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ADVANCE GEOTECHNICAL ENGINEERING

Prof. B. V. S. Viswanadham
Department of Civil Engineering
IIT Bombay

Lecture No. 24

Module – 3

Lecture – 6 on Compressibility

and

Consolidation

Welcome to lecture series on advanced geo technical engineering being offered by the department of civil engineering IIT Bombay we are in module 3 lecture 6 on compressibility and consolidation.

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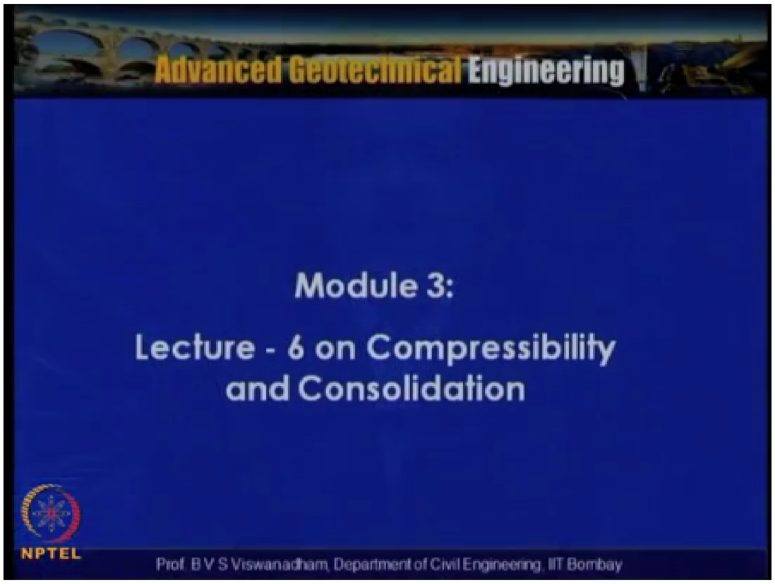

And we have introduced ourselves to the normally and over consolidate soils and we have discussed about a methods for determining method for determining pre consolidation pressure so in this particular lecture we will continue our discussion on normally and over consolidated soils.

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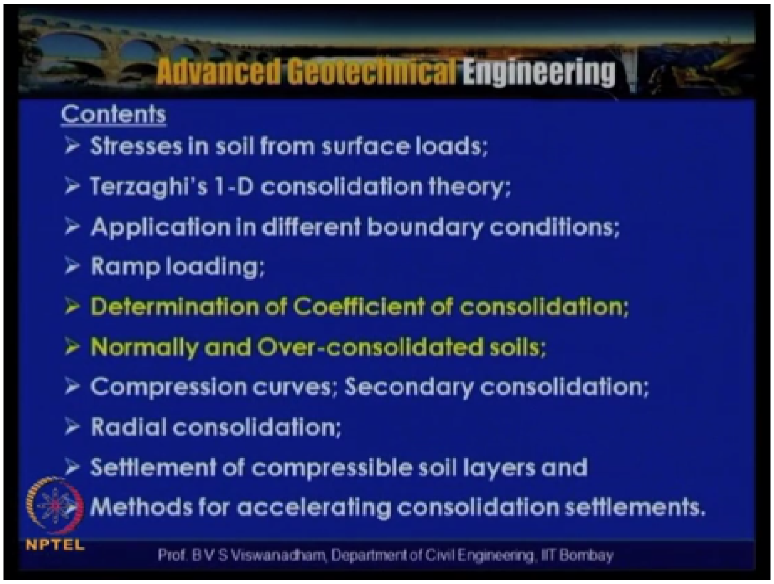

And then we will try to discuss on over consolidation ratio under consolidated deposits and there after we will try to extend our discussion to the determination of the coefficient of consolidation the only parameter in the differential equation put forwarded by the terzaghi's one dimensional consolidation theory so in the previous lecture we have defined pre consolidation pressure and we said that it is the maximum previous maxima effective stress to which the soil as been subjected in the past.

So the per consolidation pressure is the pervious maxiuamum effective stress to which the soil as been subjected in the past so based on this we can classify predominantly two types normally consolidated and over consolidated and they are also some under consolidated deposits that means that very young and very young deposits the normally consolidated deposits you know soil are normally consolidated soil is actually defined as a soil and it is called as normally consolidated.

If the present effective over burden pressure is the maxiuamum to which the soil is ever been subjected that is σ' present is ≥ σ' past maximum and over consolidated soil a soil is set to be over consolidated if the present effective over burden pressure is less than the maximum to which the soil is ever been subjected in the past that means that the σ' present is less than σ' past maximum that means that in the past the soil would have been subjected to very high you know the effective stress.

And you know the, whatever the current stress is very much less than that so in this case normally consolidated soils are what we have discussed is that these are very prominent in along the Indian peninsula and along the costal lines the most of the marine clay deposits are normally consolidated in nature so this becomes a challenge for a geo technical engineer for designing you know the structures on these place.

So in the natural condition in the field a soil either may be normally consolidated or over consolidated in some cases under consolidated.

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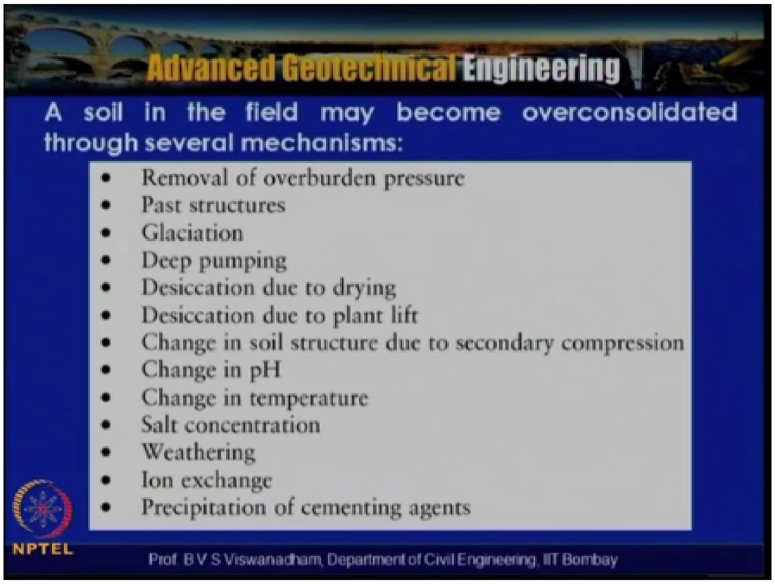

So soil generally you know become over consolidated through several regions and we have several mechanisms and several reasons one is that removal of overburden pressure that means that if a past structure or a if over burden was existing and if that is removed then there is a possibility that the soil might have actually gone into over consolidator state okay and the some of the past structures when they have removed these the soil still will experiences are remembers the stress which actually has been subjected in the past.

And because of the presence of the large shucks of ice of the soil and sequently when it gets undergoes a process of glaciations then the soil also you know in the over consolidated state and either because of the deep pumping are desiccation due to driving desiccation due to drying and desiccation due to plant lift of water and change in soil structure due to secondary compression and importantly change in pH of the soil and salt concentration also you know can change these you know the convert the soil into over consolidated state.

And weathering some ion exchange and ageing of soils and precipitation of cementing agents is all these things never lead to you know make the soil over consolidated.

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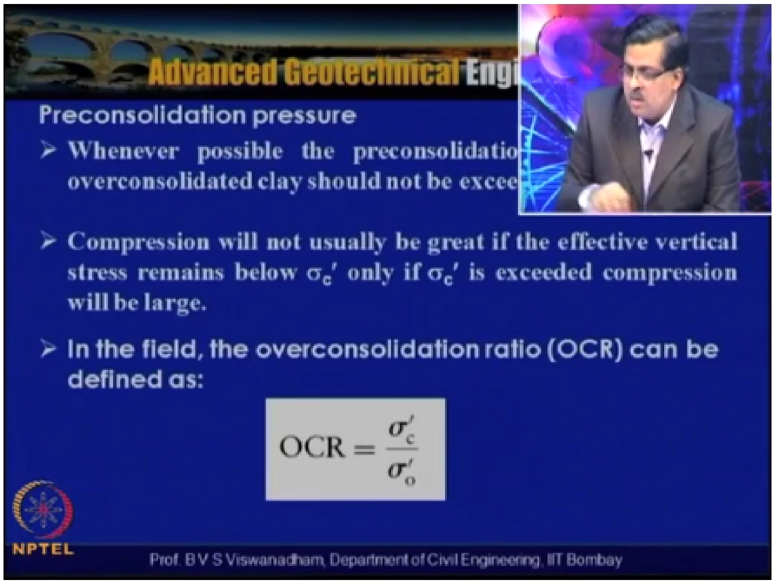

Sop in this context actually whenever possible pre consolidation pressure for an over consolidation clay should not be exceed in construction and compression will not usually be great if the effective vertical stress remains below the pre consolidation pressure and if the pre consolidation pressure is exceeded then the compression will large so for any soil if the pre consolidate if the loading which is actually is less than that pre consolidation pressure.

The settlements will be small but if the load actually exceeds you know to more than the per consolidation pressure then the soil can change into normally consolidation mode so in the field the over consolidation ration is actually defined as σ’ c / σ0’ σ’o.

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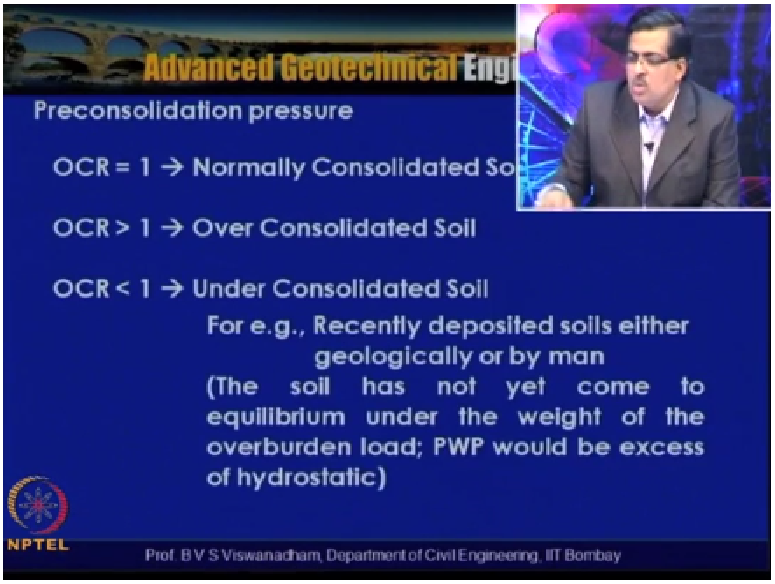

So if OCR is = 1 that indicates that normally consolidate soil and OCR >1 is called over consolidate soils in fact OCR = 2 it indicates lightly over consolidate soils and OCR also can be like you know 5 and 9 more than 9 and they are heavily over consolidate soils that means that the clay is very strife in nurture and these water content is over less and it has been subjected to very high amount of past very stress in the past.

And there are also some cases particularly it occurs in some lake beds and all where OCR >1 so this is called as under consolidated soil that is for example recently deposit soils either geologically or by man those are the soil has not yet come to equilibrium under the weight of the over burden load so the status of these you know the poor water pressure is soil is that the soil is actually not yet attained the equilibrium under the weight of the over burden above that particular layer or particular point.

Then pore water pressure would access the of the hydro static pressure the pore water pressure would be excess of the hydrostatic pressure so these under consolidated deposits are you know something like very recently deposited soils either geologically or by manmade activities so in that case OCR < 1 I called but prominently OCR = 1 that is actually called normally consolidate soils up to OCR = 2 like they are also treated as lightly over consolidated soils and the OCR value can also go up to 5, 9 and > 9 so where they are heavily over consolidated soils.

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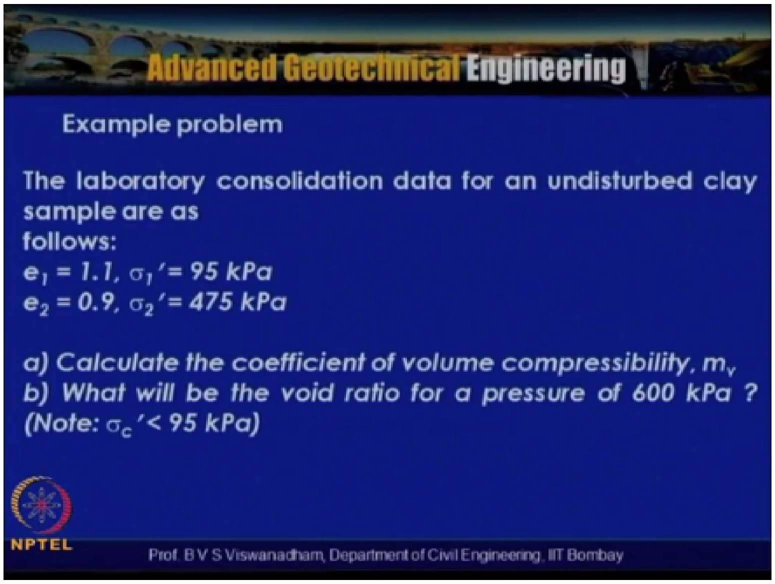

So let us look into some example problems before discussing you know the methods for determining coefficient consolidation so in this example problem the laboratory consolidation data for an undistributed clay samples are given and which is actually given as e1 = 1.1 at σ1' 95kPa and e2 = 0.9 at σ2' = 475 kPa so that σ1 – σ2 the σ2 to – σ1 is the increase in the stress that is 475kPa – 95 kPa.

So what we need to do is that when there is an increase in effective stress then they you can see that the void ratio decrease from 1.12 to 0.9 so the calculate the coefficient of volume compressibility m_v and what will be the void ratio for a pressure of 600kPa note that you know we have to σ' c < 95kPa that is the soils pre consolidation pressure is < 95 kPa.

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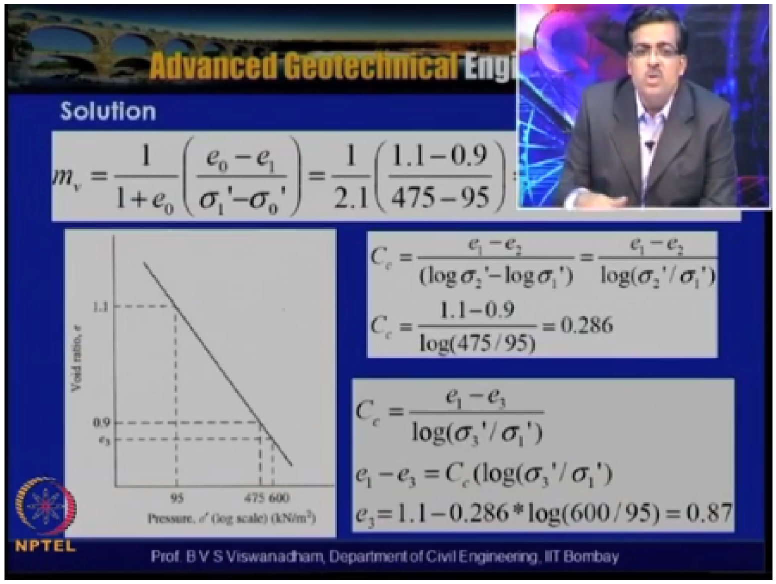

Now the solution runs, like this we have been given the data which is plotted on void ratio on y axis and pressure on the logrthimn scale that is pressure on the σ' and logarithmic scale in kNm^2 and by putting 1.1 for even and the point lies here and for 0.9 the point lies here that is at 475 kPa now we can actually determine the slope of this line is ΔA/ Δσ that is Δσ if it is in arithmetic scale but coefficient of volume compressibility can be obtained like this.

Which is nothing but 1/1+ e_0 so if there is here e1 is taken as the initial void ratio that is 1/1+ 1.1 that is 2.1 then e0 – e1 that is nothing but e1 is 1.1 e2 is 0.9 and the pressure is 475 or 95 so with this expression which is nothing but Av / 1+e0 what we are doing is that Av/ 1+ e0 and Av is nothing Δe/ Δσ' x 1/e0 so this what we got is that m_v we have got so by getting this m_v we can actually after having.

So the solemn soils volume compressibility is known then you now in this particular pressure range then you can actually calculate what is this settlement and all slowly the slope of this e log P curve in the straight line portion of this virgin compassion curve is nothing but indicated as compression index so in this slope can be obtained like this Cc = the slope of line e1 – e2 and then divided by log σ2' – log σ1' so e1 – e2 so e1 is 1.1 and e2 is 0.9 so 1.1-0.9 / log 475 / 90 so with this what will happen is that the compression index is actually coming as 0.286 compression index is coming as 0.286.

Now as the soil is in the same normally consolidated state and 600kPa is you know the right next to 475 kPa so what do we want to know is that what will is the void ratio of a soil at pressure of you know 600kPa so further by taking the same slop that is Cc is known to us 0.286 and initial void ratio is known to us that is 1.1 so e3 is required to be found out so it is nothing but Cc = e1 – e3 / log of σ3' / σ 1' now the σ3' which is nothing but you know that is new pressure that is 600 kPa.

So 0.286 that is nothing but e1 is 1.1 – e3 / log of 600/ 95 and Cc is known to us which is 0.286 so with this what we can actually get is that with a when the pressure increases to 600kPa at the end of that you know the pressure passes of consolidation what you get is that e3 value is 0.87 now it get decrease further from 0.9 to 0.87 so what we have done in this problem is the given data is plotted and then we have determined what is the coefficient of volume compress quality that we have been asked then after words we determined compress index from the given data.

And then we whereas asked to find out what is the void ratio of a same soil with undergoing the consolidation the what is the void you look the void ratio at a pressure of 600kPa so that you know is works out to be 0.87.

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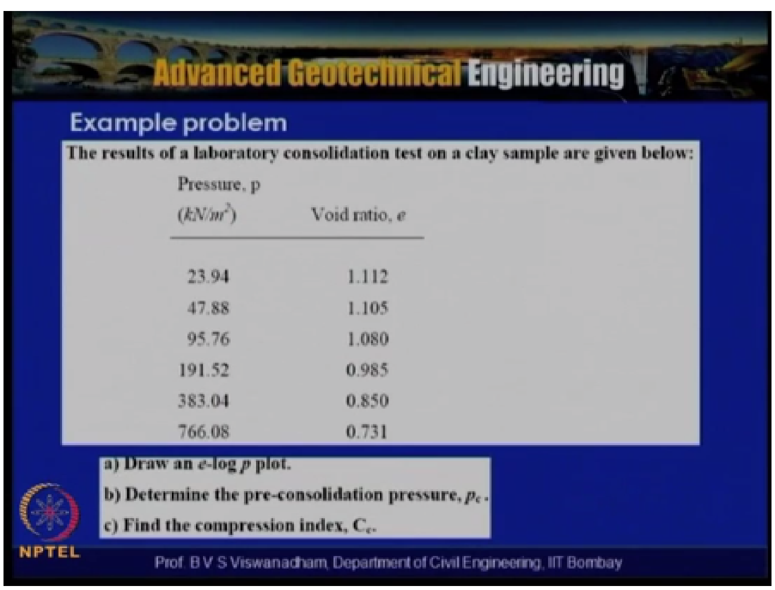

From the given data from this version belongs to lecture 5 of module 3 from the given data of pressure verses void ratio we have to plot e log p curve.

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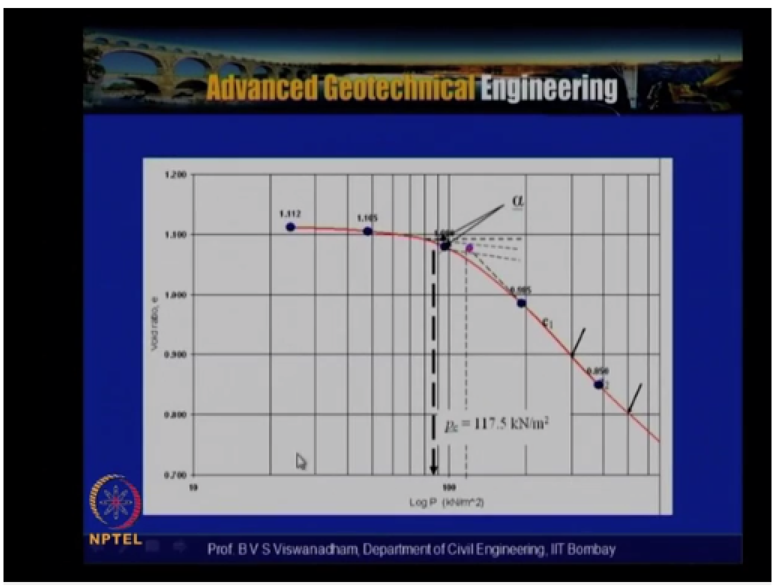

And the logrthimn of pressure on the x axis and void ratio on the y axis and once we get these plots we have to identify a point where the maximum curvature prevails and from there we have to draw ion horizontal line and then a tangent need to be drawn from that point of where the maximum curvature exists and we need to bisect this line bisect this angle let us say if that angle is say θ α that angle need to bisected and then from this point B a line need to be drawn.

And this tangent which is you know the straight line portion of the virgin compression curve need to be extended and where the point where it actually meets that bisected line and from there we can actually draw and that point is you know regarded as pre consolation pressure according to casagrande's method so in this particular problem from the given data what we have done is that we took point D and then we have drawn horizontal line.

And from the point D we have drawn a tangent for word tangent and then we bisected that angle and then we drawn a line 2.D and then we extended this you know back tangent from the straight line passed to the virgin compression curve and the point where it meets that is actually regarded as pre consolidation pressure in this problem we have got as 171.5 kPa.

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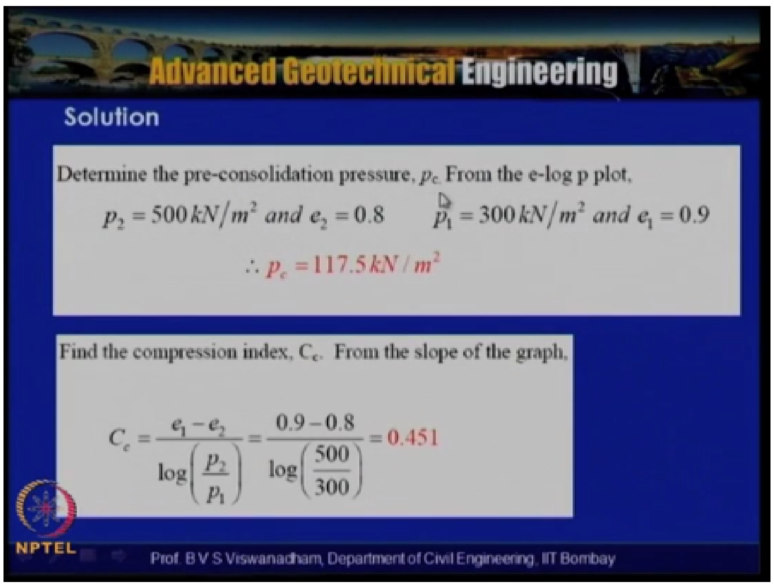

Then what we did is that we determine the pre consolidatation pressure from the e log p plot so here at P2 500kPa E2 is 0.8 and P1 300kN/m^2 e1 is 0.9 so the pre consolidation pressure.

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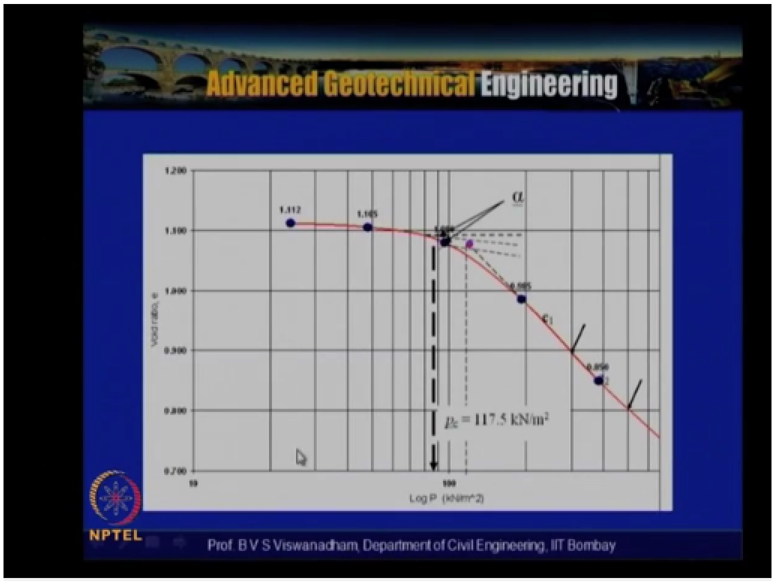

Is works out to be 171.5 kPa.

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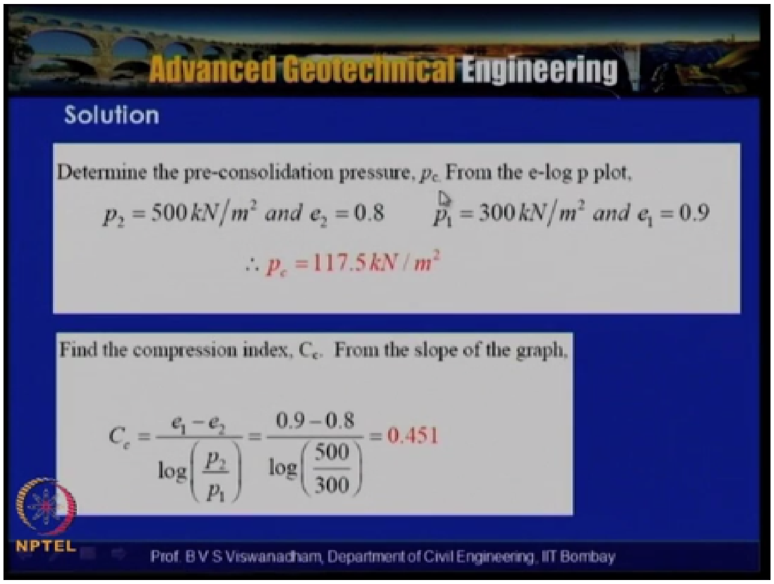

Now from the compression index we can actually find out here e1 – e2 /log of p2 / p1 so 0.9 – 0.8 /logarithmic of 500/ 300 you will get compression index of 0.451 so the compression index is actually obtained from the give data as 0.451.

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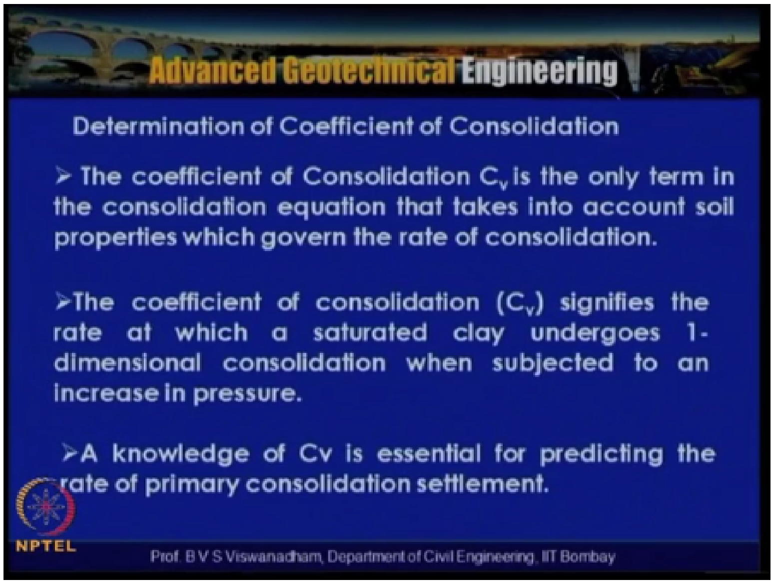

Now after having a discussed about this problems now we said that you know we will try to look into the methods for determining coefficient of consolidation and we have introduced also say over the coefficient of consolidation term of the first time in the consolidation and compressibility by joule in the consolidation equation where in we said that $\partial u/ \partial t = Cv\ \partial^2 u/ \partial z^2$ so the Cv term is the coefficient of consolidatation so the coefficient of consolidatation Cv is the only term in the consolidatation equation.

That takes into account the soil properties which govern the rate of consolidatation so the Cv is the only term or you can say the soil mechanism term in the consolidatation equation and which govern the rate of consolidatation so the coefficient of consolidatation Cv signifies the rate at which the saturated clay order goes 1 dimensional consolidatation when subjected to an increases in pressure.

So one more physical significant of coefficient consolidatation is that it signifies the rate at which the sutured clay under goes 1 dimensional consolidatation when subjected to increase in pressure, so a knowledge of Cv is essentially for predicting the rate of primary consolidatation settlement so you know the knowledge are from the consolidatation test data there are methods which are actually there also in the laboratory as methods are also there in the field also particularly when you have got a soils which are isotropic then it is assumed at that horizontal consolidatation as well as the vertical consolidatation they are same.

But if the soils are an isotropic in nature then the horizontal coefficient of consolidatation vertical coefficient consolidatation they are different, so naturally for Ch that horizontal coefficient of consolidatation is actually more than in a Cv that means that this analog us to when we discussed at the permeability the horizontal permeability in the horizontal direction is actually greater than permeability in the vertical direction.

So at that time we have discussed with that the east with which the water can flow through the soils is actually less in the horizontal plane than the vertical plane the reason what we discuss is that you know the as the σh is = $K0 \times \sigma v$ at k0 is the coefficient of earth pressure addressed because of that because of the less horizontal stress so the less you know you can say that less confinement so because of that the coefficient of permeability in horizontal direction is actually more than in the vertical direction.

As permeability and coefficient of consolidation are related we have based on the same analogy we can also say that the coefficient of consolidation in the horizontal direction is actually you know will be more that coefficient consolidation in the vertical direction so the coefficient of consolidation basically signifies at which the saturated clay undergoes 1 dimensional consolidation when subject it to in the rate at which it a saturated clay under goes a 1 dimensional consolidation when subject to a increase in pressure.

So for isotropic cases where identical properties are there then you we can take Cv = Ch so knowledge of Cv is essential for the predicting the rate of primary consolidation settlements there are also you know the field method are there for determining you know coefficient consolidation by using piezocone one can actually determine the you know the coefficient of consolidation in the field.

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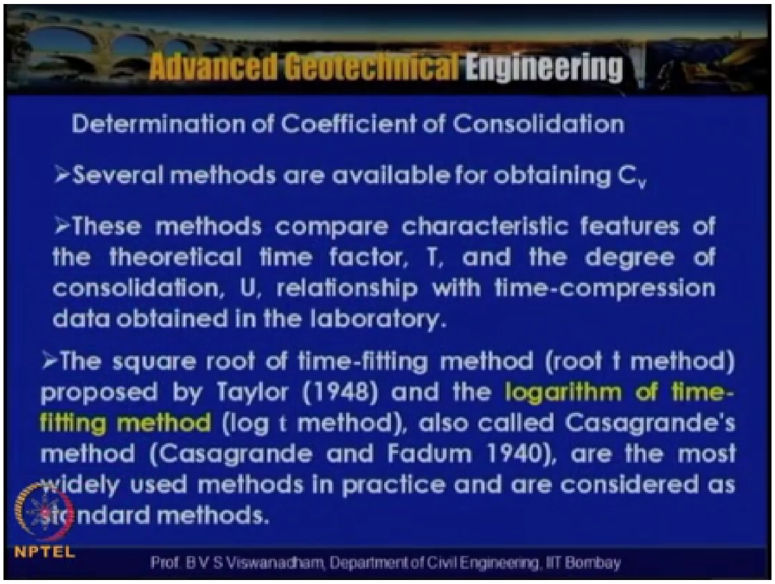

So there are several methods available for obtaining coefficient consolidation over a period of from 1940 on words the number of methods are been award and these methods compare the characteristic features of theoretical time factor T or TV and the degree of consolidation U relationship with time compression data obtained from the laboratory so from the wherever the data we obtain from the laboratory is what people compare is that the u verses TV or U verses T curve data your compared.

So these methods compare in principle characteristic features of the theatrical time factor TV and the degree of consolidation U relationship with time compression data obtain in the laboratory, so the square root of time fitting method which is also called as root t method proposed by Taylor 1948 and the logarithmic of time fitting method that is log t method and also and also called as casagrande method which is after casagrande and fadum 1940 are the most widely used methods in practice and are considered as standard methods.

So we have 2 broadly classified methods and one is you know root t method which was put forward by Taylor in 1948 and log t method which is called as a casagrande and which was put forward by casagrande and Feadum 1940 and both these are the most widely used methods in practice and are considered as standard methods so we will discuss you know these 2 methods and then also some coupe of methods we will discuss which are actually awarded in the resonant literature.

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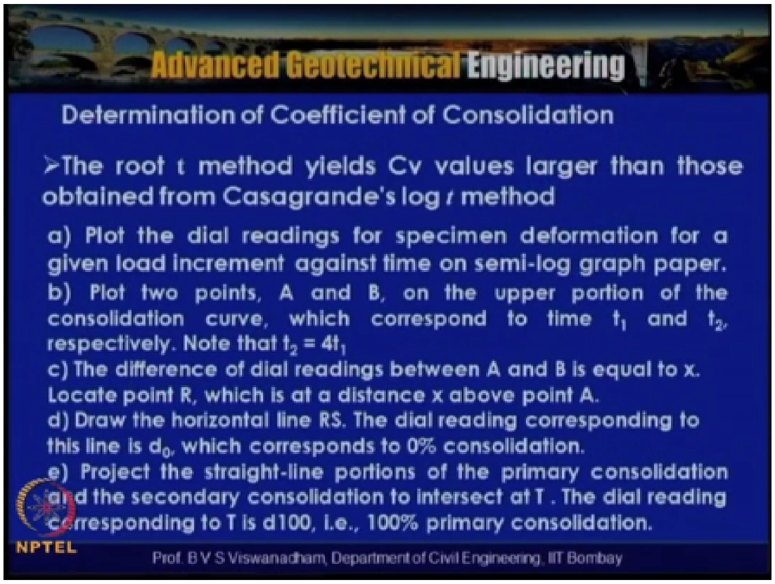

So for determining the coefficient of consolidation by using the root t method so first let us consider the root t method in the root t method the Cv values are larger than those obtained the casagrande's method so the reason we will actually discuss but what we need to understand is that we have to plot the dial gage readings for the specimen deformation for a given loading increment that means that you know we know that we have discussed that in the consolidation or odometer test each load will be kept for about 24 hours.

And let us say that if your keeping 100kPa load at the less node increment may 200 kPa so each load increment is kept for about 24 hours and give definite time and so for a give load increment whatever the time verses compression data which is the dial gauge readings the being of the placement of this load and till the end of this load and time as to be plotted on the semi logarithmic graph paper now what we need to do is that we have to plot two points A and B on the upper portion of the consolidation curve which correspond to time t1 and t2 respectively note that t2 = 4t1.

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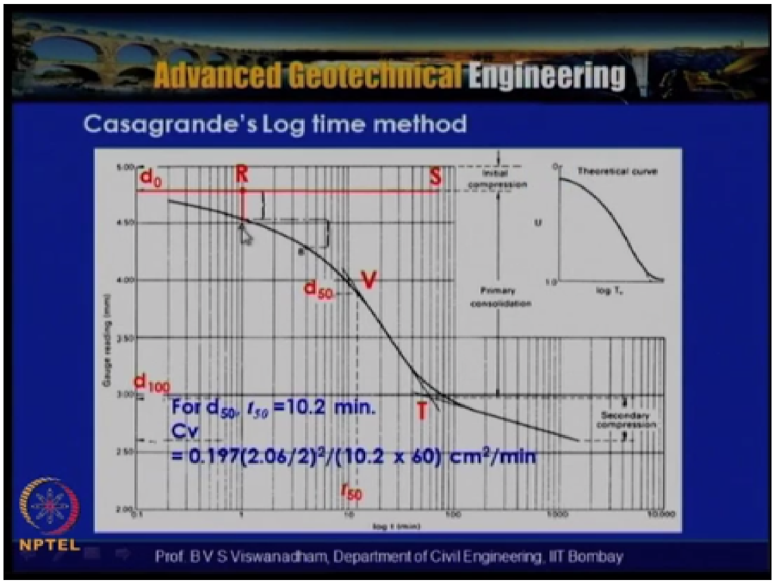

So this is nothing but you know we have to put plot 2 points on the consolidation curve so this is dial gauge reading on y axis and logarithmic of that time in minutes on the x axis and this a semi log curve and this is the u verses log Tv that is U verses Tv or U verses theoretical curve where you can see that where this is the 0% consolidation and somewhere here when you extend this portion this potion is into the secondary consolidation after the end of the primary consolidation.

So this 90% consolidation or 0.9 is somewhere here and this portion is you know so in this, so this is you know elaborated one with the time verses deformation is actually shown here. So you can see that the important part of this method is that.

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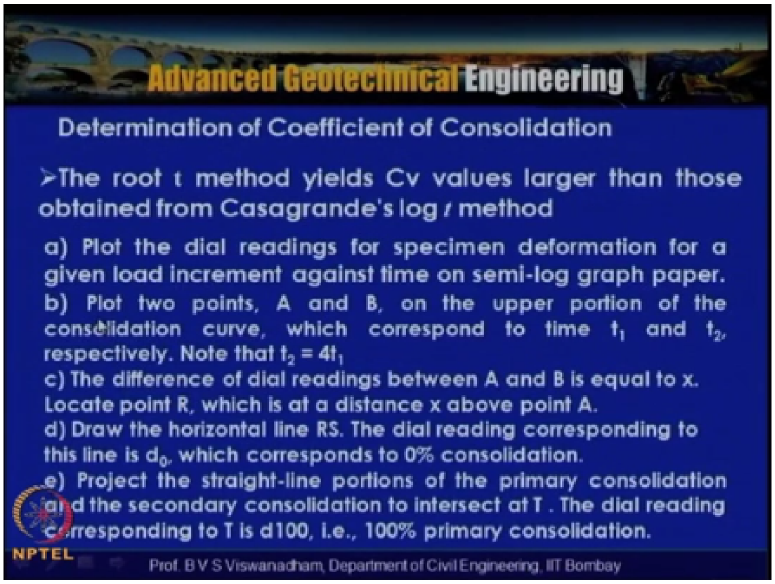

You have to plot two points A and B on the upper portion of the consolidation curve, so the upper portion of the consolidation curve means somewhere here and where the curvature is actually changing from the beginning portion you can say that 2.70 puts such a way that the upper portion the curvature such a whether which correspond to time t1 and t2, so note that t2=4t1.

So the difference in times t1 and t2 so t2=4t1 with that we have to identify two points, so after having done that the difference in dial readings between A and B is equal to x and so we have to locate point R which is at a distance x above the point A. So what we need to do is that the difference in dial case readings you know x here, let us say that if these two the dial reading vertical compression readings between A and B is say some X and above some X again a locate point R that means that another this is one x and this is the another x.

So here what we see some initial compression some primary consolidation region and this is the secondary compression and secondary consolidation region. So locate point R so we have located point R above A which is X units above the x units vertically above this one and that from through this point a drawn a horizontal line and you indicate that as the d0 that is the dial case reading at 0% consolidation. Take that as the dial case reading at 0% consolidation d0 and this is you regarded as you know d0 at0% consolidation. After obtaining that the you know draw the horizontal line Rs and the dil reading corresponding to this line is d0 which we have already said and which correspond to 0% consolidation.

Then what we do is that the project the straight line portion of the primary consolidation curve and secondary consolidation curve and intersected T then the dial reading correspond to T is at d100 that is 100% consolidation, so what we need to do is that the secondary consolidation portion and primary consolidation portion this tangent we have to extend further like this and this tangent we have to extend backward and this point when you take it back and this is the point what we indicate is that for that given loading increment this point is the dial case reading corresponding to 100% primary consolidation.

That is at the end of 100% primary consolidation, so beyond this it is actually entering into the secondary consolidation and secondary compression zone. So this d100 is nothing but which is at the end of primary consolidation d0 at the 0% primary consolidation the average of you know primary initial beginning of the primary consolidation at the end of the primary consolidation is called as d50 which is nothing but d0+d10/T and the time corresponding to d50 is regarded as t50 okay.

So note here the d50=d0+d100/2 and the time corresponded to the d50 is regarded as t50, so this line indicates that which is extend towards for example in this case it is 10.2 minutes.

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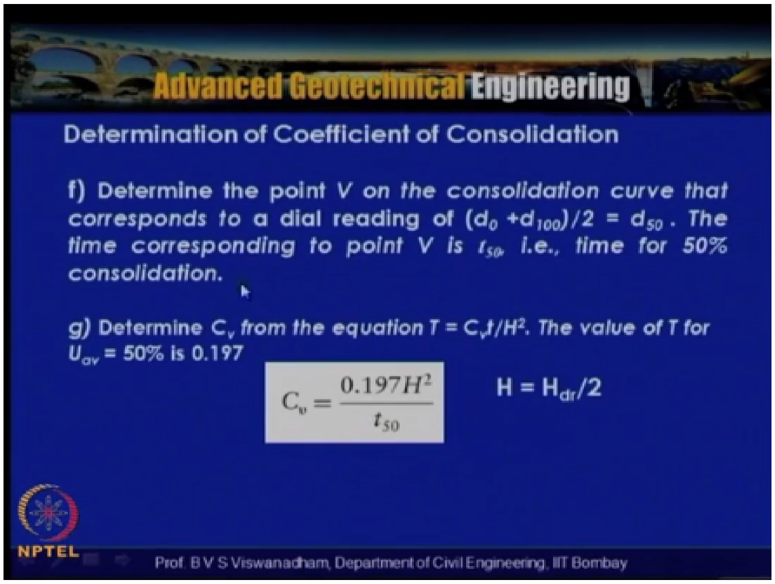

So we need to determine the point v on the consolidation curve such that the you know the reading correspond that correspond to a dial reading of d0+d100/2 which is equal to d50 the time corresponded to point v is called the t50 that is time for 50% consolidation curve. So in order to determine Cv from the equation what we need to do is that for 50% consolidation Tv is nothing but 0.197.

So by using TCv/H^2 and H is nothing but H drainage square that is H is nothing but the depending up on the drainage for example in case of consolidation test we have got you know these filters stored in both top and bottom so which is Hdr/2, so we can write Cv=0.197 that is the time factor for 50% consolidation into H^2/t50, so from the graph what we do is that we actually simply measure what is t50.

Once we get that one we can calculate by knowing the thickness of sample divided by 2 in case of w drainage we can get the Cv value. So for example, here for d50 let us say for d50 that let us say the time here is shown as 10.2 minutes so Cv can be obtained as 0.197 into 2.06/2 that is nothing but this is you know thickness of the sample divided by 2 whole square divided by 10.2x60 then you know we will get the coefficient of consolidation in cm^2/min.

So in the logarithmic time method what we have done is that for a given load increment dial case reading verses logarithmic of time we have to plot and then what we need to do is that, we have to indicate two points mark two points on the you know the dial case reading logt curve and such that t2, t1 is at A or t2 is at B let us say and t2=4t1 and that is the time lack difference and then you know that the vertical dial case reading difference between A and B points he say let us say x.

Then with another distance x above locate point R and then draw line Rs to that and the point along that particular line where along that line where it meets to the dial case reading it indicates that d0 and then when we extending the end of primary consolidation tangent and then the straightening portion of the primary consolidation portion and the secondary consolidation portion when they meet at the point t and this is actually is indicated or regarded as d100 and d50=d0+d10.

And with that we can actually locate a point you know d50 here on and if that point is B when we drop a vertical that is the d50, so with that what we can actually get is the by knowing d50 we can actually calculate for 50% degree of consolidation. Tv=0.197 so with that we can actually get what is the you know the so called coefficient of consolidation.

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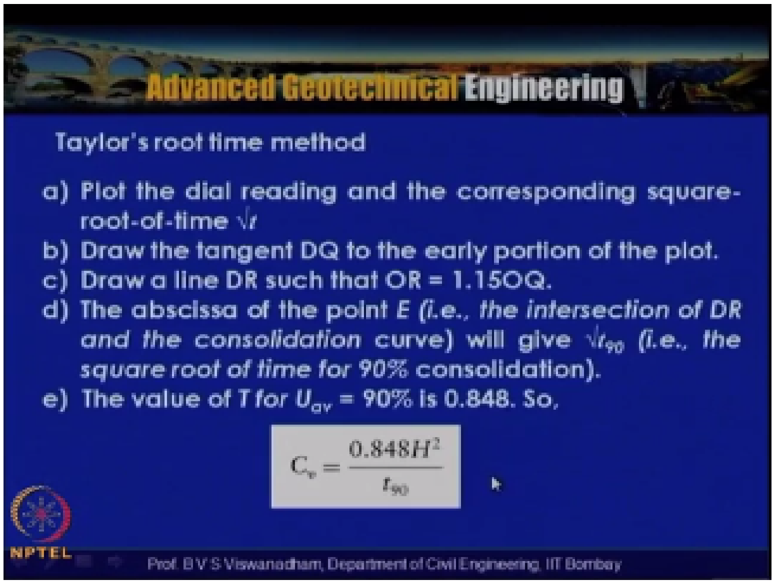

The next method is Taylor's root time method here what we need to do is that this is also for a given load increment plot the dial reading and the corresponding square root of time, so here dial reading on the y axis and on the x axis a square root of time is actually required to be plotted. Then that we have to draw the tangent dq to the early portion of the plot so here in this particular this is the.

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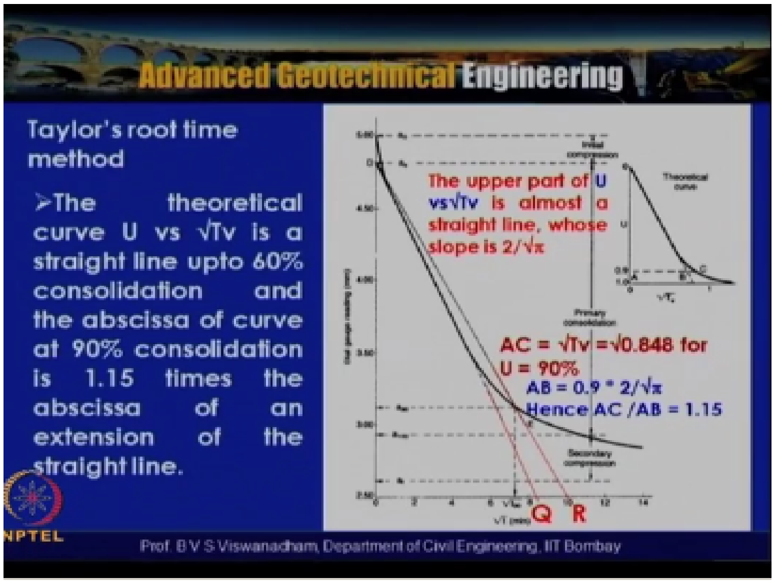

Taylor's root time method so you can see that the x axis actually is marked with the √t that is minutes √T which is minutes so whatever the time which we take that we have to plotted in the √T scale on the x axis and the dial scale readings whatever we record we can actually plot here. so in this one assumption is that the initial portion is actually assumed to be a straight line so normally for you know certain soils where you know the secondary re-consolidation clay soils you know the getting you know this straightening portion is difficult.

But in the position with the where if the organic pattern is in same not prevalent if the soil is actually slity in nature there can be possible if that the state level portion can be obtained. So in this case you know we can actually draw a line a tangent such a way that passing through the initial portion of the curve which is the straight line portion I draw a line which is actually is dq is here, okay.

So this is what the dq is mentioned draw the tangent dq to the early portion of the plot and draw the line dr such that OR=1.15 OQ so we will see how OR= this is O and if this is O here OR=1.15OQ that means that OR=1.15OQ, so this is you know we draw the initial portion the dq and another line which is actually originates from d again which is you know the r here. so how has been obtained is that if you look into this theoretical curve where u verses √v again we you know we said that you know this is analogist to u and Tv and u and √Tv and u and the settlement or compression verses √T, so these two are analogous, so because of this what we do is that this u and you know √v the nature of the curve is like this so this is 0% consolidation and this is 90% consolidation.

So this vertical height difference is 0.9 and this is 1, so this triangle has this ordinate is 0.9 this ordinate is 1. So here the upper part of the u verses √Tv is almost straight line you can see that the upper part of the u verses Tv is almost straight line this is for you know for this is based on $Tv=\pi/4\ (u/100)^2$, so by using that one we can actually say that you know this slope of this line you know is nothing but $2/\sqrt{\pi}$.

The slope of this line is nothing but $2/\sqrt{\pi}$, so with this what we can actually obtain now is like this, this slope of this straight line portion of this u verses √2v is $2/\sqrt{\pi}$ this is actually obtained from you know for primary consolidation equation for u<60% we said that u=p/4 u/100, $\pi/4\ (u/100)^2$ so that one when you simplify we would actually get you know $2/\sqrt{\pi}$ as the slope, okay. So now for the state level portion so we can try that AC, AC is nothing but that is here for 90% consolidation AC is nothing but √2v is nothing but 90% consolidation time factor is 0.848.

So which is you know √0.8484 and AB, AB is nothing but vertical ordinate this triangle if you look into that OAB then OA=2.9 and the slope is $2/\sqrt{\pi}$ then AB becomes $0.9 \times 2/\sqrt{\pi}$. So with that what will get is that AC/AB, AC/AB you know is obtained as AC/AB is nothing but AC is nothing but $\sqrt{0.848}/0.9 \times 2/\sqrt{\pi}$ which one if you specify we will get AC/AB as 1.15 that means that the theoretical curve U verse √Tv is a straight line up to 60% consolidation and the excess of the curve of 90% consolidation is 1.15 times the extension of an absence of the extension of this straight line.

So the theoretical curve U verses √Tv is a straight line up to 60% consolidation and the absence of the curve at 90% consolidation is 1.15 times the absence are of an extension of the straight line so using this classic what w had said is that the or = 1.15 times uq is actually a considering the energy and then the character by using the characteristic of the u vs √ TV we can say that or = 1.15, 1.15q can be ser once we get that you know once we draw this particular you know these two lines.

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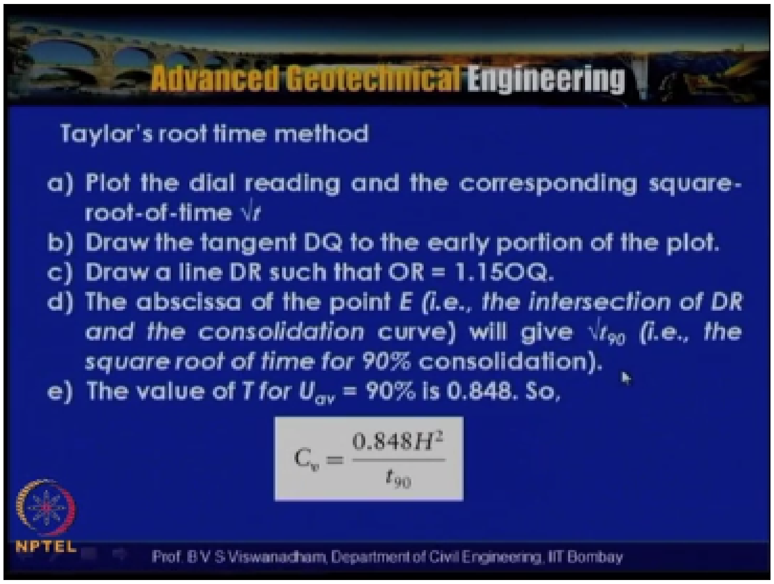

The abscissa of the point e that is the intersection of dr and the consolidation curve will give you √ T90 that is the √ of the time for the 905 consolidation that is that point where this dr we will intersect the consolidation curve that is this point is actually got regarded as E and the vertical when you drop we get is that time required from 90% consolidation, so this is 90% consolidation this is 100% consolidation and this is regarded as the 0% from this point D you know is regarded as the 0% consolidation this 99% consolidation.

So the value of the T for Uav is 905 is 0.848 so Cv cn b obtained as 0.848 into H2 / t90 so here also in this, this thing H is depends upon the drainage path, single drainage and double drainage and based on that we can actually calculate Cv and which is nothing but 0.848 into He / t90 so this is was discussed already so with that by using that procedure which we have discussed in the Taylor's root T method we can actually find out what is the.

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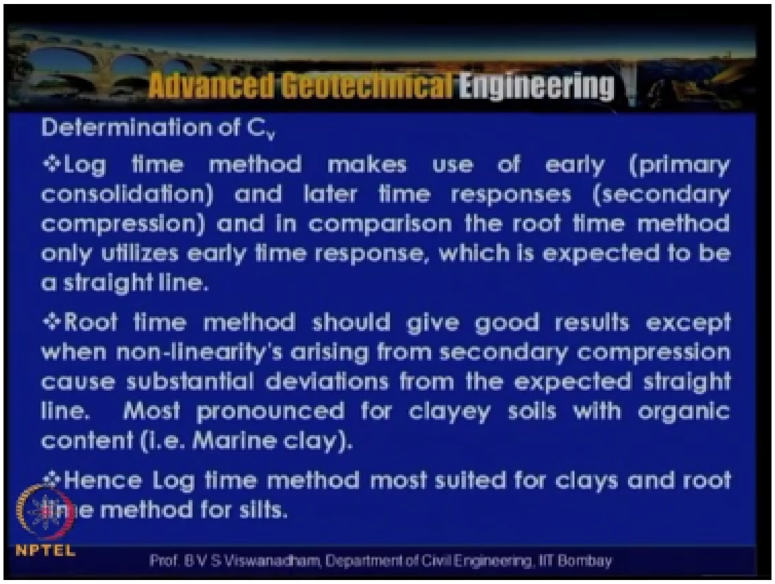

We can actually find out what is the you know the degree the quotient of consolidation and if you look into the chief differences between these two methods and long time method makes use of early pre consolidation makes use of early primary consolidation and lateral time responses that is secondary compression and in comparison the root time method root time method only it ways early time response which is expected to be a straight, so lock time method makes use of early as well as lateral time responses.

But in comparison root time method only uses the initial portion of the consolidation and which is assume to be a straight line, and root time method should give good results accept with non linearity problems arising from the secondary compression caused substantial deviations from the expected straight lines, so if there is a secondary consolidation you know situations when they are actually happening then you know the root time method you know will not be able to give the good result.

Because that the basic problem is that the non linearity which actually arises because of the secondary compression, so most pronounced for clayey soils with organic and so this non linearity is actually pronounced and you know of the you know dial case rading vs √ T curve or u vs √ TV is actually tend to be non linear and the straighten portion may not be expected, so there is for marine clays so this clayey you know we can actually we can put like that as you know logarithmic time method.

As sys for not only consolidation and it takes into consolidation later time response that is secondary consolidation we can say that the log time method is most rooted for a clays as usually marine clays and root time method for since and where the organic matter is you know even for organic since which is question but if it is absence of organic matter then that can be concern, so log time method is actually most rooted for clays and root tim method can be set as most rooted for shares.

And in the reason past then there are other methods which are actually have come they called early stage log time method and these methods you know this one of these reason methods this will actually put for Robinson.

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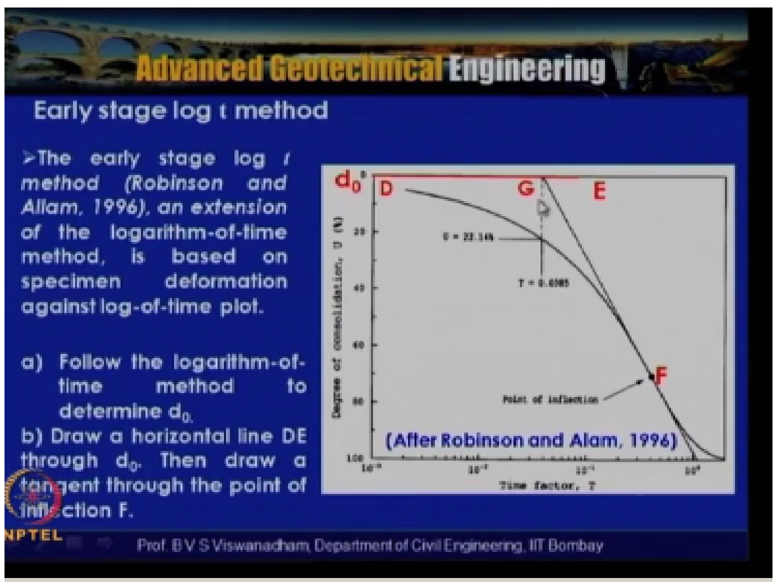

And Allam in 1996 and this is the extension of logarithmic time method and the early stage of the logirtghimic time method, so here what they have done is that you know the early stages of so this is you can say that this you know the logarithmic time method you know was actually extended by this Robinson and Allam in 1996 and this was done basically by looking into the field that are where the quotient of consolidation equation values are very high when compared to the laboratory data.

So the early stage of log –of –time method that is after Robinson and Allam 1996 is an extension of the logarithmic time method and is based on the specimen to formation again is the logarithmic of time plot, so in ten first step we follow the logarithmic of time method to determine d0, so here also to determine d0 we have to follow the procedure which we adopted so what we have to do is that we have to you know we want to first plot the time is reading vs the logarithmic of time.

Then we have to plot and indicate 2 points such a way that a and b and such a way that the vertical compression difference is say x and then okay horizontally on horizontal axis there is points a and b located such of that TB – T TB = 4 times TA and then we can actually determine d0 which is corresponding to 0% consolidation, then what we do is that draw the horizontal line DE through the you know this d0 point corresponding to that 0% consolidation and then they draw a tangent through a point of inflection.

That is through the point of inflection where the straight line portion is there and beyond which actually there is you know the secondary consolidation that is the 100?% 90% consolidation and 100% consolidation is actually come here, so extend this tangent line like this and the point where this meets you know this horizontal line DE is indicated as G so this particular point is regarded.

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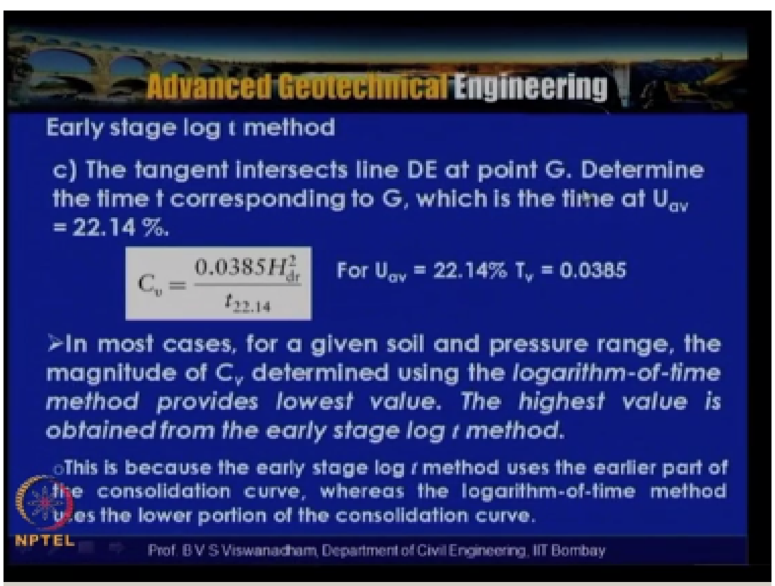

As the tangent intersect the line DE at G so this tangent intersects the line DE at G and then determine T time T corresponded to G which is the time at Uav = 22.4% that is the which is this is the time which correspond to Uav = 22.4% for so for 22.4% consolidation the time factor is Tv = 0.0385 so by using this and we can actually calculate the Cv which is nothing but 0.0385 Hdr^2 / the time for 22.14% consolidation, so with this what we can actually get is that you will get the you know the.

By using the early stage of logarithmic you know the consolidation test for a given load increment we can calculate the consolidation we can calculate the quotient of consolidation and we would not actually wait for the consolidation test to complete as for given load interment as that data is starts coming and we will able to plot and then try to get you know the equation of consolidation form the early part of consolidations, so in most cases for a given soil in pressure by in our magnitude Cv determine.

Using logarithmic of time method provides the lowest value the highest value is obtained from early stage of the logarithmic time, so this is because for a given soil and pressure range the magnitude of Cv determine using logarithmic of time method provides the lowest value and this is the highest value obtained by the early stage of so if you compare with conventional logarithm time method and the early stage log t method value is on the higher side the reason is that this is beaks the early stage of logarithmic time method.

Uses the early part of the consolidation whereas the logarithmic time method uses the initial as well as the lower portion that is the lower portion where you know the component of secondary consolidation also comes into picture, so because of this the you know the early stage logarithm of time log t method will actually has higher values connected values are in the higher side.

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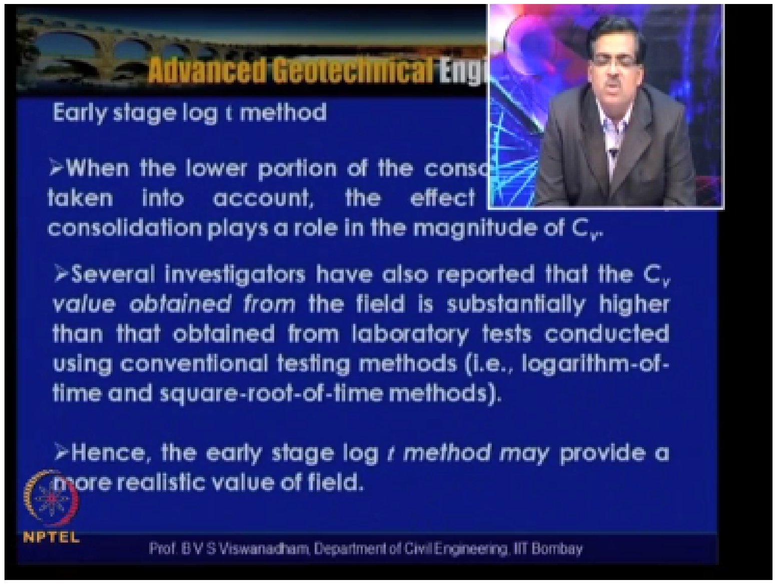

And when the lower portion of the consolidation can be taken into consolidation the effect of secondary consolidation plays a role in the magnitude of Cv so several investigation also reported that Cv value obtained from the field is substantially higher when that obtained from the laboratory test conducted using conventional testing methods that is logarithmic of time and square root of time method, so use of early stage logarithmic time method in a provide a more realistic values of the field.

That is that what this authors contention is that by using this early stage logarithmic of time method you know it if it gives the realistic values which may match with the field values, so when lower portion from the consolidation curve is taken into consideration the effect of the secondary consolidation plays a role and because of that the magnitude of Cv decreases, so several investigator soil, so reported that the Cv value obtained from the field is substantially higher then that obtained from the laboratory test.

Conducted using conventional testing methods like logarithmic of time and square root of time method and by adopting this early stage logarithmic time method the values may provide you know have a good match with the realistic values in the measured in the field.

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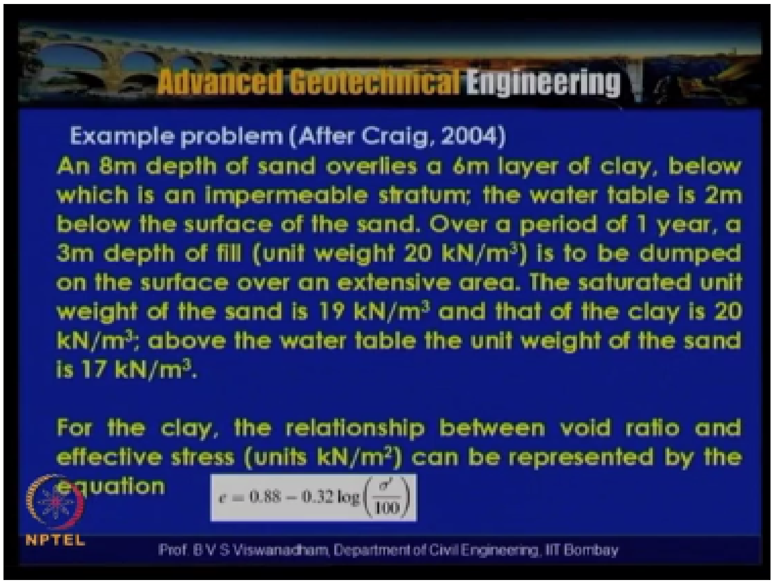

So after having discussed you know this you know methods for determining quotient of consolidation you know let us look into we what we have done is that in the determination of methods for consolidation we have discussed with about the two standard methods and one early stage method which is given by Robinson and Allam in 1996 now let us consider or example problem where you know the if the problem statement works out like this we have got 8m depth of sand overlies is 6m layer of clay below which is an impermeable stratum.

The water table is 2m below the surface or sand and over a period of only a 3m depth of the fill is to be dumped on the surface or over an extensive area that means that the fill externs to large areas the saturated unit weight of the sand is 19KN /m^3 and that of the clay is 20KN/m^3 and above the water table the clay the unit weight of the sand is 17KN/m^3 so for the clay the relationship between the wide ratio and the effective stress and KN.m^2 can be represented by the equation.

Which is given in the problem statement as e = 0.88 – 0.32 log of σ - / 100 so here we have you know the 8m depth of the sand overlies is 6m layer of clay and below which there is you know the water table is 2m below the surface of the sand and here if you notice here the fill us actually not dumped or a you know instead it is dumped over period of 1 here, the so the construction period of is takes bout I year for the fill to reach about the maintained about 1 year to reach or 3m height on the soil straight which given.

And this saturated unit weight of the sand is the 18KN/m3 and that of the clay is 20KN/m3 and there is unit weight of the soil above the water table e of the sand is 17KN/m3 and then here if you look into this the relationship between the wide ratio the effective stress are given that relationship is actually worked out from e log σ or e log p curve which is nothing but = 0.88 – 0.32 into log σ - / 100 where the σ – is measured in KN/m2.

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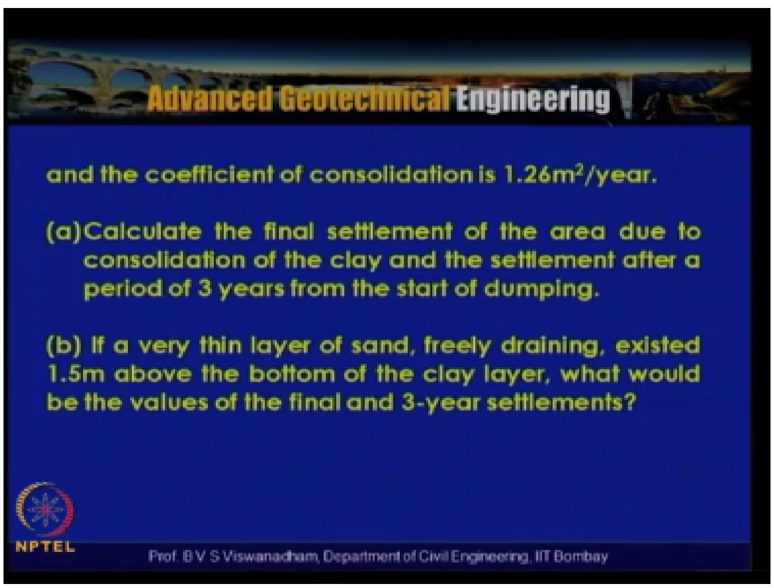

And the is also given the quotient of consolidation of this soil is 1.26m2/y you know that the quotient of consolidation the unit weight is m2/unit or m/s m2/y or cm/minute and this is the units are the equation of consolidation of this soil in the of the clay is 1.26m2/y so what we need to do is that calculate the finical of the area due to the consolidation of the clay and the settlement after period of three years but the start of dumping, so we need to calculate you know the final settlement of the area.

Due to we consolidation clay and the settlement after period of 3 years from the start of dumping then if you are actually having a very thin layer of sand rely draining time and existing is existed 1.5m/ the bottom of the clay layer then what will be the value of final and 3 years settlements, so first is that clays homogenous but naturally there are some runs of the clay and where you know which actually had been located generally this when you have got some clay to posits so they are stratified in nature.

And sometimes there is a possibility that large thing sand lenses an actually come suppose if these things and layers are not located from the soil investigation and if the settlements area actually estimated without considering this presence of this thing sand layer then the settlements will be catastrophic in nature that is what actually we are going to demonstrate to this problem, so here if a thin layer of sand and the freely draining type and existed 1.1m above the bottom of thick layer then what will be the values of the final and 3 years settlements.

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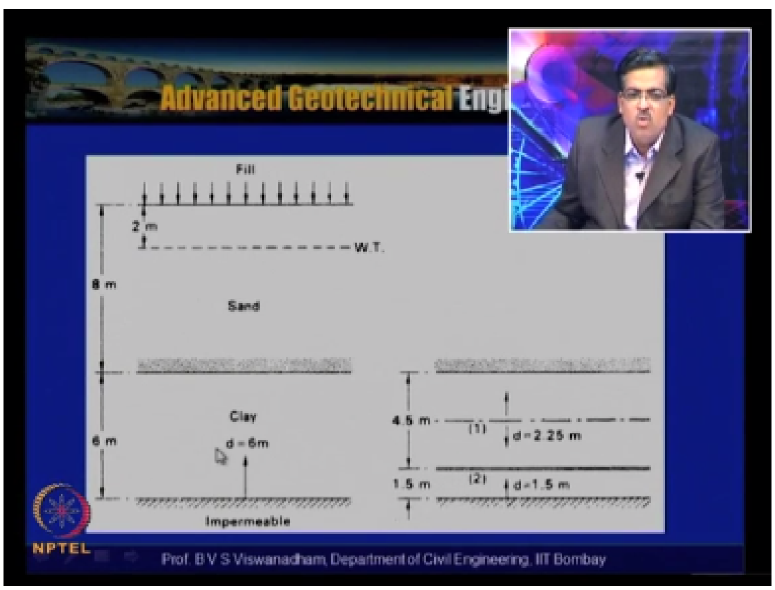

So these starts a which is actually given the problem is explained here the bottom layer is impermeable and upper layer is here is sand, so 8m layer is sand here and water table is 2m below the ground surface and we can see that here that play is 6m thick and the second portion what we have is that this you know we have got in layer but a thin layer of sand is actually show here, so this is 4.5m this is 1.5m if so this is 1.5m below the grace layer and this is the homogenous layer.

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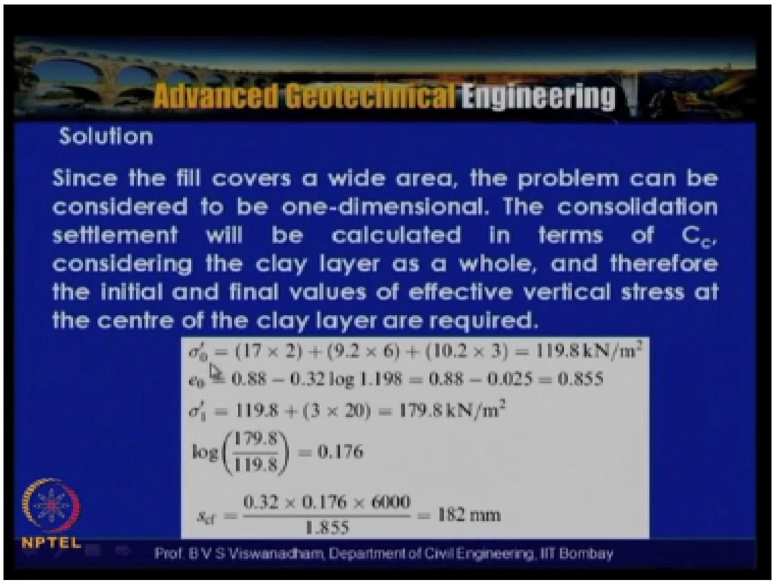

So since the field covers the wide are the problem can be considered to be 1 dimensional the consolidations settlement will be calculated in terms of Cc and considering the clay layer as a whole layer and therefore the initial in final values of effective particles stress at the center of the clay layer are required, so we can actually calculate σ_0 - σ_0 – that is at this center of this layer we know that because here the access pore water pressure dissipated is minimum layer so we calculated the in the center of thick layers σ_0 -.

So this is actually σ_0 - = 17 into 2 that is above water table 9.2 x 6 + or 10.2 x 3 so this is σ_0 dash that is taking pore water pressure out of it then e0 which is you know 0.88 – 0.32 x log 1.198 because here σ_0 – is you know 119.8 / 100 will get this then you know what we have is that e0 low initial wide ratio from the e of data is 0.855 and σ_1 dash because here we wanted to say that 119.8 + 3 x 20.

So this actually has been loaded over period of 3 years so this σ_1 – is 179.8 different per meter square so the logarithmic of 1799.8 / 119.8 which is 0.196 176 so with that what we get is that the settlement is you know about 182mm, so in this particular problem we will actually stop here where in we actually discussed about how we can actually determined the final consolidation settlement and this is the part of the problem only where in we have calculated the you know the settlement.

Which is coming out as if this clay undergoes consolidation the total settlement is a consolidation settlement will b 182mm and then further we actually have to account for you know if you notice that the time required for filling you know the placing the fill along the soil is about 1 year so then we have to do correction for the construction period correction on this construction period correction concept is introduced then we will try to solve the part two of this problem and then.

We will try to take into the effort of say thin naturally occurring thin layer of sand and how that effects in accelerating the consolidation generally if you know this is one of the classical example sometimes if it is not recognized during this site investigation if the structure is constructed thinking that the soil is you know homogenous and free from this lands of sand layers and weight is the settlements can be you know they can strophic in nature.

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NPTEL
Principal Investigator
IIT Bombay
Prof. R. K. Shevgaonkar
Prof. A. N. Chandorkar

Head CDEEP
Prof. V. M. Gadre

Producer
Arun Kalwankar

Project Manager
Sangeeta Shrivastava

Online Editor/ Digital Video Editor
Tushar Deshpande

Digital Video Cameraman
Amin Shaikh

Jr. Technical Assistance
Vijay Kedare

Project Attendant
Ravi Paswan
Vinayak Raut