Geology and Soil Mechanics
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Lecture - 55
Tutorial on Permeability - b

Welcome everyone on the fourth tutorial section of Geology and Soil Mechanics course. So, today we are going to continue our discussion on permeability and today we are going to discuss some very high-level problems on permeability especially on seepage and flow lines. So, basically, today we are going to discuss about the Casagrande solution and a little bit of mathematics about how to use the parabolic equation to draw the phreatic line. So, let us start with our first problem.

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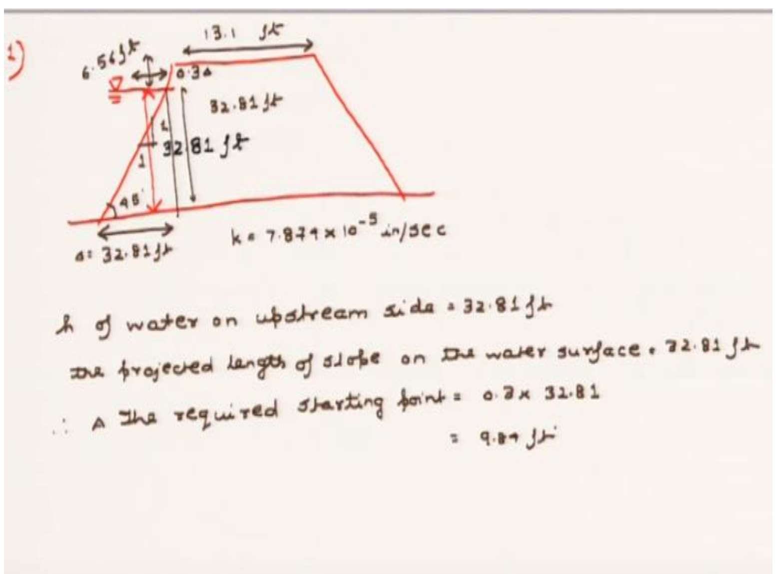

It says that a dam is given to us where basically the water at the upstream level is at a height of 32.81 feet and the water on the downstream level is at 0. So, basically now you have to you are not given the phreatic line and you have to draw the phreatic line through this earth dam. The other dimensions are given as the top of the dam is given as 13.12 feet and this height is given as 6.56 feet.

The permeability of the earth dam or the soil is given as 7.874 into 10 to the power - 5 inch per second. So, now we are going to draw the phreatic line first and we will take help a little bit of mathematics here from the parabola so the first thing is that the height h of water on upstream side is equal to 32.81 feet that is this height and the projected length of slope on the water surface will be equivalent to the slope of this line multiplied by the height so basically this is nothing but this slope is given as 1:1 that means this is 45 degree.

So, this will be equivalent to 32.81 feet as well. Now this length is 32.81 feet and this length as well is 32.81 feet. So, as we have discussed in the lecture that the parabola will start from a point which is basically at a distance of 0.3 delta where delta is 32.81 feet. So, the required starting point will be equivalent to 0.3 into 32.81 which is equivalent to 9.84 feet.

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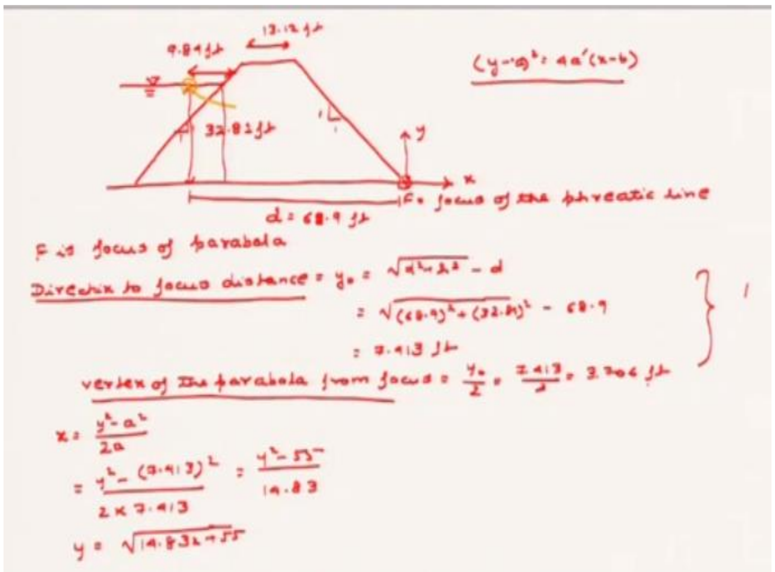

So, now our dam upstream level is known to us as well as you know from where basically the parabola is going to start. So, this distance is known to us. This distance is given as 9.84 feet. So, this is the starting point of our parabola. So, is where the parabola will start. Now we all know that F is focus of parabola and the point F lies exactly here. So, this is the focus of the phreatic line because the phreatic line itself is a parabola.

So, taking a little bit of help from the mathematics directrix to focus distance is given by y 0. Now this will be equivalent to this length is d so this is equivalent to 68.9 feet. Now I already know that this length is 13.12 feet so 68.9 feet so this will be equivalent to d square + h square - d. Now d is given as 68.9 feet so this distance will be equivalent to 68.9 square plus as we have found out that the height h or the height of the water in the upstream level in 32.81 so that is 32.81 square - 68.9 is equivalent to 7.413 feet.

Remember that these slopes are in 1:1 that means they are in 45 degree. So, now we have known the distance of directrix to the focus. Now we will find out the distance of vertex of the parabola from focus. Now that will be equivalent to y 0 by 2 so that will be equivalent to 7.413 by 2 which is equivalent to 3.706 feet. Now all these relations come from basic mathematics. So, basically, I am not going to discuss all these relationship you have to remember these relations.

So, now you have to find out the xy coordinates of the basic parabola. So, the x coordinate of a parabola because we know that the equation of a parabola is generally given as y minus a whole square is equal to 4a into x minus b. So, from this basic relation we can get that y square minus a square by 2a sorry this is a dash so y square minus a square by 2a.

So, this will be equivalent to y square minus now a square here is the vertex of the parabola sorry the distance from the focus so basically it will be 7.413 square by 2 into 7.413. So, this is equivalent to y square - 55 by 14.83. So, you we get y is equal to root over of 14.83 x + 55. Now the x at different points are known because this is the x grid this is the y grid. So, the x at different points are known to you. If you start from 0 point then basically you can take different point because this 68.95.

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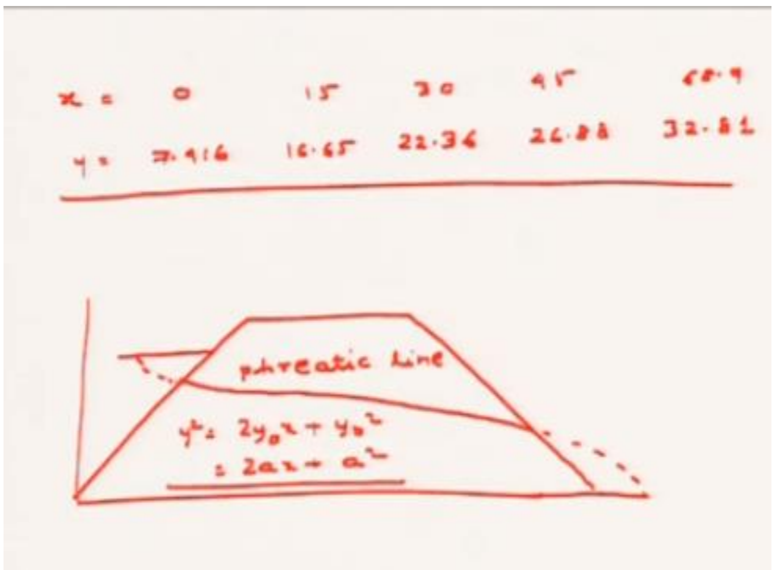

So, you can take points like let us say 0 then 15 then 30 then 45 and 68.9. So, taking all these relations, you get the values of y s 7.416 then 16.65 then 22.36 then 26.88 and 32.81 respectively. So, this is how you draw the phreatic line. So, now if you take the entire embankment then this line will be dotted where it will start from here and in here and then from here again this line will be dotted.

So, this is your phreatic line that is the equation of y square is equal to 2y 0 x + y 0 square or 2ax + a square. So, this is how you can find out the phreatic line. Now let me repeat this entire part. The first thing that you are going to do is find out the focus of the parabola. You know what is the focus of the parabola. The focus of the parabola is at the base of the dam. So, first we are going to find out the distance on the directrix from the focus and that you are going to find out with the simple relation described as a square - d.

Now d is basically the distance of the d is basically this distance where basically you find out the where basically we found out the point 3 delta where basically the phreatic lines or basically you can say the point in the water where basically the phreatic line starts. So, from there to the end point of the embankment is basically the distance d. Now it may be either given to you or you have to find out from the mathematical relations.

So, d square + h square h is the height of the water on the upstream side - d from there you find out the relation of y 0. Now the distance of the vertex from the parabola is exactly half of the distance of the directrix to the focus which is the property of the parabola so basically from there y 0 by 2 and there from there you find out the vertex, distance of the vertex from the focus. Utilize that relation in the equation of x utilize the relation in the equation of x and basically you will find out that what is the relation between x and y that is what that is what we want to find out because that is how you are going to find out the phreatic line. Now let us consider this is just a basic problem now let us consider this problem in a more advanced level.

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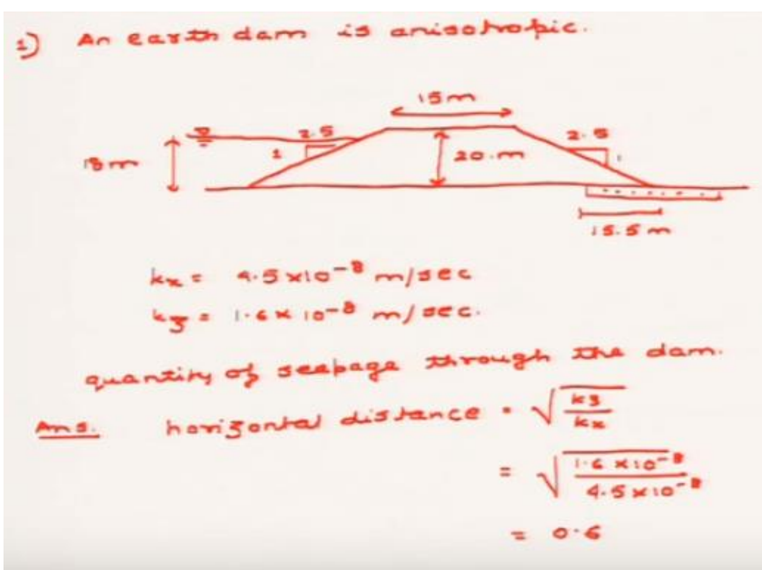

So, here basically the problem is now given to you as an earth dam is an isotropic so the figure for this earth dam is actually given and it is given as this slope is given as 1:2.5 and this slope is given as 1:2.5 this distance is given as 15 m the height of the earth dam is given as 20 m. The height of the water on the upstream side is given to be as 18 m and there is a blanket drain that is provided then that is a distance of 15.5 m from where the blanket drain is provided to the end of the earth dam.

Now you are asked said that the hydraulic conductivity of this earth dam in horizontal and vertical directions are respectively 4.5 into 10 to the power - 8 m/sec and 1.6 into 10 to the power - 8 m/sec. Now you are asked to find out the quantity of seepage through the dam. Now we all know that basically when there are 2 different coefficients of horizontal and vertical permeability then what you have to do in case of an earth dam or basically when you have to draw a seepage or a flow net is that you have to consider a transform section. So, this is what we are going to consider the transform section.

Now how do you consider the transform section? You multiply the horizontal distance by a certain factor and keep the vertical distance as same. So, what is the so how do you solve this. You multiply the horizontal distance by root over of k z by k x this factor and keep the vertical dimensions unaltered. So, if that is the case then 1.6 into 10 to the power - 8 divide by 4.5 into 10 to the power - 8 is equal to 0.6. So, every horizontal dimension is going to be multiplied by 0.6 while the vertical dimensions are kept same. Now let us see that when you multiply with the 0.6 then how does your dam means how does your dam look like.

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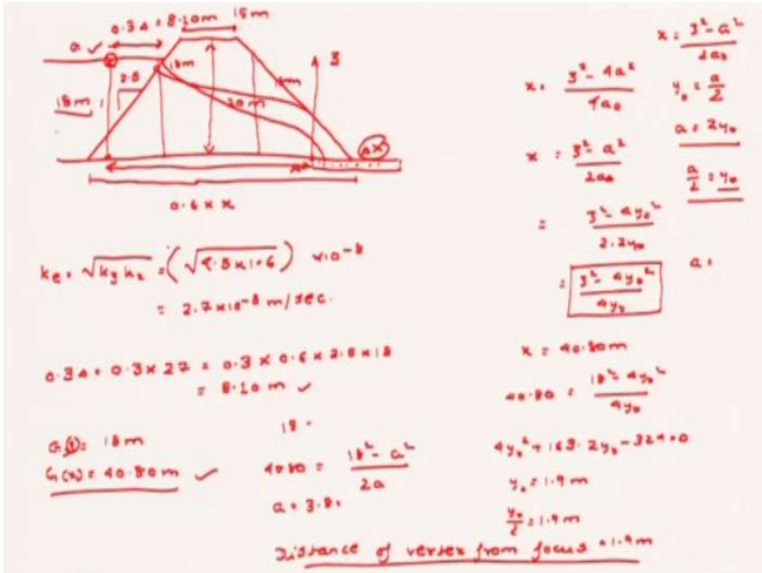

So, now this is the dam this is the earth dam. This is the z direction this dimension is obviously the vertical dimension is unaltered. So, this is obviously 18 m again. The height is 20 m again and the horizontal length I mean this length this length whatever it is has been multiplied by 0.6 into x whatever the dimension may be. This is what the this is what is the altered dimension.

Now let us see that how to solve further. So, the equivalent coefficient of permeability first we have to find out. The equivalent coefficient of permeability is k z into k x. So, this comes out to be 4.5 into 10 into 1.6 into 10 to the power - 8. So, this comes out to be 2.7 into 10 to the power - 8 m/sec. Now again you have to take help of whatever you have done here.

So, basically now you have to find out the phreatic line. So, with for that you have to take help of the parabola. So, how you are going to take help of the parabola. Now the focus of the parabola is at the point a. So, basically the blanket drain is here. Now what is the advantage of providing a blanket drain that has already been discussed in lecture but still I am telling it that basically the blanket drain will reduce the flow net here.

That means basically if a flow net actually goes here at this point it will bring down the lines here. So, now instead of the directrix instead of the focus of the parabola being at this point now we have the focus of the parabola at this point. This is now not the point because all the phreatic lines as well as all the because the phreatic line as well all the flow lines and all the flow lines will come at this point will all merge at this point.

So, basically now this is the focus of the parabola. So, at this point a again you have to find out this 0.3 into sigma 0.3 into delta sorry. So, 0.3 into delta is given by 0.3 into 27. Now this is obvious where you got this 27 because this is 0.3 into 0.6 because this is the horizontal dimension that is multiplied. Now as we have seen that this ratio was in 1:2.5. Now since this is 1:2.5 so this is multiplied by 2.5 into 18 so this comes out to be 8.10 m.

So, then you know now that this distance is actually equivalent to 8.10 m because and this is the point from where the parabola is going to start again. So, once we know that this point is equivalent to 8.10 m now what you are going to do is that we are going to find out the coordinates of point G. Now what is the point G. G is basically this point. So, how do you find out the coordinates of the point G.

Now you have to first consider that what is what is the 0 0 point. Once you find out what is the 0 0 point then from there you find out the coordinate of the point G. Now obviously the z along the z direction it is 18 m. So, G z is 18 m while G x is equivalent to 40.80 m. Now 40.80 m you if you consider along this line because this is where the this is where the focus the vertex of the parabola this is where the focus of the parabola is.

So, once you consider this is the focus of the parabola from here if you consider this length then it comes out to be 40.80 m. So, if this is correct then we will take help of this equation the basic equation of parabola x is equal y square - a square by 2a. So, x is equal to here instead of y square let z 0 square - 4a square by 4a 0 the same as this equation y square by 2a you can write that as well z square - a square by 2a 0 okay and form here we will get the relation because here basically 4a square is given of the fact because you know that the vertex the distance of the vertex from the parabola of the focus is actually y 0 by 2.

So, that is why this has been this a square this 4a square and 4a 0 has been added because we all know that here basically a is equal to 2 times of y 0 so this comes out to be z square - 4y 0 square by 2 into 2y 0 which basically is z square - 4y 0 square by 4y 0. If you consider a is equal to 2y 0 where a where a by 2 is equal to y 0 where y 0 is the distance of the vertex from the parabola this.

So, now if you put the values then you will see that x for a particular point is actually known to you. Now which point for x for which point is actually known to you. X for this point from where the parabola has started is known to you. That is why you have founded out for the g point. That is why you have founded out the z and x coordinates of the z point. So, now we just put those values so for x is 40.80 m for this point z square z square is 18 m. So, 18 square - 4y 0 square by 4y 0.

So, solve this equation then it comes out to be 4y 0 square + 163 2 y 0 - 324 equal to 0. So, we y 0 is equal to 1.9 m. Now if basically we consider the sign if we keep the symbol same then basically this is not y 0 but this is actually y 0 by because this is actually not y 0 but this is actually y 0 by 2 1.9 m. So, distance of vertex from focus is 1.9 m. Distance of vertex from focus we established to be 1.9 m.

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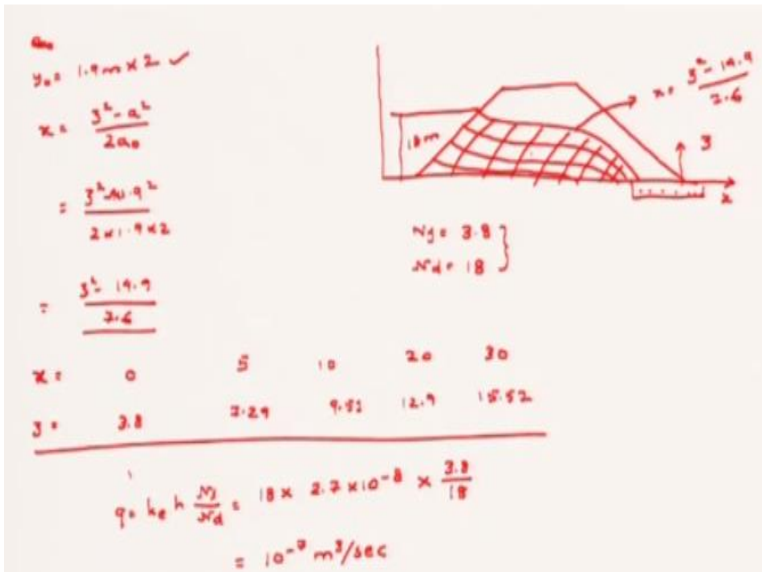

So, if that is the case then we will just substitute this y 0 value in the equation which is 1.9 m we will just substitute this in the equation and the original equation x is equal to z square minus whatever the original equation was z square - a square by 2a 0 so this comes out to be z square - 1.9 square by 2 into 1.9 into 2 4 into 1.9 square so this comes out to be z square - 14.4 by 7.6.

Now this again let me tell here that basically this y 0 that whatever you have found out this y 0 is nothing because you have considered that y 0 is actually a by 2. So, basically this is the distance of the vertex from the focus. That means it is equivalent to distance of the vertex from the focus distance of the vertex of the parabola from the focus. So, in order to get the actual y 0 you have to multiply it by 2 that is what we have done here that y 0 into 2, 1.9 into 2.

So, if you now put that is equivalent to a or whatever you see so when I put the values then this is what the equation. Now let us follow the similar process that you know the x for a series of numbers which basically starts from let us say 0 then 5 then 10 then 20 then 30 and the z for all those values will be 3.8 then 7.24 then 9.51, 12.9, 15.57. So, these are the values that we will get. Now let me repeat this before I again let me repeat this procedure before I can go to it**.** Now what we did was that initially first we transformed the entire section. Then what we did was that just like the Cassagrande method we just multiplied it with 0.3 delta. Now I have multiplied with 0.3 into 27 because 0.3 is the 0.3 factor 0.6 in order to transform the 27 m in order to transform the 18 m okay in order to transform the 18 m in the horizontal length we have multiplied with 0.6 and then basically multiplied with 2.5 because the slope is in the ratio of 1:2.5. So, we got 8.10 m.

Now 8.10 m is basically that the parabola starts in water. So, that point if we call that point by G then G has the we find out we found out the coordinates of the point G. So, G has 2 coordinates along x and z direction. So, for z direction it is obvious that is 18 m because the height of the water on the upstream side is 18 m while G for x direction is basically 40.80 m that you can easily find out from all the given lengths 15 from all the given lengths because we know that this length is 15 m and once we know that this length is 15 m then we know that how much is this length because this length is again 18 m so this length is also 18 m so multiplied by 2.5 2.5 and we will get all the required lengths.

So, from there we actually founded out the G x is equal to 40.80 m. Once we found out G x is equal to 40.80 m since that point already lies on the parabola so basically what we do is that we substituted that value of x and z in the original parabola equation. Now we all know that in the equation of the parabola that the equation of the parabola actually consist of z square - a square by 2a 0.

Now this a is nothing but the distance of the directrix from the parabola that is what we have said previously that a is nothing but the distance sorry distance of the directrix from to the focus okay distance of the directrix to the focus. So, since this is the distance of the directrix to the focus we also know that the distance from the vertex to the focus is basically half the distance of the directrix to the focus.

So, that means y is equal to a by 2 y 0 is equal to a by 2. That is what I have said here. So, just substitute the value of a putting the value of a we get that z square - 4 y 0 square by 4 y 0 that is the equation that we want. So, now just you substitute the value of x and z so we will get in terms of y 0. You can also substitute the value of just x and z to get a as well. You can also substitute the value of x and z to get a as well. So, we can substitute the value of x and z to get the value of a as well let us say this is 18 this is 40.80 and this is 18 square - a square by 2a okay that also you can do.

Anyone of the process is applicable so then you can find out the a which basically will be equal to 3.8 m. Once we founded out the value of a once we founded the value of a then we can find out easily the y 0 and then you can substitute the value back to get the values of corresponding to values of x what are the values of z. So, now from the entire dam you know what is your phreatic line so here is the phreatic line and here this the equation of x is equal to z square - 14.9 by 7.6. This is what the equation of the phreatic line. Now this is x this is z and this is where the blanket drain starts. So, similarly all the points that means all the flow lines will be like this and all the equipotential lines will be like this perpendicular to the flow lines. We also know that the height of the water from the upstream side that is this height is 18 m because all the vertical dimensions are unchanged.

So, once this point this has been done then once this has been done now you can easily find out that what the number of drops so in this case the number of flow lines are basically 3.8 1 2 3 and this is 0.8 let us say and the number of drops basically is considered to be 18. So, then q is equal to k e into h into N f by N d. Now we all know that the height of the water is 18 because on downstream side there is a blanket drain so it is 0 almost.

K e or the equivalent coefficient of permeability that we have also found out that basically is equivalent to 2.7 10 to the power - 8 2.7 into 10 to the power - 8 into number of flow lines that is 3.8 number of drops 18 multiplied so 10 to the power - 7 m cube per second. So, that is how we basically found out found out using the flow net what is the value of the seepage loss.

Now for this let me tell you that for this a little knowledge of mathematics is required because the only fact that we know is the equation of the parabola and this has already been discussed in the slides and one thing that is very important when basically it is an isotropic dam then you have to always remember that you have to multiply the horizontal distance by a factor. Here the factor is 0.6. It is basically the ratio of k z by k x that is the permeability in the vertical direction by the permeability in the horizontal direction square root and all the vertical dimensions are to be unchanged kept unchanged okay and also the equivalent coefficient of permeability has to be found out so from there only we found out that what is value of q.

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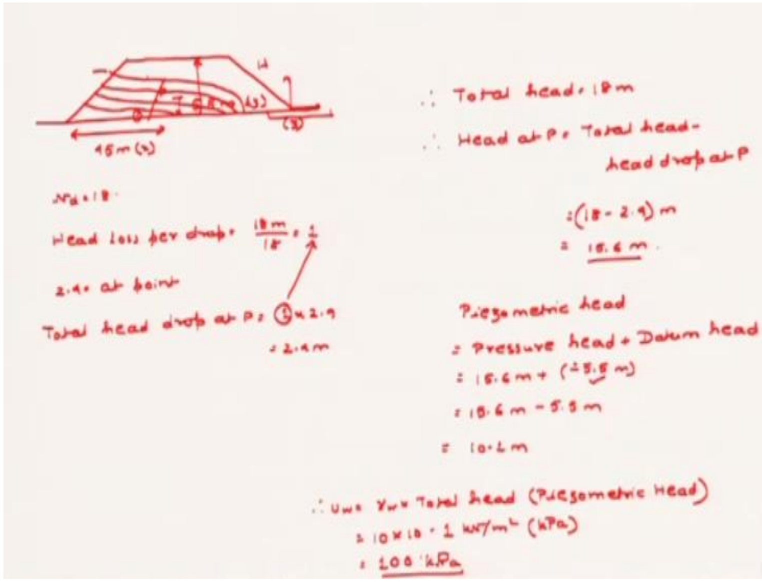

Now another question that is asked here is you have to find out the effective stress at a certain point. Now that point where basically the effective stress has to be found out is at this point P which basically has a coordinate of 45 m of x and 5.5 m of z. So, how do you find out that what is the pore pressure at that point. That is pretty easy because first find out that if you draw the flow net first find out that what is the drop at that point okay that means how many drops are basically the point is experiencing.

So, here we will see that basically the total drops the total number of drops or N d is basically is 18. So, 18 drops means in order to get from 18 m since the head on the upstream is 18 m so from in order to get from 18 m to 0 m 18 drops are required. So, what is the drop. So, what is the then head loss per drop. That is obviously 18 m by 18 that is equal to 1. So, what is the number of drops when basically you cross at the point P.

Now from the diagram from the diagram here if you consider this is the point P then basically let us say that 2.4 drops are observed and basically the when basically it is at the point P. So, if the number of drops is 2.4 at point P then total head drop at P is obviously equal to 1 into 2.4 that means 2.4 m. This one is equivalent to head loss permeability drop. So, total head is 18 m. Head at P will be equivalent to total head minus head drop at P.

So, that is 18 - 2.4 meter is equivalent to 15.6 m. So, the pressure head at point P has been found out. Now let us consider the datum head because we already said that when basically you have to find out the pore water pressure at a certain point and under any conditions especially in soil then basically you have to consider the piezometric head. The piezometric head means it is the sum of the datum head and the pressure head because the velocity head is 0 as the flow of water through soil is very less.

It is like in 10 to the power of - 8 m/sec 10 to the power - 9 so basically the velocity will be velocity can be very less. So, pressure head plus datum head. Now the pressure head at point P is 15.6 m and what is the datum head. We have already said that this point P is at a distance of 5.5 m from the base. So, if you consider the total height that means the total height of the dam is - 5.5 meter.

If you consider the total head of the dam means this height as H then basically the elevation head starts from here. That means this is 0. This point is 0 because we considered this point to be 0. So, z starts at this point this is where the blanket drain starts. So, along z since it is going upwards so basically the pressure head is dropping the datum is dropping. So, since the datum is dropping so that is why we have subtracted it.

That means it is minus plus 5.5 m. If it goes downwards that means the datum head is actually been added. So, 15.6 m because you know that the pressure head at the lowermost point is highest or the datum head of the lowermost point is highest and as you go up negative heads come. So, 15.6 - 5.5 m which comes out to be 10.1 m. So, the pressure at this point will be equal to gamma w into the total head which is nothing but the piezometric head so this is 10 into 10.1 kN/m square or kPa equivalent to 100 kPa.

So, that is how you find out the pressure head at this point. Now again let me tell you that this is quite easy because once you draw the flow lines then it is quite easy. First you find out what is the head loss per drop. Then see that at that point how many head loss are actually occurring. You may consider I have considered here 2.4 you may consider whole numbers like you may consider 3 you may consider 2 it does not matter but that is all an approximate number.

So, graphically you have to visualize that how many head drops are actually occurring at that point. So, the head drop if the number of head drops at that so again coming back to the problem so basically the head loss per drop you have to find out and you have to graphically visualize that how many number of head drops are actually observed. It may be a full number it maybe an it maybe an integer it maybe a fractional it does not matter.

You can even consider it as 3 head drops here. So, the total head that you have considered should be subtracted from the head drop at that point in order to get the head at that point and as we all know that basically the total head will be equivalent to the piezometric head which in turn is equivalent to the pressure head plus the datum head so you find out the total head multiply with gamma w and then we will find out the pressure at that point.

Now this helps sometimes to find out the effective stress at that point because you know that the once you find out the total stress then subtract this pore water pressure from that number then you will get the effective stress at that point and in order to get the pore water pressure actually then you have to first consider you have to first know the phreatic line because without graphical interpretation you cannot find out what is the pore water pressure at that point.

So, in order to find out the graphical interpretation you have to take help of the basically mathematical equation of all the parabola of the parabola and you have to find out some know some basic relations like distance of the directrix from the focus or the distance of the vertex from the focus of the parabola and the like the distance of the vertex from the focus of the parabola is half the distance of the directrix from the focus of the parabola or the basic relations that I have covered here like this y 0 by 2 and d square plus h square minus d and all these things and anisotropic flow nets as we all know that it should be multiplied with a factor that basically modifies the horizontal distance while keeps the vertical distance as same and then drawing the flow net and then finding out what is the seepage loss. So, this ends the permeability chapter.

Now we are going to discuss about the consolidation problems. Now before we start about the consolidation problem today actually we will we are going to discuss a very simple problem on consolidation and that requires some basic concepts of over consolidation.

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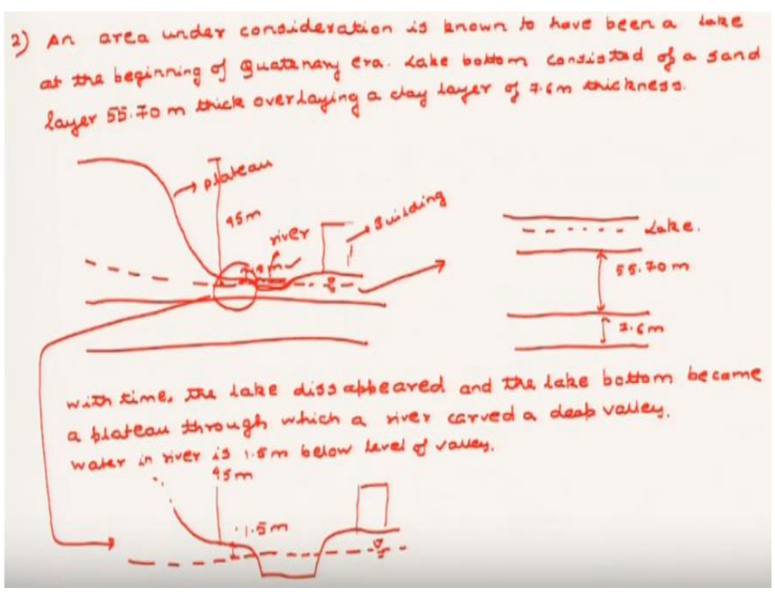

So, let us start with the problem. An area under consideration is known to have been a lake at the beginning of quaternary era. Lake bottom consisted of a sand layer 55.70 m thick overlaying a clay layer of 7.6 m thickness. Now let us see the diagram how does it look like. So, this is how it looks like and this is where the present water table is and a building is constructed here. So, this is let us say the lake bottom.

Now the how the lake bottom now this is where the building is constructed and this view when enlarged of the lake bottom looks somewhat like this. This is the lake this is the layer of sand this is the layer of clay because this is a sand layer of 55.70 m so this layer is a 55.70 m and this is a clay layer of 7.6 m thick and this is the lake. So, with time the lake disappeared and the lake bottom became a plateau through which a river carved a deep valley.

So, this is how the figure now looks like. This is the river. This is the plateau and it is it has been carved through a deep valley. Now the plateau is now some 45 m above the bottom of this valley. So, this plateau this height is somewhat 45 m okay it is said and the water in the river is 1.5 m below the level of the valley. So, water in river is 1.5 m below level of valley. So, that means this is the water level.

This is said as this is the water level so this height is some 1.5 m. Now it is difficult to draw here but this height is somewhat 1.5 m that means if you enlarge this part so this is how it looks like this then the river carved a deep valley then here this is the river this is the water table this is the phreatic line and this height is 1.5 m. This is the plateau part okay so this goes up this from this is here so from this point it is 45 m 45 m and this is where the building is constructed.

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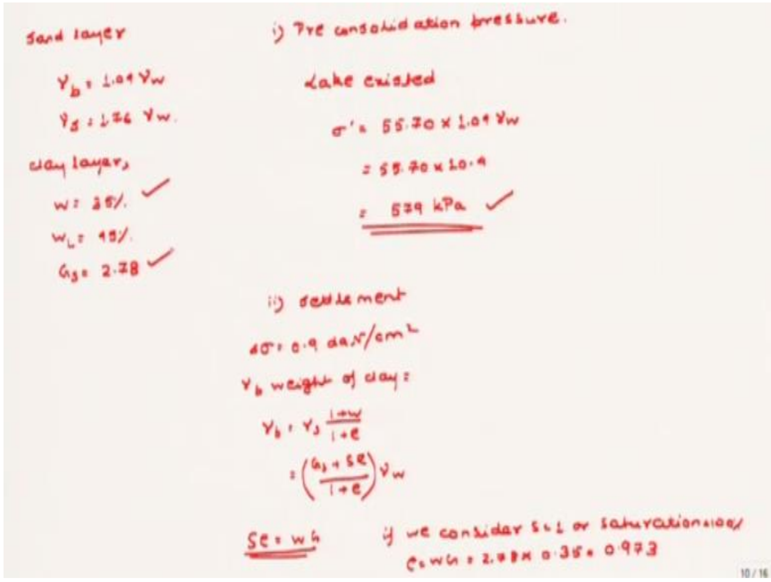

Now the first question that is asked is given the sand layer as gamma b as 1.04 gamma w gamma s as 1.76 gamma w clay layer as w as 35 percent W L that means the liquid limit as 45 percent and G s or the specific gravity of soil solids as 2.78. You are asked to find out the preconsolidation pressure first. Now how do you calculate the preconsolidation pressure because finding out the preconsolidation pressure is the first fact that requires nothing.

Now you know that basically a preconsolidation pressure is basically the pressure at which the soil has been subjected to the maximum stress or the largest effective vertical stress in its geological history. So, basically you have to consider from the time that the lake existed to the point when basically the lake has disappeared. Now the lake disappeared means basically what happened is that the pressure got released.

So, basically you have to find out the preconsolidation pressure at that time when basically the lake existed. So, the time when the lake existed if you considered then the sigma dash okay because you have to find out the preconsolidation pressure where the preconsolidation pressure at the without neglecting the effect of pressure so sigma dash will be equal to how much for the sand layer so sigma dash will be equal to how much at that point at that point if you consider the lake existed at the top then this entire length of sand of 55.70 m and we have to neglect the weight of clay that means you have to neglect the 7.6 m height.

So, 55.70 multiplied by 1.04 gamma w so that means 55.70 into 10.4 because the unit weight of water is 10 so this comes out to be 579 kPa. So, this is the time when the lake existed. Now when the lake has got off then basically the overburden pressure was released. So, obviously this is the largest stress that was experienced in history. So, that is why this is the preconsolidation pressure. In the second question, it is asked that as I was telling from the beginning that a building was constructed on the other side so basically if that lake was removed and if it was made a settlement then in nature in almost in all the cases in practical you have to find out that what is the settlement.

So, you have to first find out you have to first find out that what is the stress that is imparted by the building which is given here. It is given as 0.9 daN per centimeter square. So, this delta sigma that is the stress that is the extra stress that is permitted in this layer. So, in order to find out that let us see that how we would proceed. Now first let us find out that the settlement first let us analyze the situation.

See for sand there will be only elastic settlement for sand there will be no consolidation settlement. Consolidation settlement is only possible for clay. So, the only possible settlement is due to the layer of that 7.6 is due to this clay layer of 7.6 m. So, in that case you have to first find out that what is the vertical effective stress at the mid height of the clay. That is the basic thing. So, for that what we will do is that we have to first find out the gamma b of clay or the unit weight of clay.

Now how to find out the unit weight of clay. Now we all know that gamma b is equal to gamma s into 1 + w by 1 + e or basically you can go from simply G s + S e + by 1 + e into gamma w okay either of this formula. Now if you consider this then if you consider this then basically we have to find out e. Now e also we know how w G is equal to S e from the basic soil relations.

Now if we consider S equal to 1 or saturation 100% now that we have to consider anyways because it is the bottom of the lake. Now basically it is always saturated. So, e is equal to w into G. Now G is given as 2.78 and w is given as 0.35. So, multiply both of them we will get 0.973, w is given as 35% G is given as 2.78 so you will get e equal to 0.973.

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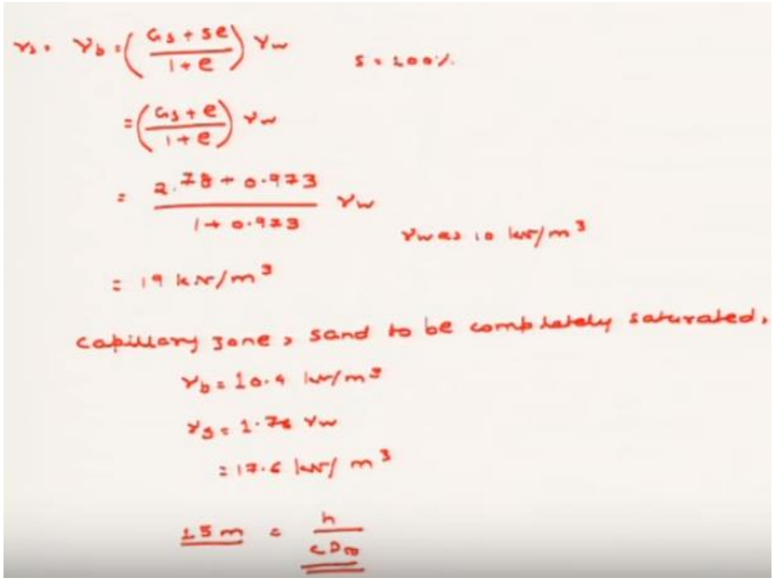

So, moving to gamma b G s + S e by 1 + e into gamma w. So, this comes out to be G s + e by 1 + e into gamma w okay. Now G s is given as again how much 2.78, 2.78 + e you founded out to be 0.973 divide by 1 + 0.973 into gamma w. So, this comes out to be as 19 kN/m cube taking gamma w as 10 kN/m cube considering the saturate. Now because this is equivalent to gamma s because s is equal to 100% for this entire lake.

Now there is one more thing that you have to consider in this case. Remember that basically the water table wherever the water table is it is below the it is at the clay layer and basically there will be a capillary rise in the sand layer. So, in the capillary zone we will consider the sand to be completely saturated. If that is the case then for dry sand the gamma b for dry sand the gamma b is given as 10.4 means 10.4 kilo newton per meter cube.

Then gamma s saturated it is already said that what is the saturated sand gamma weight and that is given that the weight density of the water table. This is the weight density of the water table so it is given as 1.76 times of gamma w. Now this weight density so this is equivalent to 17.6 kN/m cube okay.

So, then the thickness now you have to find out that what is the height of this capillary zone what is the height or what is the height of this capillary zone. So, height of this capillary zone let us consider that this height of this capillary zone to be 1.5 m. Now you can find this out easily from h by c into D 10 from this Hazen's formula okay but it is given that the saturated sand but here in this problem it is given that the height of the capillary zone is 1.5 m.

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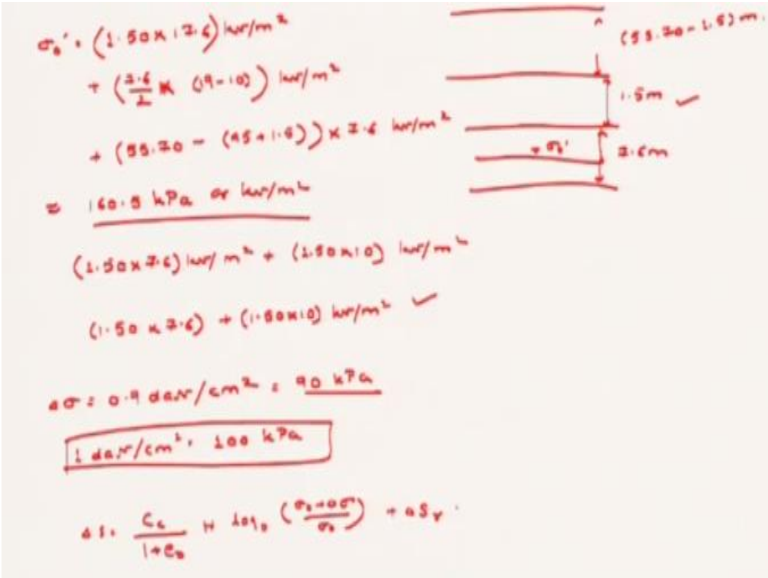

Now since the height of the capillary zone is 1.5 m so we will have sigma dot that means that the middle of the clay layer if you consider now the sand layer has a height of capillary zone of 1.5 m then 7.6 m you have to find the height at here that is the mid height what is the sigma 0 and above it this length is 55.70 - this 1.5 m. So, if you find it out then this is 1.50 into now what is the unit weight of sand at that point is 17.6 so 17.6 kN/m cube meter square this is for this layer.

For half of the clay it will be 7.6 by 2 plus 19 - 10 N/m square. Now there is a reason why I added 17.6 here. The reason why I did it is basically because of this fact that 1.50 into if you consider the dry weight of sand then it will be 7.6 kN/m cube but since it is in capillary zone so you have to add the water unit weight instead of subtracting it while in the case of clay since it is below the water table so basically you have to subtract the unit weight so that is known to everybody because this has already been taught in the effective stress of capillary effective stress in capillary rise and the last and the final part is basically for the topmost part 55.70 minus now we are considering this at the time when the building is drawn.

So, basically this has been carved off and now only if you can see only 45 + 1.5 that means if this is the height of the layer initially that means if initially it was 55.70 m at the beginning now only the layer of sand that remains is 45 + 1.5. So, obviously this will be 45 + 1.5 into 7.6 N/m square because we have to find out the effective stress at that point. So, the total comes out to be somewhere near about 160.5 kPa or kN/m square.

Now again let me discuss because a little of effective stress has come in this concept so let me again discuss that how did I did this. This has been considered at the points where basically the building is constructed. So, when the points of the building is constructed you have I have already said that the river has carved a deep valley. That means that layer of sand has actually vanished. So, now only 1.5 m of the sand only 1.5 m remains and out of this only 45 m at the top there is a plateau.

So, 1.5 m is basically the height of the capillary zone. That is why I said that the question where basically the capillary zone is already said to be given in the question that is 1.5 m. If it is not given you can find out from this Hazen's capillary constant h by c into D 10 where basically the Hazen's constant has to be given. So, since 1.5 m is already given so we already said that the saturated sand has a unit weight of I have already said that the weight of the saturated sand is 1.76 gamma w.

So, obviously 1.76 so basically the weight of the sand in the capillary zone will be 1.50 into 7.6 due to sand only but as you know from the concept of effective stress that basically 10 kN/m square has to be added. So, 1.50 into 10 because the suction because it is because it is expressed in suction because it is expressed in capillary rise so that is why it is multiplied by 10 in order to increase the effective stress.

So, 1.50 into 7.6 + 1.50 into 10 kN/m square is the final value for this part. Now since the river has carved a deep valley so basically 45 + 1.5 is the total height that has been removed due to the lake. So, 45 + 1.5 has been totally removed. So, 45 + 1.5 that is to be subtracted from the original length of 55.70 sand layer and again it is multiplied by 7.6 because it is just the dry unit weight.

So, finally that all came out to be 160.5 kPa. Now once you know that 160.5 kPa you also know that the value of delta sigma is 0.9 daN/cm square okay. Now actually the unit of 1 daN/cm square is equivalent to 100 kPa. So, this is basically equivalent to 90 kPa. Let us convert everything into kPa. So, once this is done now it is easy to calculate the settlement because you already know that delta sigma is 90 kPa the stress at the middle of the clay layer I hope that this 7.6 by 2 so 3.8 so stress at the middle of the clay layer you know to be 160.5 kPa.

So, from there you can find out that what is the settlement because you know that the settlement formula is C c by 1 + e 0, e 0 we have already founded out for the clay layer that is also known to us because the e 0 is 0.973 into H into log 10 of sigma 0 + del sigma by sigma 0. But there is one more trick here. Because the clay layer initially we said even though we said that we ignored the weight of clay but the clay layer was actually said to be over consolidated because now the overburden pressure from the top of the clay layer has been removed.

So, obviously this settlement has to be added with another settlement that basically is due to the over consolidated clay layer. Right now, I am stopping it here because so right now I am stopping it here and in the next lecture we will consider the effect of the more on problems on consolidation and how you have to take the effect of preconsolidation settlement in order to find out the answer of this problem. Thank you.