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NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

CDEEP
IIT BOMBAY

ADVANCED GEOTECHNICAL ENGINEERING

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Lecture No. 25

Module-3
Lecture – 7 on Compressibility and consolidation

Welcome to lecture series on advanced geotechnical engineering which is the course you know being produced by the Indian technology Bombay department of civil engineering and we are in module 3.

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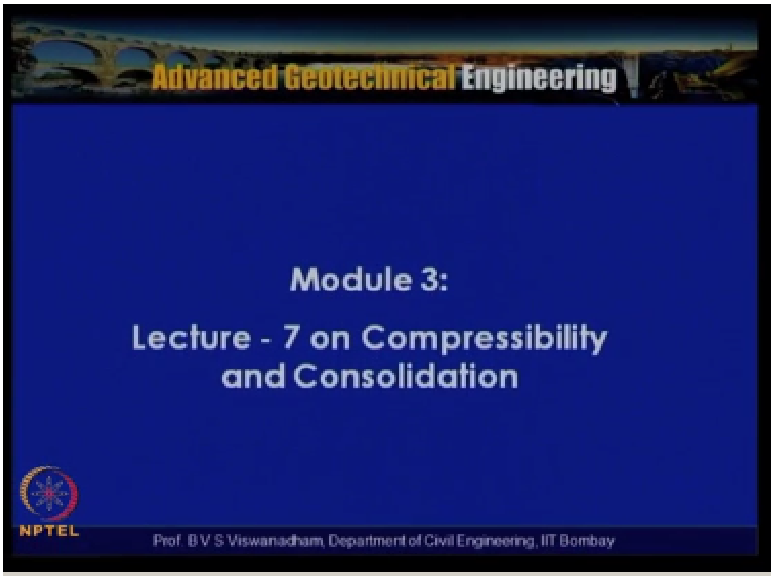

Lecture 7 on compressibility and consolidation.

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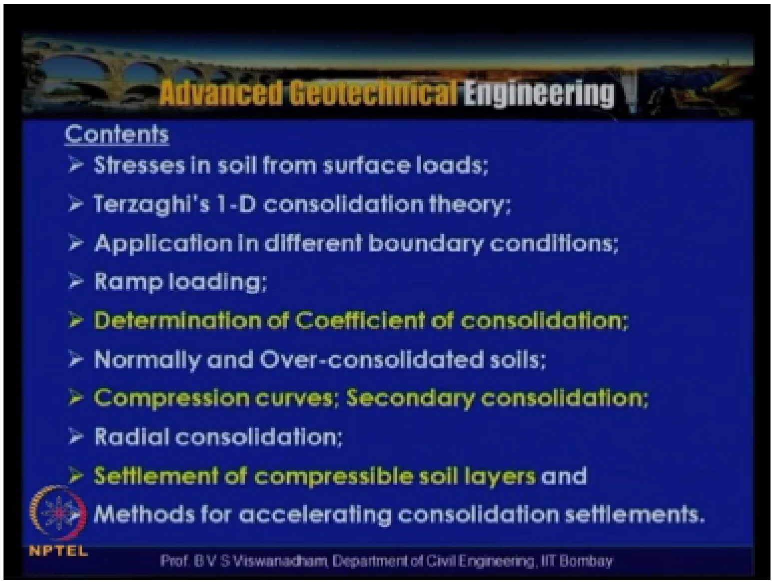

And we have been actually discussing about the methods for determining quotient of consolidation in this particular lecture also will try to discuss about the another method which is the rectangular hyper polar method and then we will try to discuss about the secondary consolidation concepts and then how to determine settlements of a compressible soil deposit from the compression curves and that is settlement of the compressible soil layers and we also look into you know when we have.

You know construction period when it actually happens for a certain period of time how the construction period can be accounted or corrected in the you know in completing time rate of settlements then we will continue the problem which we introduced ourselves in the previous lecture.

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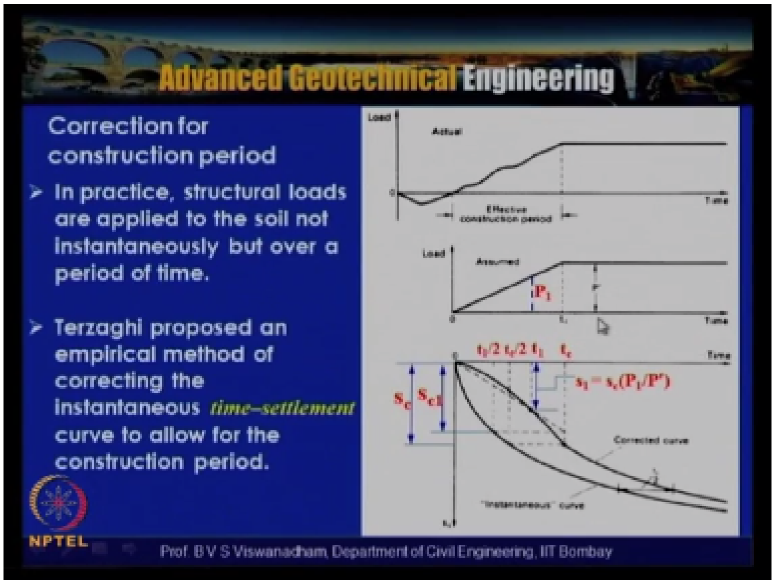

So the correction for construction period has we can see in this particular slide in practice the loads which are actually apply to soil we are not instantaneous but over a period of time we are applied over a period of time that is that if you wanted to construct a embankment of about 6m high it cannot actually happen all of set, so in that case you know it takes over a period of time and it can be you know a constant years rate at which the height will increase or you look into the stages like you know two stages or 3 stages.

Depending upon that when you take the rate it can be also set as constant so initially when actually acquire the site that can be some acquisition or in other so in this case there can be some you know the reliving of pressures there is removal of the load and then reloading again because of the some rest of tradition profile and then you know the fill will start convincing up so this is you know the load vs time let us say that you know tc that is the time required for construction lt us say that 6 months.

Amy be in the field or 1 year in the field that is called time required for constructing let us say that embankment of 6m or h meters height, so in this case if you are having in embankment of certain height and which causes a pressure of say p – then tc is said as time period of construction now what we if you look into this you know as per the theory of one dimensional consolidation and it assumes that you know the load is place instantaneously that means that here we will see that the entire you know this is due to instantaneous loading.

But as we know that this particular portion is not actually subjected into load you know first 6 months let us say that the load will not exist at all in that case you know we actually end up you know having the higher order of settlements but for a long period of you know after long period of you know elapsing long period after construction then again they tend to be same that is what you can see that so here what we see is a corrected curve, so how to you know obtained this corrected curve.

That we look into it and then we apply this in the problem which we are going this which we are discussing from the previous lecture onwards, so in practice what we are summating is that the structure loads are apply into the soil not instantaneously but over a period of time so Terzaghi's proposed an empirical method for correcting empirical method of correcting the instantaneous time settlements curve sin settlement curve to allow for the construction period, so Terzaghi's has come out with an empirical method.

Of correction for instantaneous time settlement curve to allow for the construction period, so what w do is that the net load p – is the gross load?

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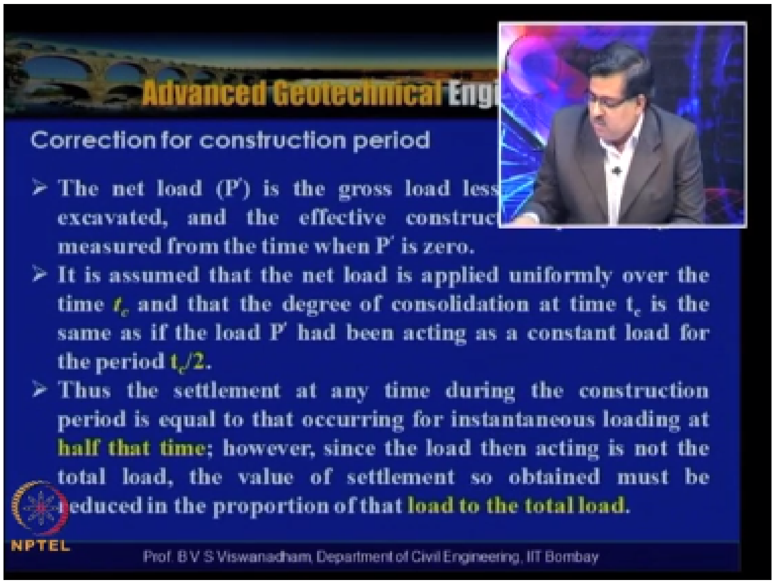

Less the weight of the soil excavated and the effective construction period tc is measured from the time when p dash is 0 that is when p- is 0 means the construction period is actually measured from the period the not the excavation all those things from this stage onwards the construction period is measured from this stage to stage that is tc, that is the construction period now it is assumed that the net load is applied uniformly over the time tc and the degree of consolidation at time tc is same as.

If the load p – at been acting as a constant load for the period tc / 2 so it is assume that net load is applied uniformly over the period of time tc and that degree of consolidation at time tc is same as if the load p- has been acting as a constant load for the period tc/2 that is after construction period that means that the settlement any time during the construction period is equal to that occurring for instantaneous loading at after time, that means that you know if settlement is there the settlement at any time.

During the construction period is equal to the that occurring for instantaneous loading at that of the time however since that load then acting is not the total load the value of the settlements so tend must be reduced in proportional of the load to the total load, so in view of days let us define here let that tc is the time which is required for construction that is to raise to the pressure of p – and if that settlement is say sc then what we are saying is that at tc / 2 also the consolidation so what we are saying is that if the settlement are degree of consolidation at tc/2 and tc are assumed to be same.

So what we try to look into this is that consider at any time t between 0 to tc at pressure t and which is having an ordinate p when here the lording pressure and at this point let us say the time t1 and if you know if you are trying to get this t1 / 2 that t1 / 2 the settlement is say sc1 here, so the settlement at time t1 should be less than that, so inn order to account for that w can write that settlement at that particular point is nothing but s1 = sc into P1/ P- what we have done is that we actually a portioned.

With we have apportioned with P1 / P- so P1 is actually less than P- sp P1 / P- into the final consolidation settlement we said that is s1 so this is nothing but what we have done is tht we actually use this principle of triangles for this area for this zone and then this zone and then we try to compute the settlements here, so from the similar triangles we can write P1 / P- P1 is actually.

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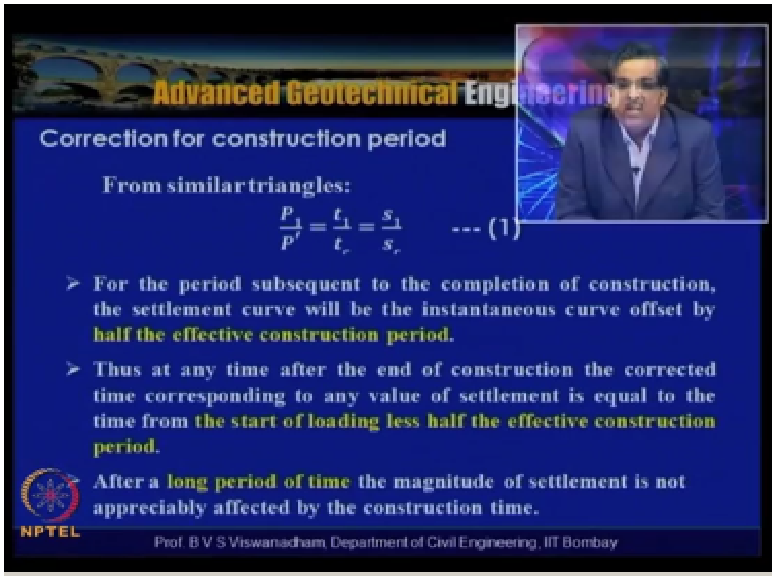

Pressure within the construction period P- at time tc so at that time is that t1 / tc = s1 / sc so for that period subsequent of the completion of construction the settlement curve will be instantaneous curve off send by the off the effective construction period that is what we are saying is that this particular one it is off the construction period that is tc/2 but at long period r elapsing long period after the construction the both remain to be same, so thus at any time after the end of construction the corrected time corresponding to any value of settlement is equal to the time.

From starting of the loading less of the effective construction period from here what we understood is that thus at any time after the end of the construction the corrected time corresponding to any value of the settlement is equal to the time from the start of the loading less the of the effective construction period that means that you know what we have to do is that we have to take or detect you know after that shorting starting of the loading let us say that if it is 3 is given.

And construction period say takes you know 6 months that 3 years – 6 months is around 2 and half years is for example is the, the period that means that what we are doing is that we were detecting this effective construction period, so after a long period of time the magnitude of settlement is not of the effective construction period that means that if construction period takes 1 year that is 3 years / ½ it is 2 and half years after long period of time the magnitude of settlement is not appreciably effected by the construction time, so what we are doing is that two important things which we understood is that.

The instantaneous curve and corrected curve are initially during the construction period they are not the same, so what we are doing is that as the loading intensity is less than what it is actually assumed in the instantaneous curve competition so we correct the settlements such a way that you know the and then also any time after the end of the construction the corrected time corresponding to a any value of the settlement is equal to the time from the start of the loading less ½ the effecting construction period.

And after sub after long period of time the magnitude of settlement is not appreciably affected by the construction time.

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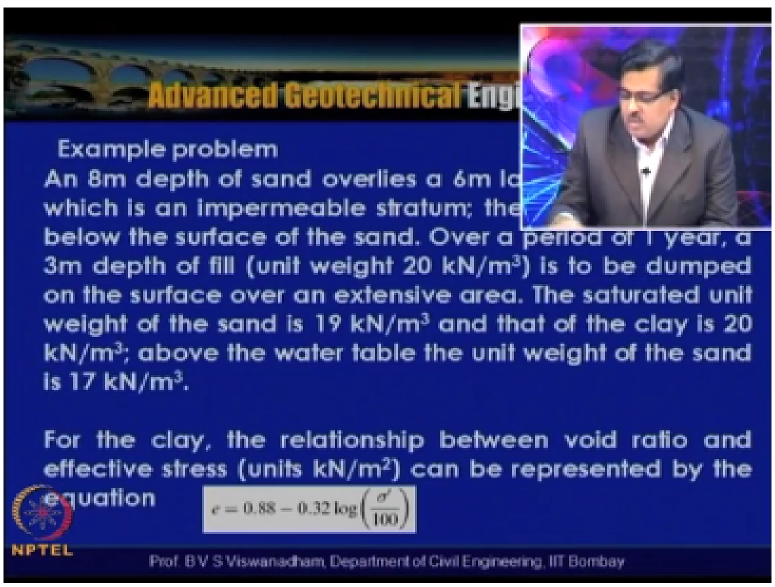

Now let us look into this example and 8m depth of sand overlies is 6m layer of clay below which an impermeable stratum is there the water table is 2m below this surface of sand and over a period of one year, so here the construction duration is 1 year please note the construction duration is 1 year a 3m depth of the fill which is actually having a unit weight of 20KN/m3 is to be dumped on the surface over an extensive area that means that the area is the filled area is actually spreader over large areas.

So the saturate unit weight of the sand is 19KN/m^3 and that of the clay is 20KN/m^3 and above the water table the unit weight of the sand is 17KN/m^3 so for the clay the relationship between the wide ratio and the effective stress is given and this is nothing but e = 0.88 – 0.32 log of σ- / 100.

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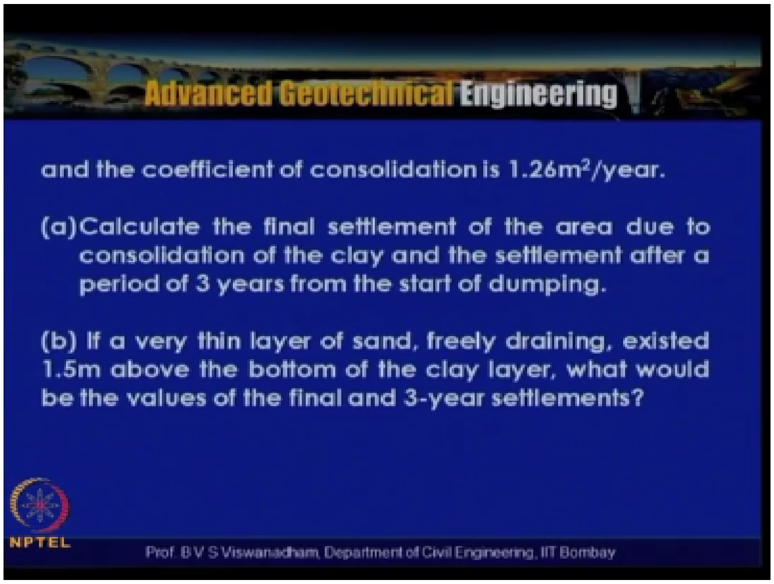

So what has been asked is that calculate the final settlement of the area due to the consolidation of the clay and the settlement after period of 3 years from the start of dumping and quotient of consolidation is given that is 1.26m2 per year and if a very thin layer of sand freely draining type existed 1.5m above the bottom of the clay layer what would be the values of the final length 3 years settlements, so this is the you know figure based on the problem.

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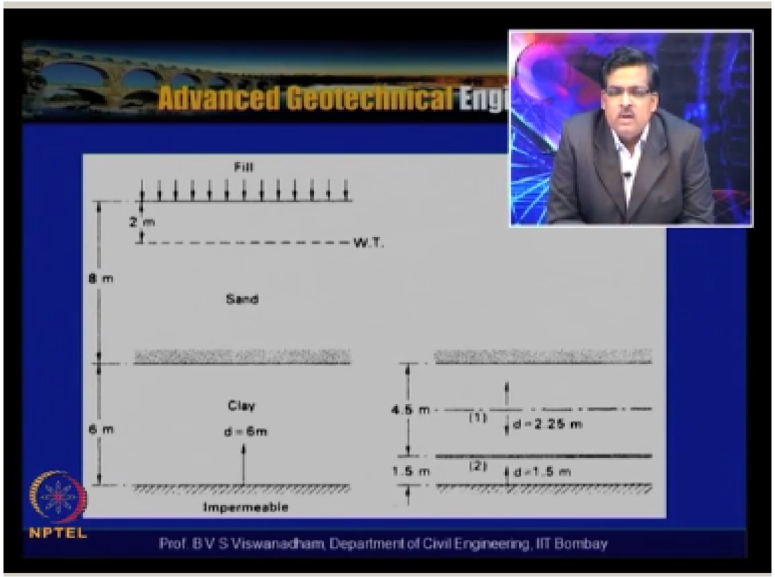

What we have discussed we have got a 6m thick clay layer and which is having a thickness of 6m clay layer having 6m thickness impermeable stratum here and so this is you know one way drainage water flows in this direction and this is the open layer for this clay layer and this layer is having a thickness about 8m and 2m is depth of water table from th ground surface and on this a fill of you know 3m height is placed over period of 1 year and it is also possible that you know in some locations.

That can be chances of you know thin lenses of sand layers particularly in all in deposits they can exist and these deposits this type of thin lands of sand layers can call you know what is their effect we can actually see, so in this given problem we have a layer of this is 4.5m and this is 1.5m so this problem is actually after grad 2004 very classical problem where it has been discussed what is the effect of the you know this thin lenses of sand layers on the time rate of settlements.

So this we have discussed but any how we will try to you know we capture what has been discussed as we have seen that the fill covers a wide area the problem can be constructed been on dimensional.

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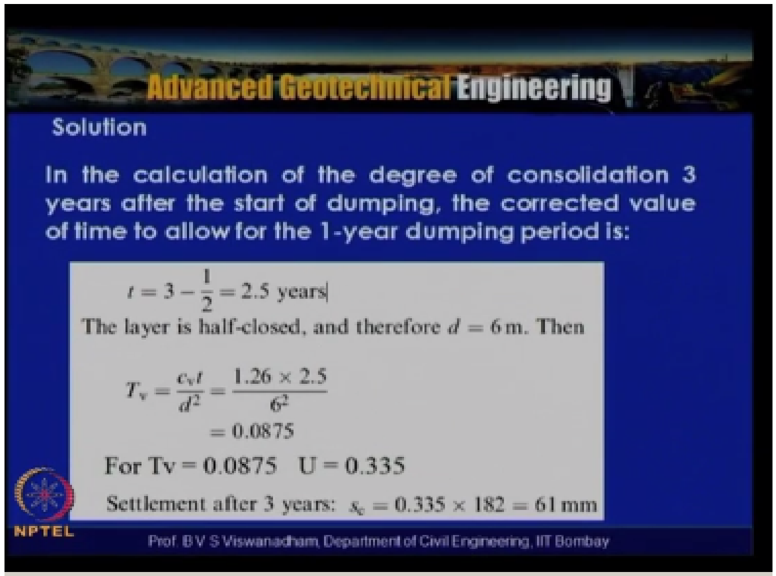

That is one w have discussed the consolidation settlement will be calculated in terms of Cc considering that clay layer as a whole and therefore the initial and final values of the effective vertical stress at the center of the clay layer are required, so with this once we calculate we get 182mm is the settlement and which is you know which is the ultimate consolidation final consolidation settlement now here because of the increase in the construction of you know the fill having a height of say.

3m or a period of time I year now what we need to do is that we need to calculate the settlement after 3 years that means we actually have to correct by using the Terzoghi's method what we discussed t = 3 – tc/2 where T_c is nothing but the time required for constructing 3mm that is 1 year, so 3 – ½ 2.5 years in the calculation of degree of consolidation 3 years after the start of dumping the corrected value of the time to allow for the 1 year dumping period is nothing but 3 – ½ that is 2 and half years.

So the layer is off close that nothing but a single drainage therefore t = 6m now from Tv time factor is equal to TCV/ H2 or Tc/d2 where in what we get is that 0.0875, so by using Tv = π/4 U/100 whole square where we can actually get for U = average consolidation as 0.335 so as we know the final consolidations settlement which is 182mm and settlement after 3 years will be 61mm settlement after 3 years will be will only be 61mm that means that 0.335 is the degree of consolidation we have computed.

Based on the data which data which we are having and the settlement after 3 years we say sc = 0.335 x 182 that is 61mm.

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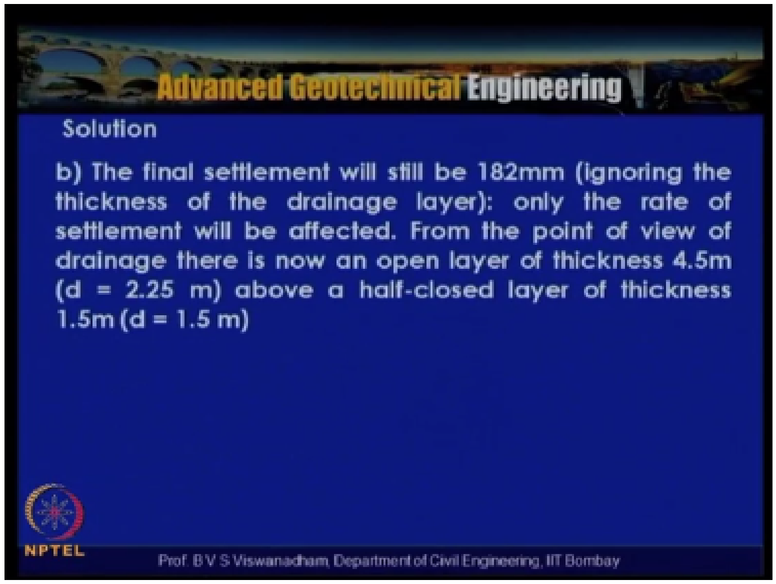

Second problem what as the second part of the problem has been asking that the final settlement will still be 182mm for even for the second problem but only thing is that the rate of the settlement will be affected why because if you are having a thin layer of sand and where it actually has got the you know let us say that the layer receives the water and has got the drainage capability then you know it can actually work as from the bottom portion it actually in more case one way drainage and the portion.

Above 1.5m it can work as two way drainage so in the sense what is happening is that here we actually have the positive effect of this clay layer the sand layer on the clay layer if it is directed in advance then you know there is a possibility that this settlement can be accelerated, so from the point of view of the drainage there is now an open area open layer of thickness 4.5m of thickness 4.5m that is above the half closed layer of thickness d 1.5m, so that is if we look into this see here this portion is behaves like a 1 way drainage the water from here shown down to this one.

And this portion which is actually having a drainage part of 2.25m half of the water goes this said half of the water goes this side and we assume that this layer has got a capability of pumping the water out from this layer this side this portion to this portion and in this case now let us see what we do is that this upper portion of the layer actually having 4.5m thickness and bottom portion is having 1.5m thickness and total thickness of clay layer is 6m with this you know can actually the effect of this.

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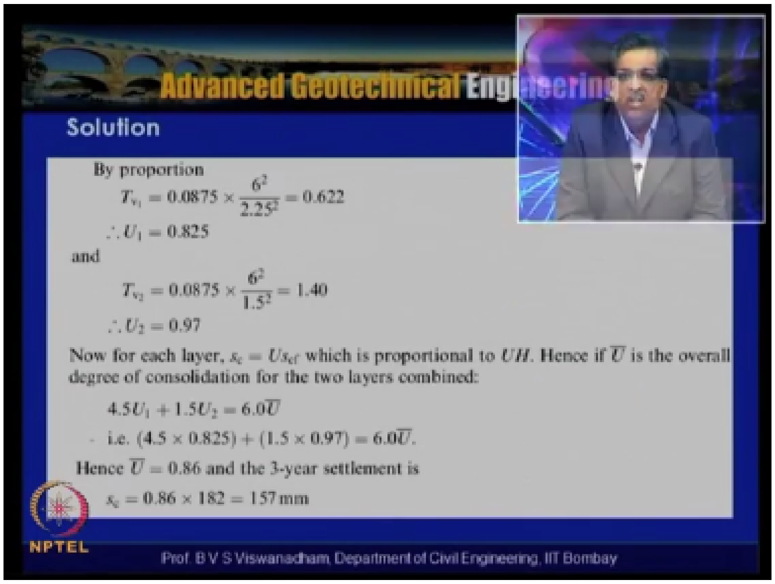

Like this so upper portion of the curve that is Tv1 for this you know we can actually calculate you know what is the you know the based on the drainage Tcv / H2 and that is nothing but 2.25/2 that is T is nothing but 3 – ½ so and Cv is 1.26m2 per year divided by that is 4.5/2 you will get 0.622 for 0.62 0.622 by using you know the we can actually get the degree of consolidation as 0.825 and then the bottom layer which is you know which is nothing but half close layer, so which is nothing but half close layer.

So which is nothing but Tv2 can be obtained like 3 – ½ into Cv is 1.26 / 1.5^2 with that what we get is that 1.4 so with this what we get is the degree of consolidation as 0.97 now if you look into this now for each layer sc = U into scf now we have to get the you know by using the weighted average method you have to get the U bar, now upper layer is having a 4.5m thickness and bottom layer is actually 1.5m thickness so 4.5 x u nd + 1.5 x U2 = 6U bar because U1 = 0.825 U2 = 0.97 and so U bar is actually obtained as 0.86.

Now for so settlement after 3 years can be obtained as final consolidation settlement we are actually obtained as you know 182mm and when we have only 6m thick layer of consolidation as 6m thick layer of one way of close layer we said that the settlement of only 61mm will occur, but if we are actually having a thin sand layer where sc = 0.861 into 182 that is 157mm so that means that if we are in from the soil investigation data.

If we faint to recognize this type of occurrence of thin layers of sand and the design of this building is don from the baring capacity and settlement point of view and of the settlements of this order of 157mm occurs within you know period of say 3 to 4 years of from the start of the construction of the building or a structure and the structure which is you know going to be you know this will be going to replace going to have experience the distress because they allow goal settlements in that play.

Are not more than 50mm so in this case what we can see that you know the settlements are very excessive in nature and they can actually cause the stress and failures to be structures, so this example clearly demonstrates the effect of the thin layers of the sands on the you know how they can actually have accelerating effects on the rte of consolidation but unfortunately if it actually occurs in the universe site and if it is recognized you know well in advance yes there is a possibility that the settlements.

Can be accelerated but if you fail to recognize the nil effects of discuss but if these, these layers are when there is a possibility that the settlements will be accelerated but it is r2 to find this typ of things you know occurring the repeatedly, so in view of you that you know there are several other methods which are there for acceleration consolidation, so those things will be discussing while at the seeing about the methods for accelerating consolidation settlements, now after having discussed about that particular problem.

Let us try to discuss about the another method which is rectangular hyper polar method and which is after Sridhar run and prakash 1985.

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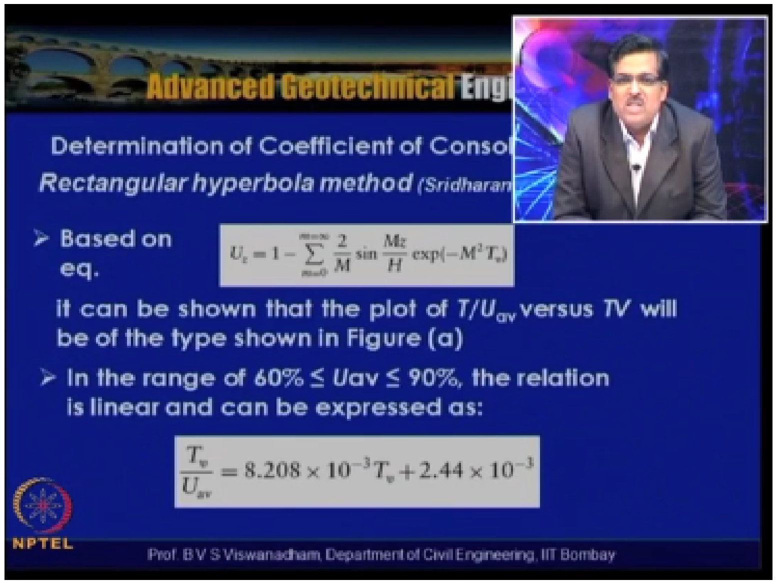

And based on this equation which we have shown her Uz = 1 - ∑m = 0 to ∞ 2/M Sin Mz/H exponential of – M2Tv, so it can be shown that the plot of T/Uav versus Tv T suffix V will be of the type shown in figure a which we will be showing and in the range of 605 to 90% of average degree of consolidation the relation is linear and can expressed as Tx/ Uav = 8.208 x 10 $^{-3}$ T suffix V + 2.44 into 10 $^{-3}$.

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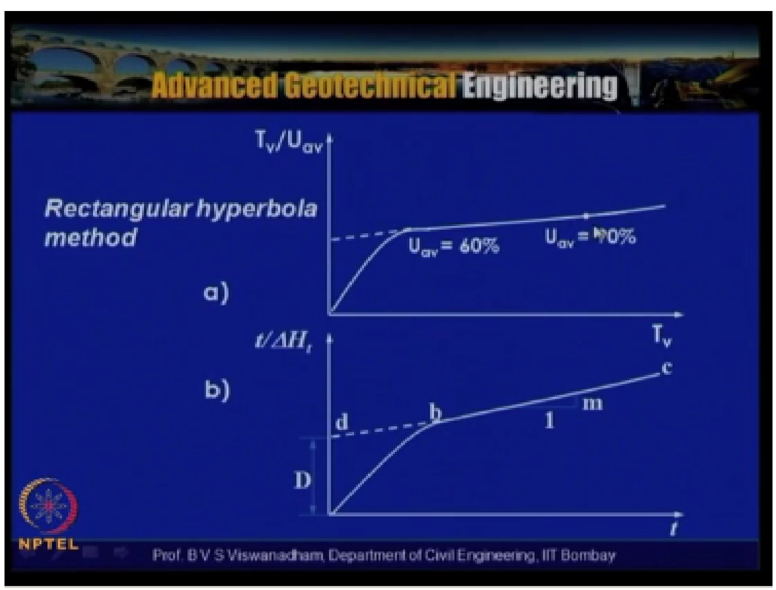

So this is what actually shown here then the rectangular hyperbola method T suffix V TV versus Tv / Uav when it is plotted here we can say that this portion is non linear and then this portion is linear and that Uav between 60 to 90% what we are actually saying is that this is in the range of linear line the relation is linear and can be expressed as this particular expression now similarly with by using this we actually plot t/ ΔHt with time, time required for consolidation then we actually get this part of variation.

Like o, o b and c so this slope of this line is m that m to the vertical ordinate and 1 to the horizontal and this point b and c that is actually 60% and 90% and d and this ordinate in the of size is D.

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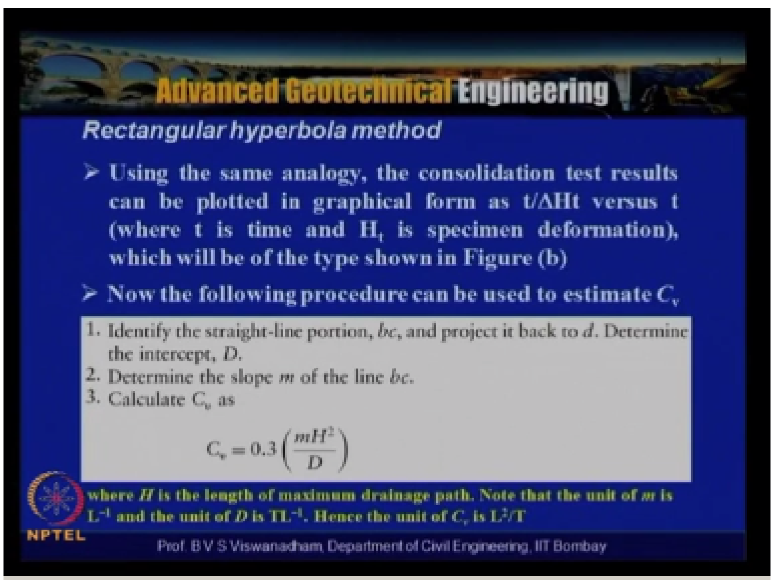

Now using the same analogy the consolidation test results can be plotted in graphical form as t/ ΔHt versus time were t is the time and Ht is the specimen formation which will be of the type shown in the figure b that is what actually we have shown and this is the plot which is time of t by t/ ΔHd versus time t now the following the procedure can be used to estimate the Cv, so once we establish once we plotted from the sample to formation data Hd and ΔHd is nothing but the sample to formation data which is regarded for the particular.

Load increment and versus time of consolidation so identify this straight line portion bc and positive backward to d determine the intercept, so what we need to is that we have to plot t/ ΔHt with time and then identify the linear portion exchange this backward and determine what is this intercept d, now determine the slope m of the line bc that inclination of the slope m now calculate Cv and as Cv = 0.3 x $1H^2/D$ now here we can checked whether it is it giving units of meter square per second or not the while the authors.

While setting this one H is the length of the maximum drainage path that is if it is single drainage or double drainage and note that the unit of m is L – 1 that is unit of length is 1/L and unit of D that intercept is T/L unit of d is T/L so if we look into this 1/L into that is 1/L into L^2 x T/L on simplification what we get is that Cv as the L^2 / T that is nothing but m^2/s m^2/y or m^2/d, so that is this how you will actually try to get the quotient of consolidation by using the rectangular hyperbola method.

Now we actually have in the beginning while discussing the consolidation we said that the consolidation component of a 5 grain soil is 3 components one is you know elastic and second component is the nature component which is you know the primary consolidation settlement and primary consolidation portion and thirdly what we said is that due to secondary consolidation or secondary compression and this total you know ∑ of all these 3 put together is called total settlement which is nothing but.

Due to elastic settlement cause consolidation settlement and then secondary consolidation settlement the secondary consolidation settlement that to occur on soils like PT type of soils or certain type of you know soil like materials.

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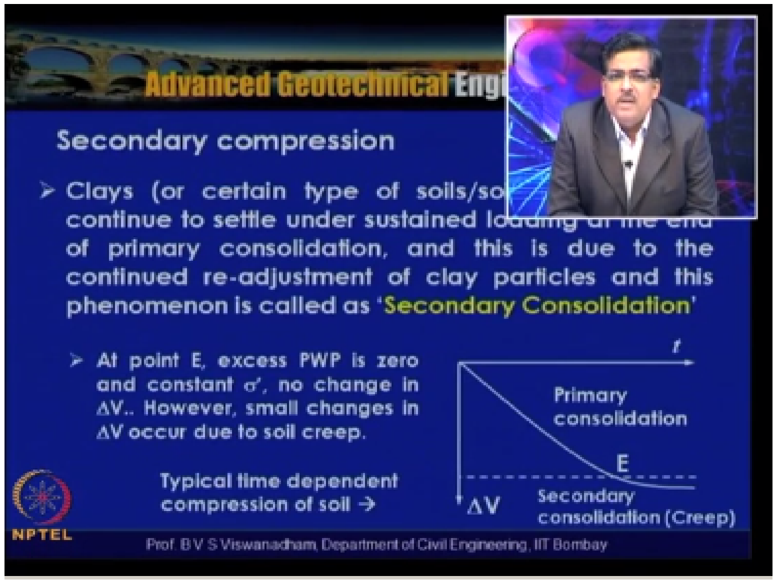

Municipal soil ways the undergo very high degree of secondary consolidation so clays are certain type of soils are soil like materials or soil like materials continue to settle under sustain loading at the end of the primary consolidation and this due to the continued re – adjustment of clay particles and this phenomenon is called secondary consolidation clays particularly this also called as creeping of soil as you know the secondary creep or secondary compression, so clays of certain type of soils.

Or soil like materials continue to settle under sustain loading at the end of the primary consolidation and this is due to the continued re-adjustment of the clay particles and this phenomenon is called secondary consolidation now if you look into the Cr this particular slide where figure that times versus ΔV ΔV is nothing but the volume change is plotted here, and that is nothing but ΔH and here A x ΔH is nothing but ΔV now we up to e we can say that the process of the consolidation.

Primary consolidation it actually happens so initial way at small times the hydraulic gradients are very high the flow is very rapid and as the time elapse is and it comes closer to the completion of consolidation the hydraulic gradients you know they dropped down to almost 0 and no flow conditions occur in the settlements almost the 0 excess pore water pressure condition provide and which is also will be that you know when there is no change in the loading the access effective stress is also changes will be minimum.

Then we can actually say that you know soil consolidation is complete and all but when the curve also tends to become asymptotic to the horizontal and then it pretends as it that consolidation is complete but in certain step of soils that is actually beyond point e even under the constant effective stress the soil undergoes you know the multiple structural changes and because of re-adjustment of the particles under because when the particles undergoing the creep there is a possibility.

That this secondary compression or secondary consolidation are creep can result, so at point e access pore water pressure is 0 and a constant σ- appears and no change in ΔC occurs, but however a small changes in ΔV occur due to this soil creep so this is a typical time determinant time dependent compression of the soil is actually shown here, so secondary consolidation settlement is more important than the primary consolidation.

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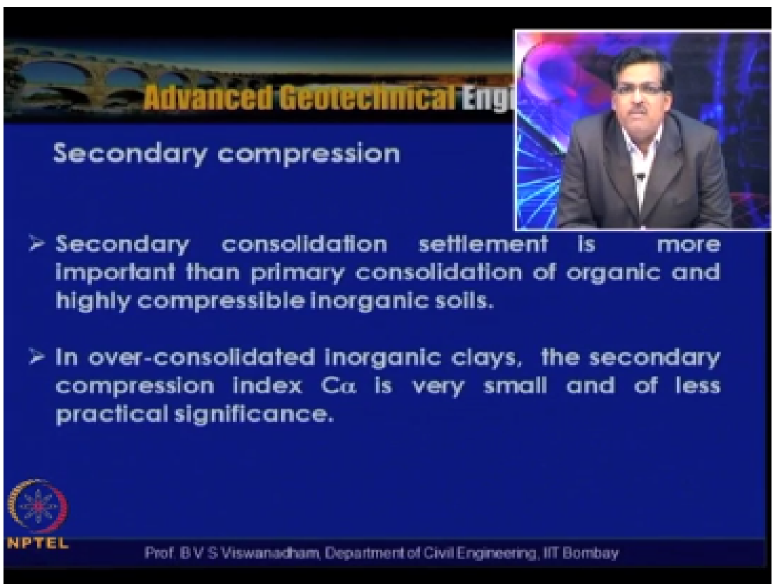

So secondary consolidation settlement is important than the primary consolidation basically if you are having a organic and highly compressible in organic soils, so if you are having organic particularly in the marine clay or highly compressible in organic soils there is positively that the secondary consolidation settlement will be much more than the primary consolidations settlement in work consolidated in organic layers the secondary or consolidated in organic clays the secondary compression cα is very small and it is of less practical significant.

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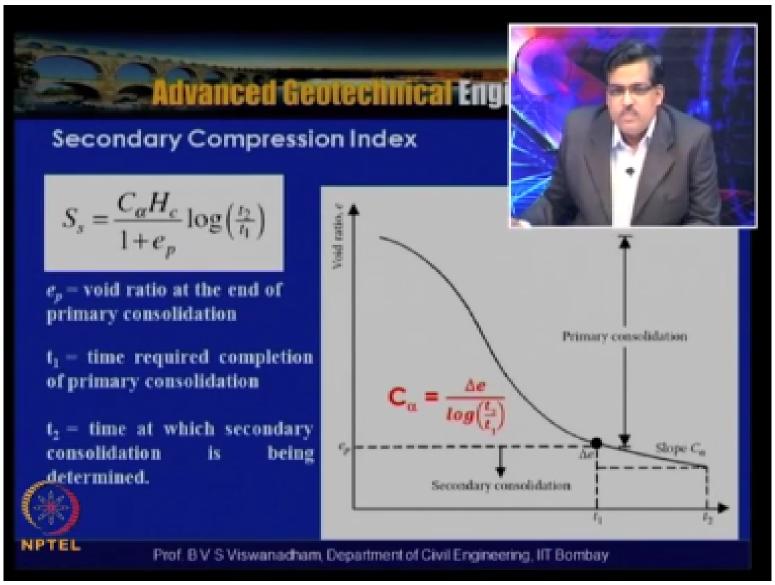

So in this particular slide wide ratio versus time is actually shown here and the level in scale, so this is the end of the primary consolidation but beyond this time we consider that time t1 is let t1 is the time at the end of primary consolidation the soil undergoes a change in wide ratio that is c Δe and the time let us say is t2, so t2 – t1 let us say is you know that is the slope of this line is indicated by cα is cα is nothing but Δe / logarithmic of t2 /t1 so cα is nothing but logarithmic of c log t2 /t1.

So the settlement is actually is written as secondary consolidations settlement is nothing but cα into Hc / 1+ e_p when epis nothing but the wide ratio at the end of the primary consolidation that is ep is nothing but the so initially we will start somewhere here and at the end of primary consolidation we reach here, so from ep to Δe the change will be there so that is nothing but here is indicated as sc = ss= you know cα that is the secondary consolidation quotient into Hc by 1+ep into logarithmic of t2 /t1 so t1 is the time required for completion of primary consolidation and time two is the time at which.

The secondary consolidation is being determined so it can be of let us say one logarithmic cycle that is let us say t2 = 10 times t1 then it is cα = you know that is c = 1.

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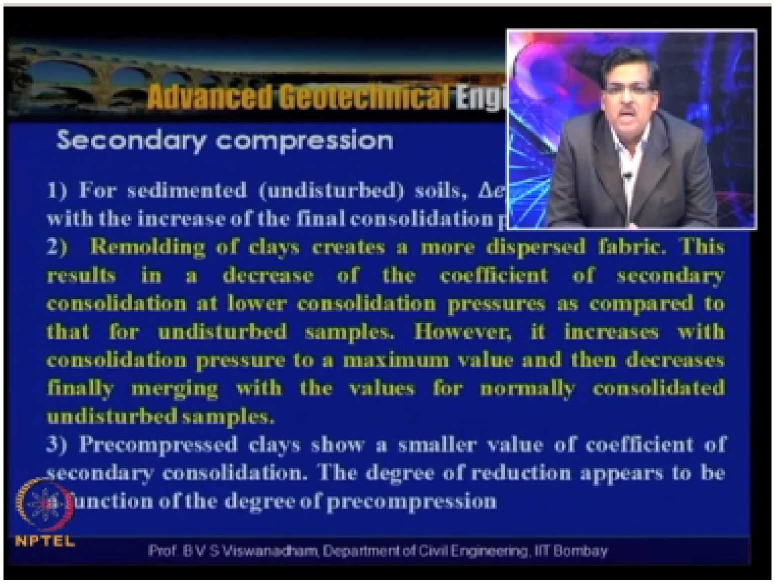

Now from further according to ms 3 1973 for sedimented un disturbance soils for sedimentded understood soils Δe/ Δ log t decreases with increasing the final consolidation pressure, so sedimented under distributed soils Δe/ Δ log t decreases with increase in the final consolidation pressure and the molding of clay creates the more dispersed fabric so this results decrease in the effect of quotient of secondary consolidation at lower consolidation pressures as compared to that for the un distributed examples.

However it increases with consolidation pressure to a maximum value and then decreases finally margin with values of normally consolidated understood samples, so remolding of clays created more dispersion fabric the clays you know soil fabric changes and this results in it declares of the quotient of secondary consolidation at lower consolidation pressures as compared to that for the un disturbance examples however it increases with consolidation pressure to a maximum value and then decreases finally.

Margin the values for normally consolidated and distributed samples so pre compressed clays are pre load in place show a smaller value of quotient of secondary consolidated so the degree of the reduction appears to be the function of the degree of pre compression the degree of the reduction appears to be a function of degree pre compression.

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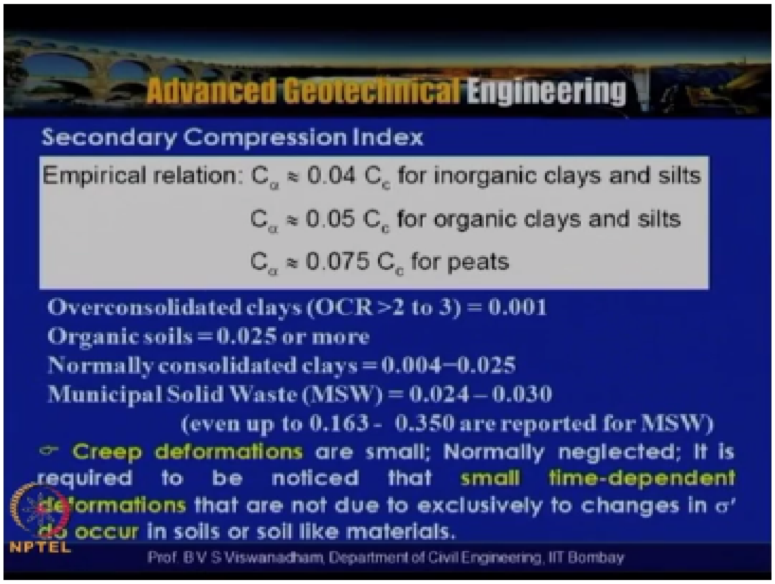

So there empirical correlations are actually available you know for secondary compression index cα for in organic clays and silts which is cα = 0.04 times Cc when Cc is the compression index for in organic clays in silts for organic clay silts it is regarded as 0.05 times Cc and for p it is that is fibers nature type of soil types which is actually p to which is the part of mr lands cα is equal to can be as high as 0.075 into Cc for over consolidated clays with over consolidation greater than 2 to 3.

You know the second the compression index will be only 0.001 organic soils it is 0.0252 or more and normally consolidated soils will have 0.004 to 0.025 then as I said that that municipal solid based is a material which is generated from the is a man made waste and variant actually has got a combination of 40 to 50% of biodegradable waste and then other united materials like construction ways and so in this mixture of hectors mixture of materials causes you know very high normally for the you know this ranges from 0.024 to 0.03 but even up to 0.1632.36 are reported.

By Shiva Kumar or babu at all so the creep deformation are small and normally neglected it is required to the whole value you know we need to notice that you know the creped formation if you look into that this compression index is values are very, very small when they compared to compression index so the creep formations are small but normally neglected but it is report to be know that the small time depended formation that are not due to exclusively to change in x,- do occurrence soils and soil like materials.

So in case of municipal soil ways is occurs sue to you know on going to bide to composition where in this actually you know results in the changes in the you know very large changes in the secondary compression index in fact in the case of municipal solid ways it actually is defined as $c\alpha1$ and $c\alpha2$, $c\alpha2$ which is the due to in the you know by a decomposition and $c\alpha1$ is the initial part of secondary compression which is in the you know if you are having a $c\alpha$ of say 0.167 0.1673 0.163 and you know out of that 10 to 20% is of $c\alpha1$ and the rest of the portion is $c\alpha2$ so after having discussed about.

The secondary compression and how this can be used in calculating then we know we can calculate we can see how the settlement of compressible layers can be calculated in one dimensional settlement this is basically one dimensional settlements and so in the clay layer of thickness say Ht is subjected to increase in pressure increase due to $\sigma0$ – at the mid of the clay layer to $\sigma1$- so settlements are always computed at the mid up to the clay layer the reason we have discussed is that.

At that mid that of the clay layer there is you know during let us say 50% degree of consolidation or 905 degree of consolidation there is certain amount of pore water pressure at to be dissipated so in U of that you know settlements are actually computed at the mid of the clay layer so if the clay layer of layer of.

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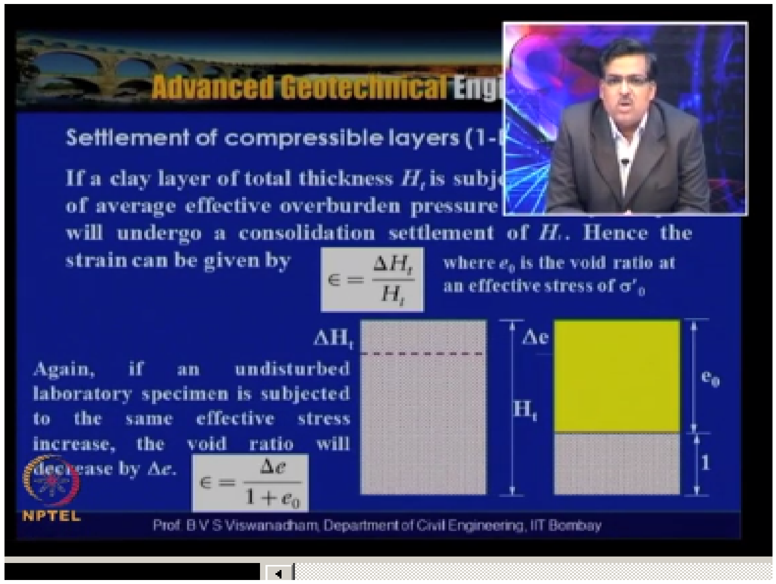

Total thickness Hd s subjected to increase in of the average effective or but in pressure from σ0 – to σ1- it will undergo a consolidation settlement of H1 hence the strain can be given by the strain is nothing but so vertical strain which is nothing but ΔHt / Ht and so this is actually shown here schematically when you are having in the field a soil when it is subjected to partial from σ_0- σ1- ΔHd is the settlement and Hd is the horizontal thickness so the strain is nothing but ΔH2 /Ht but if you are having you know volume of the wide.

And volume of the solids here which is actually indicated as 1 and total volume is 1 + e_0 are specific volume which is you know defined as 1+e_0 is v that is specific volume is nothing but 1+wide ratio is the specific volume and if the change in void ratio is say Δe and w can actually say that change in volume to original volume which is nothing but Δe / 1=e_0 so this is also you know equal to strain, so again if an under stable laboratory specimen is subject to be the same effective stress increase then the void ratio will decrease by Δe so the strain is actually given by Δ / 1+e_0.

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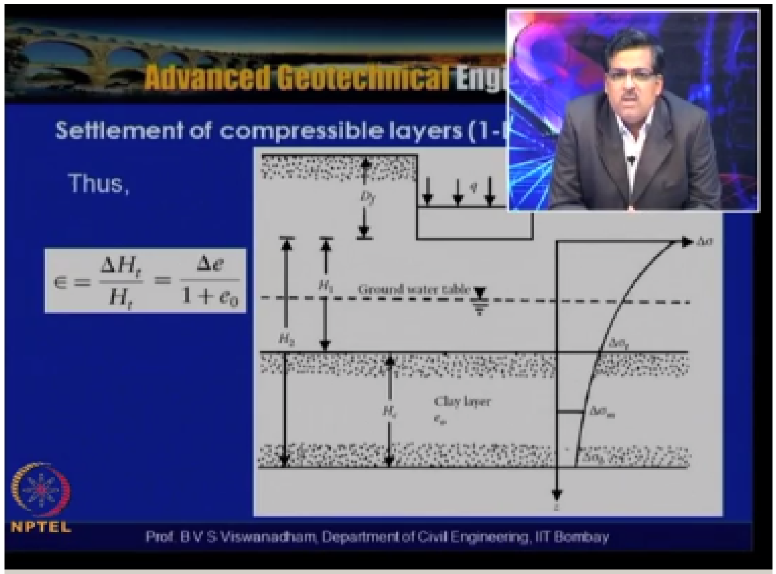

So with this what we actually obtained is that by equating you know this strain due to change in thickness and change due to strain in void ratio both appears to be same now $\varepsilon = \Delta Ht /Ht$ and $\Delta e/ 1+e_0$ so we can actually calculate $\Delta e = \Delta Ht$ into $1+e_0/Ht$ now in this particular figure you know it is actually shown here like we are having a clay layer and which is having distance of say H1 from the base of the foundation H2 from the you know from the bottom of the clay layer is H2m away.

And top of the clay is H1m away the thickness of the clay layer is H2 – H1 so He is the thickness now here what will happen is that whenever we load a certain structure and or increase in stress is nothing but you know whatever we have discussed in the stress is due to loads on soils that w have actually discussed, so based on the appropriate whether it is a circular shape or whether it is a strip loading or it is uniformly loading are is a raft loading accordingly what we need to is that we have to calculate.

The increase in stress in different portions of so what exactly we need to do is that we have to divide this clay layer into suppose if it is 6m each layers is actually divided into say 6 1m of thickness at each one we you know at a 0.5m within that layer we calculate what is the increase in thickness and we know the effective stress at that particular point then the $\sigma_0 - 1 +$ this Δ is $\sigma 1$ but is actually is the increase in stress, so we can calculate what is the small increase in consolidation settlement.

That is Δ1 Δ2 Δ3 like that up to Δ6 the total which actually is resulted as the we know the consolidation settlement the more we actually have like you know short thickness of layers then the more you know effective is the determinant of the you know the settlement determination of settlements, so now we can actually have in the two cases one is that the soil can be normally consolidated completely that means that you know the we can actually have a virgin compression.

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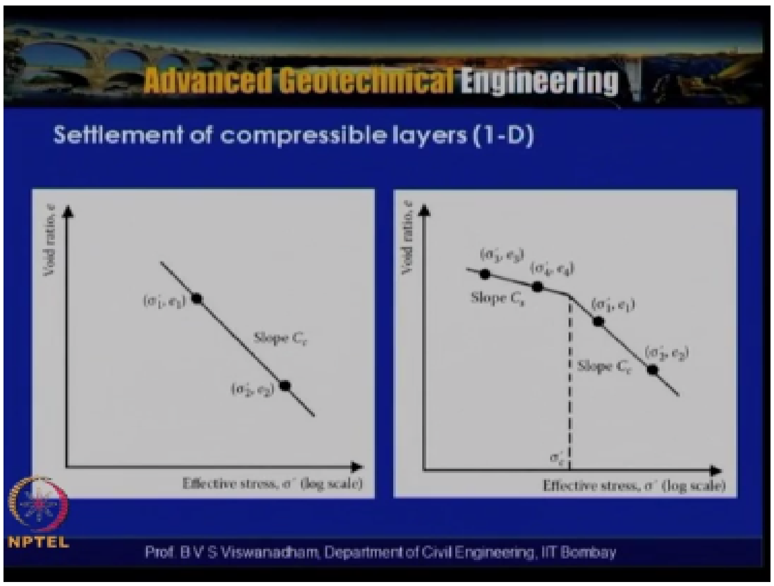

Curve like this then the slope of this curve is the compression index then we can actually calculate the consolidation settlement, but it can be also like we can have a or consolidated portion and normally consolidated portion sometimes we are actually having if this is the σc- and this is the pr consolidation pressure then you know if the load is only up till here then we actually have you know the settlement only due to over consolidate portion, but if you are having a settlement here.

Then if you are having a loading here σ1- here then we have to calculate settlement from here to σ_0- that is initial pressure to this one from here to here, so the total resulted due to over consolidated portion as well as the you know the as well as the normally consolidated portion sometimes if you are not able to capture the over consolidated nature of the clay layer from the consolidation test data and then you know we actually calculate settlements by assuming that this soil is normally consolidated.

Then we tend to predict very high order of settlements and sometimes it results in the conservative mode of estimation of settlements, so from this slide the deliberation what we can discuss is that if you are having σ_0- = σc- then you know we can say that is consolidations settlement is equal to.

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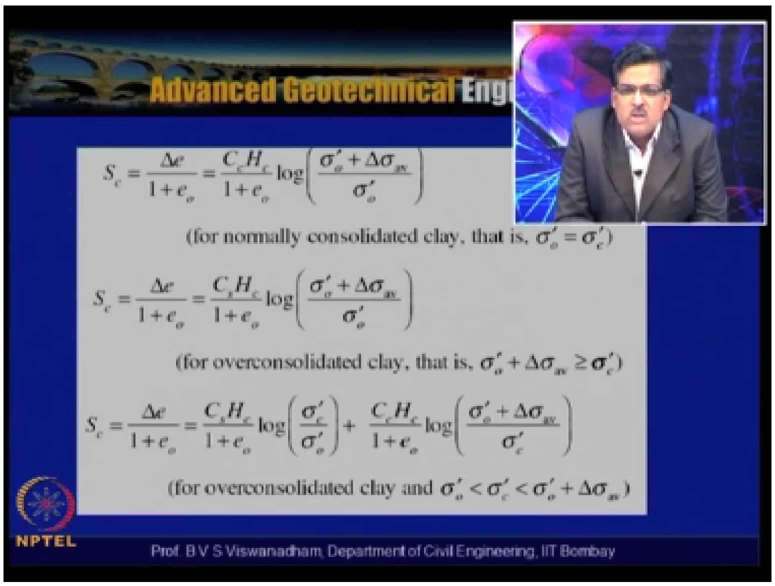

Δe/ 1+ e_0 = Cc/Hc / 1+e_0 where Hc is the thickness of the clay layer so whether it is half drainage full drainage enter thickness is going to undergo the settlement, so we have to consider either full thickness of the total thickness of the clay layer and Cc is the compression index e0 is the initial void ratio at an effective stress of σ_{0-} so log of σ_{0-} + Δ σ average which is like you know it can be of the that mid depth of clay layer and σ_0- so for normally concern clay that is σ_0 is in order see and over consolidated clay suppose if you are having you know only up to σ_0c and then there is over consolidated portion then we actually have to.

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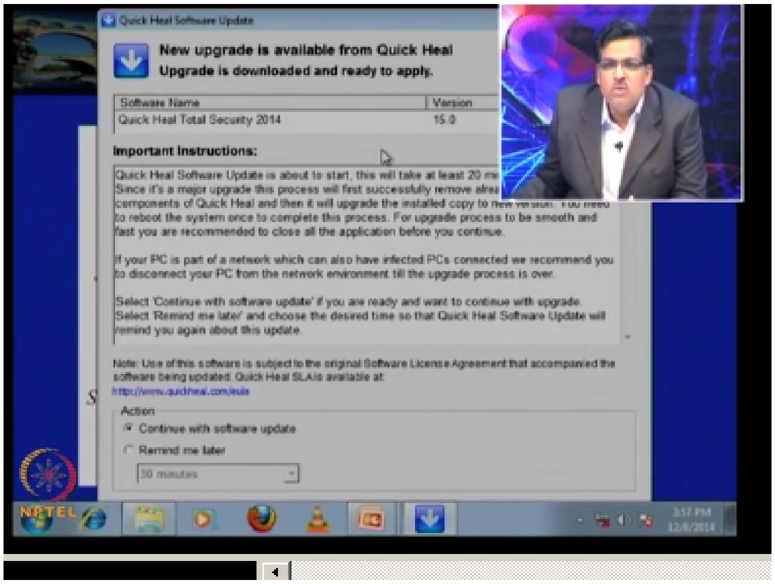

Then we actually have to use this Cs that is the slop of this line is the over consolidated portion is Cs so this settlements solve will be very low if you are actually having a over consolidate soil and if the loading is only up to σc up to the pre consolidation pressure than the settlements will be very minimal, but if you are having like the loading is say somewhere here then we have to calculate this portion and we have to calculate this portion so that is actually here it is listed it is nothing but Cs into.

Hc by 1+e0 log $\sigma c / \sigma_0$ so here σ_0 to σc that is that we have accounted from here to here then for the σc to next one that is increased here, so that is nothing but Cc/ here it is that consolidated portion that is the compression index is actually accounted here Cc by Hc / 1 + e_0 into log $\sigma_0 + \Delta \sigma av / \sigma c$- so like this by using these compression curves one can actually determined the secondary consolidation settlements one can determine the you know the consolidation settlements.

So this one need to you know this is actually based on the compression curves which are actually reduced from the testing data and once this data's are available then is possible that one can calculate what is the how long it will take to occur the settlement and what is the magnitude of settlement, so the empirical methods for to obtain Cc.

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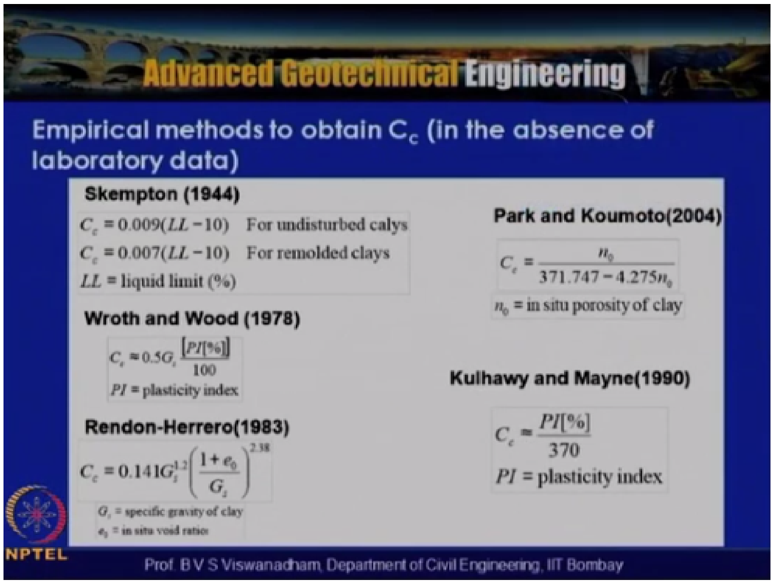

In the absence of laboratory data let us say that if you are actually having a this scan t laboratory data or field data then one can actually you know estimate there are methods are the empirical methods of their estimate compression index, so then from there we can also estimate non security compression index also, so here is according to skempton 1944 Cc = 0.009 LL – 10 this for un distributed clays for remolded clays it is 0.007 into LL – 10 so liquid limit has to be given in percentage here.

That means of liquid limit is say 50% 50 – 10 into 0.007 which we used where we get the compression index for the remolded clay, similarly worth and wood 1978 they postulated Cc = 0.5 times Gs into pi percentage by 100, so Gs is the share modulus and this is actually used for calculating the for postulating the Cc value from the plasticity index as well as the Gs and rendon in Herrero 1983 they have given again based on the Gs here is not the share modulus it is the specific gravity of the clay, Gs is the specific gravity of the clay and e is nothing but the initial void ratio so Gs is nothing but the specific gravity of the clay and $Cc=0.141Gs^{1.2}(1+e0/Gs)^{2.38}$ and similarly the Park and Koumoto 2004 they actually have given empirical method to calculate the Cc from the in situ porosity of the clay which is n0,in situ porosity of the clay from the porosity value is that they have given.

And Kulhawy and Mayne 1990 they have given Cc=PI/370 where plasticity index is taken as you know in percentage, so you can see that compression index actually having you know direct relationship with plasticity index most of our soil deposits actually they do exist at you know at plastic limit, so the plasticity index is you know it is high then the compression index is also very high that is for the clays of high compression in Ch type of soils, the plasticity index value will be very, very high.

So then the compression index of such type of clays also is expected to be on the higher side. Now let us consider and example where.

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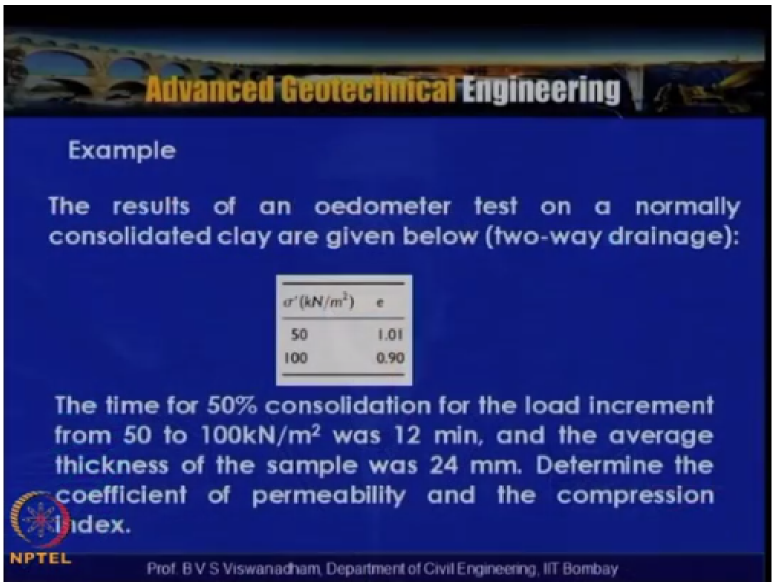

The results of an oedometer test of a normally consolidated clay are given below is the two way drainage and we have σ'kN/m^2 the void ratio e that is at 50kPa and 1.01 and at 100 it is 0.90, so the time for 50% consolidation for the loading increment for 50 to 100 kN/m^2 was 12 minutes and the average thickness of sample was 24mm and we need to determine the coefficient of permeability and the compression index.

So in this particular problem the time for 50% consolidation for the load increment from 50 to 100 kN/m^2 was 12 minutes, so time for 50% consolidation for the load increment from 50 to 100kN/m^2 is given as 12 minutes and the4 average thickness of sample was 24mm and determine the coefficient of permeability and the compression index.

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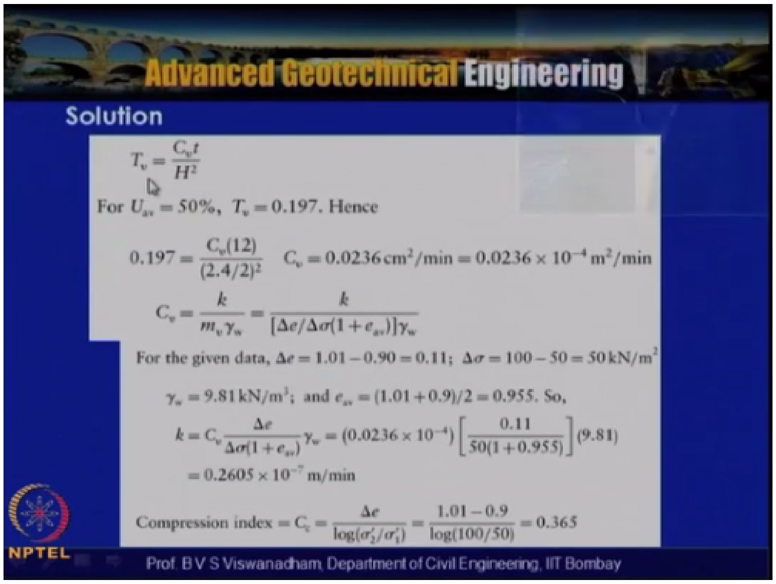

So based on the data here we can actually calculate $Tv=tC/H^2$ and Uav=50% so it has been asked actually the two way drainage and 50% consolidation, so for Uav=50% Tv= that is average degree of consolidation 50% $Tv=\phi/4\ (U/100)^2$ so with that we can actually calculate time factor as 0.197. so with by knowing 0.197 Cv this time is what we need to say 12 minutes so the 12 minutes divided by 2.4/2 with that what we get is that Cv= you know $0.0236\text{cm}^2/\text{min}$.

So we can actually get $0.0236\text{x}10^{-4}\text{m}^2/\text{min}$, so with this what we can actually get is that by knowing the Cv value, we can actually you know calculate now coefficient of permeability as we know that by knowing k=Cvmvγw or we can write also Cv=k/mvγw with k divided by mv is nothing but Δe/Δσ′(1+av) γw, so with this from the given data we can actually get Δe as 1-0.1-0.9 so that is nothing but 0.11 and Δσ is nothing but 100-50 that is 50.

And by using this we can actually also get the some coefficient of consolidation as well as the coefficient of permeability that is $0.2605\text{x}10^{-7}\text{m/min}$ and the compression index is now can be calculated by using Δe that is 0.11/log(σ2′/σ1′) which is nothing but 1.01-0.90/log(100/50) which works out to be by 0.365 the compression index is actually works out to be 0.365. so it is also like this from the by knowing the consolidation properties of soil in the laboratory like by using let us say we have got from here from the laboratory data.

And we can also calculate what is the time required for the soil if the same consolidation to occur in the field. Like for example, then in that case what we do is that we actually project our analogy of the results from the laboratory to the field, so in that case how we get is that the time required for the field is equal to time required in the laboratory into (hf/h laboratory)^2 is nothing but if the time required in the laboratory once you know like here in this case say 12 minutes into, suppose if this is the result which is actually obtained for a two way drainage layer having say 6m thick layer.

So 6/2 divided by 0.24/2 that is 24 among divided by 1000/2 and by whole square which you will be able to get what is the time which we actually will take for the soil layer to undergo consolidation in the field can be forecasted. So in this particular lecture what we have discussed it is that we discussed the coefficient of consolidation determination based on you know rectangular hyperbola method which is according to Shridhar and Prakash 1985 then we also have discussed that how the construction period correction can be done according to method which is actually postulated by Terzaghi's and Forlish in 1936.

And then we have also solved a problem and we also have discussed that effect of the thin land cells of sand layers on the time rate of settlements not the magnitude of settlements the time rate of settlements will be very fast in the case that what will happen is that in the given not the final consolidation settlement but you know the rate at which for example per given period of three years if you do not recognize the thin layer sand the settlement will be very less, but the structure will be subjected to high distance because of the prevalence of the neglected or ignored thin layer of sand.

Then there after we also have discussed about how we can actually compute the settlements and also we discussed about the secondary compression and secondary creep in this particular lecture.

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