Soil and Water Conservation Engineering
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Lecture - 37
Gate-Type Questions on Drop Spillway

Welcome students our next lecture on the solution of some Gate Questions on this specifically the Drop Spillway. So, in this lecture we will discuss about some of the Typical Gate Type of Questions on the design of Drop Spillway.

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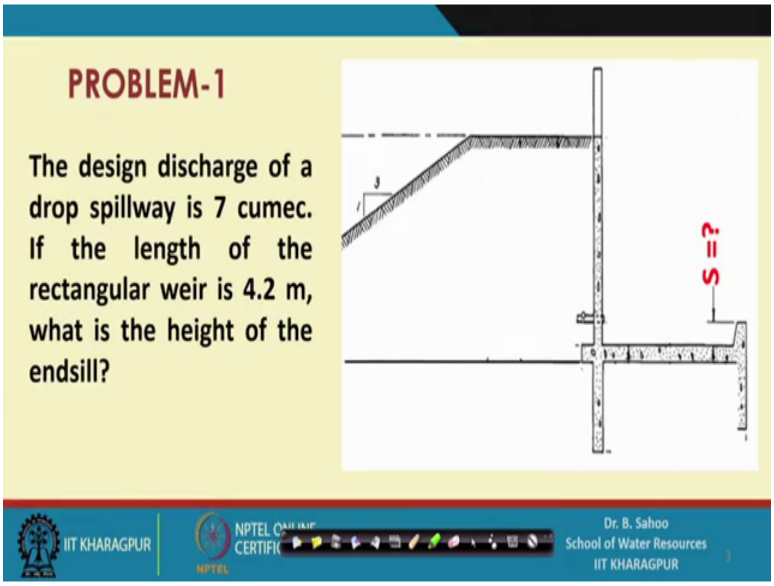

Now, if you look to look to problem number 1 on the slide. The question is the design discharge of a drop spillway is 7 cumec. If the length of the rectangular weir is 4.2 metre, what is the height of the endsill?

So, from here you can see discharge q is given 7 cumec. The length of the weir is given as 4.2 that is equal to l and you know that the height of endsill that is s equal to d c by 2. So, d c means that is the critical depth, to compute critical depth we have to use the formula q square divided g l square whole to the power 1 by 3.

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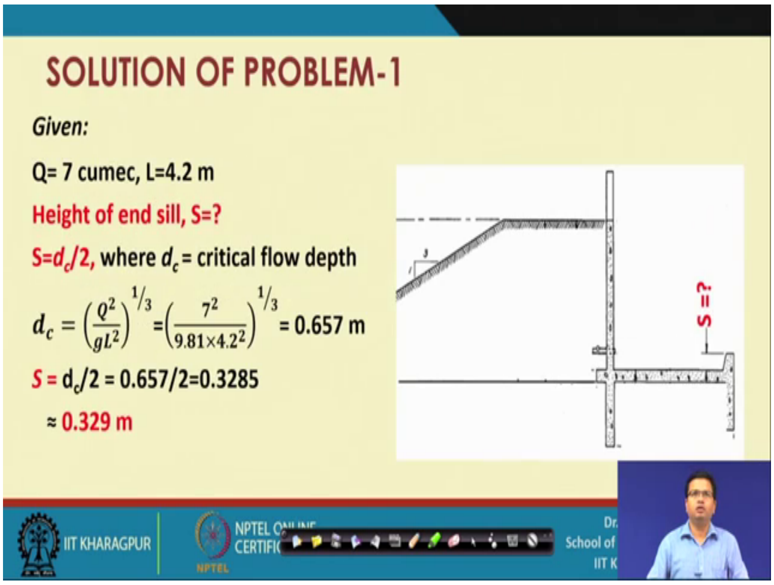

So, by putting these values we will get d c equal to 0.657 becaus e Q equal to 7 g equal to 9. 81 and L equal to 4.2. So, we will get 0.657 as the critical flow depth.

So, once the critical flow depth is known, the endsill height can be estimated as d c by 2. So, that is equal to 0.657 divided by 2. So, you will get approximately point 0.329 metre ok. So, this is a typical question on the design of endsill if you will know the design discharge ok.

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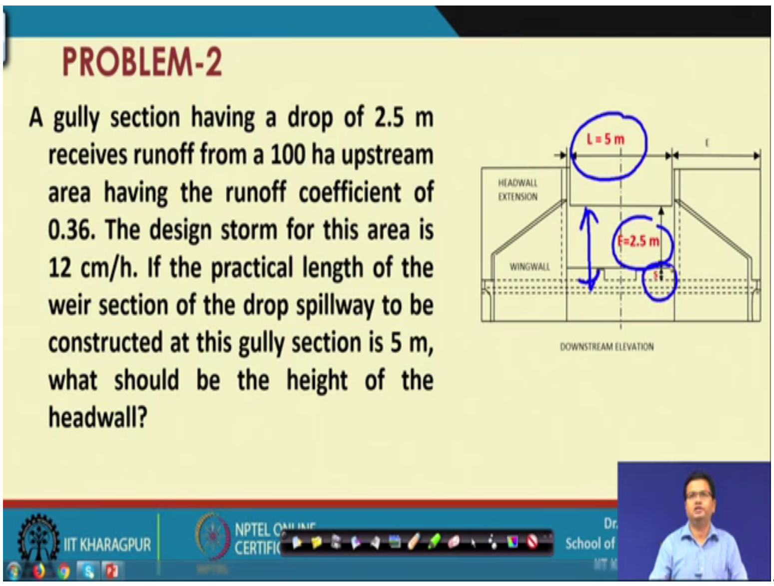

Now, coming to the second problem; you have already solved similar type of problems. So, the question is that a gully section having a drop of 2.5 metre receives runoff from a 100 hectare upstream area having runoff coefficient of 0.36. So, here the gully section is having a drop means that is your F, F equal to 2.5 metre as shown in this figure.

So, your F equal to 2.5 metre and your catchment area is equal to 100 hectare because it is the area which is contributing runoff to the gully section and the runoff coefficient of this catchment is 0.36. So, k is equal to 0.36 the design storm for this area is 12 centimetre per hour so; that means, i the rainfall intensity is 12 centimetre per hour which is occurring mostly for the duration of equal to the time of concentration of this catchment ok.

So, once i is known the runoff coefficient k is known area is known. So, you can use the rational formula to compute what is your peak runoff; that is your design peak runoff. So, that equal to q equal to c i a or k i a ok. So, then the question is that if the practical length of the weir section of the drop spillway to be constructed at this gully section is 5 metres so; that means, L should be 5 metre the length of the weir should be 5 metre. So, once l is known the question that what should be the height of the headwall.

The height of head wall can be given as f plus s so, you can see this height in the figure. So, the drop plus the height of the endsill s so, in this case the value of drop is given as 2.5 metre. So, you need to we have to compute the, what is the height of endsill that is equal to S. So, you have already estimated what is the height of S in the previous question. So, in a similar way you can estimate the height of endsill that is s equal to d c by 2 or critical depth of flow divided by 2. So, for this the first step is to compute what is your design key value ok. Now we will estimate the design key value by using the rational formula.

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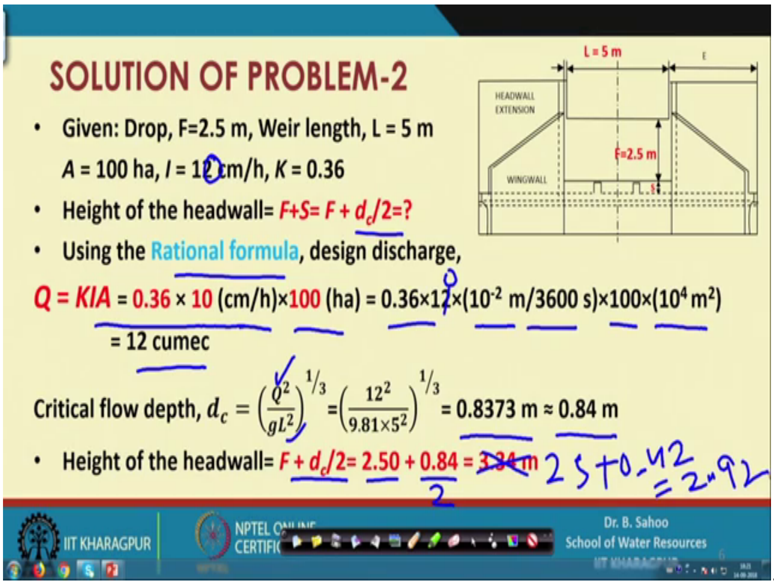

We can see here the given value of drop is 2.5 metre, weir length is 5 metre, area of catchment is 100 hectare, design intensity of rainfall is 12 centimetre per hour and runoff coefficient of the catchment is 0.36, the height of the endsill height of the headwall is given by F plus S; so, S equal to d c by 2 so, you will get F plus d c by 2.

So, in this formula first you have to compute what is the value of d c to compute the value of d c you need the value of Q the design discharge and the length of weir ok. So, Q can be estimated by using the rational formula which is nothing, but Q equal to KIA. So, K equal to 0.36 I A is equal 10 centimetre per hour and sorry here I equal to 10 centimetre per hour and A equal to 100 hectare ok.

So, we will get 0.36 into this is 10 into 10 power minus 2 into 3600. So, it is the unit conversion from because this is in centimetre 10 centimetre for hour; so, from centimetre per hour to metre per second. So, for that you have to multiply with 10 to the power minus 2 divided by 3600 into 100 hectare 100 hectare is your catchment area. So, into 10 to the power 4 metre square is the area so, that is the conversion factor you are using.

So, you will get 12 cumec so, from this you will get 12 cumec your design discharge. You will put this value of 12 cumec here L equal to 5, then you will get d c equal to 0.8373 metre so, they nearly equal to 0.84 metre. So, height of the headwall will be equal to F plus d c by 2 that is F plus s. So, you will get 2.5 is F and d c is 0.84 so, this d c by 2 will be is a mistake here d c by 2 will be equal to 0.24 so, this value is wrong. So, you will get 2.5 plus 0.42 ok. So, you will get equal to 2.92 metre ok. So, the height of headwall will be equal to 2.92 metre ok. Then we will get another type of problem in problem number 3

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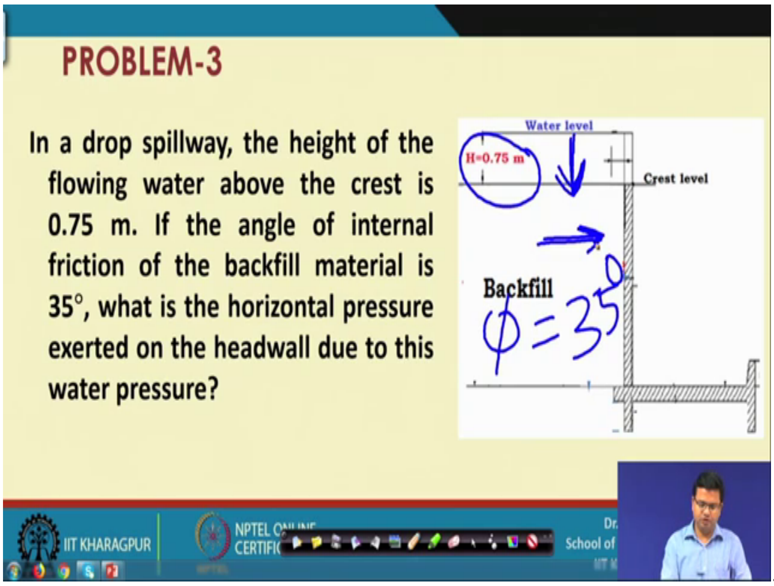

In a drop spillway the height of the flowing water above the crest is 0.75 metre if the angle of internal friction of the backfill material is 35 degree, what is the horizontal pressure exerted on the headwall due to this water pressure? So, what is given here the height of the flowing water? So, the value of H is given as 0.75 metre ok and the angle of internal friction of the backfill material is 35 degree. So, phi is given as 35 degree.

Then what is the horizontal pressure exerted on the headwall due to this water pressure, generally whatever the water level is there it exerts a vertical pressure ok. So, it exerts vertical pressure on this backfill material and this water pressure will be converted as or converted into the horizontal water pressure if you multiply with the k b value you have already studied what is the value of k b. So, that is the ratio between the horizontal to vertical water pressures or horizontal vertical pressure so, that is equal to given by one minus sin phi divided by 1 plus sin phi. So, whatever vertical pressure will be getting from this water so, that will get transmitted to this backfill and that is the vertical pressure, then you have to convert into the horizontal pressure ok. So, with this concept now we will solve the problem.

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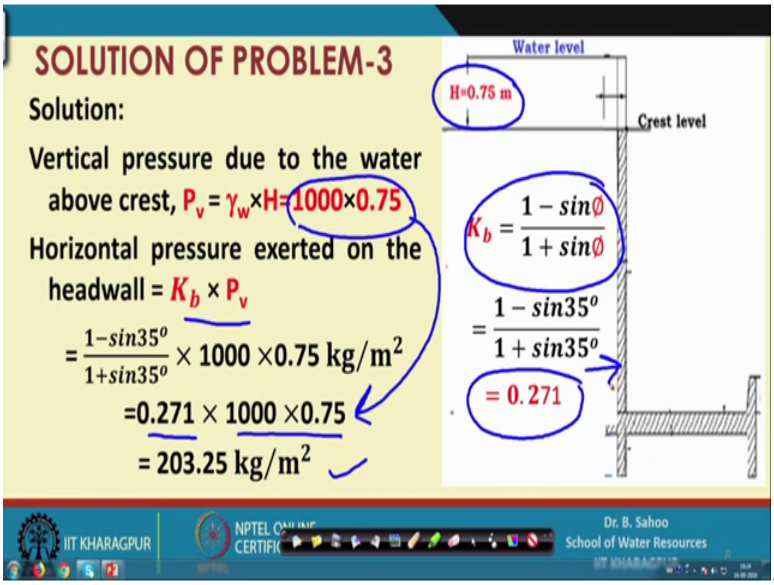

The vertical pressure due to water you know that P equal to gamma w into H gamma w is the specific weight of water. So, that equal to 1000 kg per metre cube and H is equal to given that equal to 0.7 5 metre ok. So, horizontal pressure exerted on the headwall will be K b times P v and K b is computed as 1 minus sin phi divided by 1 plus sin phi and here phi equal to 35 degree. So, you will get the value of K b equal to 0.271.

And if you multiply that value with this vertical pressure P v, then we will get 0.271 into 1000 into 0.75 which has come from here ok. So, you will get 203.25 kg per metre square. So, this is my horizontal pressure which has been transferred to the backfill material because of the water level that is equal to 0.75 metre ok, and that is exerted on the headwall ok. Now this is clear. Now we will go to our next problem.

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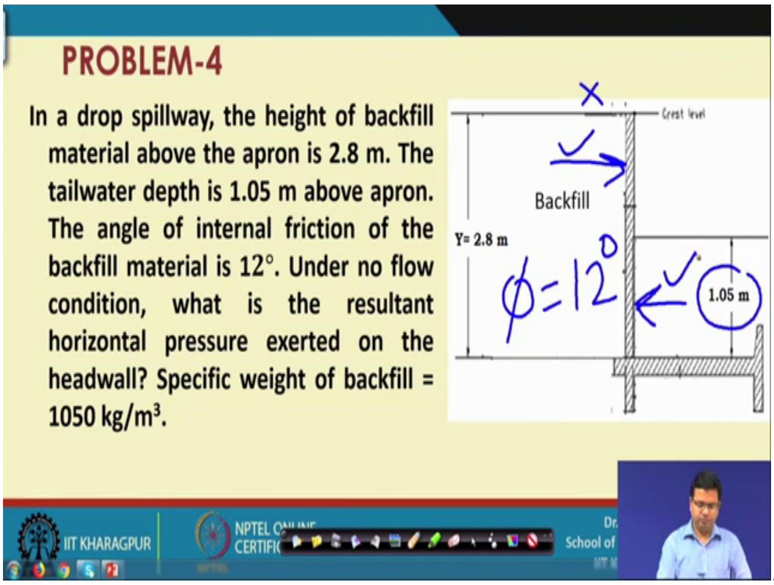

So, this is another typical problem in a drop spillway the height of backfill material above the apron is 2.8 metre. You can see from this figure the height of backfill material is given as 2.8 metre that is equal to Y. The tailwater depth is 1.05 metre you can see from this figure the tailwater depth is given as 1.05 metre above the apron the angle of internal friction of the backfill material is 12 degree so; that means, for the backfill material phi equal to 12 degree under no flow condition what is the resultant horizontal pressure exerted on the headwall specific weight of backfill is 1050 kg per metre cube.

So, it is telling under no flow condition. So, no flow means there is no water here there is no water above the crest so, it is just like a dry cell ok. So, no water pressure is there on the head water ok, so that will be equal to 0. So, here what I have to do? You have to calculate what is the resultant horizontal pressure. So, the resultant pressure there are two horizontal pressures: one is acting in the positive direction because of the backfill material and another is acting in the reverse way because of the tailwater because this is your tailwater of 1.05 and the resultant will be the upstream water pressure horizontal water pressure minus the downstream water pressure ok. So, with this concept we will now solve the problem.

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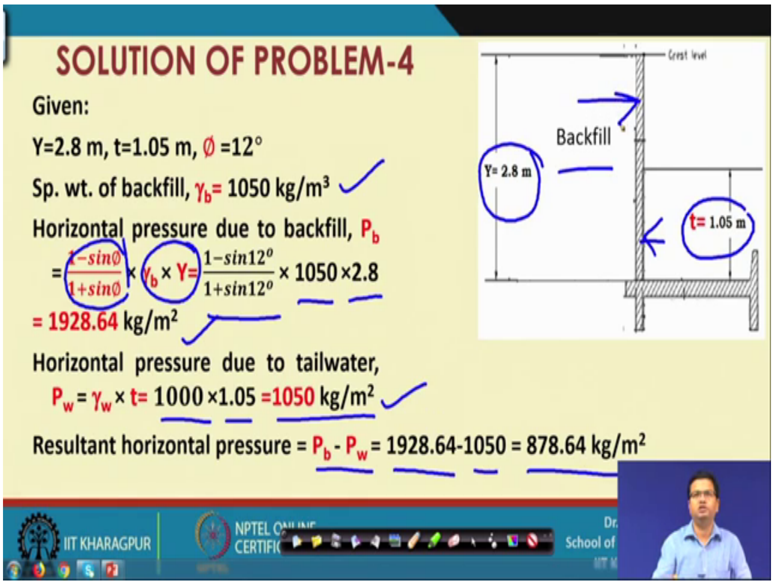

So, from this figure you can see Y is given as 2.8 metre that is the height of the backfill t is the tailwater depth that equal to 1.05 metre phi is given as 12 degree. That is the angle of internal friction of this backfill material and the specific weight of backfill is given as gamma b that equal to 1050 kg per metre cube.

So, similar you can calculate what is your horizontal pressure due to backfill the vertical pressure will be equal to the weight of this backfill material for a height of 2.8 metre and that you can compute as gamma b into y and if you multiply with the factor k b , then that will be converted into the horizontal pressure ok.

So, our vertical pressure is gamma b into Y. So, this vertical pressure into the k b that is equal to 1 minus sin phi divided by 1 plus sin phi; so, that will be equal to your horizontal pressure ok. So, you have phi equal to 12 degree so, it will be 1 minus sin 12 12 degree divided by 1 plus sin 12 degree into gamma b equal to 1050 and 1.8 is 8 is the height of the backfill ok. So, by multiplication you will get 1928.64 kg per metre square. So, that is the upstream water pressure sorry upstream pressure because of the backfill material ok.

Now, you have to compute what is the horizontal pressure due to tailwater which is having a depth 1.05 metre which is acting the opposite direction ok. So, for that simple formula you know that is equal to gamma w into t the height of water depth. So, gamma w you know that equal to 1000 kg per metre cube into 1.05. So, you will get 1050 kg per metre square. So, the resultant horizontal pressure will be P b minus P w. So, that equal to 1928.64 minus 1050 kg per metre square. So, you will get 878.64 kg per metre square which is acting on this headwall in this direction ok.

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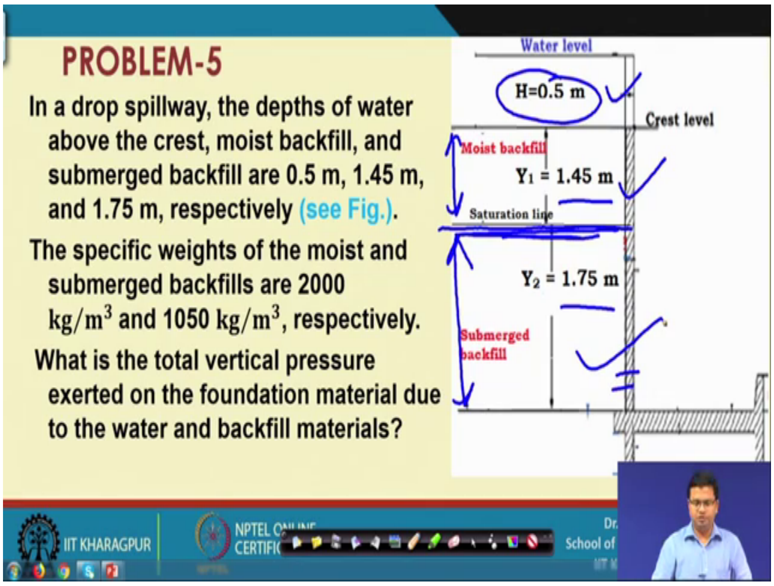

Now, we will go for our next problem number 5 in a drop spillway the depths of water above the crest, moist backfill, and a submerged backfill are 0.5 metre, 1.45 metre and 1.75 metre respectively. So, you can see the figure, the depths of water depth is given as 0.5 metre that is given by H ok.

Then the depth of moist backfill that is given by Y 1 that equal to 1.45 metre and Y 2 which is submerged that equal to 1.75 metre. If you will remember in our previous classes we have studied for different type of drainage condition like type a and type b type of drainage condition. So, there is saturation line here and here there is a filter. So, because this saturation line you will get this area this backfill these backfill materials submerged ok.

And because of because your saturation line is here so, this soil will be naturally moist and the specific weight of this moist backfill is given as 2000 kg per metre cube and the submerged backfill is given as 1050 kg per metre cube and you know the specific weight of water is 1000 kg per metre cube ok. Then question that what is the total vertical pressure exerted on the foundation material due to the water and backfill material. So, simply you have to calculate what is the vertical pressure.

So, vertical pressure equal to gamma into H ok. So, the total vertical pressure will be equal to the vertical pressure due to this water the vertical pressure because of the moist backfill having depth of 1.45 metre and the vertical pressure because of the submerged backfill. So, all these 3 components will be added ok. Now with this concept we will solve our problem.

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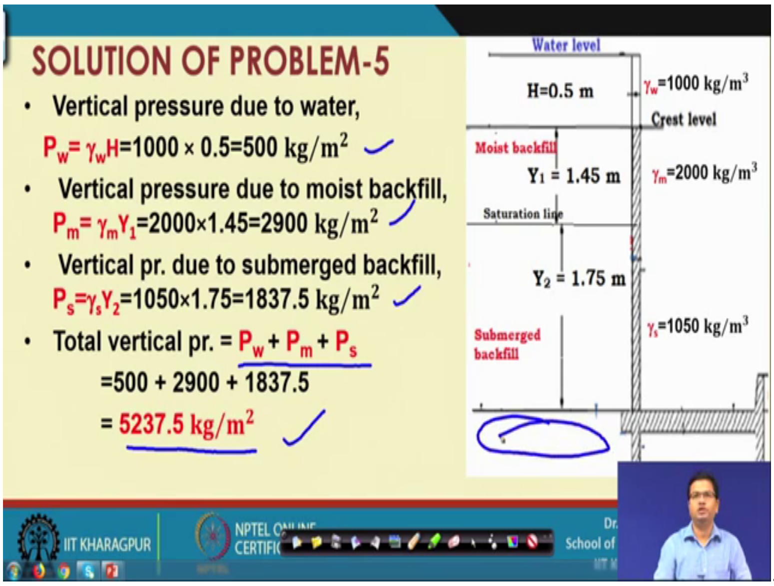

So, vertical pressure due to water is 1000 into 0.5 so, that equal to 500 kg per metre square. Vertical pressure due to moist backfill will be equal to 2000 is your gamma m into 1.45 is the depths so, you will get 2900 kg per metre square vertical pressure due to submerged backfill. So, gamma s equal to 1050 into 1.75 is the depth Y 2. So, you will get 1837.5 ok.

So, once these three forces, three pressures are computed, now you can add this three. So, we are getting 5237.5 kg per metre square. So, this is a total weight vertical pressure which is exerted on this foundation material ok. So, this is a simple problem, now we will solve another problem.

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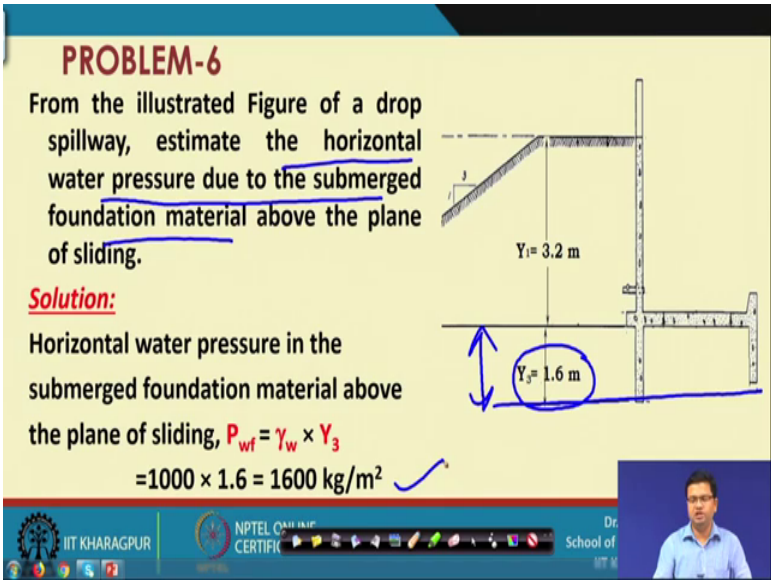

From the illustrated figure for a drop spillway estimate the horizontal water pressure due to the submerged foundation material above the plane of sliding. So, you know what is the plane of sliding the plane of sliding is along this line ok. So, along this line you have to estimate that estimate the horizontal water pressure you can see estimate the horizontal water pressure due to the submerged foundation. So, in the submerged foundation; that means, this is your submerged foundation and the depth is here Y 3 equal to 1.6 metre.

So, very simple the water pressure will be equal to gamma w into Y 3 ok, so that will be equal to 1000 is your gamma w 1000 kg per metre cube is the specific weight of water and height equal to 1.6 metre. So, that equal to 1600 kg per metre square. So, this is the horizontal water pressure because of the water which is inside this foundation material ok.

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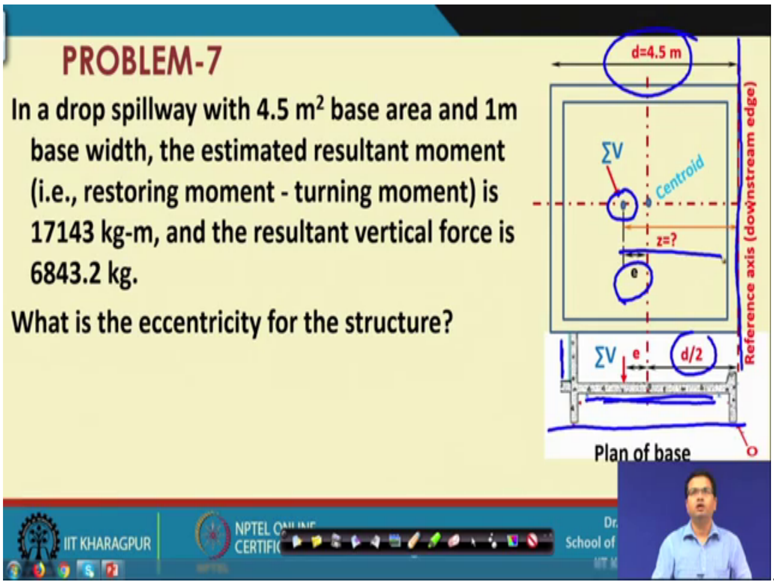

Now, we will solve another typical problem in a drop spillway with 4.5 metre square base area and 1 metre base width the estimated resultant moment the estimated resultant moment means it is restoring moment minus sum of the restoring moment minus sum of the turning moment.

So, that is given as 17143 kg metre and the vertical resultant vertical force is 6843.2 kg. So, sigma V is given ok. So, it is asked what is the eccentricity for the structure; you will see this right hand side figure the eccentricity is computed as this d is given as 4.5 because it is a 4.5 divided by 1 metre. So, you will get d equal to 4.5 metre ok.

And d by 2 where the centroid through the centroid line will be equal to 4.5 divided by 2 ok. So, this is our d by 2 and this drop spillway this is the headwall and this is the plane of sliding ok, and this is the contact surface ok. So, you have we have taken origin here and our line of reference axis are the downstream is you can see this is our reference axis ok. So, from this all these moments are calculated and the vertical force V is acting here because the headwall is this side. So, naturally the vertical forces will be acting little bit nearer to the headwall from the centroid. So, this distance is e so, you have to estimate what is the value of eccentricity e.

So, from this figure you can see e is equal to z minus d by 2 ok. So, from this figure you can see d equal to z by 2 because this is my z value ok. So, we can calculate what is our eccentricity. So, first step is the since we know this d value equal to 4.5 so, we have to estimate what is my value of z ok.

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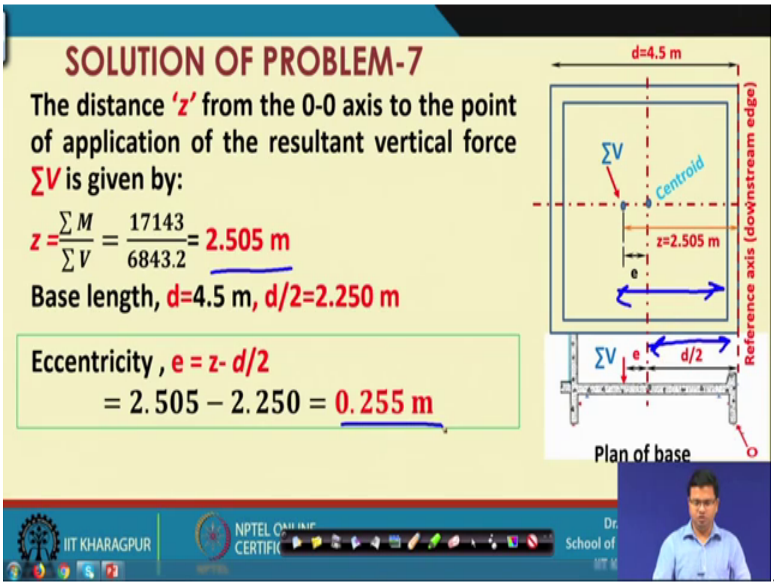

So, to estimate the value of z, we know that z equal to sigma m divided by sigma V. So, sigma m is the resultant moment that is given as 17143 kg metre and sigma V is the resultant vertical force that is given as 6843.2. So, we will divide you will get 2.505 metre and d equal to 4.5 metre. So, you will get d by 2 equal to 2.250 metre.

You can see from here that z is greater than d by 2 since z is greater than d by 2 which is in this case in this figure you can see this value is larger the 2.505 and d by 2 equal to 2.25 so, this is my d by 2 ok. So, if you will make it minus e equal to z minus d by 2, so, you will get 2.505 minus 2.250. So, you will get 0.255 metre. So, the eccentricity is 2. point 0.255 metre.

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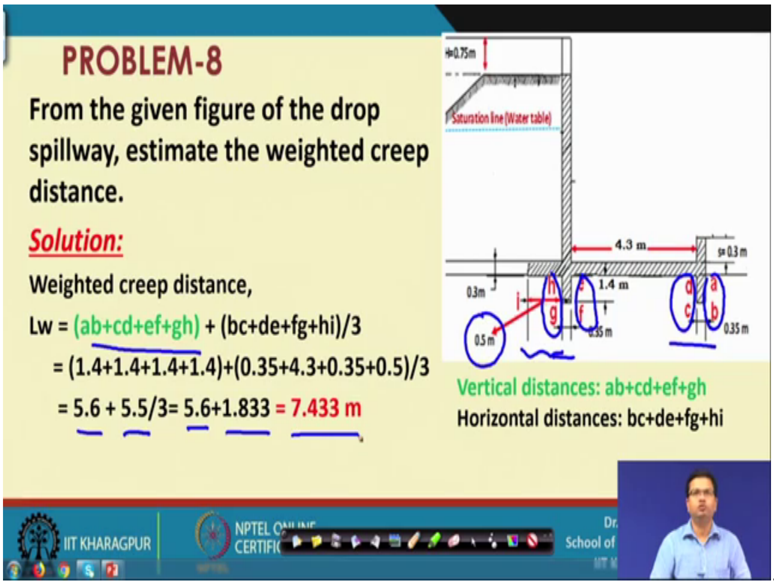

Then our next problem on the weighted creep distance. So, in this figure you have to estimate what is the weighted creep distance the figure is given and all the dimensions are also mentioned in this figure. So, you know that weighted creep distance is equal to sum of all the horizontal distances at the contact surface or along the line of piping failure plus one third of sorry it is the sum of all the vertical distances plus one third of the distances which are horizontal or flat in nature.

So, in this case first you identify what are your vertical distances. So, you can see here the vertical distances are ab then cd ef and gh and this values are 1.4 metre all are 1.4 metre. So, you will get the sum of all these vertical distances that equal to ab plus cd plus ef plus gh all are all are equal to 1.4 plus 1.4 plus 1.4 plus 1.4 all are same. So, you will get 5.6 metre.

Then the horizontal distances, the horizontal distances are here bc then fg then this 4.3 that equal to d and also this distance so, that is your hi. So, bc equal to 0.35 d equal to 4.3 fg equal to 0.35 and hi equal to 0.5 metre ok. So, you have to take one third weight of these horizontal distances.

Then you will get the length of this horizontal distance equal to 5.5 divided by 3 so, you will get 1.833 plus 5.6 you will get 7.433 metre. So, the weighted creep distance equal to 7.433 metre ok. So, this solves our problem.

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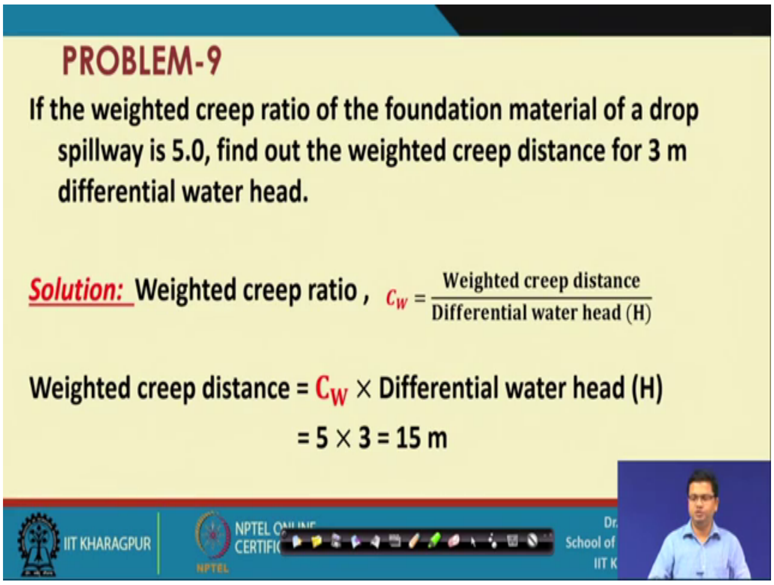

Our next problem is, if the weighted creep ratio of the foundation material of a drop spillway is 5 metre. So, the C w value that is your weighted creep ratio is given as 5 find out the weighted creep distance for 3 metre differential head. So, the 3 metre differential head means it is the differential head between the tailwater and the upstream water ok, and we know the formula the weighted creep ratio is given as weighted creep distance along the foundation material divided by differential water head.

So, you will get weighted creep distance that equal to C W times differential water head h and C W is given as 5 and differential water head as 3 metres. So, you will get 15 metres so, the weighted creep distance is 15 metre it is very simple question.

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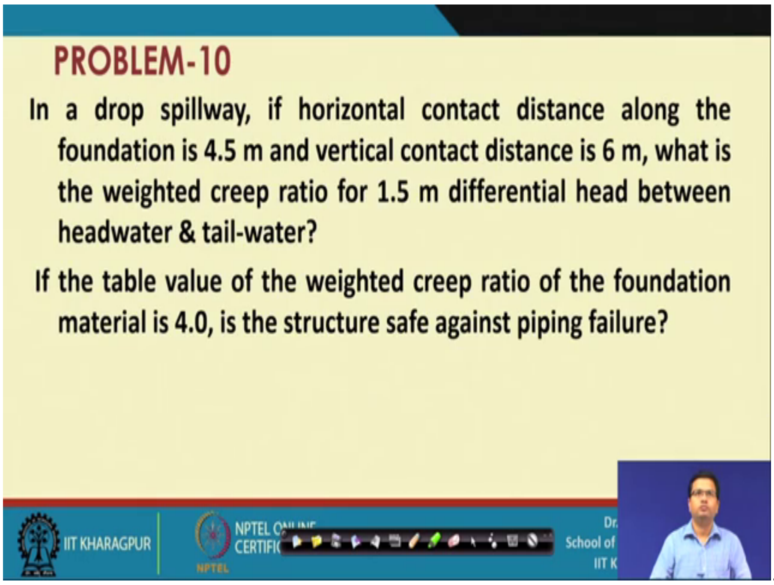

Now, problem number 10 in a drop spillway if horizontal contact distance along the foundation is 4.5 metre and vertical contact distance is 6 metre, what is the weighted creep ratio for 1.5 metre differential head between headwater and tail water. So, this is a similar problem the horizontal contact distance is given as 4.5. So, for calculating the weight you have to take one third of that distance then vertical contact distance is 6 metre. So, you have to take as such 6 metre ok, then what is the weighted creep ratio for 1.5 differential head. So, h is here 1.5 metre differential head ok.

So, if the table value of the weighted creep ratio of the foundation material is 4 is the structure safe against piping failure. So, the given value the foundation material value is given as a 4 C w value you know that if your structure or computed value of C w is greater than the table value then the structure is safe against piping failure. So, if we can compute if you will compute that C w value which is greater than 4 then you can see that you can say that the structure is safe against piping failure ok.

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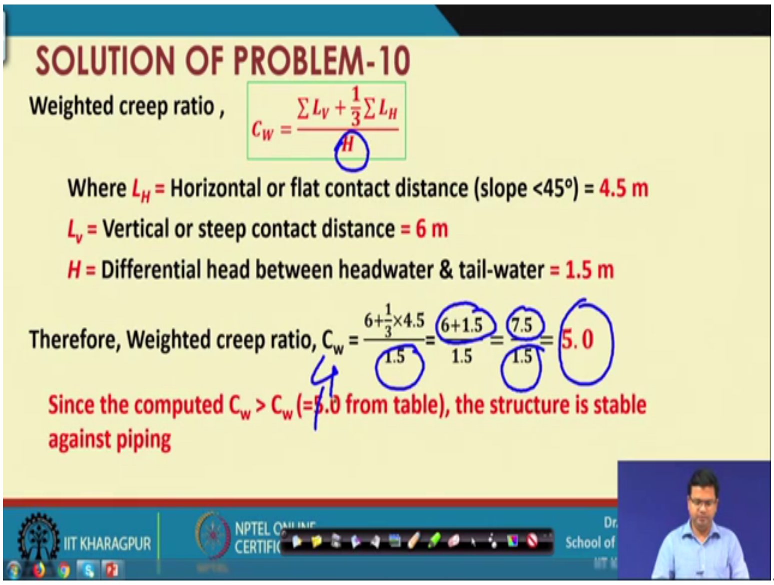

So, the solution is given here C W can be estimated as sigma L [vocalized-noise]. L V is the sum of all the vertical distances which is 6 m given and L H is the horizontal or flat contact distance which is 4.5 metre you have to take one third of this width. So, one third of this width that is equal to 6 plus 1.3 into 4.5. So, you will be getting 6 plus 1.5 ok. So, that equal to 7.5 and this divided by H.

So, your H is given as 1.5 the differential head ok. So, you will get 7.5 divided by 1.5 that equal to 5 so, the estimated value is 5. C w is 5 and that is this is greater than the table value the table value is given as 4 you can say this is 4 not 5. So, since the computed C W is greater than 4. So, the structure is stable against piping ok.

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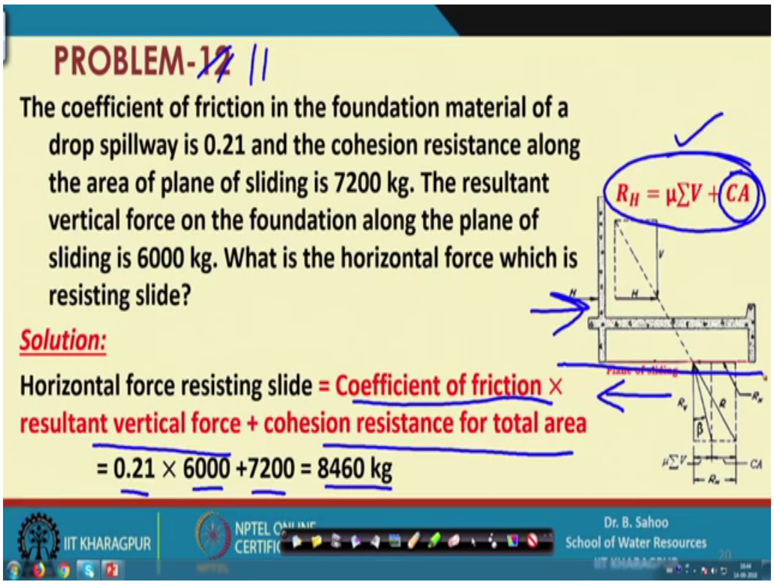

Now, we will solve the next problem. So, this is problem 11 the coefficient of friction in the foundation material of a drop spillway is 0.21. So, coefficient of friction mu is given and the cohesion resistance along the area of plane of sliding is 7200 kg. So, that is equal to C A if you remember you have studied. So, it is 7200 kg is equal to C A the resultant vertical force on the foundation along the plane of sliding is 6000 kg. So, sigma V here equal to 6000 kg. So, what is the horizontal force which is resisting slide?

So, you have to compute what is the value of R H you can see from this equation you have to compute what is the value of R H mu is given that equal to 0.21 sigma V that is given as 6000 kg and C A is already computed so, it is given as 7200 kg. So, you will get the horizontal force resistance slide equal to coefficient of friction times resultant vertical force plus cohesion resistance for the total area from this equation.

So, we will put the value of mu that equal to 0.21 into 6000 plus 7200 you will get 8460 kg and this is the horizontal force which is resisting slide it is acting along the plane of sliding in the opposite direction and that is balancing the horizontal force on the headwall ok, which is acting above this plane of sliding ok. So, this completes our the gate type of questions the solution to different gate type of questions ok.

So, we will stop here and this is the end of our lectures for the 8th week and similar type of gate problems also you can solve and you can go through this what are the assignments are given and the assignments are similar to your also gate type of questions and this will I think clear your knowledge and the fundamentals on the design of drop spillway.

So, thank you very much.