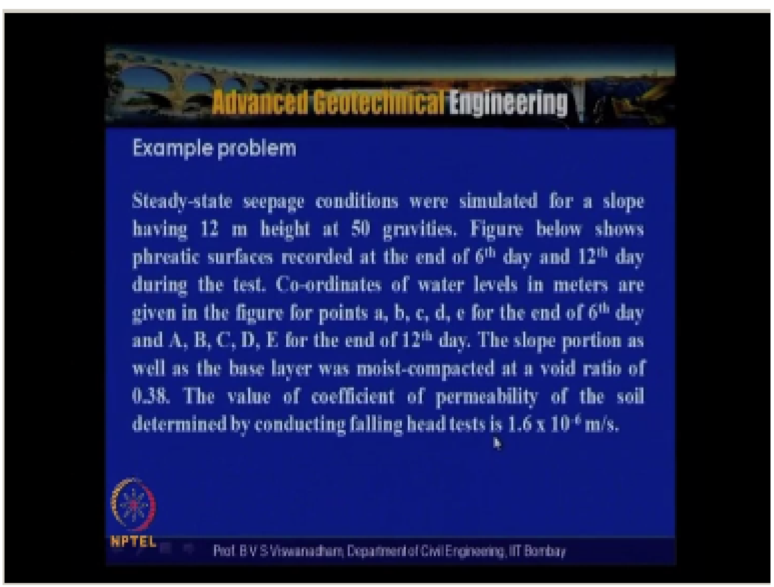

So this particular example problem basically consists of steady-state problem conditions were simulated for aslope having 12 meter height at 50gravities and figure below shows us the shows the you know pre attic surface are given and these are actually obtained from this interface model test and the slope portion as well as the base layer was moist compacted in void ratio 0.38 and the question the perimeter the soil is 1. 6. 10 $^{-6}$ meter per second.

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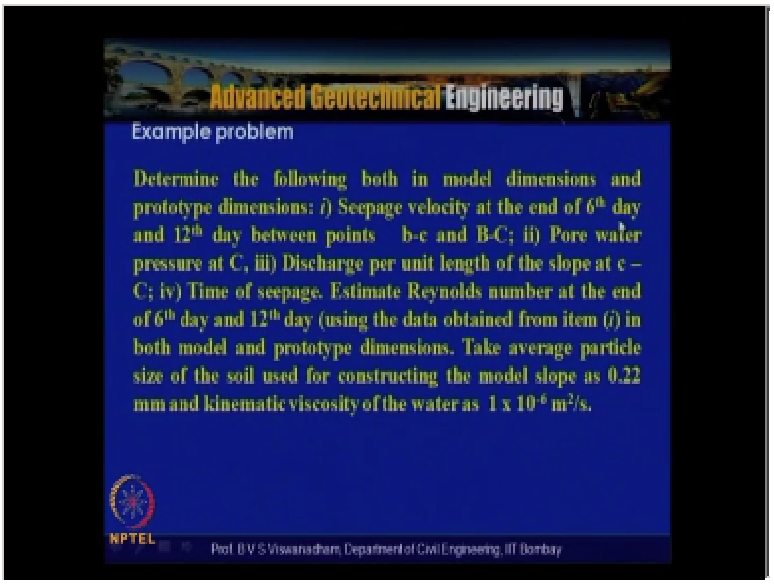

And what we need to do is that seepage velocity at the end of the 60-day and 12 today between points bc and bc that will be shown and pour water pressures and discharge per unit length of the slope at the C&C and time of seepage so average particle size is given as point 22 mm and kinematic viscosity the water is given as 1 cent a stroke that is 1 into 10^{-6} meter square per second.

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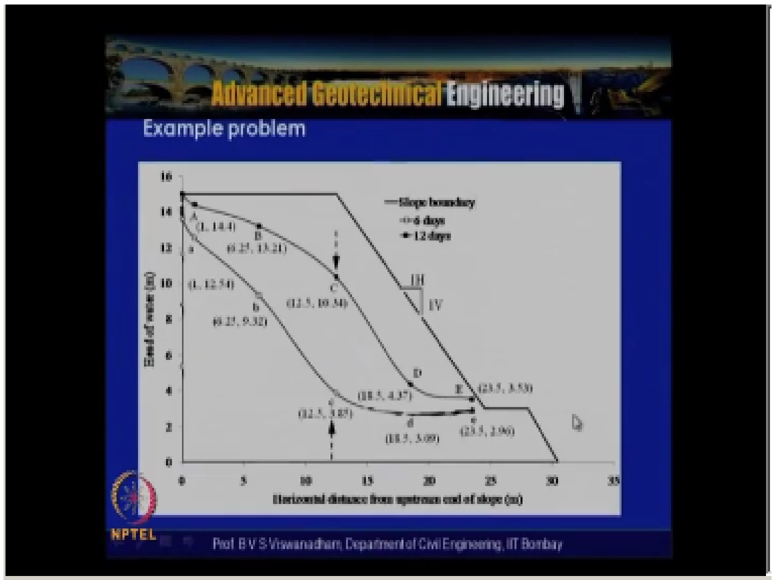

So this is the typical problem statement and the solution can be addressed by using this particular formula so if you want the velocity now we can actually between B and C and B and C that means that this is the periodic line 463 this is the periodic line for 12 today so what actually has prognosis from this direction.

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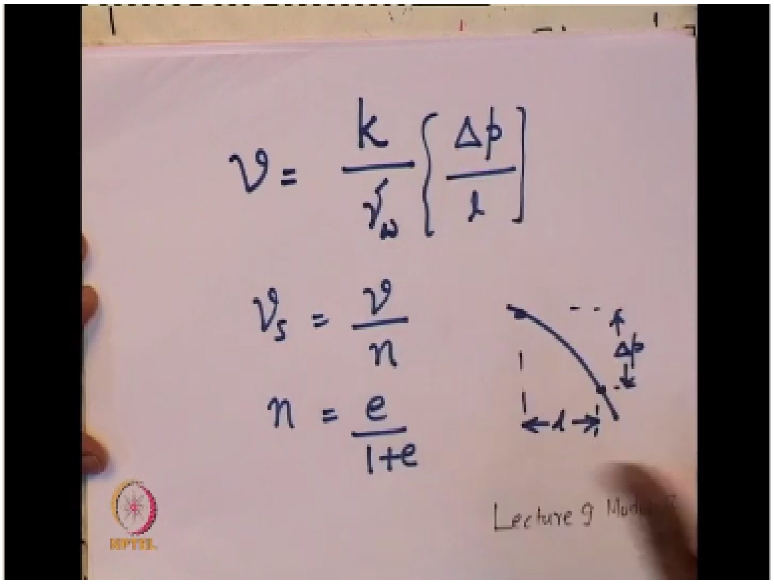

So by using this V = K /γ W K is the permeability of the soil that is 1.6^{-6}meter per meter cube second one point6 into 10^{-6} meter per second γ W that is 9.81 keen per meter cube Δ P that is you know this difference the pressure difference that is 6.25 is the horizontal coordinate13.2 one and 10.34 so this is about 3meter pressure difference or a horizontal distance of 6 meters.

So Δ P / L you get the velocity that is the discharge velocity now by knowing the porosity void ratio n = e / 1+ 1 e we can actually calculate what is the seepage velocity so seepage velocity at the sixth day and seepage velocity at the you know time of you know twelfth day can be found out and similarly you know by knowing the velocity you can also estimate what is the Reynolds number so by knowing the velocity you know by knowing the particle size effective particle size.

And taking the kinematic viscosity we can get Reynolds number and then we can check whether the Reynolds number is less than 14 allowable limit so what we have seen is that this particular problem statement and the these are the periodic surface which are actually measured through experiment so from the measured data how we can actually calculate you know basically the discharge velocity seepage velocities and pour water pressures at different points during the course of experiment during the course of the seepage can be established.

So this is atypical example wherein we can actually use the data and calculate whatever we have actually done through the experiments and they went to the discussions and lectures you can actually use and solve this problem so in this particular lecture we try to understand about you know connected through different shaking systems as well as through the containers.

And then we try to understand two typical construction process one is the effect of pile installation whether installation of pile in NG is important or 1g is important and what is the consequence of that and on also one construction process which we have discussed is that excavation in front of the wall you.

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