NPTEL

NATIONAL PROGRAMME ON
TECHNOLOGY ENHANCED LEARNING

CDEEP
IIT BOMBAY

ADVANCED GEOTECHNICAL ENGINEERING

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Lecture No. 20

Module-3
Lecture – 2 on Compressibility and Consolidation

Welcome to lecture series in the course advance in go technical engineering we are actually discussing module 3 on compressibility and consolidation.

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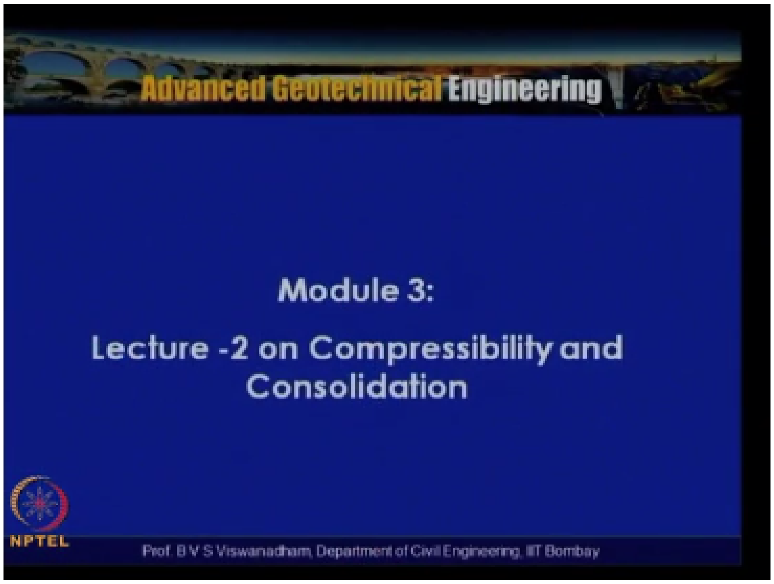

And in the lecture 1 we introduced ourselves to stresses due to surface loads so in this lecture 2 we will continue further in this particular topic that is in module 3.

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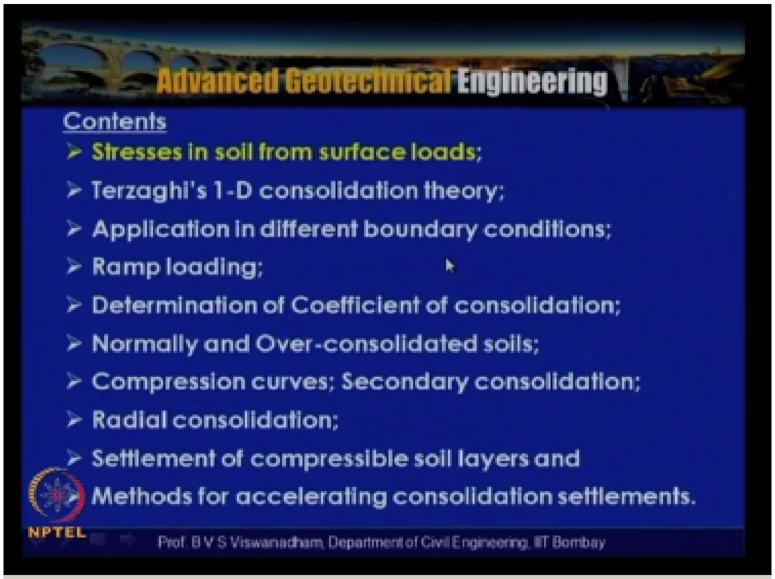

Lecture 2 we are going to concentrate on the stresses in soil from the surface loads and we have discussed with that when the soil is can soil can be subjected to you know different shapes the loading can be of differ shapes it can be analog shape or it can be a circular shape or it can be rectangular area or it can be in the area of irregular shape or it can be of like in that loading intensity can vary from 0 to q and remain may constant like you know m main construction or glayvey construction or damn construction.

Or in case of landfills we have certain you know very flat slopes and the heights can even range up to 200m or so, so it will be interesting you know to learn about this particular topic and to compute the stresses in soil from the surface loads, so we have actually introduced in the previous lecture that Boussinesq theory and westergaard theories and from the by from the Boussinesq theory the number of you know the detections can be made and here we actually have.

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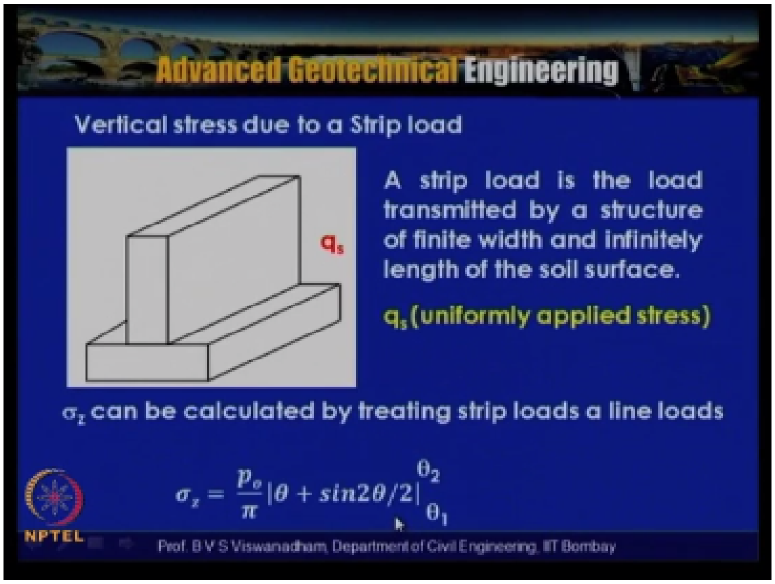

Try to discuss about in the previous lecture or about the vertical stress due to the strip load that means that if you are having a strip foundation and if it is connected with either literacy a wall which is actually has a found continues foundation running or length L then these strip load is the load transmitted by the structure of the finite width and infinitely length infinitely long surface soil length along the soil surface, so the σz we can be calculated by treating their strict loads as the line loads by treating strict loads as the line loads.

So $\sigma z = P_0 / \pi\ \theta + \text{Sin } 2\ \theta / 2$ within $\theta 1$ to $\theta 2$ so $\theta 1$ and $\theta 2$ are nothing but $\theta 2 - \theta 1 = \theta$ where they are the you know dependent upon the location of the point of interest of the this particular stress that is from the left side edge of let us say that if you are having a strip load and if it is at a distance certain distance from this point and certain distance from this point and of the angle subtended from you know for with the vertical and with the horizontal here is $\theta 1$ and then with this vertical and then this point is $\theta 2$.

So $\theta 2 - \theta 1$ that is angled is actually over the breadth of the foundation, so we actually have said that $\sigma z = P_0$ is nothing but you know nothing but q qs / π and $\theta + \text{Sin}2\ \theta / 2$ this is what actually we have discussed in the previous lecture.

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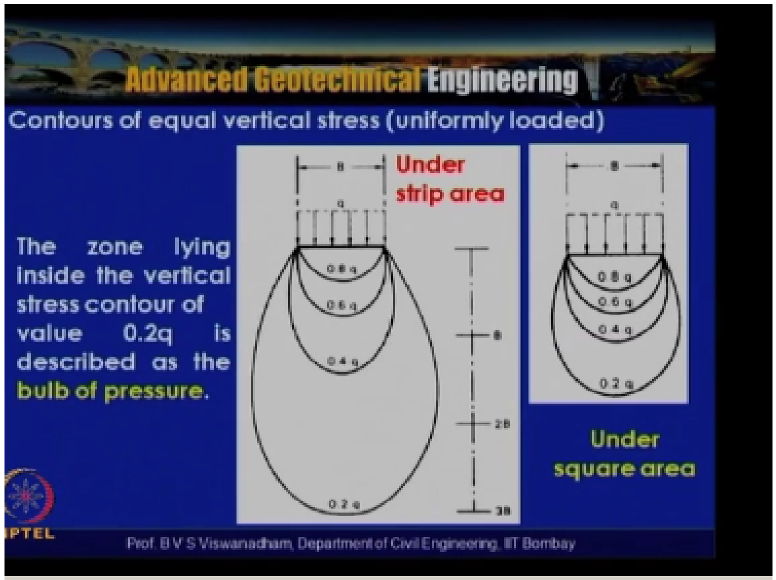

And the contours of the equal vertical stress of uniformly load intensity which are actually given here and the pressure bulbs you can be seen here under the strict area, they the depth of influence can actually go up to 3b and in case of square area the depth is limited so the zone lying inside the vertical stress contour of value 0.2q is described as the so within this zone and this is called s the pressure bulb the spread of the pressure bulb for the strip area is large compared to the square area so this is here for the a2 a the square area.

Or a square foundation or a 14 subjected to uniform loading density that a strip putting that strip foundation subjected to a uniform intensity is actually shown here, and the zone within this is actually called as the bulb of pressure or pressure bulb, and here what this we can shown is that under the strip area the zone of influence the depth of influence will be large compared to this square area, now let us consider a strip carrying uniformly vertical loading on a infinite strip.

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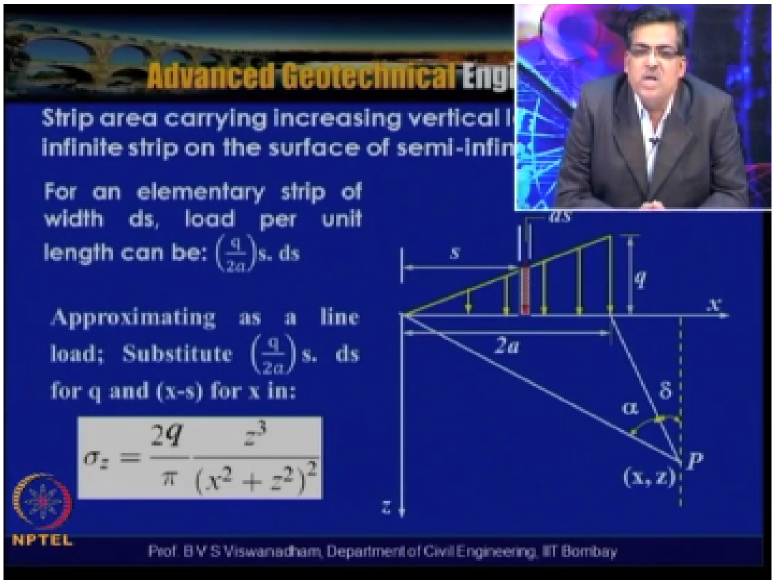

On the surface of semi in valid mass that means that let us assume that we are having a certain strip of width 2a it can be B = B = 2a and the loading intensity is 081.and it is q at this point that is x = 0 so this along the x axis and this along the depth axis that is z axis now at x = 0 the loading density is 0 q = 0 and x = 2a the loading insanity is equal to q, so there is linearly varying loading intensity, so there is the increasing vertical loading on an infinite strip and then this percolate to plane of this figure.

Let us assume that the load is actually is in spreading over you know infinite length and in added to you know calculate the vertical stress in the due to increase in loading the type of loading like this or what we do is that let us assume that we wanted to calculate the stress at the particular point p and if this let p be the point below the this soil surface that is you know this is the coordinates of this point are x and z where this distance is x and this distance is vertical depth is z, now for an elementary strip.

Let us consider a small strip here that is of the breadth is equal to some ds the small strip and let us assume that then loading density per unit length can be calculated by you know by this particular ordinate vertical ordinate can be calculated by similar triangles or this is a q/2 that is that here at x = s let us assume that there is a small strip of elementary switched strip of ds is then and it is a distance s, so this or vertical ordinate / s and this from the similar triangles from this similar triangles here.

This triangle and then this triangle we can calculate this magnitude as q / 2 into s and that is the you know the load and then the loading density at that particular point into ds will give the so called you know load per unit width that is called the what we do is that we treated like a small line load, now let us assume that this distance is s so when this is equal to s x then this will be equal to x – s now approximating as a line load, so this is approximated as a line load now so the line load of certain intensity.

Running of the infinite length and with the intensity of this line loading is nothing but q / 2a s into ds, so now what we need to do is that we need to substitute in the exponential for the vertical stress σz = 2q / π into z3 / X2 + Z2 to the raise 2 in this for q substitute q/ 2a s into ds so that what we do is that because of this small strip load we get what is the you know small d σZ then when we integrate for the that length of the 0 to 2a what we get is that the vertical increasing vertical stress due to the particular load intensity.

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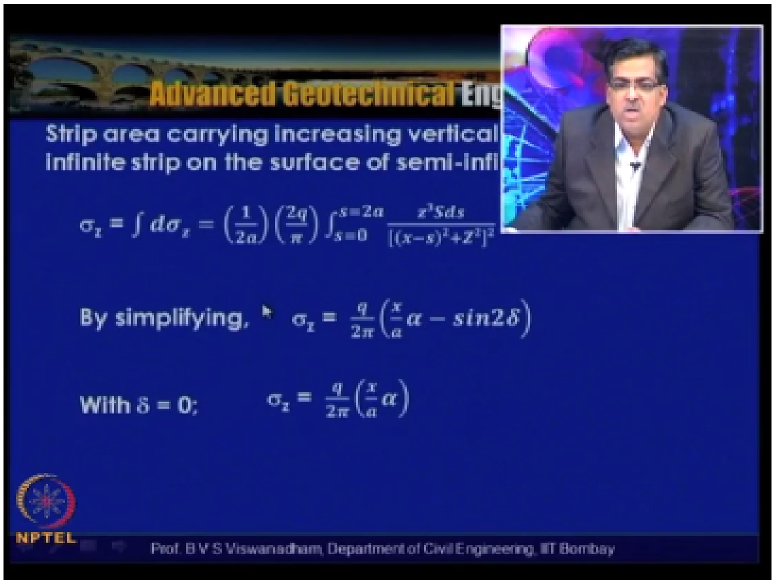

So this further we can actually continue like the σz = the ∫ of d σz and with by substituting you know the 1/2a and 2q/π into when s saying limits are nothing but this s is ranging from 0 that is at x = 0 and x = 2a there is s = 02 s = 2a and Z^3 into s ds / x – s whole square + Z^2 to the rise 2, now here what we did is that we substituted for q / 2a into s into ds/cube and x – s / x and Z is θ is Z, so by integrating and then simplifying what we get is that σz = q/ 2π into x / aα – Sin2 α Sin2 δ so this αa in δ which are nothing but this inculcation.

That this is δ and then this is α and this δ so let us assume that we are actually have interesting way point at this particular point here, let us say that in that case that δ = 0 when this loading then when we are actually interested in calculating the stress at this particular point then the loading density at this particle point and you know then that case this δ will be equal to 0 now we are actually having a case where α that is covering the breadth of this so called strip of width da and δ.

Now this with δ = 0 and σz = q / 2π into x / α where after once we get the based on the you know the different the depth requirements and once we compute this α then α need to be express in the radiant's, so with αz = q/2π into x / a α – Sin2 δ and when δ = 0 that is right below the you know where the loading density is actually is high, and then we can actually calculate the σzs q / 2π into x / a into α, now let us consider further we by using the same concept let us see that how.

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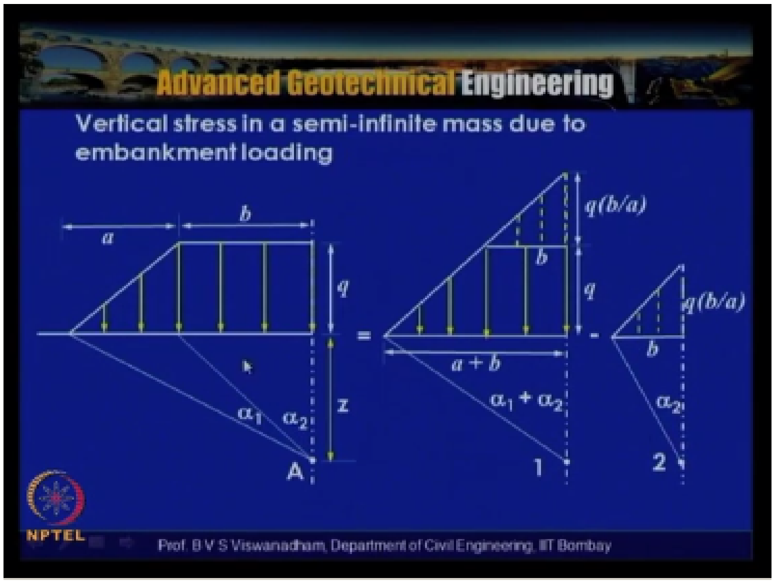

You know we can actually construct the embankment you know the stresses below the embankment loading or let us assume that we are having certain area loading over certain area and because once we you know we learn about the consolidation and in order to calculate the settlements you and to calculate what is the increase in stress due to loading, let us say embankment loading or due to land fill loading or due to certain you know damn are loading so in this case let us consider.

Simple embankment is you know simplified with having an horizontal distance a and horizontal distance of this slope portion is a and this is actually b so this vertical in the load intensity is simplified by you know having q is the loading density and as we go down here the loading density falls here, so here what we can do is that we can actually use the same concept now at this point here this point is write lies write below the write below this point q and $\alpha 2$ is this inclination and $\alpha 1$ in this inclination.

And now what we do is that we will use the method of super position and what we do is that in order to compute the vertical stress it is semi infinite mass due to embankment loading what we need to do is the simply extent this line further and calculate by using again similar triangles between this triangle and this particular triangle and this particular you know triangle, so what w get is that w can actually calculate this with equivalent to b so from this similar triangles again we can actually get to what is the load intensity.

That is nothing but q into b/a so this is this particular loading is assumed as a factious loading and we converted that embankment loading into a triangular strip having loading density varying from q0 to q+q into 1+ b/a and a + b is the total you know horizontal distance of the strip and the point is actually lies write below the that is at the center of the you know embankment, so this is the point so this angle is nothing but the α1 + α2 and this width is nothing but a + b now because as this loading is not there.

So what we need to do is that this particular stress additional loading due to the specious portion what we assume need to be detected, so that point the stress due to that one is say σz1 and stress 2 due to this portion is says σz2 so σz at point a = σz1 – σz2, so here this particular you know triangle which is nothing but having intensity q into b/a and breadth b so this triangle is having b and then this inclination because for this breadth b the angle is α2 so this is the α2 angle, so once we determine.

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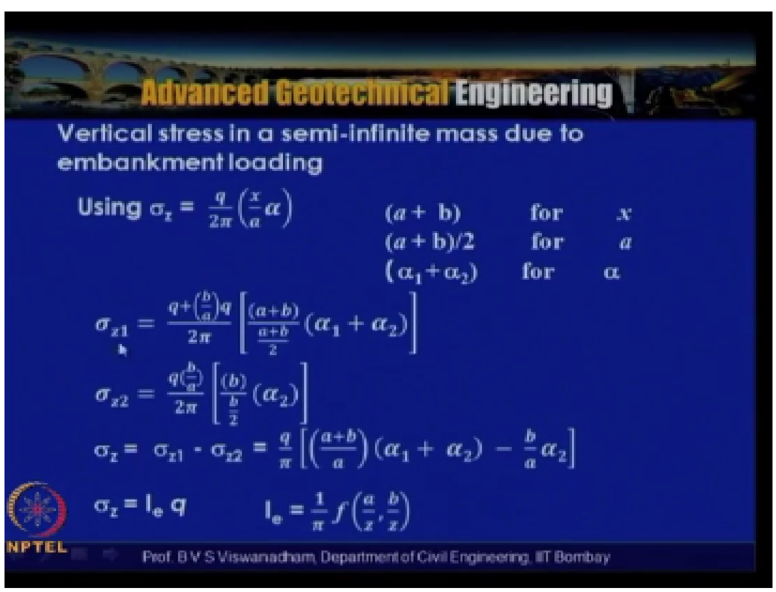

We simplify further you know by using we have said that if the loading density if the load and the reference is actually write below the you know the where over the loading is maximum the point below the soil surface then using $\sigma z = q / 2\pi$ into x / α now what we do is that use of we substitute $a + b$ for x and $a = b / 2$ for a $\alpha 1 = \alpha 2$ for α so for $\sigma z1$ $\sigma z1$ that is the stress $\sigma z1$ that is the stress due to you know this particular point into the entire this triangle so the loading intensity is nothing but $q + b/a$ into q.

That is why we are written for q we have written $q + b/a$ into q 2π into for x now we are writing because the strip width is nothing but $a + b$ so we are writing $a+ b$ and then $a+ b / 2$ that is for a that is nothing but this portion now into $\alpha 1 + \alpha 2$ so and similarly you know for $\sigma z2$ which is nothing but q into b/a into 2π into b/2 into $\alpha 2$ so when we you know take the difference that $\sigma z = \sigma z1 – \sigma z2$ is nothing.

But q/π, q is nothing but the magnitude of the embankment how to let that is by if you know the embankment loading having let us say you know 2D is an embankment is constructed with the feed material having a newer unit weight of $20 kN/m^3$ that 20 into let us say embankment height is a 5m then it is about 120 kilo Pascal’s or $12 kN/m^2$.

So $120\ r^3/\pi(a+b/a)(\alpha 1+\alpha 2-b/a\ \alpha 2)$. Now so this is indicated as σz=i influence factor that is the Ie, that is Ie is nothing but the influence factor for embankment loading, where Ie is nothing but this entire multiplication that is this $1/\pi(a+b/a)(\alpha 1+\alpha 2-b/a\ \alpha 2)$ which is actaully nothing but you know the function of $1/\pi$ into function of (a/z.b/z) where the a/z is nothing but the distance a or that argental portion of the embankment and distance b which argental portion of the slope of the embankment slope portion of the embankment and the horizontal portion of the, from the first of the embankment to the central line of the embankment.

Where we can write that a/z and b/z so σz=Ie(q) so this for this actually the Osterberg charts re available and where we can actually use this Osterberg charts.

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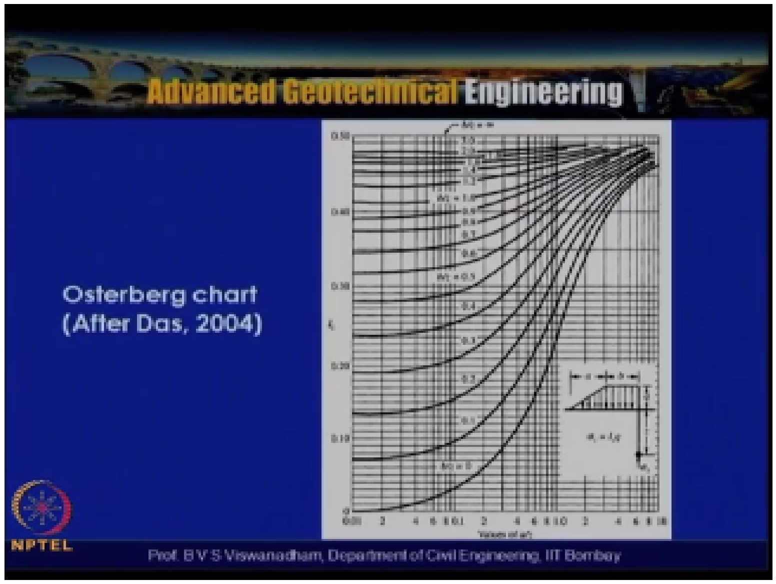

And then try to get the you know the stress values so for example here, the Ie embankment that is Ie influence factors are given and here the values of a/z ranging from 0.01 to 10 are given here and this can be used for even for embankment with b=0 that means that if you are having only a triangular stiff loading then the entire this b/z=0 so then this curve we have to use and then we actually have depending up on the a/z value we can actually calculate the influence factor σz into this influence factor into the loading density, σz=Ie.q we will be able to get what is the increase in vertical stress due to you know the embankment loading.

So what we need to notice that this point will give the embankment stress at this point or in this case if we are talking about you know the stress suppose the b=0 then that means that the stress actually occurs only at the centum point. Let us say that we are having you know the loading which is symmetrical about you know let us say about the x axis where you know at the center it is actually having about intensity q and then on the both the sides actually is reducing to 0.

So in this case what we need to do is that we need to calculate the influence factor and multiply with 2 so that you know we get the load intensity u to this and then loading intensity due to this one. For example here, when we have this is the symmetry of the embankment and if you wanted to take this stress due to embankment of the remaining portion then this multiplied into 2 we will able to get this stress due to the complete embankment, that is the total embankment distance.

So this Osterberg charts are actually used for calculating that the vertical stresses for the embankment loadings where you know the theory which is actually is deduced from the triangular strip having you know linearly varying increasing load and from there what we have deduced is that we have deduced the $\sigma z = \sigma z1 - \sigma z2$ and from there we have actually got the expression for Ie as a function of a/z and a is nothing but the argental distance of the embankment in the slow portion.

And b is nothing but the horizontal distance of the embankment from the crust of the embankment to the center line of the embankment. So by using this the increase in vertical stress at different points can be calculated.

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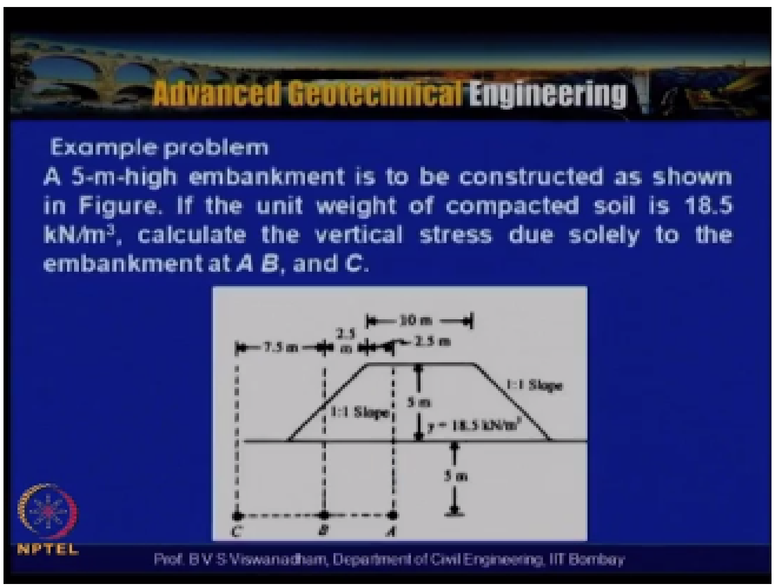

Let us look into an example, having you know example problem having a 5m high embankment basically it is to be constructed as shown in the figure and if the unit weight of the compacted soil is 18.5kN/m^3 and calculate the vertical stress due to soil to the embankment loading so there can be initial effective stresses but however what we are interested is that by treating this mass as weightless sedum we calculate what is increase the vertical loading due to solely due to the embankment loading only at point A at point B and at point C.

So if you notice that you know we do not have the symmetry here what is at the center but we need actually the embankment loading so if you look into this portion at point A the this portion of the embankment causes the loading and this portion of the embankment causes the loading so if you call this portion of embankment as portion A and portion B and the σz at A=$\sigma zA1$ and $\sigma zA2$, if this is portion A this portion is called as A1, this portion you called as A2.

Then the σzA is nothing but $\sigma zA1$ and $\sigma zA2$, so both need to be added. Now here when it comes to this point we are having an embankment of you know this particular shape so the stress you do this portion and the stress due to this portion and stress this to this portion need to be detected, so this portion this stress need to be detected. Now when it comes to this point here we construct a fissures embankment and then afterwards we again remove the loading due to the, load due to the stress increase stress due to this much portion so with that what will happen is that we get the increase the stress at a point c away from the embankment also. so here what we need to do is that, by using the same notations and by using the method of super position we can actually calculate the vertical stresses at point A, point B and point C.

The method is that we first we have to you know see how the embankments can be divided and if any fissures portion need to be added it can be added and then you know then again the stress due to that particular fissures portion need to be detected, once that is done we will actually able to get the stresses at point A, point B you know point C and if required if you are having any point here at the toe that is like say B1 that also can be calculated.

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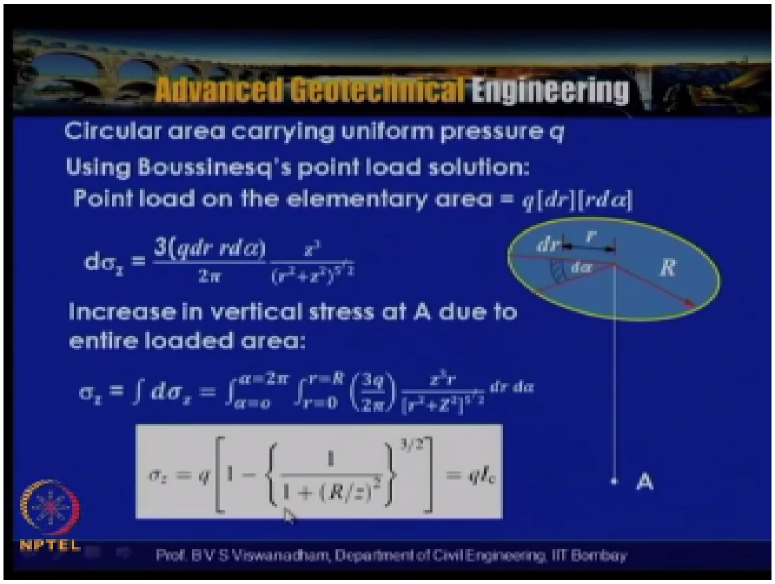

Now by let us sat we have actually discussed about you know the linearly varying load and embankment stresses due to embankment loading and for certain type of loading in the loading areas we can also have you know the circular areas carrying the uniform intensity, that means that it can be a ring foundation or it can be a foundation for semy with a raft of having 2r diameter let us say, and in that case you have a ring A raft of having 2r diameter so that means that we subjected to r let us say that you, we have say oil storage tank having you know diameter of about some 46m also then if it is subjected to oil of certain unit weight over certain height and it is subjected to certain increase in stress. So in order to calculate the increase in stress due to you know any oil storage tank having certain diameter or with certain loading density we can actually in practical applications we may have this type of circular areas carrying uniform pressures.

Sometimes we also can have you know the ring foundations that means that if you are actually having r1 and r2 where r2 is greater than r1, so r2-r1 portion that much is the breadth of the ring and over which the loading is actually happens with uniform intensity q. So using Boussinesq's point load solution so this can be reduced for example in this particular slide and we are actually having a circular shape loaded area having at the center and we are actually calculating the but increase in vertical stress at the center point of the below the center of the you know this so called circular area and subjected to uniform load intensity.

If r is the radius that is 0 here and extended here, now consider you know a small sector where you know with an angle dα then you know this portion this length of the arc which is nothing but L.r.dα, L=r.dα, and assume that the small strip is actually having you know this so called the this distance radial distance is dr, the strip with here is dr and it is at a distance r from the center. now what we do is that we calculate this particular end of the this length is nothing but rdα, rdα, dα is angle so dr x rdα is the you know this area and they assume that the point load in this area is nothing but q[dr][rdα].

So what we are doing is that we have taken a small strip having a dr x rdα dimensions and we are multiplying by the uniform load intensity q then point load on the elementary area is given by q[dr][rdα]. So weare actually using the Boussinesq's point load solution, now due to that so called you know the small element load is subjected to increase in intensity q[dr][rdα] we can calculate dσz=3qdr[rdα] so is nothing but $3q/2\pi[zq/r2z2]^{\pi/2}$ this is what actually we have discussed for Q what we substituted is that the small bq is nothing but $q.dr.rd\alpha/2\pi[zq/r2+z2]^{\pi/2}$.

Now we increase in vertical stress at A due to the entire loaded area so in order to get this what we need to do is that the entire area is 0 to 2π, α is actually ranging from α is going to 0 here and then α=2π and the radius that is this circle and then this vertex is actually given by r=0 to r so we need to do the double integration σz=dσz= integral of dσz= integral of α=0 to α=2π integral of r=0 to r=2π and for the dσz is we can substitute here.

Where $(3q/2\pi)\ z^3r$ so this particular r into $(r^2+z^2)^{\pi/2}$ dr.dα, so once we substitute and you know the integrate the do the double integration and substitute what we get is that σz=q within square brackets $[1-1/1+(r/z)^2]^{3/2}$ so this particular you know portion this particular component of this particular equation is calculated as influence factor for the circular loaded area. So for different R/z values so this particular increase in stress due to at the center of the loaded area.

Suppose if you are actually wanted due to load due to the if you, if the increase in stress due to circle this loaded area away from the center then we need to have, we need to use some other influence factor values but this is actually valid for the increase in vertical stress, stress due to the load subjected to uniform load intensity having q and that to at the center of the loaded area only. so $\sigma z=q(1-(1/R/z)^2)^{3/2}$ there is a qIc, where Ic is nothing but the influence factor for the circle load area.

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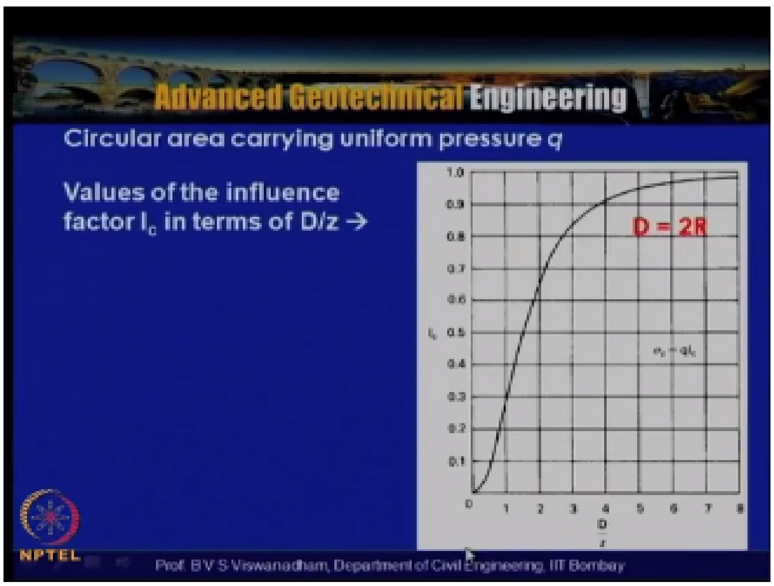

So if this we can actually get by using charts also so here the circular area carrying uniform pressure so if the chart which is actually given here in terms of 2R/z where d=2R and Ic that is the influence factor so what we can get is that by knowing the d/z for let us say that we have a d/z value of 1 and thus influence factories point 3, so that means that 0.3 into q that is the increase in stress due to the particular the circular load area and this vertical stress is at that you know the center of the circular loaded area.

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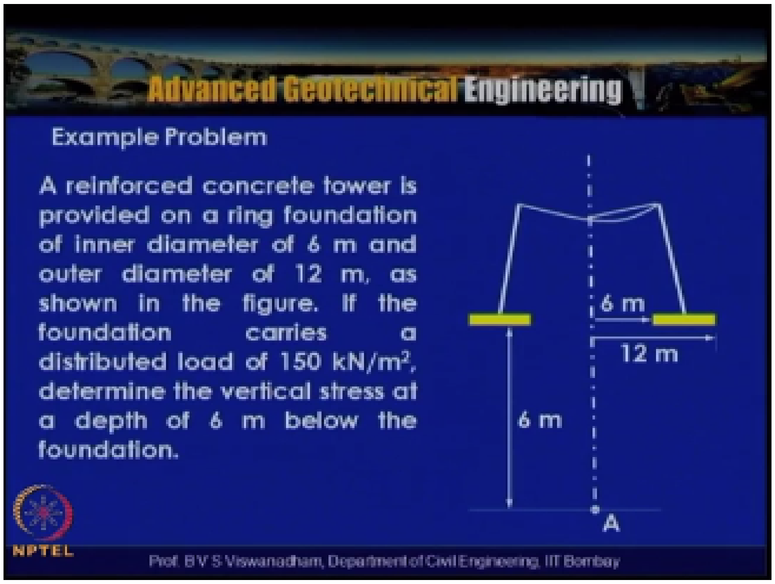

So consider an example here, where a rectangular concrete tower is provided on a raft on a ring foundation and this mostly theses simony foundations particularly in you know the cool base of thermal power station in steam plants you will find this simony, simonies and they are resting on ring foundations and in this particular problem the inner diameter of the ring foundation is given as 6m and outer diameter is given as 12m that means that here the inner diameter so the breadth of this ring foundation is nothing but 12-6 m that is 6m.

And on this you know angularly if you say that we are having a angular ring having you know the breadth of 6m. So on this area due to you know the loading difference sorts of loading due to the shell the shelf of the shell of the you know these element. Then you know this subjected to a 150 kilo Pascal's of loading so we need to calculate what is the vertical stress at the center at 6m depth below the foundation.

So for this you know we have if you notice here the central portion is not subjected to any loading, so what we need to do is that you calculate the in order to get the σzA you know calculate the vertical stress due to the entire area that is entire diameter that is 24m diameter and minus the stress intensity due to the you know this particular portion because this is particular portion is not loaded only this portion is subjected to load then you know what we can get is that we will get that net increasing in stress due to the loading on the ring foundation.

So we need to use the same equation that is in case of R first we need to use here 12m then we get the σz then afterwards we need to use the R=6m then we get the vertical stress that is 1 $q(1-1/1+12/6)^2)^{3/2}-q(1-1/6/6)^2)^{3/2}$ so the net difference σz1-σz2 we get the so called the increase in vertical stress at a depth 6m below the so called ring force concrete tower having a ring foundation which is subjected to load intensity of 150 kilo Pascal's.

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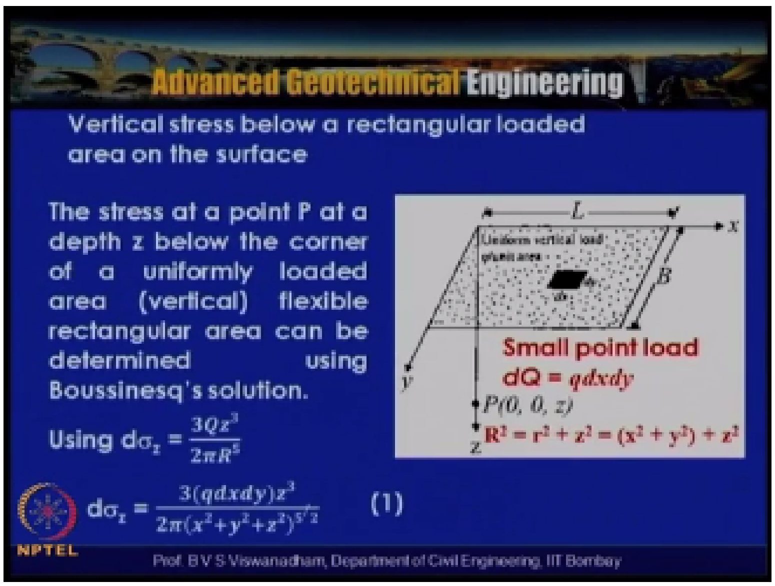

So after having you know look into you know the see the so called you know the circles area and the embankment loadings, let us also look into the vertical stresses below a rectangular loaded area where in this particular figure where we it can be seen that this is the x axis and this is y axis and this is the uniform vertical load q per unit area and we are having a rectangular loaded area L is the length along the x axis and b is the breadth along the y axis and this is the z.

So we are actually calculating at one of it is corners of the rectangle so let us say that if you are having a rectangular area of 2l/2b so that means that we actually have to multiply with the 4 times of that particular you know low mean density by this is nothing but the method of super position. So again you know in order to calculate the increase in load intensity due to a rectangular load area, so here if you want to calculate let us say for square load area when l=b so with that also you will able to get for the square loaded area, so here let us take for l and b and at one of the corners like you know this corner is under consideration now so we are actually calculating the, this $x=0$ $y=0$ and along the z axis that is you know the depth z.

So you know we can actually calculate what is increase in stress due to, so again what we do is that we actually use the Boussinesq's point loaded solution as we have done in the circular load the stress at point P due to you know so the small increase in the stress vertical stress due to point load acting on the small step which is actually is dark kind of portion here having dx along the x axis and dy along the y axis.

So the area is dx dy and the load intensity is q per unit area so qxdx dy is the small point load here acting at this particular point. So using $d\sigma z=3Qz^3/2\pi R^5$ and with $R^2=R^2+z^2=x^2+y^2+z^2$ so here what we can do is that 3x for Q what we do is that qdxdy so qxdx dy into z^3 there by $2\pi x R$ for R what we are writing is that $x^2+y^2+z^2$ that is root over to the raise 5 so we get $(x2+y2+z2)^{5/2}$ so $d\sigma z=$ we have got something like $3Qdxdy\ z^3/2\pi\ (x^2+y^2+z^2)^{5/2}$.

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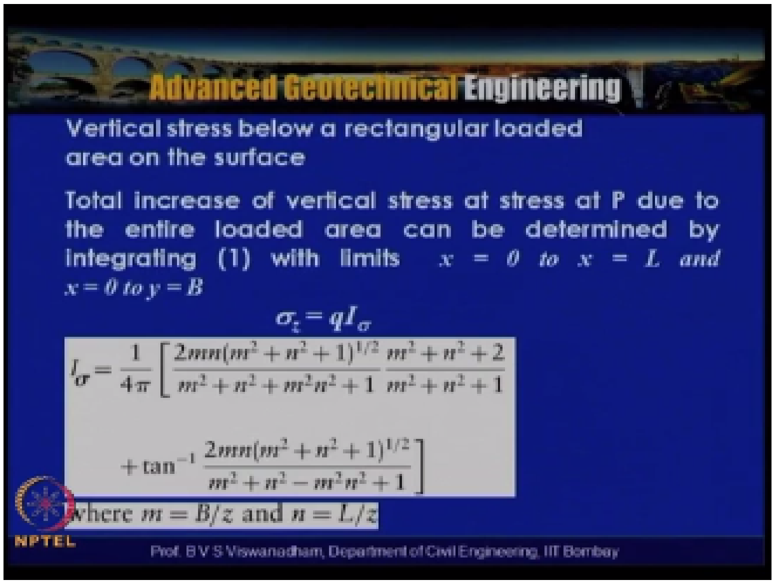

So here by using this vertical stress below a rectangular loaded area on the surface so for this total increase in vertical stress at point P due to the entire loaded area can be determined by integrating with the limits like x=0 to x=L and y=0 to x=B, if you integrate in this limits like with L and B then we actually get one of the, at one of the corners what is the integral stress due to the loaded area.

So this is simplified with σz=qIσ, so here this Iσ or Ir it can be like a rectangular load area where Iσ=1/4π[2mn/m2+n2+1)1/2 into divided by [m^2+n^2+m^2+1 x m^2+n^2+2/m^2+n^2+1+ $\tan^{-1}$2mn m^2+n^2+1)]$^{1/2}$/[m^2+n2-m^2n2+1)^n] so where here m is nothing but B/z, n is nothing but L/z. So let us look once again m is nothing but B/z, n is nothing L/z,L is along the length axis and B is along the breadth axis. So here in this m is nothing but B/z, n is nothing but L/z so for this we have the Fadum chart.

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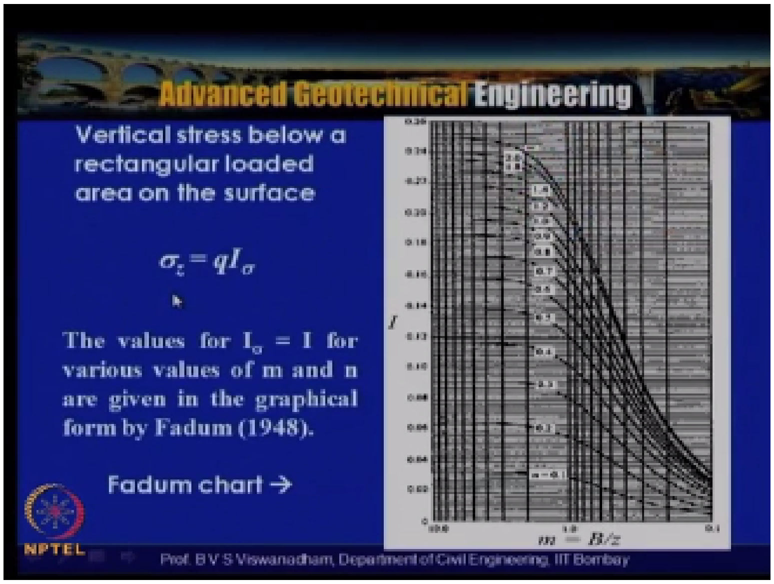

Vertical stress below the rectangular load area on the surface can be obtain by using Fadum charts the values for you know $I\sigma$=I can be obtained by using this Fadum chart which is given by Fadum in 1948 and where m=B/z and I and these are the different curves for n=0.1, n=0.2, 0.3, 0.4 like this up to 2 so here you know by knowing this values so we get the influence factor and let us assume that we are actually calculating for a square area having B.

Then we need to take say B/2 and B/2 and then we get the you know at the center to get this stress at the center. to get the stress at the center of a area which is having loaded B/2, B/B dimensions then that guess you have to take for B/2 and B/2 and in that case m=1 and depending up on the depth you can actually get.

Based on that what you can get the influence factor and that influence factor into 4 times you have to multiply to get the in load intensity to get the σz, so vertical stress below a rectangular area in the surface can be given by $\sigma z = qI\sigma$, so $I\sigma$ is obtain let us say that at z=2m and B=2m then m=1 and n= let us say that 0.3 so we will actually get the influence factor I= about 0.07, so 0.07 multiplied by q into you know the configuration whatever we consider we have to use that one.

So this is the Fadum chart to which is given by Fadum in 1948 and these are used for the in order to calculate the vertical stress below a rectangular load area and is possible for so if you are actually calculating to calculate the settlements in a soil layer particular at mid depth of the soil layer due to a rectangular loaded area then we have to use this particularly in place you know we have to add the increase in vertical stress due to this to the initial effect to stress so that we get $\sigma0'+\Delta\sigma$.

This $\Delta\sigma$ is nothing but at that particular point in the center of the clay layer how much the loaded area imposes in the vertical stress can be calculated. So this is used even in calculating vertical stresses and in settlement estimation sector.

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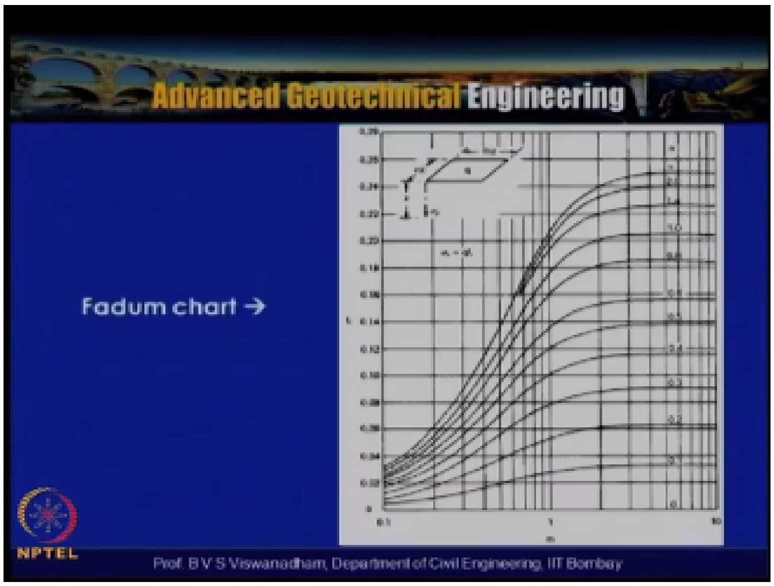

So this is another view of the Fadum chart and where in the similar way it is explore express where m and I, Ir or Iσ and where you know these you know this is are the for the different n values which is given, so this is again to give to get the vertical stress at the one of the corners.

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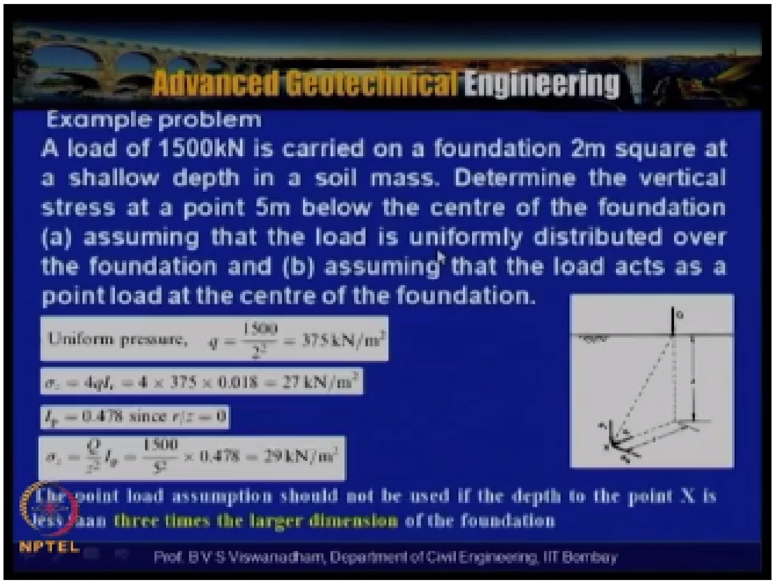

Now let us try to take one example, where we are actually having a load of 15 kN is required to be carried on a foundation having $2m^2$ at a shallow depth of in a soil base, and we need to determine the vertical stress at a point below 5m below the surface below the center of the foundation assume that the load is uniform distributed over the foundation and assume that load acts as a point load at the center of the foundation. So here we are actually you know assuming that the load is uniformed distributed over the foundation and then we are having a square foundation so 2m by 2m area is not a rectangular area it is a square area.

And another assumption what we have so the friend of AC the loading density is nothing but uniform pressure is nothing but 15 $kN/2^2$ that is $1500/2^2$ that is $375kN/m^2$ and if you look 375 kPa into area we get the 15 unit kN the load. So first is that to be a resuming as a loading density the increase in load the intensity is 375 kPa and so by taking we need to calculate at a depth of 0.5m below the center of the foundation, that means that we are having a square 2m/2m.

So here what we have is that you know we have 1m/1m four squares are there and then at each corner that is at each one of the corner let us say that left corner we are actually getting for the increase in vertical stress at a certain depth of 5m and after getting the influence factor from the curve then 4qIr so here the 4 is multiplied because of we are actually divided that area into 4 and 4x375x0.019 so this is about 27 kPa.

And now the second portion of the problem ask is that assuming that the load acts as a point load at the center of the foundation, so assuming that when R/z is going to 0 we know that Ip that influence factor for the point load is 0.4775 then also can be given as 0.478 and by for the σz is nothing but q/z^2Ip so 1500 divided by z is nothing by 5m so $1500/5^2$ into influence factor for the assumption of point load is 0.478.

So if you look into this the increase in vertical stress due to the point load is actually comes to the point load assumption for the, in the given problem comes to as 29kPa which is actually more than what we are assume for the uniform pressure. So we know to note here the point load assumption should not be used if the depth to the point x, depth to the you know if the depth to this particular point reference is less than the times the large dimensions.

For example, in this larger dimension of the foundation is say you know 2m 2x3 is 6m and 6 into the depth is say 5m, so it is, if it is less than you know the so called three times the larger dimensions then this particular point total assumption is not valid that means z one as one need to calculate the assuming as the uniform pressure.

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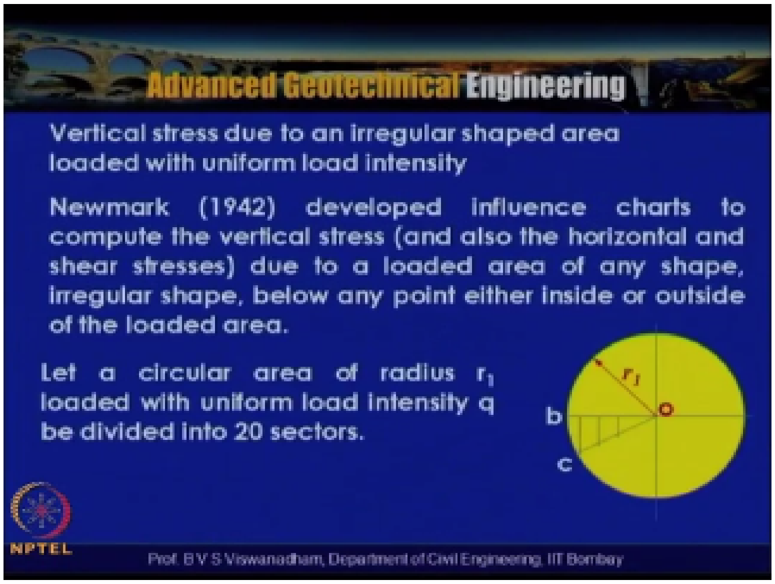

Now we have discussed about rectangular areas having square areas or sometimes we may have combination of the areas, so vertical stress due to a regular shaped area, suppose if you are having irregular shaped area loaded with uniform load intensity. So it can be a combination of circle area or it can be of any shape, let us say that it can be of any shape. So if you need to calculate the vertical stress of any irregular shaped area and for this the Newmark 19942 has developed you know the influence charts basically to compute the vertical stress.

And these influence charts also there for horizontal and the shear stresses also within the soil mass, due to the loaded area for any shape and irregular shape or it can be any shape in the sense it can be square area or it can rectangular area and that the point of interest if it is known then we can actually you know place the area drawn to the scale as for the procedure outline by Newmark then you know we can calculate the at below any point neither side or outside the soor.

So here if you noted here we notice here we can calculate the vertical stress either the point can lie neither inside or outside as a whole we did not required to divide into you know the method of super portion need not be used. So here we can actually calculate point on either side or outside the loaded area.

So for this you know the basis of this you know deducing this Newmark chart is the circular load area subjected to uniform loaded density, so we actually have deduced an expression for increase in vertical stress at the center of the circle for a circular loaded area, okay. So based on this you know particular by using this concept the Newmark developed this influence charts. Now let us see that how this actually you know conceptualize and how this can be used in calculating the vertical stresses due to the area of any shape irregular shape or any regular shape where for the point lying either inside or outside the loaded area.

Now consider a circular area of r1 loaded with a uniform load intensity q, so that means that you are having a circular loaded area, circular area of having dimension r1 and o with the center and to be divided, let us arbitrarily it has been divided into 20 sectors, so like this OBC like that it is been divided into 20 sectors that means that each the center angle is about 18˚ and then BC is that arc length like that these entire area is divided into 20 sectors so this entire area is loaded to with load intensity of q.

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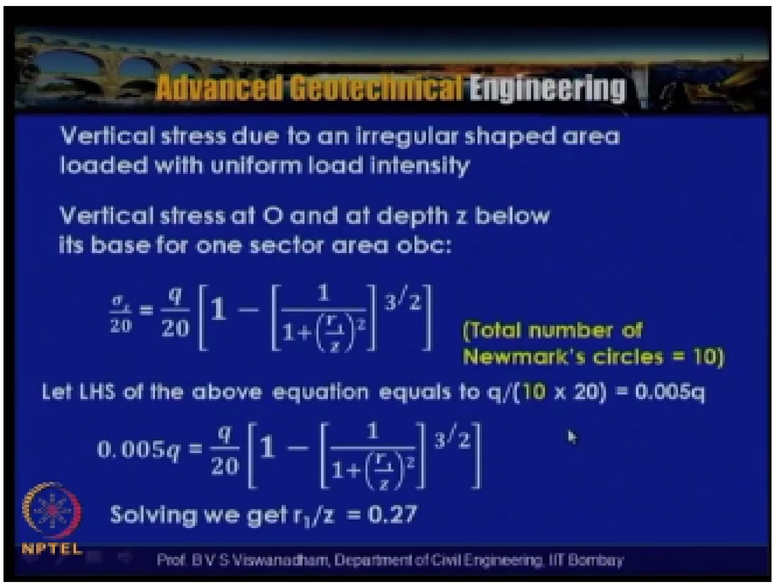

Now as I said that this is actually from the you know circular load principal vertical stress at point O and the depth z below it is base for one sector area is nothing but q/20 because that is we are actually talking about the one sector area into 1-1/1+r1 where r=r1 we have substituted now $(r1/z^2)^{3/2}$ now if that left side of the circular area is actually equivalent to load intensity of q by so if you are having now when we say that this total number of Newmark circles are divided into 10.

So there will be total number Newmark circle is obtain and these are fixed arbitrarily by q/10x20 so the influence factor for you know he is nothing but 0.005q so this is the influence factor which was considered. So for the calculating the radius of the first circle so if this is assumed as if the left hand side portion of this equation is assumed as the equal to $0.005q=q/20[1-[1/1+(r1/z)^2]]^{3/2}$

by solving we gets r_1/z=.27 that means that the first mark circle will have .27 times the diameter z so this is for the increasing vertical stress to n irregular shaped area loaded with the uniform load intensity and in this particular slide we have got the radius of the first new mark circle.

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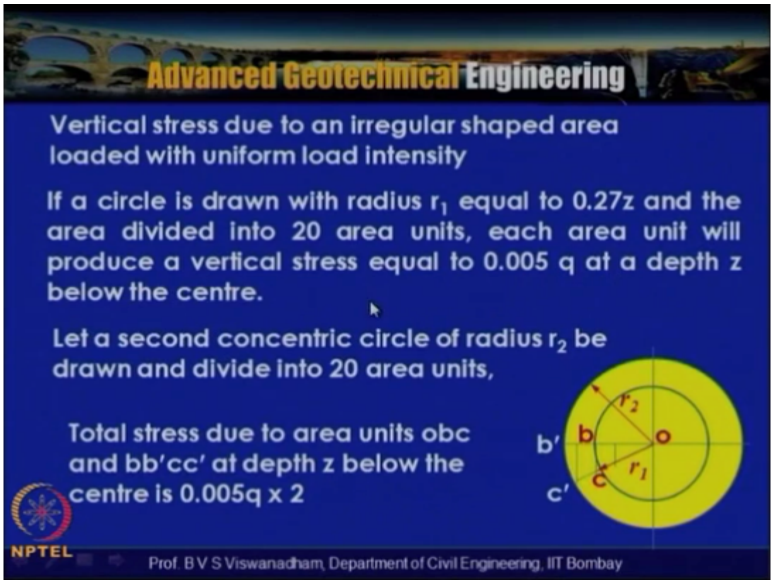

Now if the circle is drawn with the radius r_1=.27z and the area divided into 20 area units each rea unit will produce a vertical stress equal to 0.005q at a depth z below the centre that is the meaning now what we do is that we take another circle were radius is r_2 and r_2 greater than r_1 and the second concentric circle of radius be drawn and divide into 20 area units.

And the total stress due to area units obc and bb'cc' that is that this portion ob'c' this portion let us assume that this portion is 0.005q this side and this portion also we assumed that this as 0.-0056q so in order to get the radius r2.

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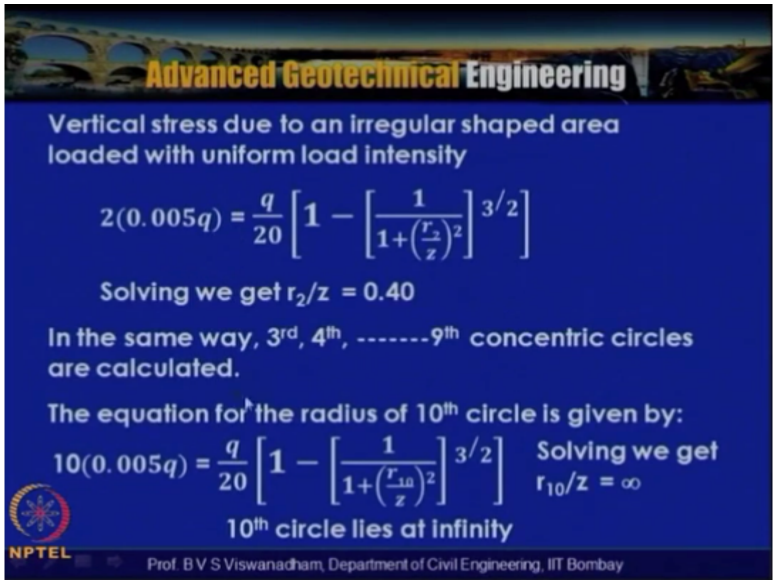

Now what we will do is that 2*0.005q= q/20*1-1/1+r_2/z whole square *3/2 so solving we get r2/z =.4 in the same way by doing for 3^{rd} circle 3*0.005q and 4^{th} circle 4*0.005q similarly 10^{th} circle 10*0.005q what we get is that we get the radius of the radius of the different new mark circles so r_1, r_2, r_3, r_4, r_8, r_9 so this all concentric circles radius can be calculated.

Now the equation for the radius of the 10^{th} circle is gain by as I said 10*0.005q so this q/20, q/20 is equal to 1-1+r_{10}/z whole square*3/2 by solving we get r_{10}/z is ∞ so the 10^{th} circle of the new mark chart is actually for vertical stress is ∞.

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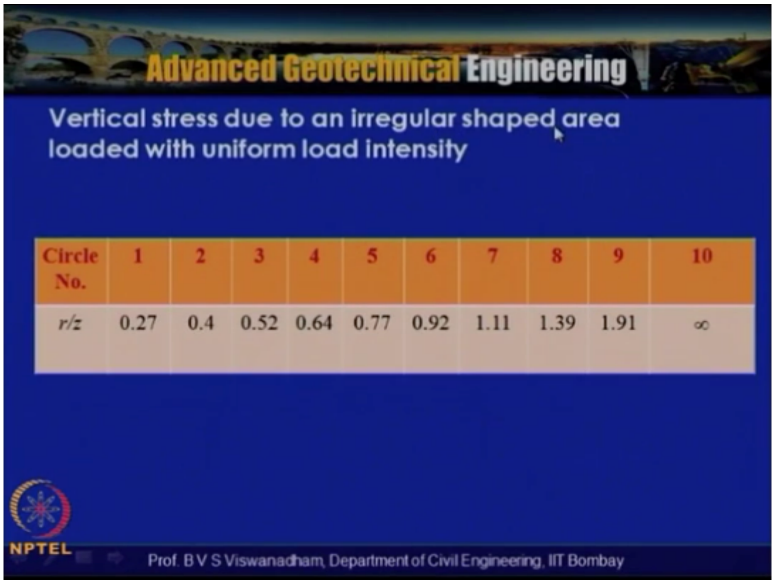

So you know with this we can actually get the new mark circles and the vertical stress is due to the irregular shaped can be found out and her in this particular table the circle number and the radius r/z1 r/z=1 this is for 1st circle 2nd circle and the 10th circle is the radius is ∞ so by knowing this values we can actually calculate concentric circles nod once the most new mark chart is ready then let us say that if we wanted to calculate this stress increases stresses due to circle loaded area.

And point is outside the loaded area and that point has to be palace in the centre of that new mark chart and what will we need to calculate is that the number of sectors points covered within that foundation area drawn to this case on the generally here transformation sheet is used to draw the loaded area so that the number of sectors count the load covering the loaded area can be calculated and with that we can actually calculate the influence that number into that influence factor into the loaded intensity.

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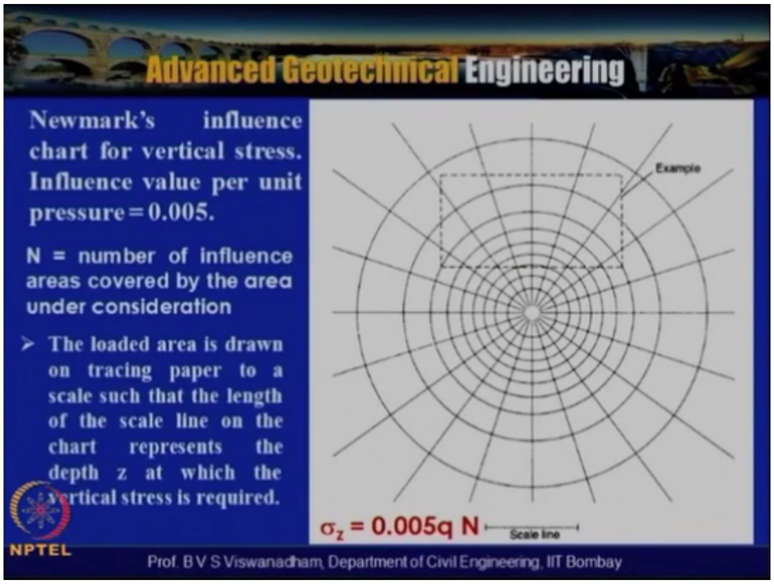

So here in this particular slide new mark chart is actually given varying actually we have the we have this one circle 1st circle, 2nd circle, 3rd circle and this is the 3rd the last circle which is at ∞ so only the 9 circles re shown here so new mark influence chart for vertical stress and influencing values per unit pressure that is 0.005 so here σz=0.005qn and n is the number of influence areas covered by the area under consideration.

Let us suppose we have an example we have a rectangular area so in this area what we do is that we calculate how many number of this rectangular areas are there and some approximations can be made because we cannot actually get the accurate number of the rectangular this areas so let us say this is 1, 2, 3, like that and when we count you may get 29.5 or it can be approximate that number is taken multiply into 2 into 0 influence factor.

Then we can actually get the you know first of all it is loaded area if it is there the loaded area is drawn on the tracing paper to a scale such that the length of the scale line the length of the scale line on the chart represents the depth z at which the vertical stress is required so if z is equal to 56 meters so the length of the scale line is actually drawn to that so that loaded area is drawn on the tracing paper to a scale such that the length of the scale line on the chart represents the depth z there at which the vertical stress is required.

So depth z is quoted by you know making the area drawn to that particular scale so the loaded areas is drawn on the tracing paper through a scale such that length of the scale line on the chart represents the depth z at which the vertical stress is required.

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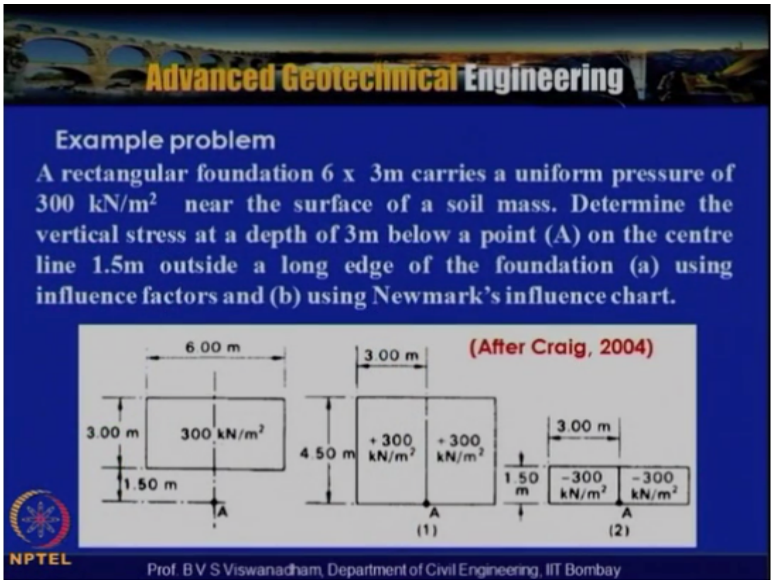

So let us take in problem were the rectangular foundation having 6 meter/3 meter carries a uniform pressure of 300kN/m^2 and near a surface of the soil mss so here what we have is that determine the vertical stress at depth 3 meter below the point A there is at this point 3 meters below this point A so we have rectangular area here and this point A is here okay .

And the outside this point is 1.5 meters long edge of the foundation and using the influence factors nd then new mark influence chart so using the rectangular loaded areas so because this area is not subjected to load what e have to use there we have to sue method of supervision so we assume that entire area is loaded now and this portion which is actually not having any load so we have to take the negative loading so by taking calculation vertical stress due to these two triangles at there so that we will get at this particular point and minus stress due to these two triangles.

So this minus this what we get is that vertical stress of the point now what by using the new mark chart what we can do is that we can actually draw we need to calculate at a depth of you know this stress depth 3meter below the point A so with scale drawn to 3 meters we can draw the area and put this point A at the with depth scale and put this point A at the centre of the new mark cart then calculate the number of squares and with that we can actually calculate what is the increase in the stress.

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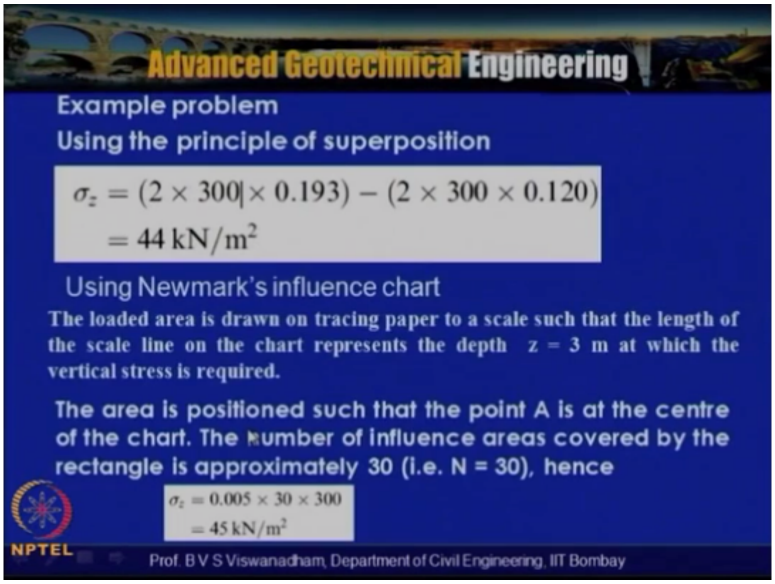

So the solution is calculated as explained here 2*300*.193-2*300*.120 so this is the due to influence factor the rectangular loaded area by using the chart we have got this by using the new mark chart we get as 45kN which is nothing but loaded area is drawn on the scale such that the length scale line of the chart represents the depth that is equal to 3 meters at which vertical stress is required.

If suppose z=5 meters then the scale of p loaded area changes the area is portion such that .a is the centre line of the chart and number of the influence areas are calculated in this particular case we get 30 so 0.005*30*300 we get 45kN so this how in how we can actually calculate suppose if you are having regular irregular shape and that is also we can applied and calculated vertical stress.

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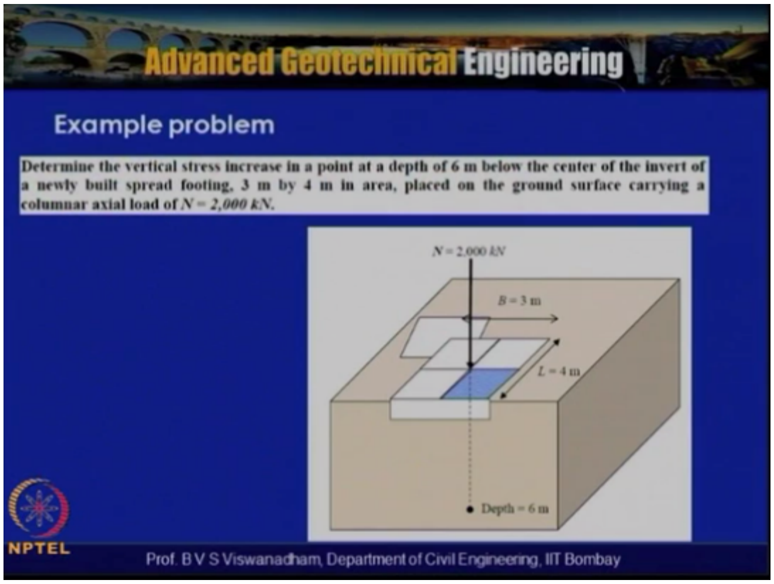

So this is another problem were determined the vertical stress increase at a point depth of 6 meter below the centre of the invert of a newly built spread footing were you know 3m/4m area so we need to calculate at this particular point so this is the 2000K load is given so what we need to do is that again use the method of supervision and at the centre so that we can actually get the vertical stress due to this portion of the triangle and this portion of the rectangular area.

This portion of the area, this portion of area, this portion of area and by method of supervision we can actually calculated the increase stress at this particular point.

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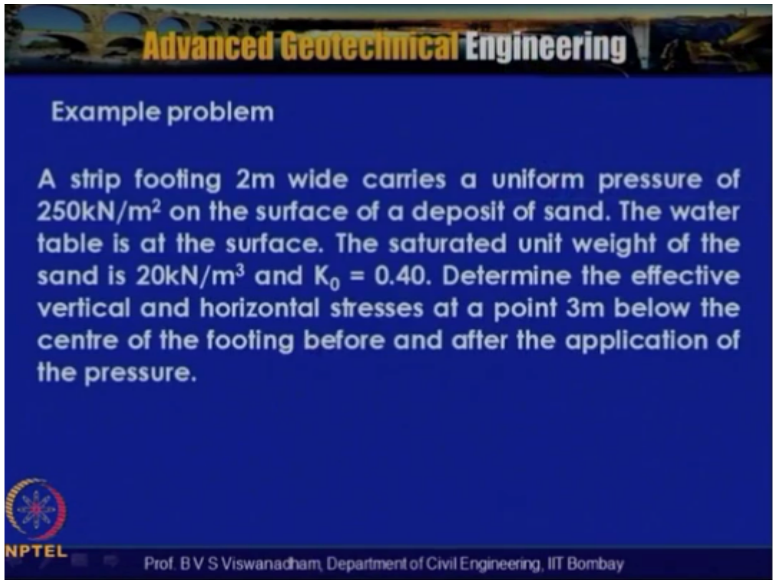

So you like this we will be actually have the number of application problems so you take this particular problem having a strip footing of 2m wide area carries a uniform pressure of 250 kilo Pascal's and the surface of the deposit of sand the water table is the surface and the saturated unit weight of the sand is 20km^3 and K_0 is .40 so determine the effective vertical and horizontal stresses at the point 3 meter below the centre of the footing before and after the application pressure.

So before the application pressure you calculate vertical stress that is effective stress and multiply by K_0 value we get the horizontal stress after loading then by applying the calculating the strip loading equation for this σz we can actually calculate the hat is the influence stress so with that we can actually get before loading and after loading what are the increase in the stresses.

So in this particular lecture we will try to understand about the stresses due to surface loads and varying when you have a different shapes nd how we can actually use the theory for calculating the stresses particularly permeability we have covered about the increase in the vertical stresses of course there is the possibility that horizontal stresses and the stressed are calculated.

And so these stresses you know the settlement of the soils and also undergoes the volume changes can take pace so further we actually look into the concepts of how this loaded areas you know cause increase in the consolidation and or you know in the consolidation does not happens how we can actually consolidation so that the settlements before the construction can be anticipate.

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