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ADVANCED GEOTECHNICAL ENGINEERING

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Lecture No. 27

Module – 3

Lecture – 9 on Compressibility and Consolidation

Welcome to lecture series on advanced geotechnical engineering and we are discussing module 3 compressibility and consolidation, and this is lecture 9 and in this lecture we are going to discuss about methods for accelerating consolidation settlements and the radial consolidation concepts. So in the previous lecture we have you know solve some examples wherein it involves long time for consolidation particularly in depending upon the type of the properties of a soil it may even where ES to complete the consolidation.

So in order to you know the construct the structures or in order to eliminate the you know the settlements before the construction of a structure they are methods which are available for accelerating these consolidation settlements. So in this lecture we will be concentrating on this aspect. So this is module 3 lecture 9.

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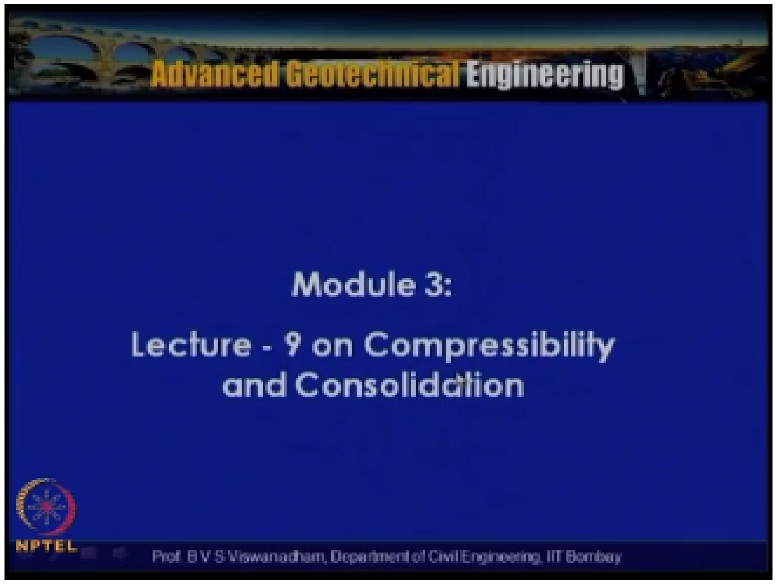

On compressibility and consolidation and we are actually addressing the methods for accelerating consolidation settlements.

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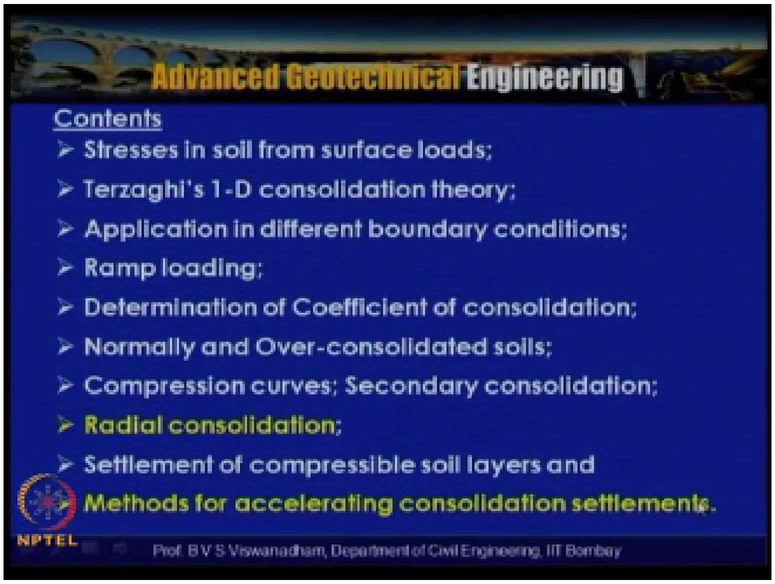

And the radial consolidation concepts in this particular lecture methods for accelerating consolidation settlements and we also said that the settlements which are elastic settlements for every consolidation settlement and secondary consolidation settlement. So majority the soils actually particularly have find rent soils they are actually a exhibit very high amount of primary consolidation settlements if they are normally consolidated or lightly war consolidation in nature.

So before any you know the discussion of a method the first and four most methods is that removal and replacement of a you know problematic soil.

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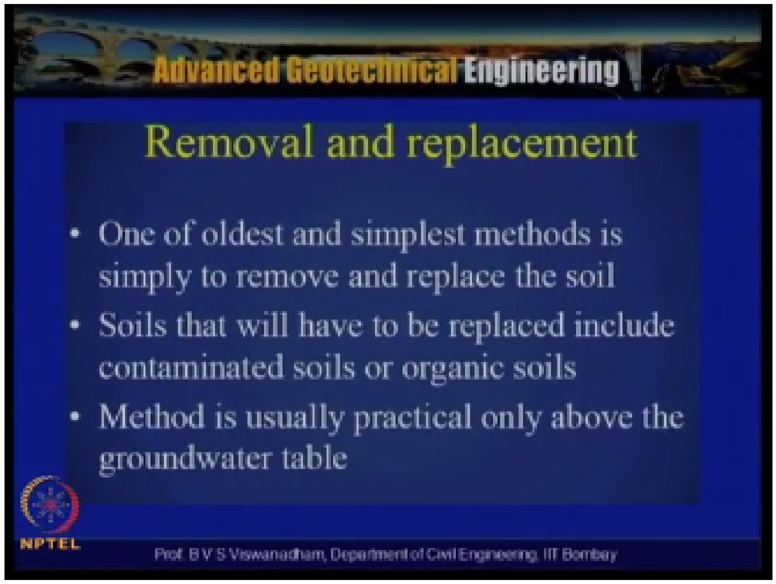

So one of the oldest and simplest methods is to simply remove and replace this soil but soils that will have to replaced include contaminated soils and organic soils if you are having marshy soil and all, so this method is usually practicable if it is above the ground water table and is also practicable if the volume of the soil to be removed or replaced is you know have limited quantity if it is involves the large quantities there will be you know difficulties or in a it will be highly and economical to you know go for removal and replacement technique.

So in the instances when it appears that too much consolidation settlement is likely to occur and the volume of the soil which actually involved also is you know large in nature.

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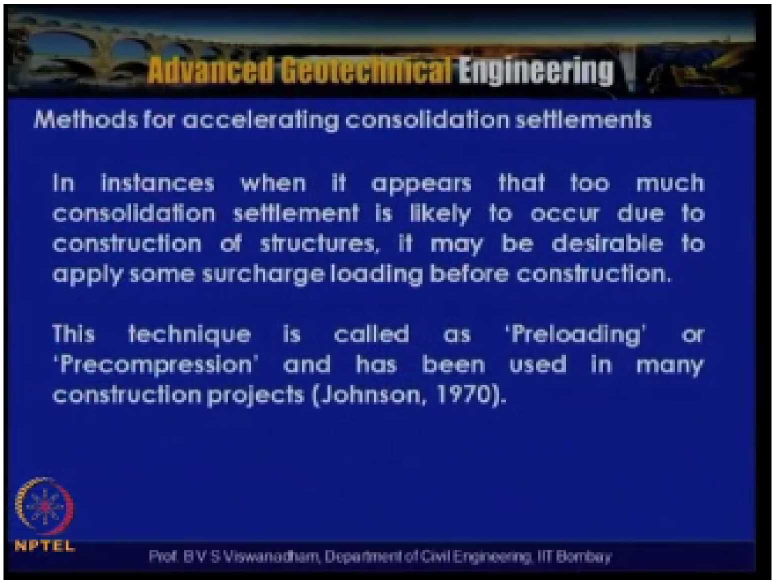

Then in that case you know the in order to eliminate the appears that you know too much consolidation settlement if it is likely to occur die to the construction of structures it may be desirable to apply some such as loading before the construction. So one of the you know earlier methods for accelerating consolidations settlements is called pre loading or pre compression in this method you know a certain amount of soil fill is placed over a pilled of time.

So we know that once you know the soil is loaded with the certain loading density what will happen is that the pore water pressure initially increases and after attaining equilibrium then it under goes dissipation. So this particular you know concept if you use once the dissipation is completed the soil you know affective stress increases then corresponding the soil shear strength increases, so in instance when it appears that too much consolidation settlements is likely to occur due to the construction of structures it may be desirable to apply surcharge loading before construction.

And this technique is actually called as pre loading or pre compression and has been used in many construction projects will success and as reported by Johnson, 1970.

So this technique is called as a pre loading or pre compression and which is actually involves a loading of the entire area under consideration by a fill of desire height. So the question what we need to address is that what is the height of the fill required, and how long we need to you know keep it and whether is a any stability issues which are actually required to be considered on when we are actually having a soft soils at the height.

The pre loading of the surcharge will and top of the soil that requires consolidation this is placement what we said is that placement of a surcharge fill on top of the soil.

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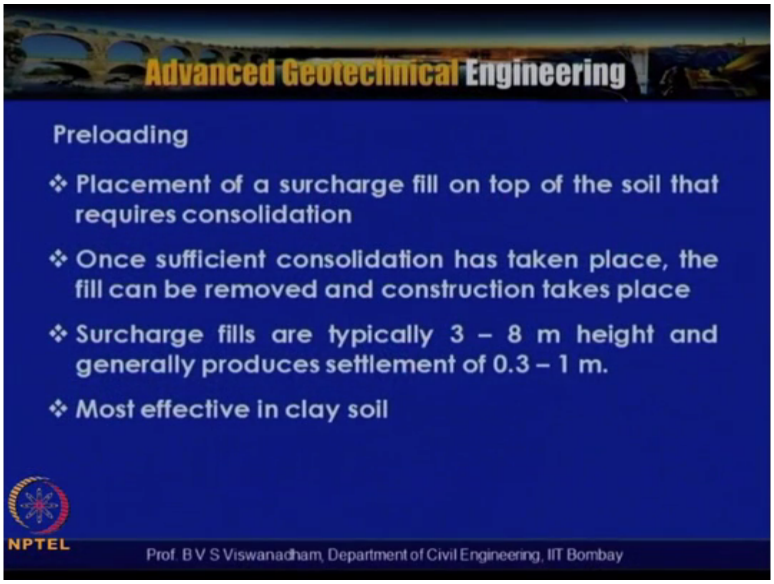

That requires consolidation and once a sufficient consolidation as taken place the fill can be removed and construction can take place that means that if we are having let us say that 10m is the total height including the temporary fill and permanent fill then once the if the temporary fill happen to be three m then the 3m can be removed and left with 7 m so that you know the after the consolidation it can be left with the permanent loading.

So once sufficient consolidation has taken place the fill can be removed and construction can take place. So this surcharge fills are typically of limited height like 3 to 8 m height and generally produces settlements in the range from 0.3 to 1 m, so this fills when we actually load on the surface of the you know soil and they produce you know the so-called you know the heights are 3 top 8 m and this actually happens because the pore water pressure which is you know gets generated the access pore water pressure is gets generated because of the placement of the fill.

And this actually once the pore water pressure generated and it tries to you know dissipate subsequently when the process of dissipation of the pore water pressure the oil actually gains the effective stress and with that to the soil actually the shear strength improves. So this is actually most effective in clay soils.

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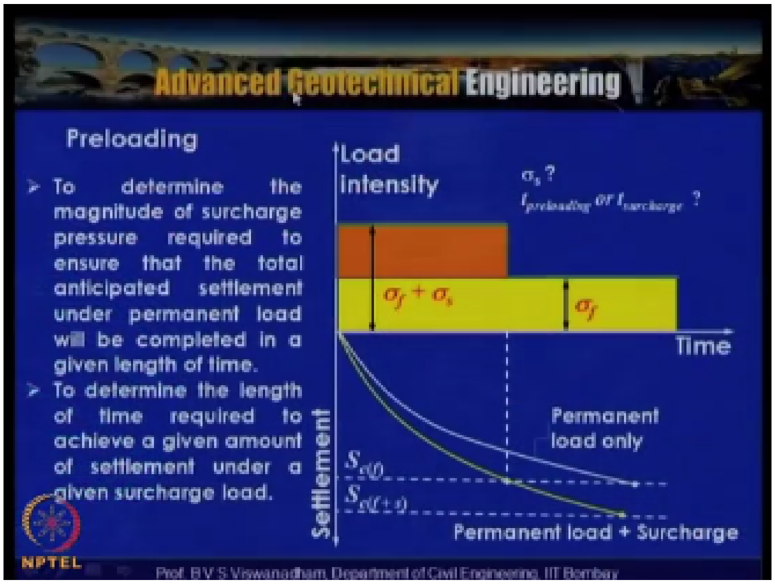

So in this particular slide a typical graphical form of this technique is actually shown here where we have the loading density on the y axis and time on the x axis and here this particular yellow fill area which is actually shown that is nothing but the permanent fill and this is you know this color which is actually Shown here which is the surcharge fill. So the question is that how much what will be the time for this pre loading or pre compression that is the this is the duration of the you know the pre compression and this is you know the loading density is σ f + σ s once this is completed then you know this will remain the permanent fill will actually will to remain and then the road environment or have been completed.

So other question is that what should be the intensity apart from σ f what will be the intensity of the σ s which is required so that the desire settlement can be achieved. So the bottom here the time versus settlement prod is shown here and this is if you are actually having permanent load only in order to get this consolidation settlement it may take long time in the sense that you know sometimes within the duration of the project it may not actually happen.

So in view of that in order to accelerate the consolidation one of the available option what we are actually thinking now is to pre load the area with a certain load intensity that is σ s. so if that actually happens the settlement profile is actually shown here this is permanent load plus surcharge we are you know can see that moment you know the end of the pre loading comes that is the duration once it complete you can see that the settlement which is actually likely to occur after long duration after placement of the fill was found to occur and because of the additional loading there an increase in additional generation of exit pore water pressure and then the dissipation of pore water pressure is you know fast and you can see that the settlements are also having higher magnitude.

So this is the, you know the time versus settlement curve of permanent load and surcharge and this is only for permanent load only. So here the in order to determine the magnitude of the surcharge pressure required to ensure that the total anticipated settlement under permanent load will be completed in a given length of time and so this is one of the objectives one of the objectives of pre loading is that basically to determine the magnitude of surcharge pressure required to ensure that the total anticipated settlement and the permanent loading will be completed in a given length of time.

And another objective is that is to determine the length of time require to achieve a given amount of time under a given surcharge load. So to determine the length of time required to achieve a given amount of settlement under given surcharged load. So we will try to see the methodology which is actually involved and this is actually very simple and wherein we actually find out generally the time which is actually define now let us say that you know we want the settlement to occur the pre loading period to be 9 months or ten months whatever it is if you are dis specified and in that particular period to achieve this settlement what will be the intensity that is required to be found of based on the sub soil are you know the clay characteristic.

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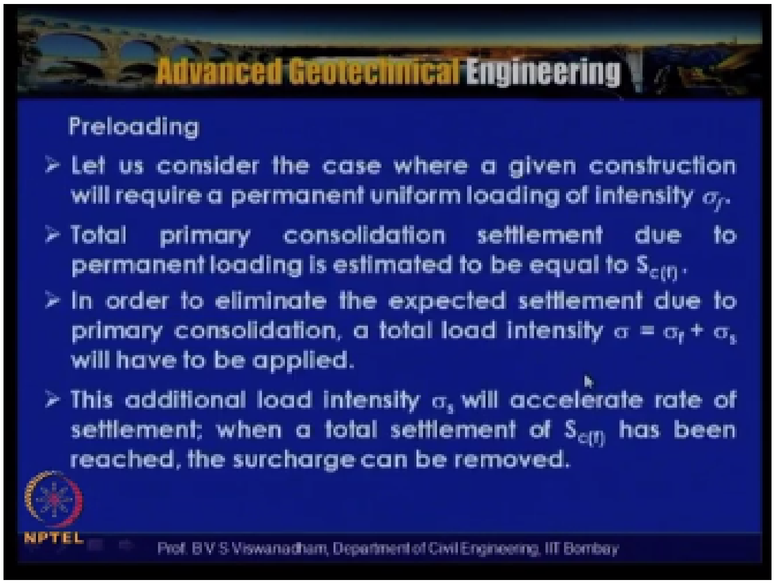

So let us consider a case where given construction will require a permanent uniform loading intensity of σ f that is what we said is that this is the σ f, then total primary consolidation settlement due to permanent loading is estimated to be equal to Sc (f) that is the you know this Sc (f) that is and in order to eliminate the expected settlement due to primary consolidation a total loading density of $\sigma + \sigma$ f $+ \sigma = \sigma$ f $+ \sigma$ s will have to be applied.

So the additional loading density σ s will accelerate rate of settlement and when a total settlement of Sc (f) has been reach with the surcharge can be removed. So the additional loading density of σ s will accelerate the rate of settlement when a total settlement of Sc(f) has been reach with the surcharge can be removed that is the additional surcharge which is place in the form of a temporary fill can be removed.

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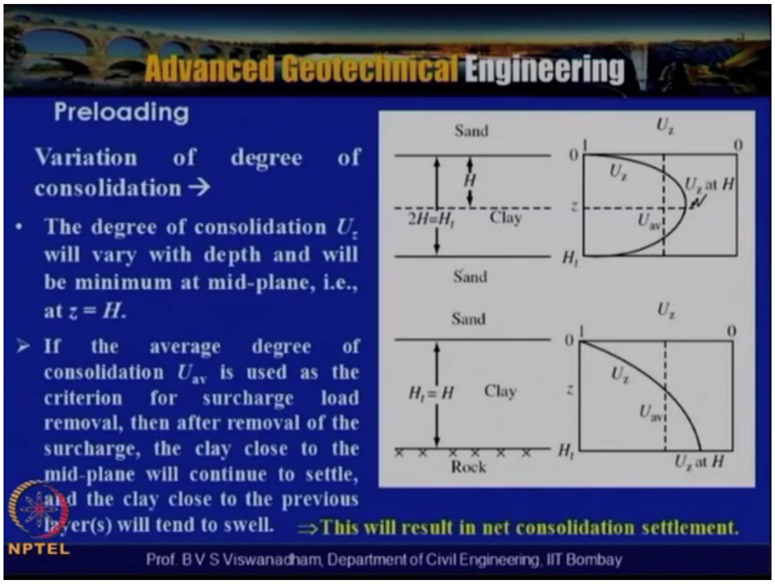

So here one thing we need to notice here at any if you are having a double drainage that is a Hd =\ 2h then water flows in the both the directions so hd = 2h and the water the drainage path is h here that is hd = 2h / 2 that is h here and this is the at any time t so this is you know before applying the pre load once the pre load is actually applied the pore water pressure you know the value of you know the degree of consolidation is attained one here and one here at the top and bottom because of the double drainage prevalence and at this mid plane you can see that the there is a major amount of pore water pressure you know have to dissipated.

So you can see that this much portion is have to be dissipated this much portion is already dissipated, so this is you know the huge at z = jh the pore water pressure at this particular plane and if you are actually having if you are taking a average consolidation and that will actually come here so in this case it appears here that you know though we actually takes certain amount of degree of consolidation but here and her already the consolidation actually has you know achieved because of the removal of the load there can be possibility that the net consolidation settlement is because of the some settlement which continue to happen here and some swelling which is actually happen here and here.

So in case of one way drainage when you are actually having hen you can see that this is the isochronal at any time t after placement of the fill and this is the bottom base where the impervious layer is actually there at the if you are having another clay layer it is actually at that particular plane and this in this case the hd = h because the drainage path of water flows in this direction only water flows in this direction because water cannot go through the rock or impervious medium.

So in this case this much portion is already dissipated and this is the mid plane consolidation here as it uz = h, so the degree of consolidation uz will vary with depth and we minimum at mid plane that is z = h so if the average degree of consolidation ua average is used as the critical for surcharge load removal then after removal of the surcharge the clay close to enplaned at the clay close to the mid plane will continue to settle and clay close to the previous layer will tend to swell that is the clay close to previous layer will tend to swell.

So because of this reason Johnson 1970 as recommended on the conservative side you know for assessing degree of consolidation for the removal of surcharge you know the consolidation degree of consolidation predicted at z = h or mid plane consolidation. So this will result in the net consolidation settlement so the entire the phenomenal what has been discussed will result in the net consolidation settlement.

So now what we are doing is that according to Johnson 1970 it is provable to use the mid plane degree of consolidation.

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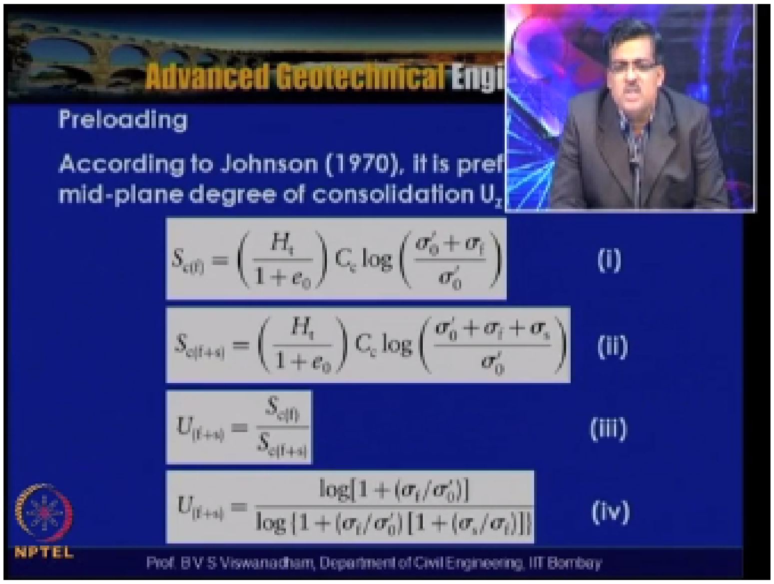

That u = u at z = h now we can write the consolidation settlement as sc = hd / 1 + e0 cc log σ 0' + σ f / σ0', so here σ f is the permanent fill and once we compute the final consolidations settlement the compute sc f + s that is fill plus surcharge so in this case hd / 1 + e0 cc log σ 0' initial effect to but in pressure + σ f + σ s / σ 0'. So we can define the degree of consolidation as sc (f) that is the you know the consolidation settlement without any preload and with the pre load and surcharge that is settlement without any preload and settlement with pre load and permanent load that is sc(f) / Sc(f) + s.

So by substituting this here 1 and 2 here in 3 we get u f + s = logarithmic of 1 + σ f / σ0' / logarithmic of 1 + σ f / σ0' x 1 + σs / σf, so here if you see that this is σs / σf this is the you know the dimensional term for σs is the magnitude of the fill surcharge to be placed σf is the permanent fill and σf / σ0' is you know nothing but the ratio of permanent fill to the initial war burden pressure.

So this particular design can be done by using this or by busing the charts which are actually available.

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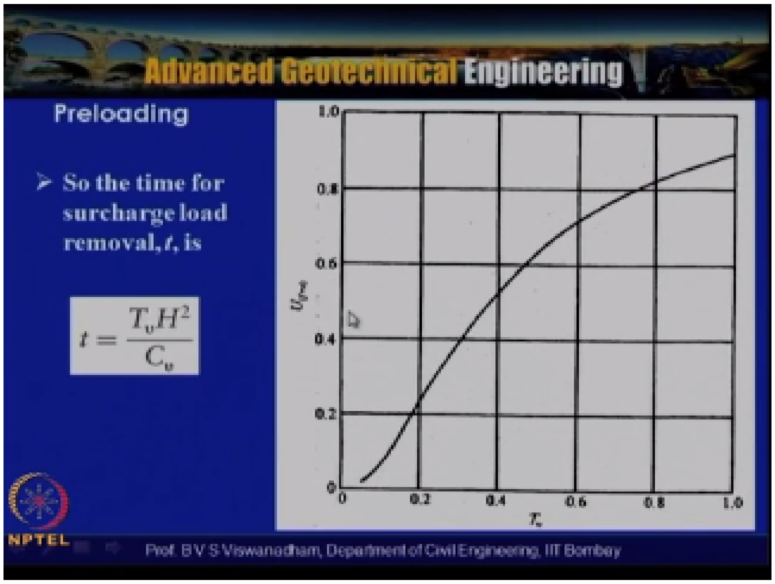

And for as been told in order to get the u f + s it is actually require to use the this particular chart to determine the time factor so by once we know the value of the suppose if you are actually let us say that we need to you know set a target for completion of the pre load is say in say definite period of time say 9 months the for 9 months and what is the time factor we can determine once the time factor is actually known to us based on that you can actually determine what is u f + s.

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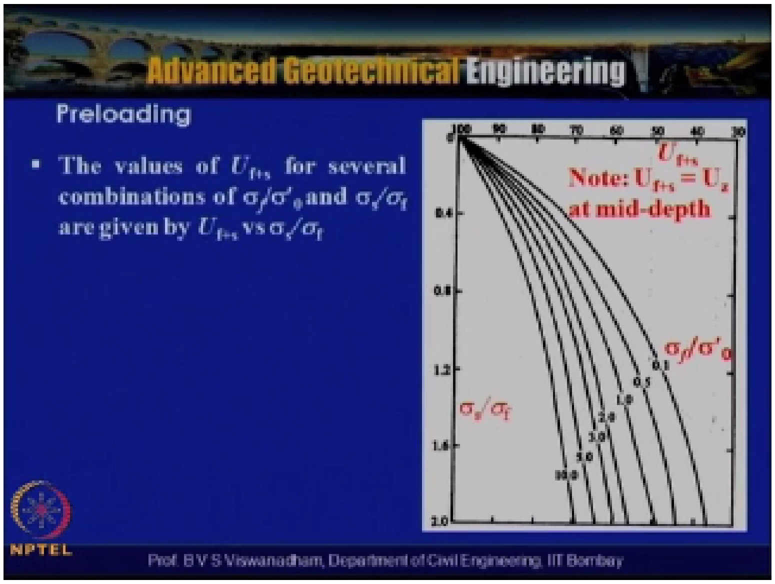

Once the uf + s is actually is obtained then by using this particular plot we can actually determine you know what is the ratio of σ s / σf, so the values of u f + s for several combinations of σ f / σ 0' this is the permanent fill surcharge to the initial effect to war burden pressure the different values are actually give here, and σ s / σf values actually given here, and note that uf + s = uz at the mid - depth that is what actually has been considered according to Johnson 1970.

Now once we know the uf + and once we know the σ f / σ0' we can actually calculate what is σs / σf required. So by knowing σ f we can Actually calculate what is the magnitude of the such as, so once the time is actually known period of placement then we can actually find out or wise personal we can also know go from once the fill surcharge is actually known we can actually also go from the reverse direction calculate what is the time.

So this once we know σ f and σ0' and σ s and σf the determine uf + s and then calculate the time factor and then calculate the time which required to be maintained in order to achieve the so. Called to the settlement which is actually anticipated because of the you know the 3itha\=out any permanent load. So this is the procedure for the preload.

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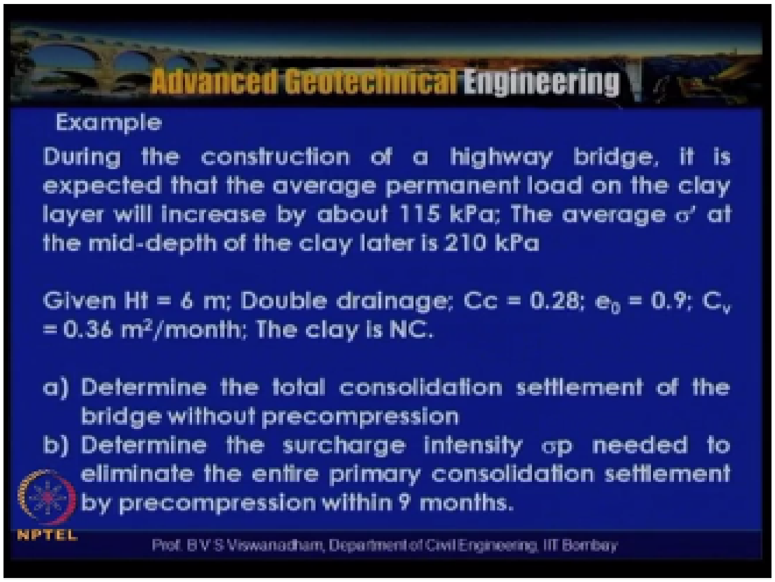

Now let us consider an example where during the construction have high way bridge it is proposed to expected that average permanent ,load on the clay layer will increase by about 115 k pa. and the average σ' at the mid depth of the clay layer is given as 210 kpa and given that thickness of the clay layer is 6m and double drainage that means that effective drainage path is 6 / 2 m cc compression index is 0.28 and effective the initial wide ratio is 0.9 coefficient of consolidation is 0.36 m2 per month.

And then the clay is normally considerately in nature, so determine the total consolidation settlement of the bridged without pre compression and determine the surcharge intensity σ p needed to eliminate the entire pre consolidation settlement with by pre compression within 9 months. So here we notice that the time which is actually required for the placement of the fill is actually define here.

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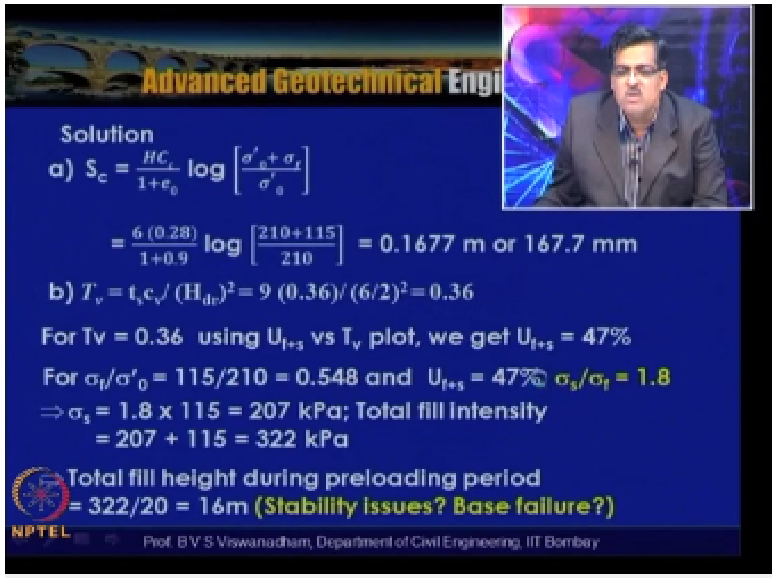

So we can actually adopt like this calculate the consolidation settlement and this settlement works out to be 167. 7mm so this cannot be a tolerable settlement for a bridge so hence by taking t v = t suffix s where the time require for surcharge cv / hd r2 once you get this we will get the time factor, now once the time factor is known to us that is 0.36 and using you know the plot which we have discus that is per σ f / σ0' that is 0.548 and uf + s is 47% we can determine like this for 47 % and 0.548 you can see that this comes to be around σs / σf comes to be around 1.8 also.

So with this what we get is that σ s which comes to be 1.8 x 115 that is 207kpa. So the total fill intensity it comes to be 2017 + 115 is about 322 kpa and this looks in to that you know if you are actually having an embayment which is actually constructed say equivalent to with if you are having unit weight of 20k n m3 as the fill material, then you can see that the height which is actually required is about 16m if you are actually having a soft clay and placement of 16m fill which requires also long time over the placement and also it need to be done in minimum 4 to 5 stages and also have the issues of stability issues and base failure and all those things cannot be ruled upped.

So in such situations you know one have to think about you know other have a news for accelerating consolidation settlements and this have involved as the you know some sort of vertical drains because in the we have also discuss one problem where if you are having a sand lengths which occurs in may be in alluvial areas and because of that what will happen is that there can be possibility of the acceleration of the consolidation.

So as the horizontal drains are difficult to install below the ground level then one of the available options is to go for the vertical drains with the partial replacement of you know the impervious soil or soil having very low permeability with a soil actually having very high permeability or having a material which actually has got that equal discharge capacity as that of you know the soil which has got very high permeability. So before that let us look and discuss about the advantage and disadvantages of pre loading.

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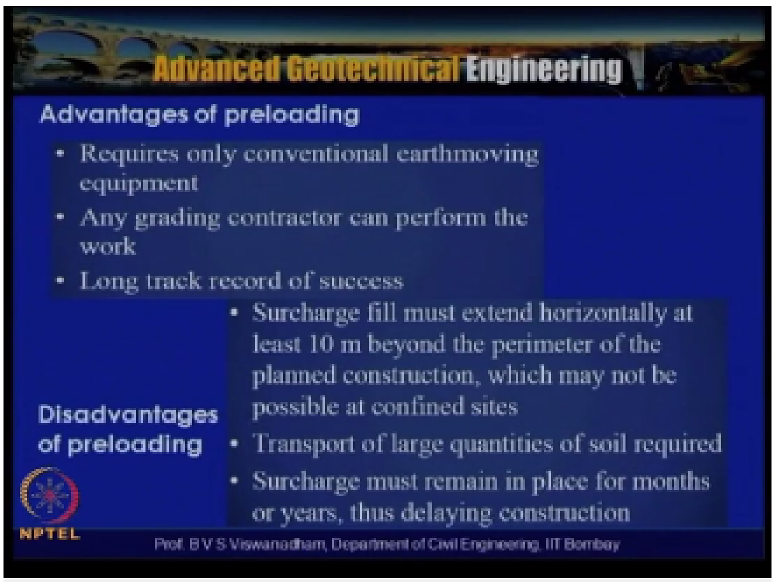

And requires conventional at moving equipment any grading contractor can perform the work long tack recorded for the success and the surcharge fill just extend horizontally at least 10m beyond the permeability of the planned construction which may not be possible at confine sight sometime sin the confine sights you have to valve and use some refused soil over technique, so that you will be able to have step slop for the particular height which is being planned and then one can actually fill within the you know area which is actually developed.

And transport of the large quantity of the soil required you know this is actually one thing where it will significant effect the carbon credits of the projects and surcharge must remain in place for months or years this deles the construction and more over placement of the fills beyond 10m can lead to you know the uneconomical issues as well as the stability issues.

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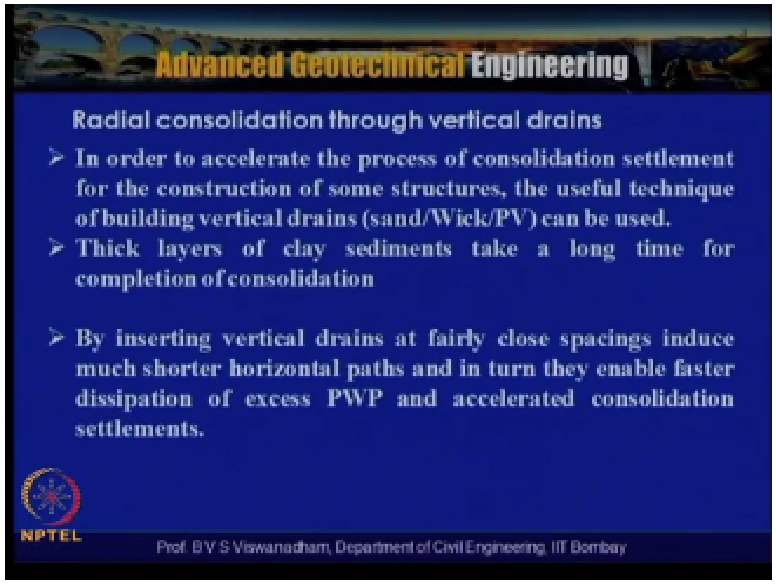

So in such situation you know we actually can talk of can be you know one other avenue which can be thought is that as discusses earlier the radial consolidation through radial consolidation through provision of wet colorings in order to accelerate the process of consolidation settlement of the construction of some of structures the useful technique for is to build vertical drains so vertical drains in fill in the form of sand it is actually started with you know the sand drains method then subsequently for a short time wick drains do exist then afterwards a free fabricated vertical drains actually have come in to picture.

So the sand drains basically they are of diameter ranging from 400 to 600 mm and they are actually placed by you know occurring a boar whole and then removal of this soil after removal of the soil the sand is actually replace the selected sand material having certain grain characteristics sand to replace and then another method of this thing which actually has come because of the dimidiates of the sand drains is to large diameter and then also the you know the construction of this things it takes long time.

So because of that you know the Wick drains actually have come the wick drains also the it involves the occurring of the bore hole and then replacement of the removal of the soil and afterwards wick drains with a geo testable bag filled with sand is actually place and but however this also have not lasted for long but in the reason past for the past two decades you know the pre vibrated vertical drains which are actually having a Pori propylene are suitable material as the core and to the pollster or Pori propylene geo testable as the jacket material and which actually is you know tailor made product which actually has got high drainage capacity even under the hostel conditions in the fill.

So the thick laze of the clay it take long time for completion of consolidation so the provision of this vertical drains what will happen is that and the you know the drainage paths actually has got the what we facility the clay you know the additional drainage paths along the radial direction. So the consolidation now in this direction it can actually happens in radically as well as in the vertical direction, so because of that what will happen is that they rapid you know rapid settlements will occur at the project sides can be ready in a short duration of time.

So by insetting vertical drains fairly at close spacing induce much shorter horizontal paths for the water pore water pressure to dissipate and in turn they enable faster dissipation of excess PWP and accelerated consolidation settlements. The vertical drains are install under a surcharge load to accelerate the drainage of impervious soils.

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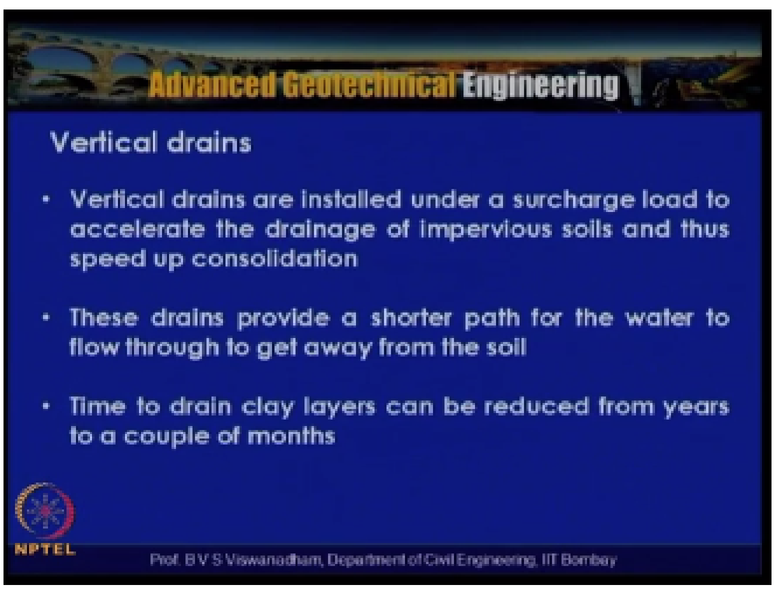

And thus speed up the construction so generally the vertical range when that place they are placed along with the pre load or pre compression so the two they go with each other where once the first of all this on the sight the drainage blanket need to be place at which also solves a restoration layer for access layer for this sight to maneuver the ricks and all and then through that the vertical range are installed and once they are both that the fill is actually placed so that the vertical drains which are actually installed in a surcharge layer to accelerate the drainage of the impervious soils and thus this speed of the construction.

And these drains provide a shorter path for the water to flow through the and get away from the soil and time to drain clay layers can be reduce from years to couple of months. So from the drastically the time can actually being shorted and with because of that we actually happens is that the time to drain clay layer is can be reduce from years to couple of months.

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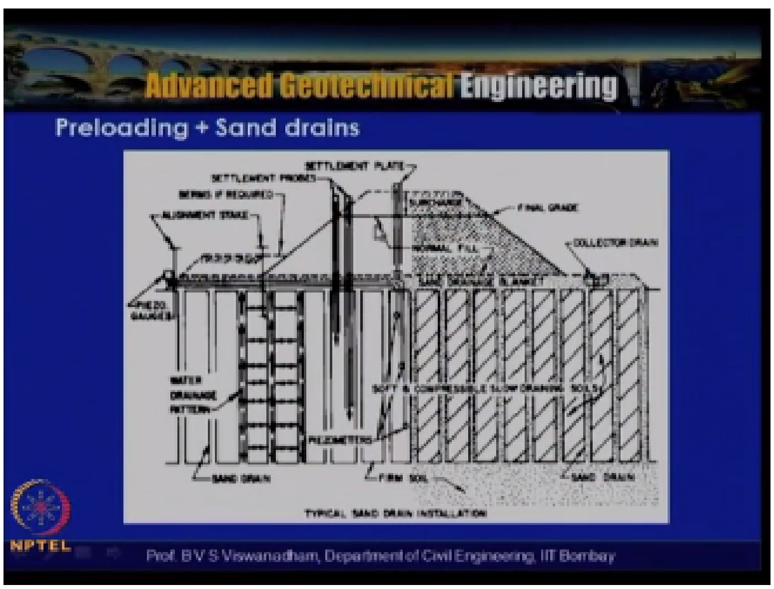

So this is a typical preloading versus sand drains cross scion is actually when here wherein a typical sand drain is actually place in a compressible soil where this is the collected drains and this is the drainage blanket so what is actually shown here is that you can see that the water migrates you know this is the end of the drainage path for this and this is what drainage path for this. So this drain actually facility as the water and the along with you know the in case for 5the double drainage water flows in this direction and water flows in this direction.

So with the because of this what will happen is that there is a combination of coupled consolidation actually happens where the radial consolidation and the vertical consolidation happens simultaneously, so when you compare the components of radial consolidation and you know the veridical consolidation the vertical consolidation component will be very less the radial consolidation component will be very high so because of that the settlements will be you know very faster.

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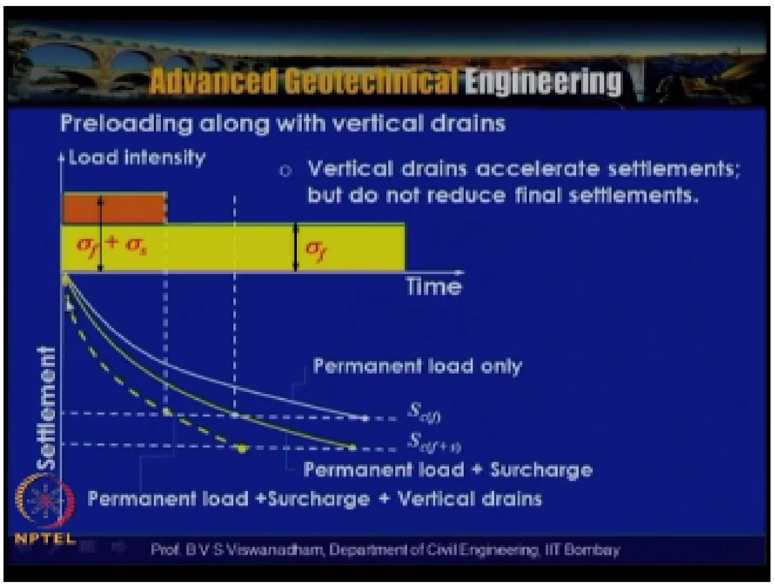

So here a pre loading along with the drains is actually shown here so with the pre loading along with the drains one situation what will happens is that the time versus settlement diagram is shown here, so this is the pre consolidation settlement which actually possible. So what we have discuss it is that when we have got only pre load and surcharge permanent loaded in surcharge we said that you know this much time we have to keep the permanent surcharge and then also the magnitude will be much higher but when we have got the pre loading along with the vertical drains there is a possibility that this consolidation settlement we can occur in a relatively short duration of time and whereas another issue is that the settlements time versus settlements the settlements variation will be relatively faster, so because of that the clay consolidates relatively faster.

So her this schematic view of pre loading along with the sand range is actually shown here so here the vertical drains one point we need to not down is that the vertical drains accelerate the settlements but do not reduce the final settlements, it is not that you know the placement of the vertical drains will not reduce the magnitude of the settlement but they tend to accelerate the settlement only.

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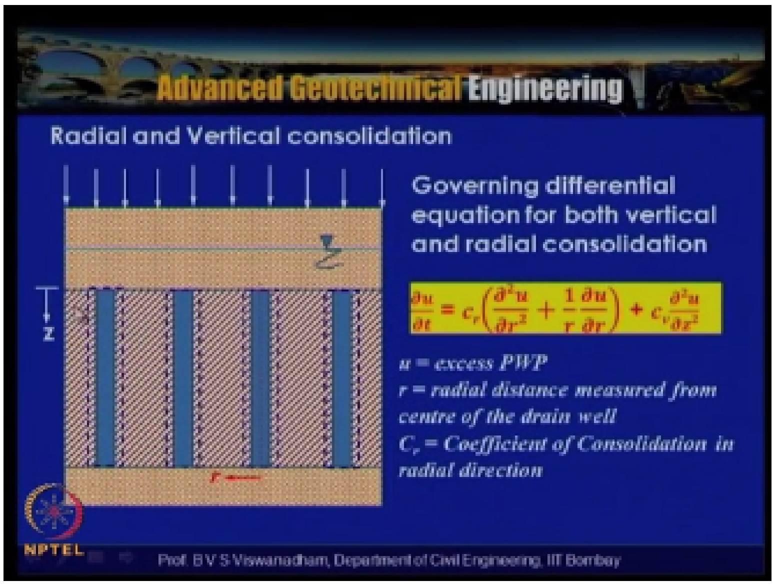

So here a relatively you know a typical cross section of a you know a clay where of thickness ht and hd = 2h the 2h is this side and it is a double drainage layer and where we are having a water table here and the filled which actually placed here, so here this under goes radial consolidation the water flows in this direction water flows in this direction and this zone water actually shown here this is actually called as this mere zone but if you look in to this each drain in the plan area it actually you know caters to a diameter which is actually called as the equaling area for a drain.

And so we need to also think about what spacing we need to pace them and what layout we need to place them, so that they will the radial and vertical consolidation can occur efficiently. So the governing differential equation for both vertical and radial consolidation is shown is shown in this year this is after Barents and where $\partial u / \partial t = c_r \times \partial^2 u / \partial r^2 + 1/r\, \partial u / V r + c_v\, \partial^2 u / \partial z^2$ so if you look in to that.

Now we have discuss a previously the one dimension consolidation where we actually have got this particular component only now because of the radial component where we have got cr that is the coefficient of consolidation the radial direction it is also referred as coefficient of consolidation in the horizontal direction as we know that coefficient of permeability is relatively more than coefficient of consolidation coefficient of permeability in the vertical direction because of σ h < σ v for normally consolidated soils.

In such situations what will happen is that the ch also will be more than cv so the because of the ch is also more than cv so that also you know the permeability is actually more and ch is also more because of that what will happen is that it contributes to the rapid consolidation of the a clay layer under consolidation.

So here the u is the access for what a pressure or is the radial distance measured from the center of the drain well so this is the drain diameter what it is called, and if you are actually having a prefabricated vertical drain it actually comes with berth and certain thickness then equivalent diameter are equivalent diameter of the value actually considered and c u is r is the radial distance measured from the center of the drain well and cr is the coefficient of consolidation in the radial direction or horizontal direction.

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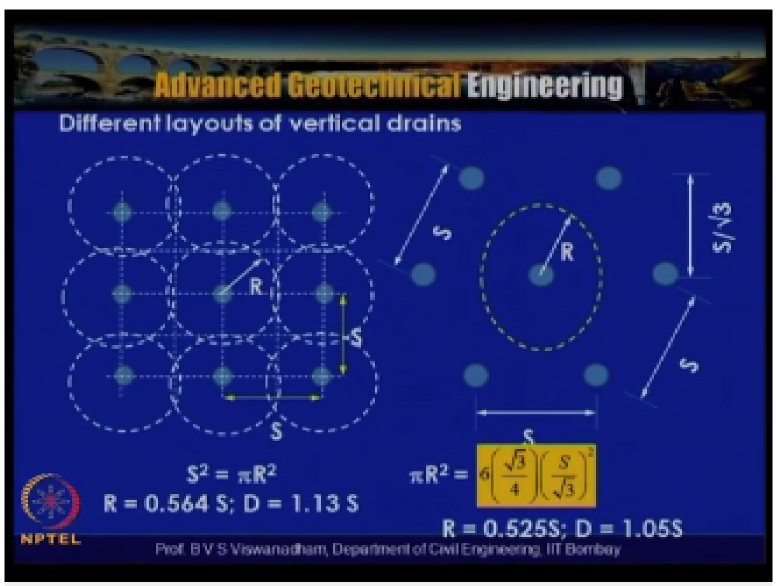

So they are two different types of layout of vertical drains are invoke one is with square layout what is called this is the square layout which is actually shown here and this is you know this is actually shown as the triangular layout so you can see that each and every the orientation of this is a equivalent triangle, so this magnitude is s is called the spacing from center to center of the drain and this height is s / √3 and this particular you know is called as equivalent radius or this area is called equivalent diameter.

So this influences that this drain caters to the this much area, so the water which is actually there in this direction will actually try to come in to this so this falsities for the drainage of the you know the water. So this drainage of the water which actually happens because of the placement of the fill above the drain, this is in the case of this square layout where you can see that the s is the center to center distance between the drain wells and this is the you know the distance s and this is the r so the equivalent radius are equivalent diameters are obtained like s2 which is nothing but s2 s x s = πr2, the πr2 is nothing but this influence area.

So with that what we get is that r = 0.564 s and r diameter is equal to 1.13s in the case of when we have got equated triangles so what we do is that πr2 that is this area is equivalent to 6 equivalent triangles we have to taken to picture so with that what will happen is that 6 x √ 3 / 4x s / √2 / simplification you get equivalent radius as 0.5 to 5 s and which is nothing but d = 1.05 s and a similarly for the prefabricated vertical drains when you look in to for prefabricated vertical drains as been tone.

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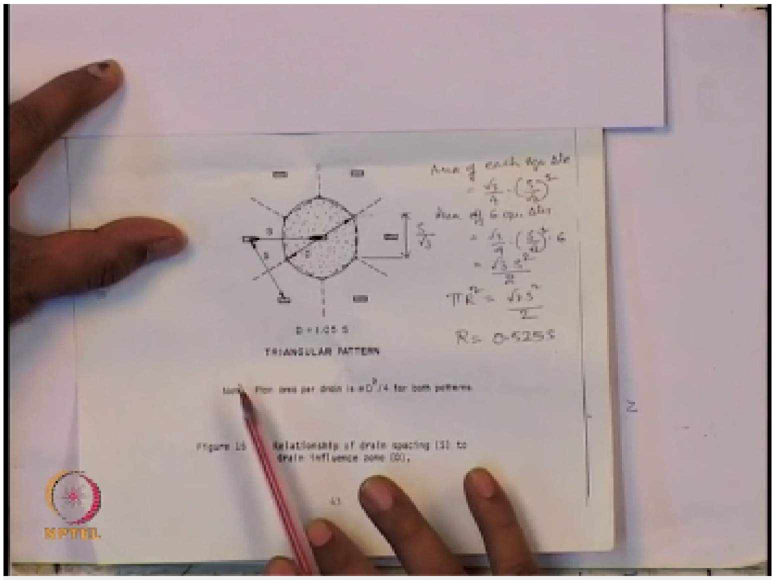

These prefabricated vertical drains are this prefabricated vertical drains are actually having certain berth and thickness and the admissions are relatively smaller compare to the sand drains conventional sand drains, so this is the influence zone and this is the diameter and so here also the same you know is calculated s2 = π r2 r = 1/ π √ πs and which is nothing but r = 0.64 s and this is for the square pattern and incase if we are having let us say is the triangular pattern and the in the triangular pattern where we are actually having this x what we can see is that so because of this 6 equated triangles we are considering.

Area of the each equivalent triangular is $\sqrt{3}/4 \times s/\sqrt{3}^2$ and with this area of the 6 equated triangles work out to be $6 \times \sqrt{3}/4 \times s/\sqrt{3}^2$ which comes out to be √ 3 s2 / 2 and which is equivalent to πr2 = √ 3 s2 / 2 where r = 0.525s so this is d = 1.05 s. so if you look in to this is this is the equivalent diameter so out of the two layout which we have discussed at the square layout and the triangular layout the triangular layout was found to be efficient inducing uniform consolidation to the soil this is actually you know reported based on the case studies which are actually you know done in the field by several investigators where by monitoring the consolidation in the field by measuring the settlements or measuring pore water pressures with that it has been found out that the triangular layout of the you know the either PVD or the san drains are conventional vertical drains will give the efficient way of consolidation of a soil.

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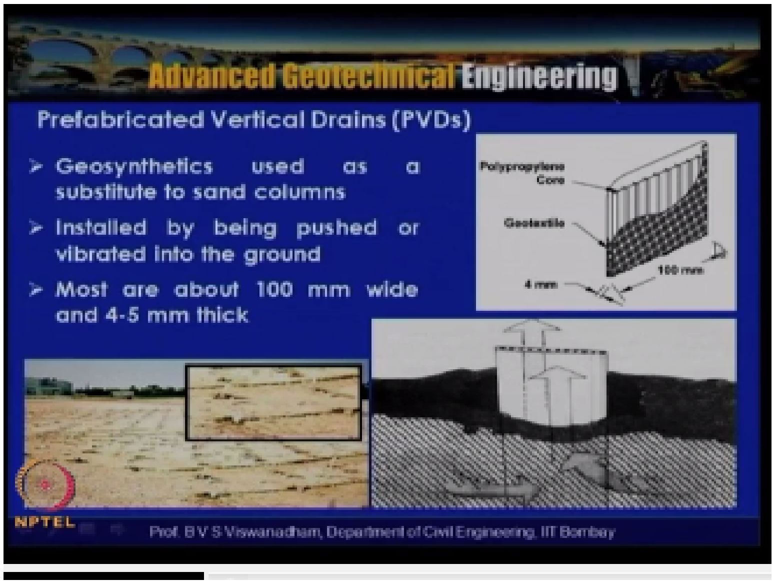

So this is typical prefabricated varietal drains which actually shown here, Geosynthetics basically there the tailor made products which are actually used as the substitute for this sand columns and now it is with the availability of this sand is becoming scares and with the that is the availability in the sense that the proper material. So because of that you know the use of this fabric materials are is one of the viable option and also these use of this prefabricated vertical drains accelerate the consolidation settlement equally as compare to the vertical conventional vertical drains.

As well as you know the installation is actually veritably simple and faster, so this actually has got a dimensions are approximately 100mm to 4 mm there are the several designs they are actually available. And the thickness is about 4mm and which actually has got you know this is the core where it vegetates the water and this geo-textiles which is basically non oven in nature and the pore size of this geo textiles to be such that the only water enters in to the drainage channels of the core channel where the pore propylene core is there and the clay is actually retained at the boundary itself.

So because of that what will happen is that there is a possibility that the water only enters suppose if the geo textile which is actually selected is not having adequate you know the large pores pore sizes there can be possibility the clay enters and then the prefabricated vertical drain channels will get blocked then the efficiency of the drains will get actually effected and they are subsequently to the consolidation gets effected.

The mostly there about 100mm wide and 4 to 5 mm thick and they come in the roles and they are actually installed as is actually shown in the ground from the drainage blanket, so once the these are actually installed then once it is subjected to loading then there is a possibility that the water actually you know uses this channel and then tries to come off, water you know once the water is actually coming out that means that the dissipation of the pore water pressure is happening that means the settlements are you know are continue to happens.

So with that the clay consolidation will be completed in relatively shorter duration. And now it is this prefabricated vertical drains are actually being used for number of applications in the case of like municipal soiled ways and in order to particularly in the bio rectal landfills and they are actually induced for you know for extracting the gas and with that what is happening is that the gas extraction is becoming efficient so with the and then also the settlements are actually also relatively faster.

And then another thing is that if you are actually having a contaminated flume there is a possibility that these things can be installed and then can be used for you know accelerating the consolidation the removal of the contaminated zone or contaminated liquefaction which is actually trapped in the certain portion in the ground and the another application which is actually in the reason past is actually coming up is that use of this prefabricated vertical drains for mitigating liquid fashion which is also in there is a material tool in this case this soils are introduce fine that is silty sand are sandy soils.

Wherein this also facilities for you know in the case of eventuality of the earthquake there will be a access pore water pressure generation and they are also there is it transient in nature and because of that what will happens there is a possibility of provision of these things these you know if you applicator vertical drains is facilities the drainage at the moment when it is required, so in the process what will happens is that the soil will be you know provided from the undergoing liquefaction, so that the structure will not be subjected to the danger which is unexpected when these are not there.

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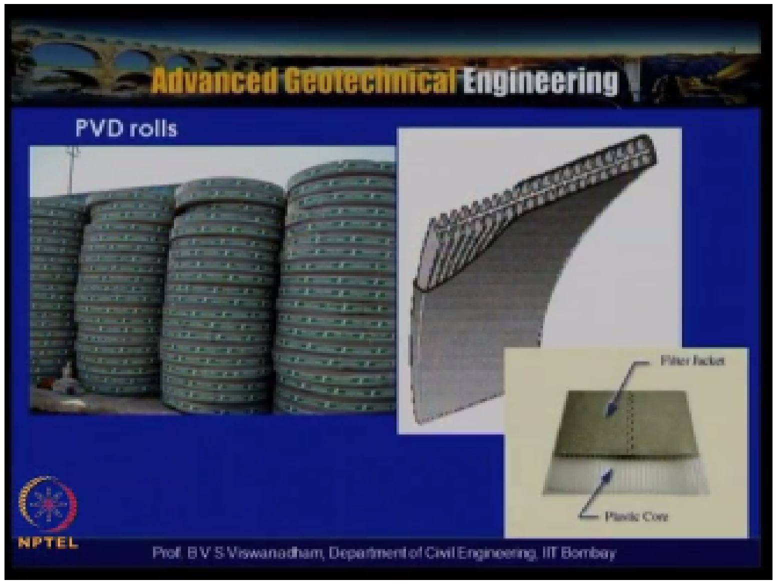

So these are you know the PVD rolls which are actually displayed here, this is which actually comes in number of the certain role length and this is the you know the core, so these are different manufacture actually has got different core styles and this is the jacket which is the filter jackets what is called it is actually made of again non oven geo textile.

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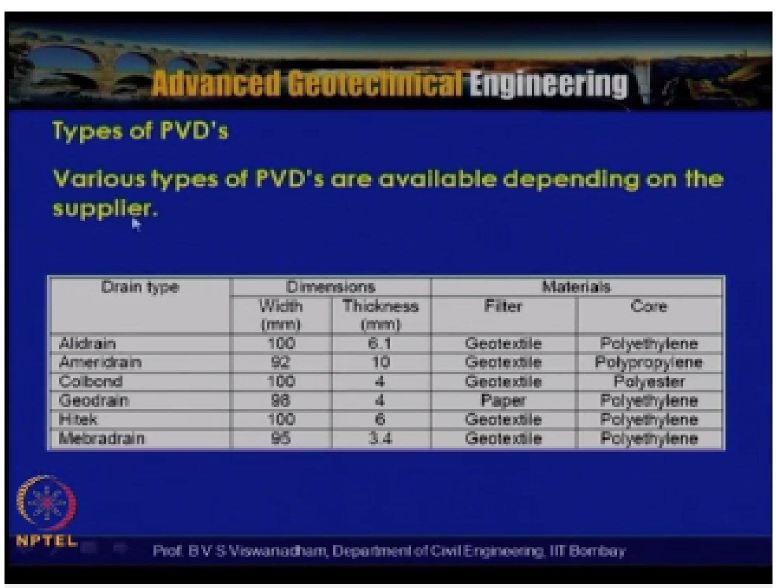

Drain type	Dimensions		Materials	
	Width (mm)	Thickness (mm)	Filter	Core
Alidrain	100	6.1	Geotextile	Polyethylene
Ameridrain	92	10	Geotextile	Polypropylene
Colbond	100	4	Geotextile	Polyester
Geodrain	98	4	Paper	Polyethylene
Hitek	100	6	Geotextile	Polyethylene
Mebradrain	95	3.4	Geotextile	Polyethylene

And these are the types of PVD’s there the dimension range from 92 to 100 mm and thickness actually ranges from 3.4 to 6.1 mm so you can see that different geosythetic style filters are there and in case of some limited life geosynthetic are used that is like the jute is also can be used as a filter and the core emplace of the core in case of limited life geosynthetic they are also several investigators actually worked on the coir as the core within the jute jackets, and these are the you know different polythlyene and polyester and polythelene these are the different core materials.

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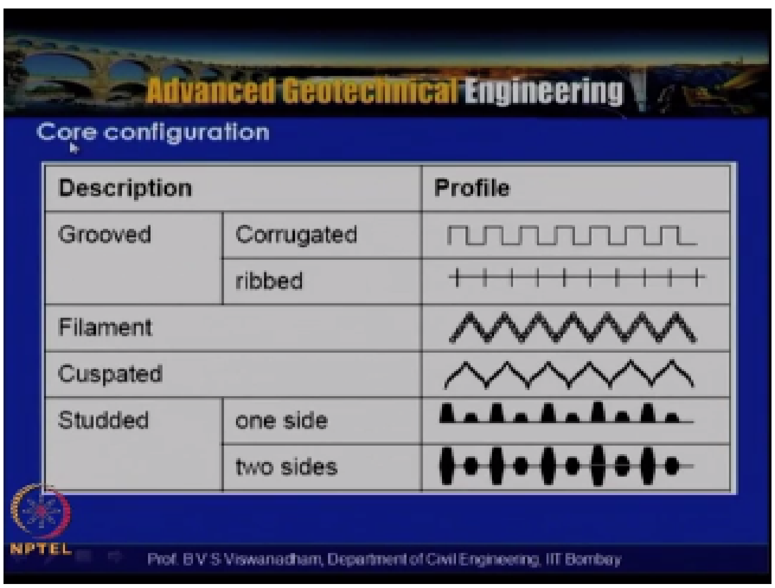

And these different core configurations are shown here water may be the core configuration under pressure it tends to be ensure that the drain will not actually you know sacrifice the discharge capacity the discharge capacity mean the sense that depending upon the permeability of this spoil the discharge capacity of the drain will be selected. So if you are actually having a core which actually sprung to collapse with because of the lateral stress then it is actually going to effect the performance of these PVD’s.

So this PVD's is also they have got he certain quality control test first of all the ten side load and strain behavior need to be investigated and also we need to see under buckling or under single buckling or to you know two buckles what will be the permeability emplane permeability and what is the discharge capacity it need to be assess will be 4 hand and once these are ensure and appropriated material need to be selected so that the you know this can be use for put in to use.

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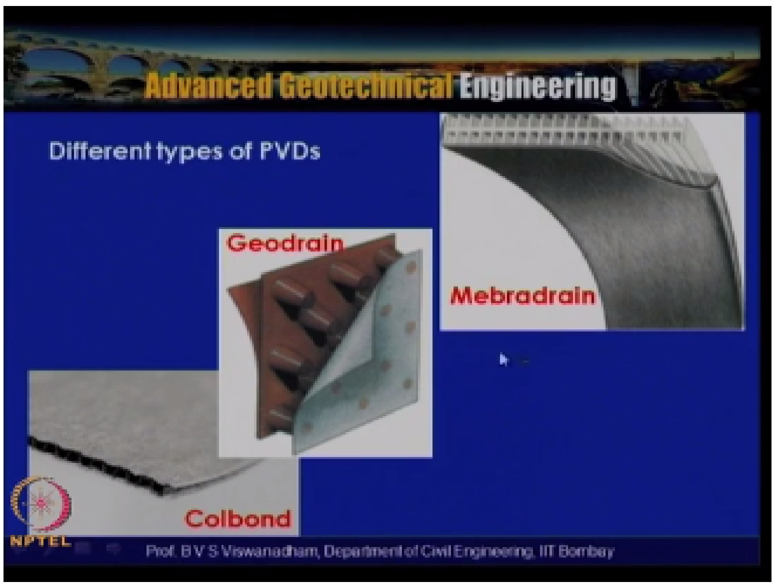

So these are the different types of PVD's which actually shown here different manufactures vary the core which is actually shown here.

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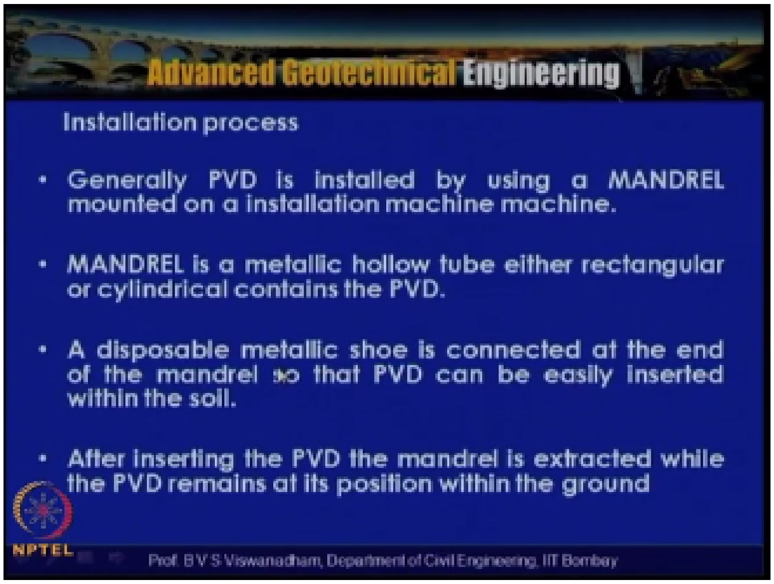

So the installation in the sense that the PVD's are installed by using a MANDREL mounted on a installation machine and MANDREL is a metallic hollow tube either rectangular or cylindrical the cylindrical one which actually contains the PVD. So a disposable metallic shoe is actually connected at the end of the mandrel so that the PVD can be easily inserted within the soil. after insetting the PVD the mandrel is extracted while the PVD remains in position within the ground.

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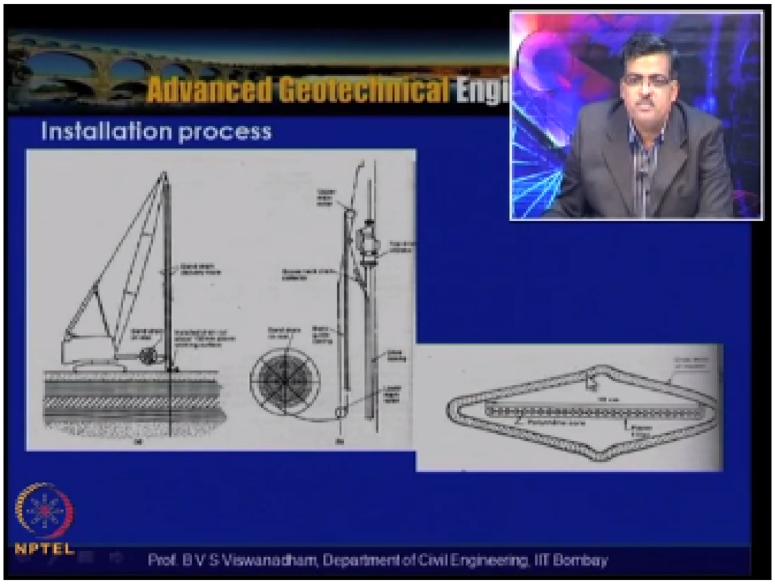

So schematic way of the rig which is actually shown here and the roll is actually mounted and connected to this now with that what will happen is that the roll which actually runs like this and the PVD is actually drew in the grounds, so this is the mandrel, so with this you know what is actually happens is that the disturbance which is actually caused and because of the installation of the sand drain it can be reduce the so-called this speed effect can be reduced and this is the PVD in position here.

So that no time the soil is in contact only it can come in contact with this soil while extracting this mandrel once the PVD actually has been placed in the desire depth.

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So this is you know the one of the sights where in New Mumbai where the marine clay which is actually is uncounted and where this is for the one of the way housing corporation where they wanted to install prefabricated vertical drains and then place the preload of 4.5 m height where in here because of the confined boundaries on the peripheries temporarily the enforced slopes actually have been constructed and within that fill area within the pond which is actually developed then in that the so-called you know the soil actually placed so before that you know the PVD's of in propagate verity actually have been selected and this is the you know a PVD roll which is actually being inserted.

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So we will actually look in to the installation how it actually happens in the field, so here you can see the softness of the clay the this is nothing but is the drainage blanket and the mandrel is actually being driven in to the mandrel is being driven in to the ground. So this is the vary house corporation which is actually existing given house corporation and this is also for you know enabling in a placement of the loads over that area.

So the consolidation is actually is planned to be accelerated by using the placement of the PVD's and the preloading, so afterwards it is put to use for the desire purpose, so you can see that now the mandrel is being exacted and the PVD actually has come out now it will be seen yeah now the PVD will be cut and the next location is actually selected and that is the placement of the sacrificing shoe and this will be penetrated in to the ground and these are actually inserted at the pre marked locations so that the desire spacing's of let us say 1m 1.5 m or a achieved and with that what will happen is that the grid pattern which is actually here in this case the triangular pattern has been selected as we have discussed in that this will actually ensure the uniform consolidation and also the ritually uniformed consolidation.

So because of that this triangular pattern has been selected you can see the ground is actually planned with the number of PVD's actually have been installed and this process continues of installing the you know PVD's where in so in a way as we can see that the installation is very rapid with that what will happen is that the PVD installation can happen in a relatively shorter duration.

Now we have actually discuss about the placement of the fill which is normally about you know we have the issues of you know the stability as well as the in procurement of this materials so in such situations in the reason past you know the one of the technique which actually coming in to the picture is called vacuum surcharging and this can be efficient up to equivalent to 4.5m fill.

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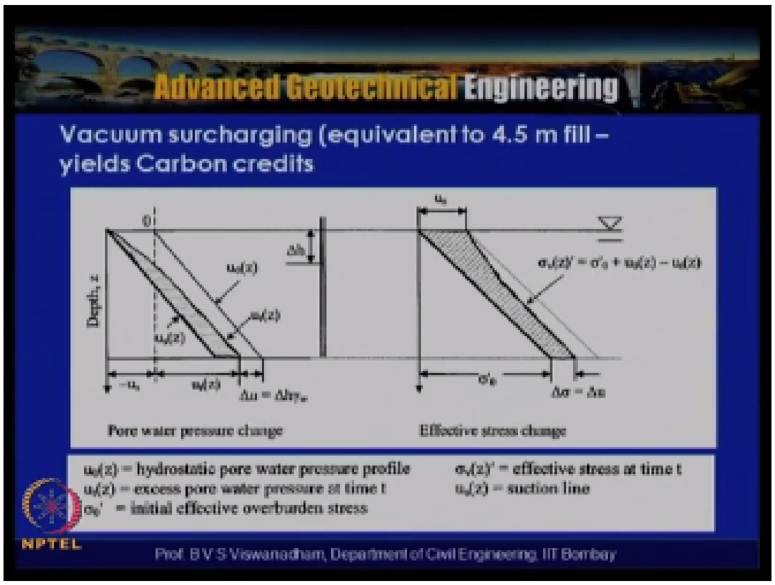

And so this can be you know done when we are actually having a requirement of a 4.5 or 8m fill and then we can also even we do along with PVD's and this technique was found to be very efficient so if you look in to this vacuum surcharge this is the conventional preload and here what we said is that then if you are actually having you know suppose if you are having a certain hydrostatic pressure pore water pressure when you load you actually have very high initial access pore water pressure and then subsequently what will happen is that the water transpose the pressure to the soil so with that the pore water actually in case of pre loading the only positive pore water pressure changes will be there.

But in case of vacuum surcharging the pore water pressure changes are under the negative sight it is actually called as reducing section to the soil, so here also what will happen is that this is the effective stress change with this what will happens as we know that once we got the negative pore water pressure which is actually induce to the soil this also was found to be very efficient in increasing y the effective stress to the soil, but the limitation is that you know the section can be induce up to 80 to 100 kpas so it i9s limited to about 4.5 to 5m, so when it is used in combination with you know the PVD's then there is a possibility that this efficiency will be very high.

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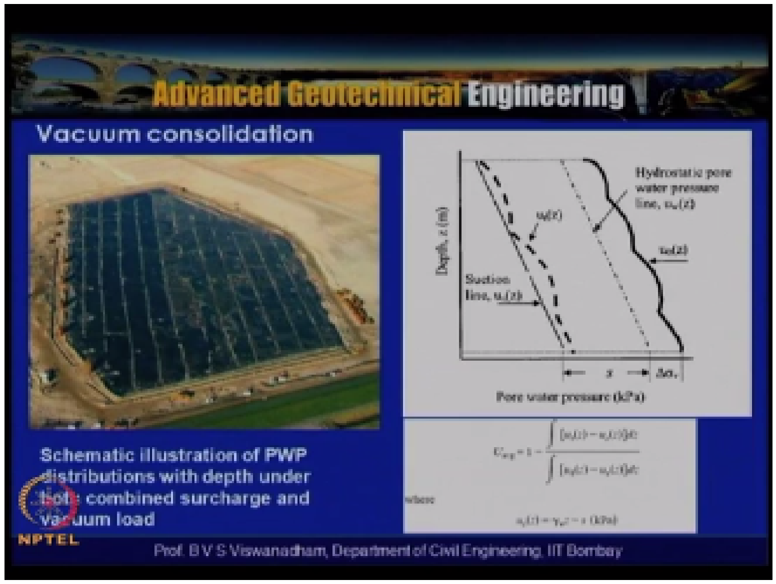

And this how it look like in the fill and another thing is that in control in this over a long you know large sight is actually difficult so in such situations this for the small sight where we can actually avoid the placement of the fills and another important issue is actually happens here is that the vacuum generation can be generated instantaneously if you are actually having a efficient or you know pumps which are actually vacuum pump which is actually place.

So here this pore water pressure changes for a soil so what will happen is that initially when if this is the hydrostatic pressure which is actually there in this sight then once we actually have the you know section is induce then what will happens is that this section will actually initially will be large and then slowly that section will get transfer in to the you know increase in the effective stress.

So the more on this we will actually discuss in the next lecture wherein we discuss about the some design aspects of the you know the pre fabricated vertical drains along with the preloading along with then drain what will happen in this particular example we discuss and we found that when you have when you do not have the drains then there is a possibility that requirement of very high you know large fill high are required.

So in such situations what will happen when we actually have combination of drains and pre load and then if you are actually having the scale city of the fill materials then one of the alternatives is to go for the vacuum surcharging so we will try to discuss about the merits and demerits of this preloading in compare with along with the vacuum surcharging in many sights vacuum surcharging pr fabricating vertical loading and also certain amount of preloading the combinations also use.

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