Geology and Soil Mechanics
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Lecture - 21
Seepage - A

Welcome back. So, in the last lecture we just talked about the construction of flow nets with the help of equipotential lines and flow lines and I hope and this is the basic and this is the backbone to understand the seepage analysis. So, if you understand this thing properly then it is it will be very clear to you that how we can find out the flow through the porous medium.

So, in the flow net construction basically with the help of equipotential lines and flow lines you will be constructing some grid or the net kind of thing which we will be solving for different information and there we have seen how you will be getting different flow channels through which the flow actually will be occurring and flow channels will be bounded by to successive say flow lines and whereas we have got equipotential drops that in N d that is happening between 2 successive say equipotential lines. So, this these few things we have seen in the last lecture. Now in this lecture we will be seeing more information about the flow nets.

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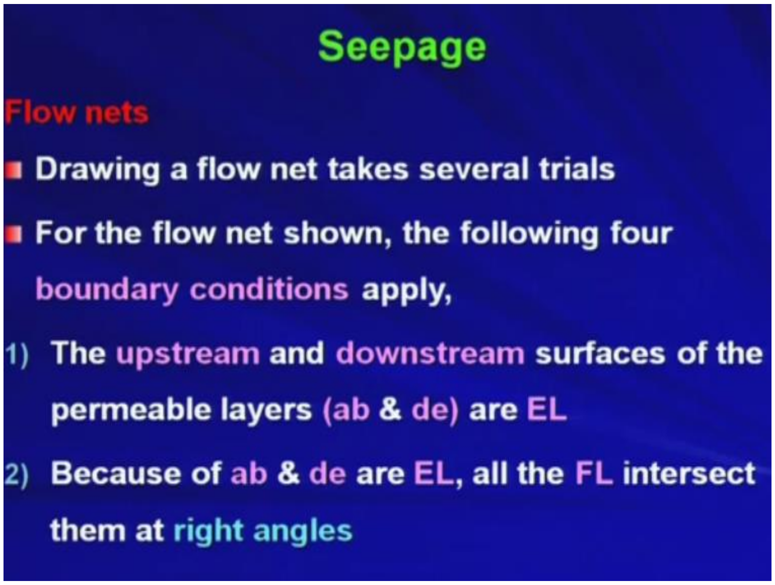

So, drawing a flow net takes several trials. As you have understood from this that see number of flow lines and number of equipotential lines are solely dependent on your own judgment right. So, you can go for say 6 number of flow lines or 8 number of flow lines or maybe 50 number of flow lines right. So, it is based on your judgment and it should satisfy 2 basic criteria. One thing is flow lines and equipotential lines they intersect in the in 90 degree and that will form 90 degree angle at the intersection point and the flow lines and equipotential lines will be or the flow domain or the region will be considered as a element right flow element should be approximately equal to a square.

So, these 2 criteria you need to satisfy when you are forming the flow lines or when you are constructing the flow nets rather. So, basically so it will take several trials. So, suppose you are starting with say 6 number of flow lines and 8 number of equipotential lines say suppose for any kind of problem and if you see that they are not satisfying this thing properly then or maybe they are satisfying this thing but you can have better opportunity to improve the result by increasing the number of flow lines and number of equipotential lines.

So, as you increase the number of flow lines and equipotential lines in the flow net your results or your values whatever you are expecting or whatever you are desiring to obtain from this flow net so those will be refined further. So, this is a kind of say optimisation kind of thing and further if you if you increase the flow lines or equipotential lines and at certain point of time you will see that you are not getting any refinement in the results.

So, that means you are getting the maximum efficient say flow nets right. So, this will take several trials. So, you cannot nobody can say that okay this flow net if you use you will be getting the right answer right. So, that depends on individual to individual perception and how you are proceeding by doing I mean systematically you have to proceed by analysing that thing through sensitivity analysis and get the results.

So, for the flow net shown whatever we have seen in the last lecture the following 4 boundary conditions apply right. The upstream and downstream surfaces, so if you if I see the flow net once again whatever we have seen in the last lecture, so let us go back.

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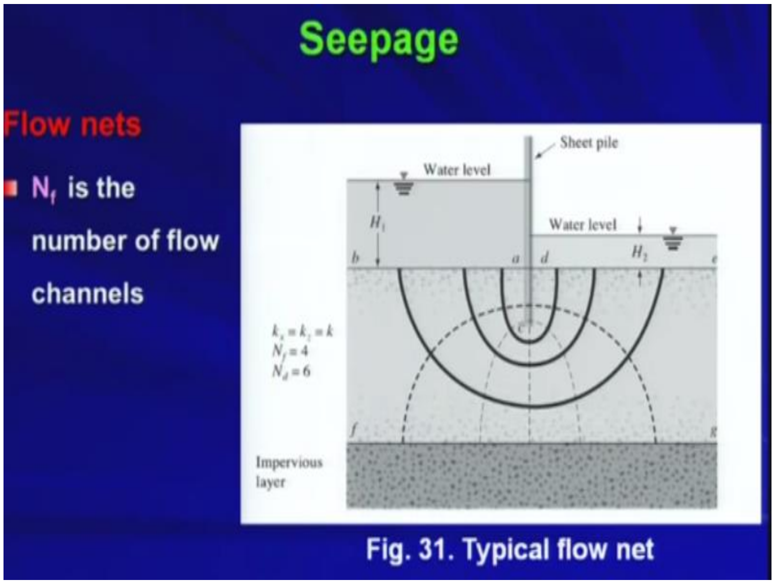

So, this was the flow net we have seen in the last lecture right or there we have seen so the thick black lines are nothing but the flow lines whereas the dash line is are nothing but the equipotential lines and we have seen how they are forming the flow channels and equipotential drops N d. So, now if you see here so we have defined several say several say lines ab, de, and gf and ac, dc all those things right. So, we will define all those things properly now.

So, now basically what are the different boundary conditions are applied in this particular flow net. The upstream and downstream surfaces of the permeable layers okay ab and de are equipotential lines. Do you agree that or not? Because already we have seen that this line is equipotential line ab that means on the upstream side the bed okay and on the downstream side the bed that is de are the equipotential lines right. So, this is the first boundary condition. Now second one is because of ab and de are equipotential lines all the flow lines intersect them at right angles. It has to be right. So, that is the I mean important criteria for flow lines and equipotential lines to be constructed.

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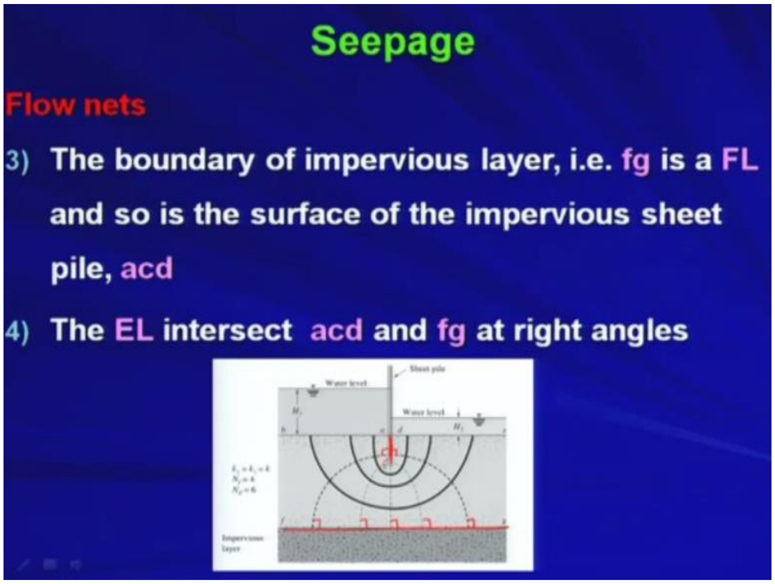

So, the boundary of impervious layer, so if I, I am putting the figure once again. So, if the boundary of the impervious layer that is fg so this is your boundary of the impervious layer, fg is a flow line right. Do you agree? Because you are considering the flow line, the flow can occur along this line. So, is the surface of the impervious sheet pile acd. So, this line is also a flow line. So, flow can occur. Flow cannot occur across the sheet pile but it can occur along the line, along that line acd.

So, it is one of the flow lines. Now the equipotential line intersect acd and fg at right angles. So, equipotential line whatever equipotential line is cutting or intersecting the line acd as well as fg they will be making 90 degree. As you can see they must be 90 degree. So, this is also 90 degree, this is also 90 degree and so on, this is also 90 degree. So, these are the things must be satisfied. Then only you can say okay this is my right flow net I have constructed okay.

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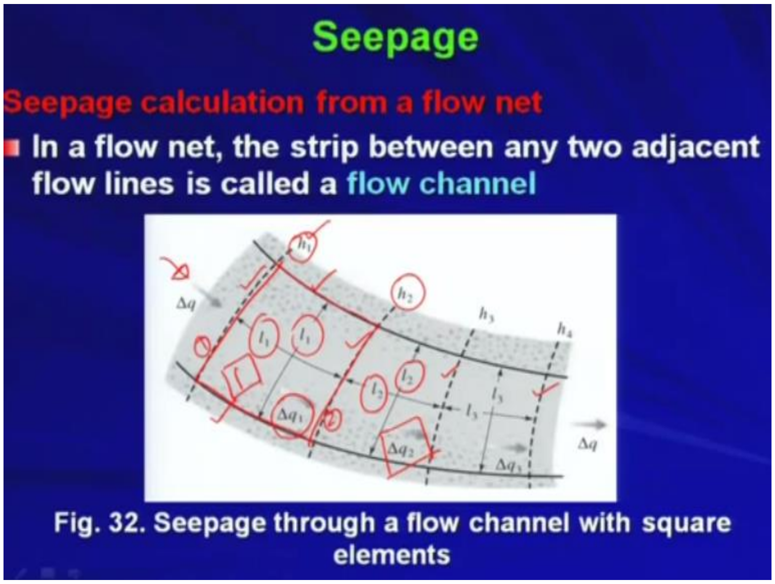

In a flow net the strip between any 2 adjacent flow line is called a flow channel right, already we have seen. So, try to understand. The strip that means the region between any 2 adjacent flow lines is called a flow channel and through which actually the flow will be happening. I mean if you if you try to remember or try to map this thing I mean by mapping it with some with some pipe flow or something like that.

Through the pipe actually within the inside or inner diameter the flow will be occurring right. So, this is something like flow channel. So, it is bounded by 2 flow lines which will be eventually which you want to map with the pipe flow so that will be nothing but your pipe surface okay. So, now if you look at, so this is very typical say flow channel with square elements. Now you can see. So, this is one flow line, this is another flow line.

So, adjacent 2 flow lines are basically forming the flow channel. The flow is happening in this direction. So, delta q is the rate of flow or the flow I mean amount or the flow quantity discharged. So, basically that is happening through this flow channel. Now you are getting different equipotential lines like this, like this like this. So, these are all equipotential lines okay. So, now from this say from equipotential line 1 if you come to equipotential line 2 you are getting the head drop.

So, it was h 1 along equipotential line 1. Now it is h 2 along equipotential line 2 and so on right and the elements okay the elements bounded by this flow line equipotential line another flow line and equipotential line this is nothing but square. So, that is another requirement for constructing the flow net. So, that dimension is given by l 1 by l 1. Similarly, l 2 by l 2 that is forming another square that is also another element. Similarly, l 3 by l 3.

Now the flow is happening say within zone 1 or the element 1 so this I say element 1 okay. Within element 1 the flow is happening say delta q 1, within element 2 flow is happening delta q 2 and delta q 3 and so on. Now if you want to satisfy the continuity condition so delta q 1 must be equal to delta q 2 must be equal to delta q 3. There is no other way out because flow is not happening or the water is completely incompressible so there is no change in volume so whatever water is getting inside the flow channel the same amount of water will be going out from the flow channel.

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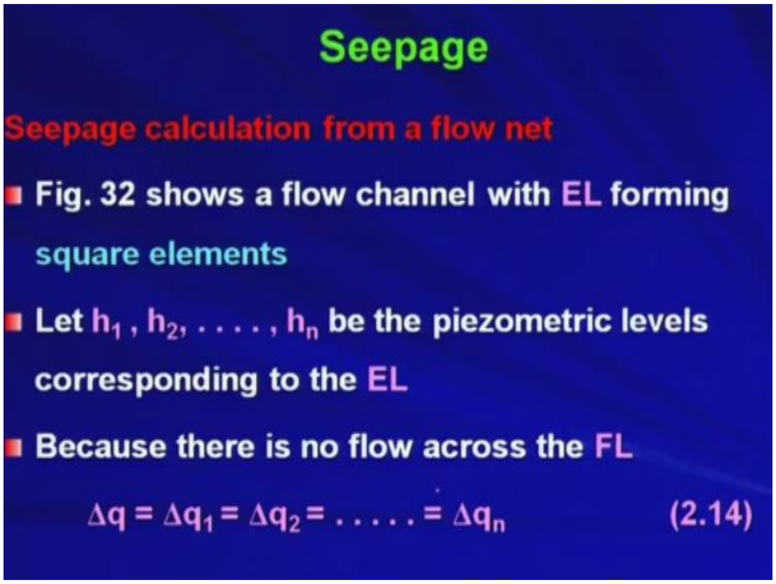

So, now this the last figure or the figure 32 shows a flow channel with equipotential line forming square elements, the last figure we have seen. Let small h 1, h 2, up to h n be the piezometric levels corresponding to the equipotential lines already we have seen in the last figure, whatever we have seen. Now because there is no flow across the flow lines because it is not allowed at all because you when you are drawing the flow lines and when you are constructing some flow channels basically flow cannot occur across the flow lines.

So, it cannot cross the I mean side I mean beside whatever flow lines are there it cannot cross those flow lines. It will flow along the flow channels only right, it is allowed. So, delta q as I told you delta q must be equal to delta q 1. What is delta q 1? That is the discharge or the flow happening through element 1 okay must be equal to delta q 2 must be equal to delta q n if you have n number of elements in the flow channel.

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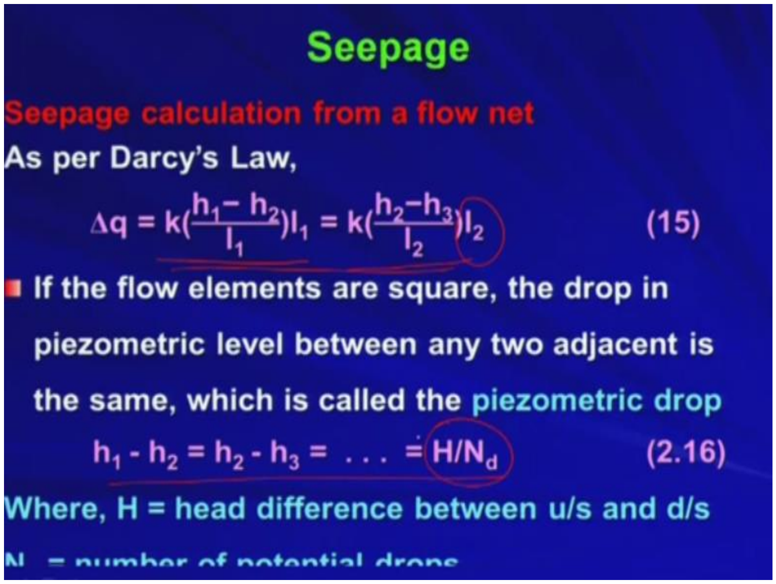

So, as per Darcy's law we can write delta q is nothing but k into if I say the k is same okay so k x as well as k z both are equal that is isotropic soil and for that say k is the coefficient of permeability. So, if that is true then delta q is given by ki into cross sectional area. Now what is I, i is nothing but from say for element 1 if I consider for element 1 what is the hydraulic gradient, i is nothing but h 1 - h 2 that is the head drop happening from equipotential line 1 to equipotential line 2 if you recall the figure whatever we have seen just now.

So, k into h 1 - h 2 by what is the length of the element that is l 1 into area. Area is l 1 into unit length normal to the screen or normal to the board right. So, l 1 into 1 is nothing but the cross-sectional area through which the flow is occurring. Similarly, so this this is giving me the flow that is the delta q 1 through the element 1. This is the flow happening through element 2 that is k into h 2 - h 3 that is the head difference happening from equipotential line 2 and equipotential line 3 and l 2 is nothing but the length of element 2 and cross-sectional area of element 2 is l 2 into 1 right.

So, if the flow elements are square the drop in piezometric level between any 2 adjacent is the same. Am I right or not? Please try to understand. If the flow elements are square okay the drop in piezometric level between any 2 adjacent is the same which is called the piezometric drop right. So, h 1 - h 2 because if you satisfy this equation right so in this equation basically h 1 - h 2 must be equal to h 2 - h 3, must be equal to h 3 - h 4 and so on. So, I am writing that thing here. So, h 1 - h 2 must be equal to h 2 - h 3 and so on. So, which is eventually capital H that is the total head difference okay between the upstream and downstream side divided by the number of potential drops.

That means how many number of potential drops you are having. So, in the flow net construction we have seen how many number of potential drops are there 6, 6 number of potential drops you had or you exhausted starting from the upstream side to the downstream side. So, that means the total head difference between upstream and downstream side divided by the number of potential drops will give you the difference in each element head or head difference at each element.

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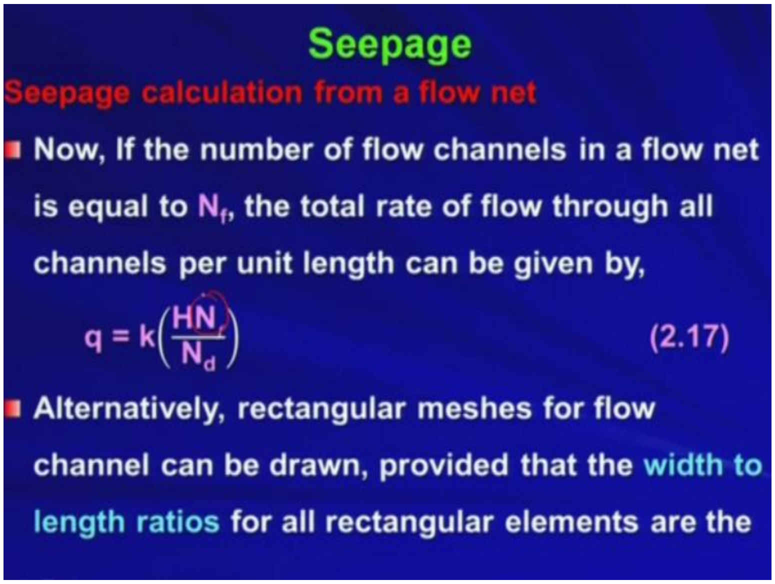

So, if the number of flow channels in a flow net is equal to N f whatever we have seen in the flow net construction that how many flow channels you are constructing the total rate of flow through all channels per unit length can be given by total q that is the discharge happening through the I mean porous medium or the permeable medium is nothing but k into H by N d that is nothing but your i.

I mean that is nothing but your whatever potential drops you have seen in the last slide right h 1 - h 2 right into N f, N f is the so k into basically if you come back here so delta q is nothing but right delta q is equal to k into H by N d right from this from whatever we have seen just now from equation 2.15 and 2.16 we can see that delta q is equal to k into H by N d.

Now this delta q is happening through n number of say flow channels. Now total flow is nothing but k into H by N d into N f that is the number of flow channel right. So, that is the total flow. So, if you are asked to find out the total flow happening through them through some permeable medium so you first construct the flow net and then you find out N f and N d and then of course h is known to you that is the head difference between the upstream and downstream side and if you know the coefficient of permeability or the hydraulic gradient of that particular soil you can find out total discharge or flow that is q.

Alternatively, rectangular measures for flow channel can be drawn because already we have seen whatever we have seen so far that is basically based on some square element. So, you are only allowing square element within the flow channel. Now you may have or you may construct the flow net in such a way that your elements are coming as rectangular right. So, rectangular measures for flow channel can be drawn provided that the width to length ratio for all rectangular elements are the same okay.

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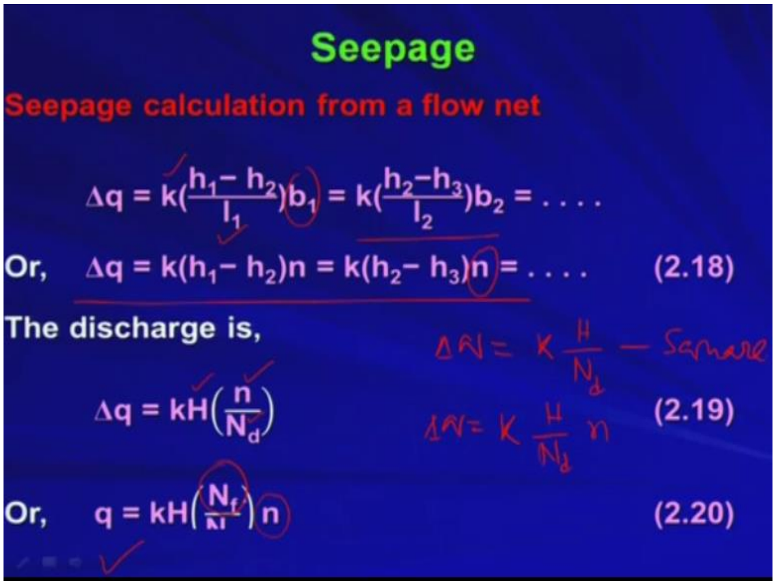

So, that means if I consider the flow channel with rectangular elements now you see this is your first equipotential lines, this is your second equipotential lines. This is your say flow line 1, flow line 2 and this is the element you have which is rectangular where l 1 is the length, b 1 is the width okay. Similarly, this is your element 2 which is another rectangular element. This is element 1. This is element 3, which is another rectangular element.

Now if this is happening, or if you are constructing the flow net with this kind of rectangular elements so you must remember that this ratio should be maintained. That is b 1 by l 1 must be equal to b 2 by l 2 must be equal to b 3 by l 3 say some ratio n. So, at least you need to do this thing if you are considering rectangular elements okay. Now if you consider rectangular elements then basically your delta q will be equal to delta q 1 equal to delta q 2 equal to delta q 3 and say up to delta q n.

So, your delta q 1 is given by k into this is the i that means the hydraulic gradient within element 1 that is h 1 - h 2 that is the head difference between 2 successive equipotential lines divided by l 1 that is the length of the element, rectangular element into area that is b 1 into 1 right. So, that will give you q 1 delta q 1. Similarly, delta q 2 can be obtained like that. So, we can write down delta q is equal to k into h 1 - h 2 into n equal to k into h 2 - h 3 into n and so on. So, the discharge is delta q is equal to k into H into N d so H by H by N d is nothing but your difference that is h 1 - h 2 into this n.

So, whatever if you remember from the square element, basically we have we had got for square element that K into H by N d so for square. Now for rectangular element basically you are getting K into H by N d into n right because this n is coming into the picture. So, total discharge will be then multiplied by the flow channel, number of flow channel that is N f okay. So, that will give you the total discharge happening in the permeable medium if you consider the rectangular elements in the flow channel.

So, now if n is becoming 1 you are getting the same solution whatever you have got for the square element. So, this is basically more general and you can have square elements as well as rectangular elements there is no issue but equipotential lines must intercept the flow line normally or the orthogonal okay. So, we have seen the total flow if you consider the rectangular element as well as if you consider the square element.

So, only difference is that small n that is the ratio of your or the aspect ratio basically for the element is coming into the picture. So, we will continue in the next lecture. So, today we will stop here and we will see in the next lecture that how you can find out other information from the flow net and other details okay. Thank you very much.