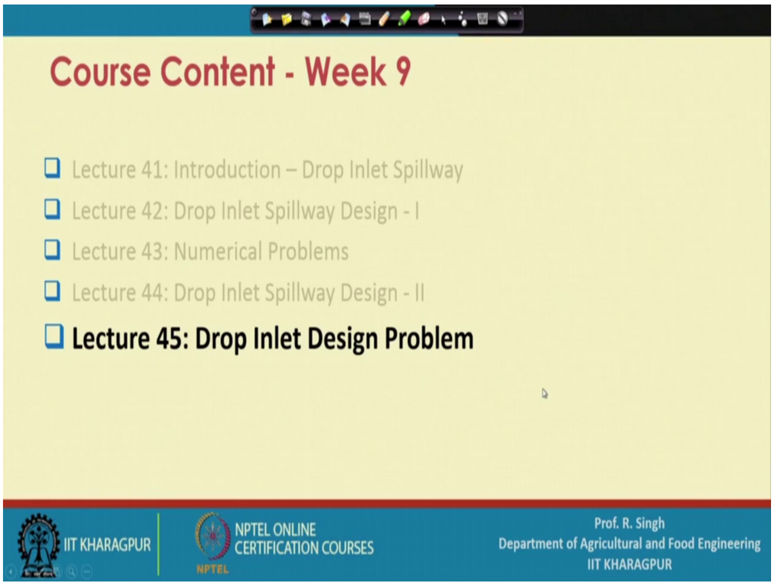
Soil and Water Conservation Engineering
Dr. Poulomi Ganguli
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture – 43
Drop Inlet Spillway (Contd.)

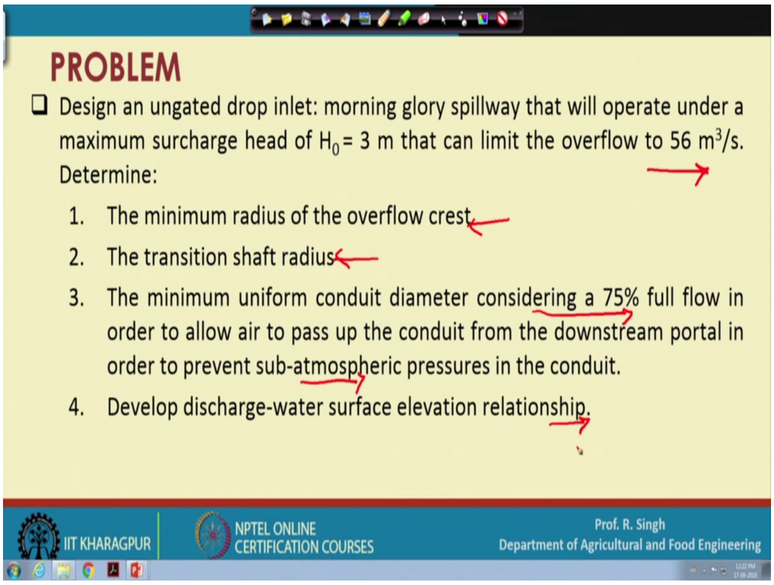
Hi good afternoon. So, in last lecture we used we covered the basic design principle of the spillway. Now we are going to solve a problem based on this, to see how the Spillway design condition prevails.

(Refer Slide Time: 00:35)



So, this is the last lecture for drop inlet spillway and here we are going to cover the design aspect.

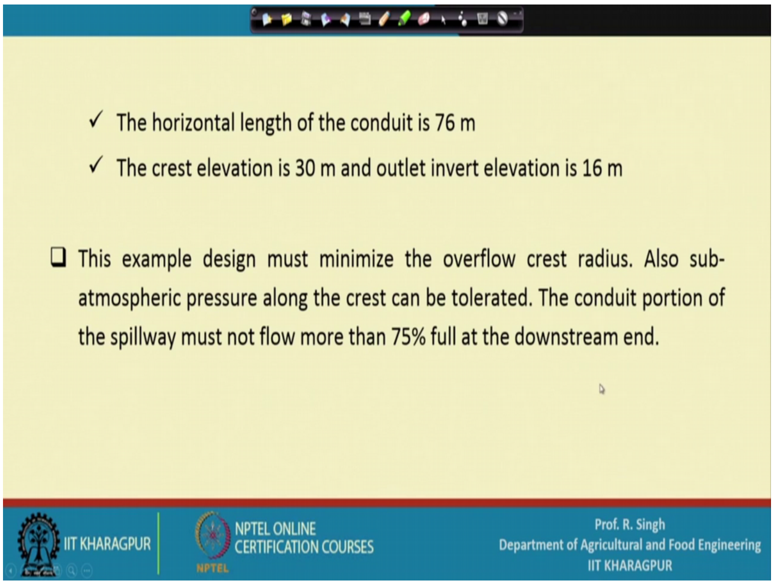
(Refer Slide Time: 00:44)



So, this is the problem statement. So, design an ungated drop inlet and here we are going to take morning glory spillway kind, that will operate under a maximum surcharge head H 0 as 3 meter, that can limit a overflow of 56 cumec.

Here you determine the, these are the set of question. So, first we will going to determine the minimum radius of the overflow crest. Second transition shaft radius and as you remember the minimum, we have to design a minimum uniform conduit diameter to consider the 75 percent of full flow, in order to allow the air pass. So, why we consider the 70 percent of the flow? To allow the losses and to allow the air pass from the conduit from the downstream portal in order to prevent the sub atmospheric pressure in the conduit and based upon this design calculation. So, develop a discharge water surface elevation relationship. So, this will be in the form of table and then we have to assume some set of conditions.

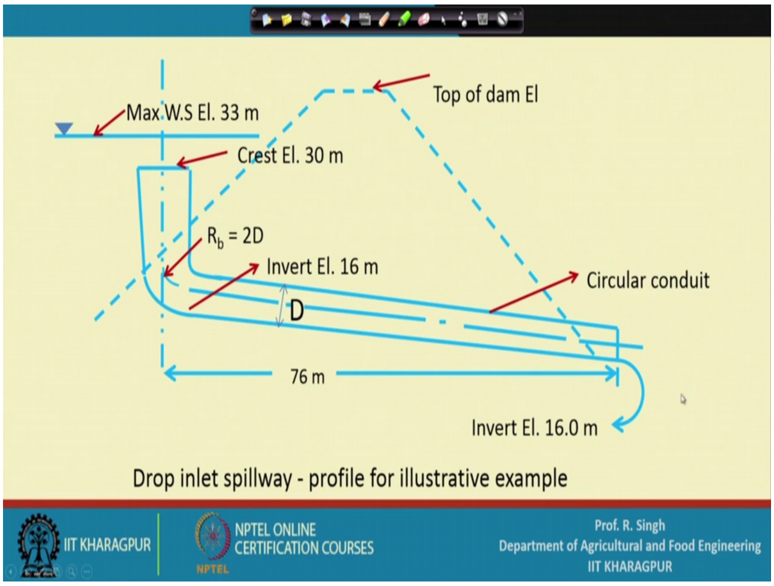
(Refer Slide Time: 02:06)



So, what are these conditions? So, the horizontal length of the conduit is assumed that 76 meter and a crest elevation is given 30 meter and outlet invert elevation is 16 meter.

So, this example design must minimize overflow crest radius and also sub atmospheric pressure along the crest should be tolerated. The conduit portion of the spillway must not flow more than 75 percent full at the downstream end. So, this should consider this condition.

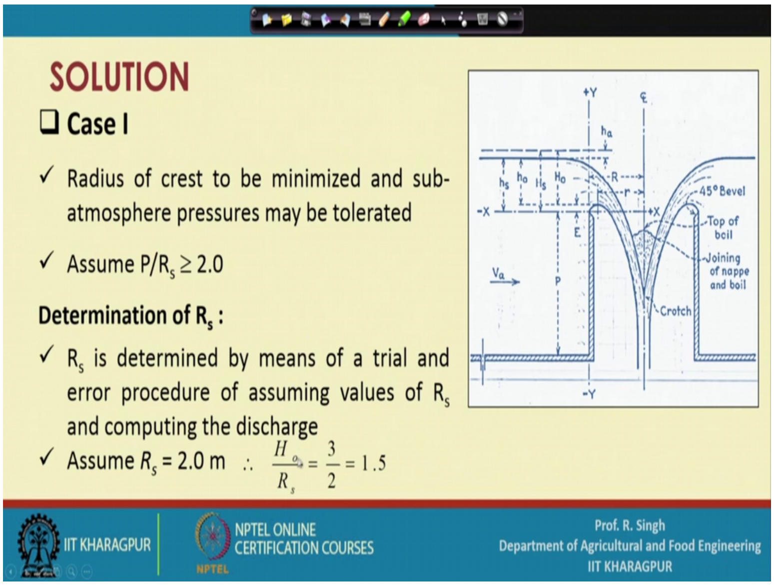
(Refer Slide Time: 02:45)



So, now this is the basic diagram. So, here the maximum elevation since, H 0 is assumed as 3 meter, sorry. So, here it says the H 0, the surcharge head is 3 meterand the 30 meter.

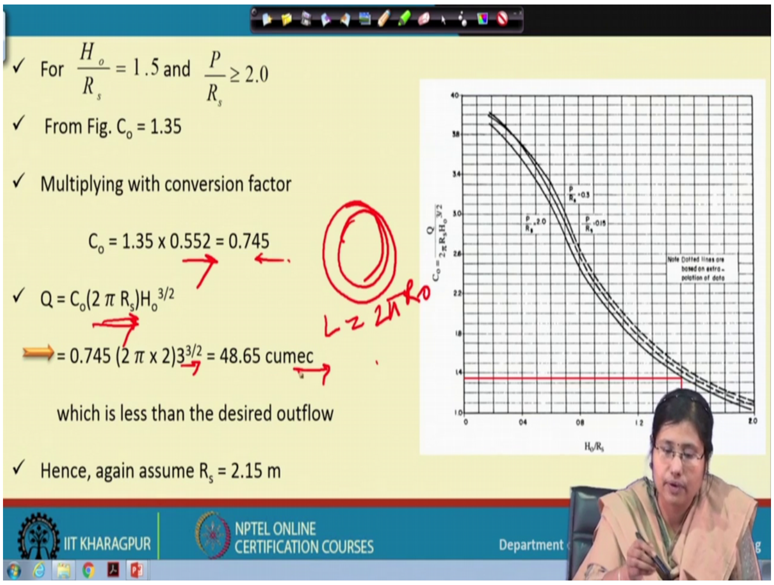
So, 30 meter is the head total head height. So, this leads to the maximum elevation of 33 meter. So, the crest elevation is given as 30 meter and 3 meter is the surcharge head. So, this is since this is a pipe kind of structure. So, the horizontal diameter is more than the lesser than that the vertical diameter here and this pipe length is 76 meter and invert elevation is given as 16 meter and it is a circular conduit and this side it is the top portion of the dam. So, this is a profile of this example.

(Refer Slide Time: 03:58)



Now, so, first we assume the radius and based on this the design problem will follow, the radius of the crest to minimize the sub atmospheric pressure that may be tolerated. So, assume the P by Rs is greater than equal to 2. So now, determination of Rs so here, the radius is given. So, Rs is determined by hit and trial procedure and assuming the values of Rs and computing the corresponding discharge. So, first assume the Rs value as 2 meter, now if you assume 2 meter the ratio between the surcharge head and divided by Rs is now 1.5 meter.

(Refer Slide Time: 04:46)



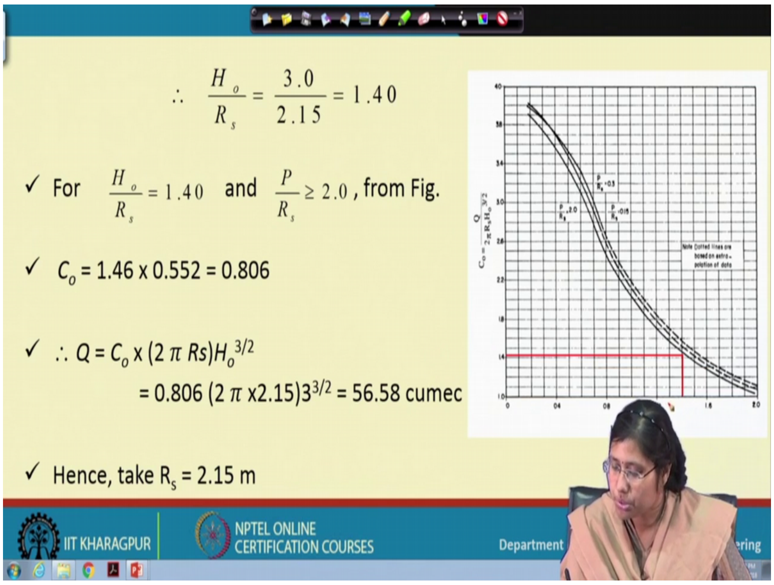
So, for this ratio of 1.5 meter and assuming the ratio P by Rs as greater than 2, so, if it is 1.5 meter, sorry;so what is the corresponding value of this coordinate here? So, is to determine the coefficient of discharge here, so, the C 0 value is 1.35 meter. Since this graph is prepared in MK's unit. So, we multiply using a correction factor to convert it into SI unit. So, the conversion factor is nothing but 0.552 here.

So, we multiply with this and then now the discharge from this portion the inlet is given by using weir equation. So, C o is the discharge coefficient and since we assume the circular cross section and the outside radius of this cross section. So, this is the perimeter is given by 2 pi R and this is again head. So, head is assumed as head is given as the surcharge head is 3 meter.

So, using this relation so, we get the discharge the inlet discharge is 48.65. So, here mean to say that P, P is nothing the pressure and the ratio between the P by Rs that is ratio between pressure divided by the radius of the flow is we assume that, this curves are obtained at different values of P by Rs.

Now our assumed flow is less than. So, this one so, this is the design flow is given the 56 cumec, but our calculated, it is less than this the 48 around 48 cumec. So, this is less than the desired outflow. So, again we assume that radius of the inlet is 2.15 meter.

(Refer Slide Time: 07:10)

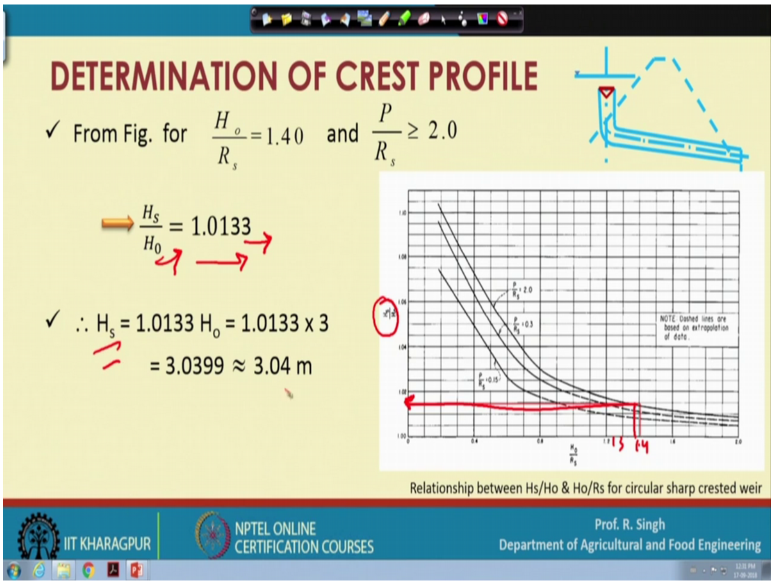


Now assuming the radius is 2.15 meter. Now, again repeat the calculation. So, here if you assume the Rs value, the head, so, surcharge head is already 3 meter as given in the problem and now your assumed radius is 2.15, now the ratio between them is 1.40.

Now, for a given values is. So, this is a divided into 4 different interval, so between 1.2 to 1.6; so here if I go gradually 1.2 to 1.3. So, this point will nothing but 1.4 and following 1.5 and 1.6. So, from this point so now, I am prolonging this line and intersect point is locating here.

So, now you can say, this is 1 and 1.4 and so and 1.8. So, each coordinate is divided into 4 parts. So, how you divide this point? So to find out the intersection so, you can divide it at different small interval. So, now, you can assume that this particular point is 1.46 and now since you have to convert the unit into SI, so, you multiply with this with the conversion factor that is nothing but 0.552. Now, your C 0 value comes out to be 0.806, now this C 0 value plug into the equation and discharge equation. So, now, you obtain the value of discharge is around 56.58 and your design discharge was 56. Now you this since it is a little higher side then design discharge, so, this value of Rs is acceptable and you can take the radius of the inlet as 2.15 meter.

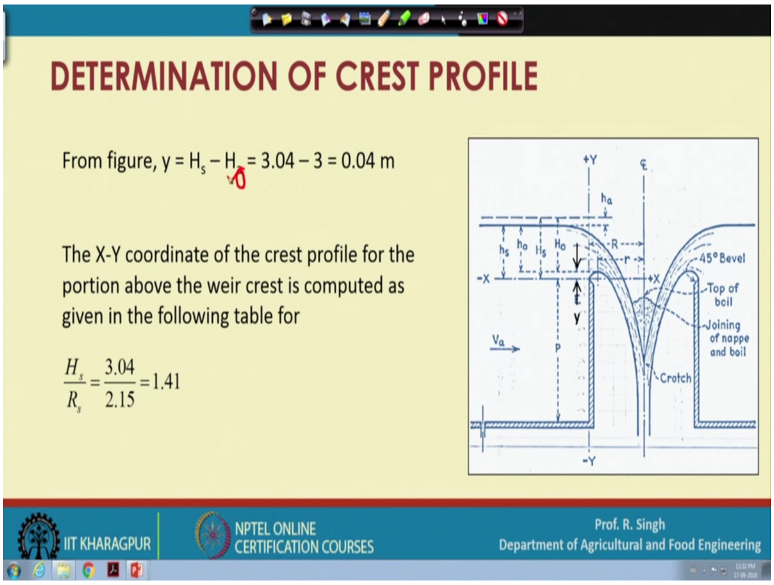
(Refer Slide Time: 09:16)



So, this equation the part you can solve now. Now the determination of the crest profile; now you have an assume value of H0 3 and Rs is now your 2.15 from earlier steps; so, from this part of the problem. Now and you assume the ratio between the pressure and the radius of the Rs is greater than 2, now you have to get the value of from this particular graph. So, specifically saying, so, all this graphs are obtained from USBR, so, US department. So, this all these design problems are given by them and then we are converting into based upon our design. So, all these graph from this graph of H0 by Rs.

And at a given pressure level, so, you have to take the calculate value of Hs by H 0. So, how you can do that? So here, suppose a value of again it is 1.3 and 1.4, so, for this values and the corresponding value here. So, you can see between 1 and 1.02, 1, 2, 3, 4; 4 divisions are present. So, using interpolation you come to the conclusion that this Hs by H 0 is in between 1. This is this particular point is, if you divide this between this point as 4 equally spaced points, so, you find that Hs by H 0 is nothing but around 1.0133.

(Refer Slide Time: 11:23)

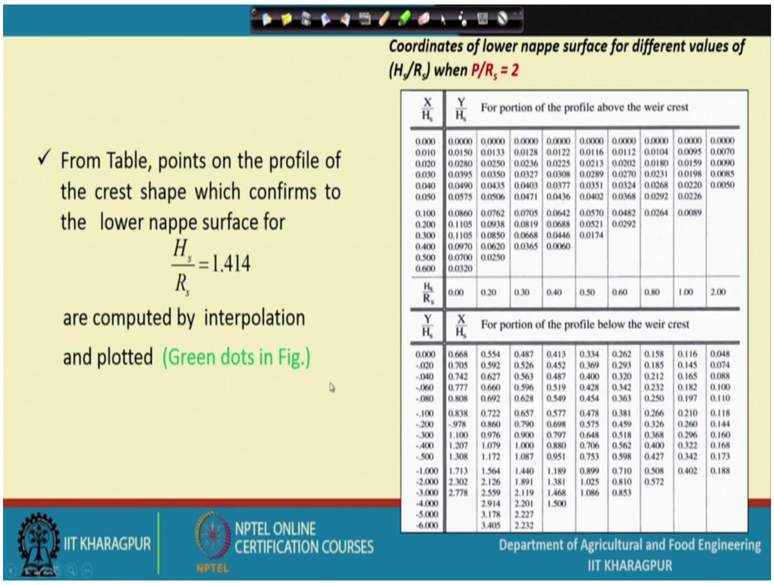


Now, you know the value of H 0. So, you multiply with that. So, now, Hs value comes as 3.04 and now.

So, this is Hs value and you have the value of H 0, you know is which is 3 meter. So, this is H 0, 3 meter. So, you know the Hs value, which is 3.04 from earlier calculation.

So, this point between these two is Hs minus Ha is nothing but 4.04 meter or 4 centimeter. Now, the X Y coordinate of the crest profile for the portion above the weir crest is given in the table in the following table.

(Refer Slide Time: 12:20)

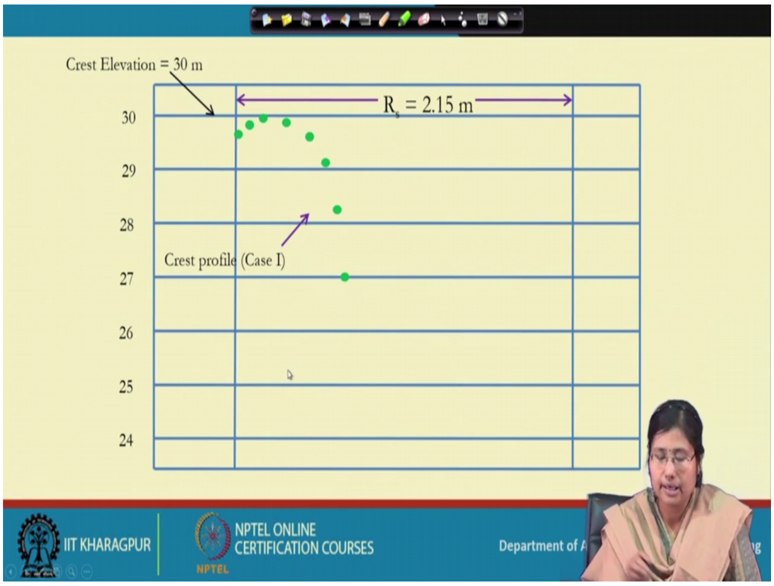


X/Hs	Y/Hs — For portion of the profile above the weir crest								
0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.010	0.0150	0.0133	0.0128	0.0122	0.0116	0.0112	0.0104	0.0095	0.0070
0.020	0.0280	0.0250	0.0236	0.0225	0.0213	0.0202	0.0180	0.0159	0.0090
0.030	0.0395	0.0350	0.0327	0.0308	0.0289	0.0270	0.0231	0.0198	0.0085
0.040	0.0490	0.0435	0.0403	0.0377	0.0351	0.0324	0.0268	0.0220	0.0050
0.050	0.0575	0.0506	0.0471	0.0436	0.0402	0.0368	0.0292	0.0226	
0.100	0.0860	0.0762	0.0705	0.0642	0.0570	0.0482	0.0264	0.0089	
0.200	0.1105	0.0938	0.0819	0.0688	0.0521	0.0292			
0.300	0.1105	0.0850	0.0668	0.0446	0.0174				
0.400	0.0970	0.0620	0.0365	0.0060					
0.500	0.0700	0.0250							
0.600	0.0320								
Hs/Rs	0.00	0.20	0.30	0.40	0.50	0.60	0.80	1.00	2.00
Y/Hs	X/Hs — For portion of the profile below the weir crest								
0.000	0.668	0.554	0.487	0.413	0.334	0.262	0.158	0.116	0.048
-.020	0.705	0.592	0.526	0.452	0.369	0.293	0.185	0.145	0.074
-.040	0.742	0.627	0.563	0.487	0.400	0.320	0.212	0.165	0.088
-.060	0.777	0.660	0.596	0.519	0.428	0.342	0.232	0.182	0.100
-.080	0.808	0.692	0.628	0.549	0.454	0.363	0.250	0.197	0.110
-.100	0.838	0.722	0.657	0.577	0.478	0.381	0.266	0.210	0.118
-.200	-.978	0.860	0.790	0.698	0.575	0.459	0.326	0.260	0.144
-.300	1.100	0.976	0.900	0.797	0.648	0.518	0.368	0.296	0.160
-.400	1.207	1.079	1.000	0.880	0.706	0.562	0.400	0.322	0.168
-.500	1.308	1.172	1.087	0.951	0.753	0.598	0.427	0.342	0.173
-1.000	1.713	1.564	1.440	1.189	0.899	0.710	0.508	0.402	0.188
-2.000	2.302	2.126	1.891	1.381	1.025	0.810	0.572		
-3.000	2.778	2.559	2.119	1.468	1.086	0.853			
-4.000		2.914	2.201	1.500					
-5.000		3.178	2.227						
-6.000		3.405	2.232						

So, the value of Hs by Rs is 1.41 now. So, for different value of Hs by Rs, so this table that is given, so between 1 and 2.

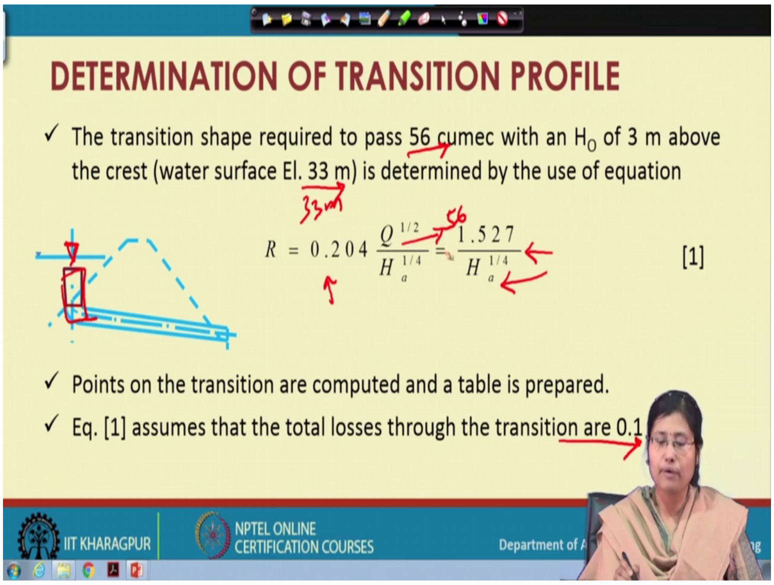
So, 1.4 lies between 1 and 2 and for different X. So, this is a differ P by Rs the pressure between P is for 2. So, we assume our entire calculation was based on the ratio between P by Rs as 2. So, for different values of Hs by Rs, we interpolate for different crest profile and then we plot this.

(Refer Slide Time: 13:01)



So, at a crest elevation of 30 meter and at a different value of X and Y and Rs, the radius at the inlet is 2.15 meter was kept and we can get the crest profile like this after interpolating this table values.

(Refer Slide Time: 13:19).

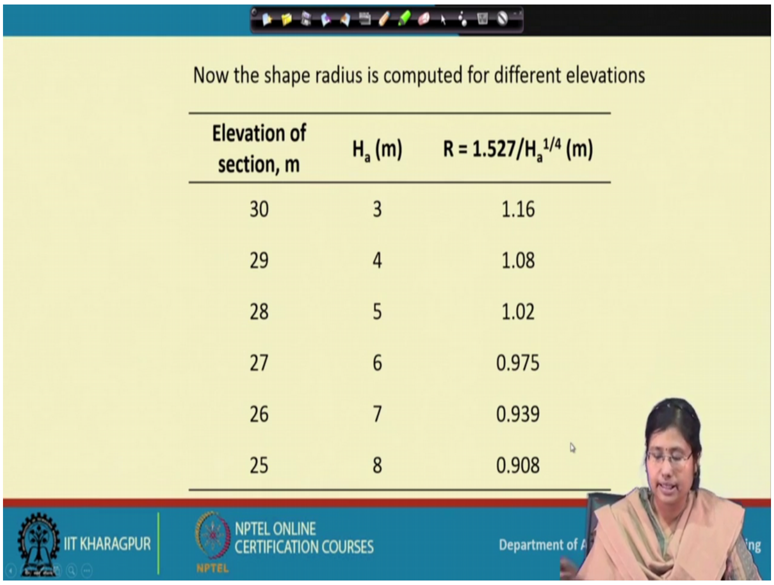


So, once we obtain the crest profile and now we determine the transition profile. So, this is a transition profile. So, crest profile was this, the top point panel. So, this design was completed. Now the second part the transition profile, the transition shape required to pass the 56 cumec that was the design discharge with an H 0 of 3 meter above the crest.

So, the water surface elevation was 30 meter and that surcharge head is 3 meter. So, total comes to be 33 meter and using this equation, which we already described in the design part. So, you plug the value of 56 cumec here and using this equation. So this equation, assume the total losses through transition are 0.1 times the Ha.

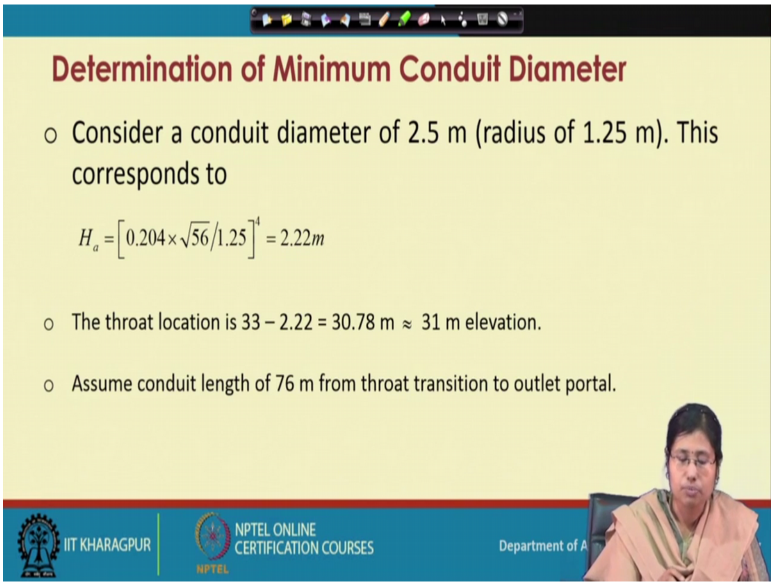
So using that; so, once you plug the 56 value here, you get the value of R as 1.527 divided by Ha. The equation 1 is obtained.

(Refer Slide Time: 14:42)



Now for different shape radius, you can be computed for different elevation. So, the elevation of the section if it is 30 meter is given and for different value of head, you can obtain the different shape radius like this and a tabular value can be obtained.

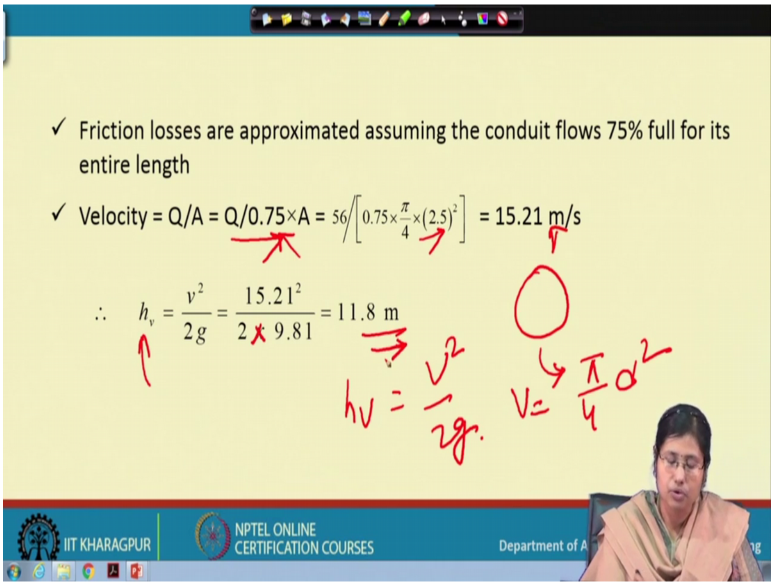
(Refer Slide Time: 15:05)



Now, the next part is the determination of the minimum conduit diameter. So, first we assume a known conduit diameter, say 2.5 meter, which is standard since the diameter is 2.5 meter, the radius is half of that. So, this is the 1.25 meter is obtained like this and this corresponds to. So, we again plug into the basic equation.

So this equation here, so equation 1. So, in that way we can get the value of H a where q was kept as 56 and this is using the assumed radius, which is the head is nothing, but 2.22. Now the throat location is 33 minus this 2.22. So, this comes to be 30.78 meter, which is nothing, but we round it to 31 meter elevation. So the assume the conduit length of 76 meter from throat transition to the outlet point.

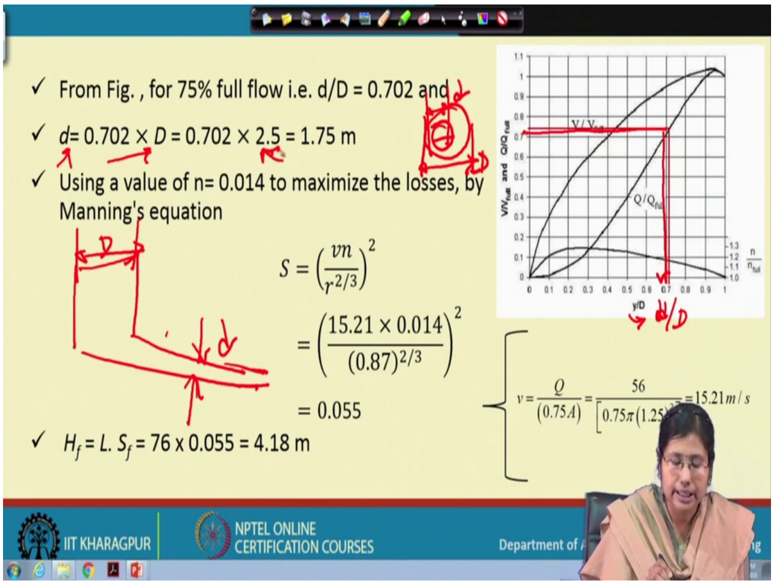
(Refer Slide Time: 16:30)



Now, we will take into care the frictional losses, since the frictional losses are approximate it assuming the conduit flow 75 percent of the entire length. So here, so this part is considered. So, the discharge divided by since it is a 75 percent of the flow. So, this was plugged here, considering this 75 percent of the flow and these are assumed diameter. So, since the cross section is assumed as a circular. So, this relation is nothing, but pi by 4 D square. So, in this way we calculate the velocity, once we obtain the velocity then, we will calculate the velocity head, which is nothing, but Hv is v square upon 2 g is the head loss due to the velocity.

So, this note, this is a multiplication and this one is come the head loss due to the velocity head is comes out be 11.8 meter.

(Refer Slide Time: 17:35)

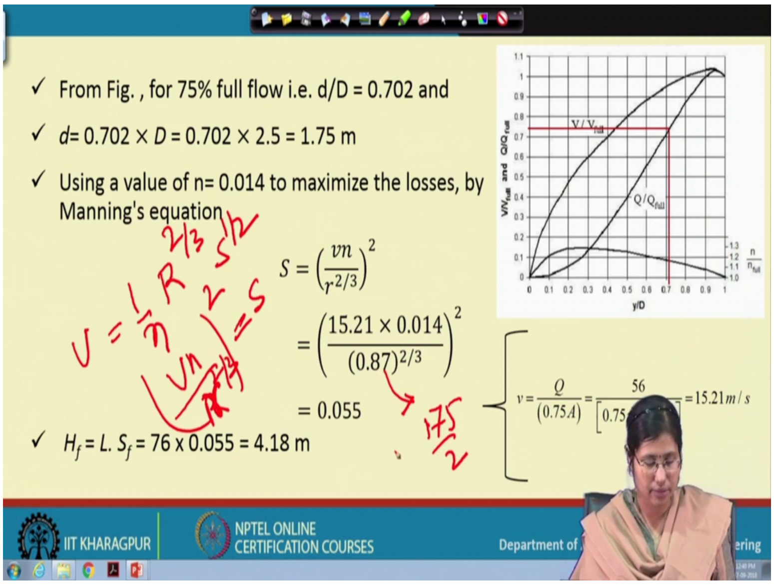


Now, since the pipe is 75 percent full. So from this graph, so, this is the ratio between v by v full and for different depth. So, 75 percent full. So, you can take the point here and here. So, this is 75 percent full.

So, corresponding Q by Q 0 is around 0.7 0. So, this is the diameter at the inlet divided by the diameter at the outlet portion. So, d by D is a ratio is around 0.70 and your diameter is assumed as the inlet sorry this is the outlet by inlet diameter. So, the inlet diameter is the bigger diameter or and a smaller diameter.

So, this one is kept as D and this one is small d. As you remember, this is the complete cross section. So, this diameter is bigger. So, this one your capital D and this diameter is the small d. So, this ratio is given by this kind of graph. So now, so small d that is the diameter at the transition point is a function of 0.702. So, here the diameter is 2.5. Now you assume the mannings roughness coefficient for naturalize flow as 0.014.

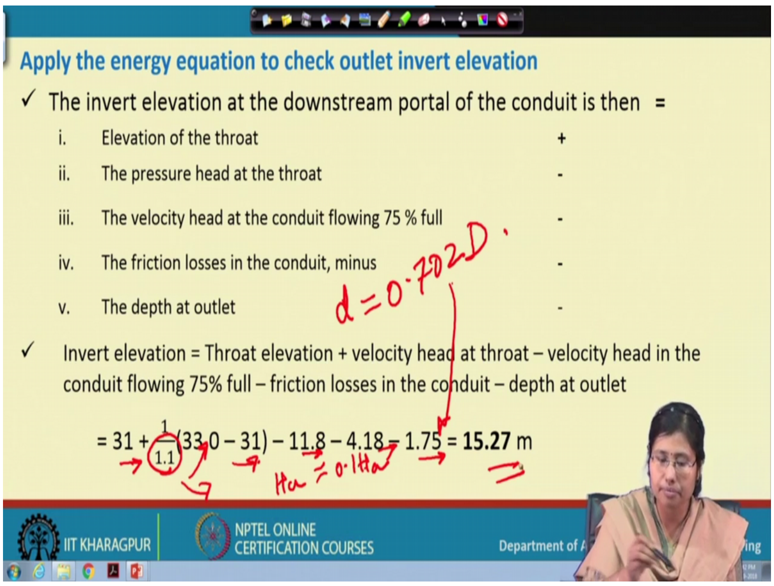
(Refer Slide Time: 19:31)



Now, this is this universal equation, the velocity of flow through open channel. So using that so, you can get the value of S; so, V n square.

So, this is done here and since small d is the radius here. So, this is small r. So, this is the value of 1.75 by 2; so, this 0.87. So, this slope is comes out to be 0.055 and now this is the head loss due to friction is the length of the pipe and the slope of the head of the slope, this to friction and this comes out to be 4.18, this is the head loss due to friction.

(Refer Slide Time: 20:36)

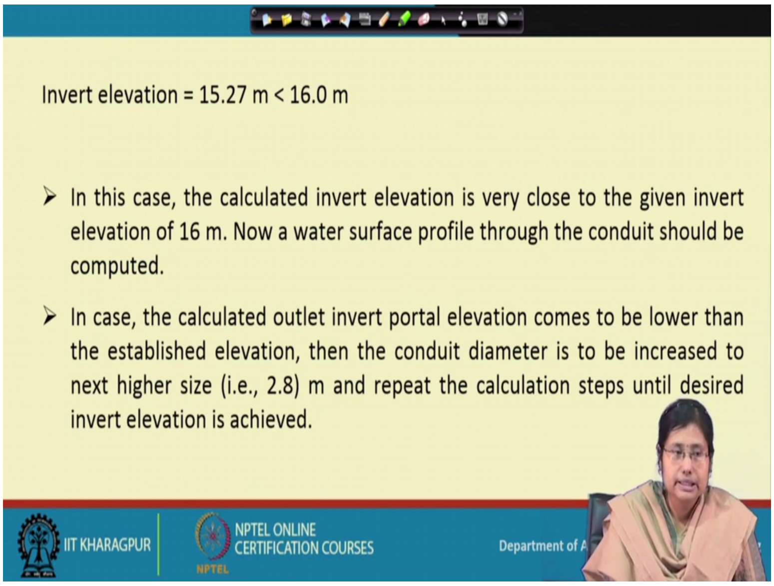


Now, we apply the conservation of energy equation to check the outlet invert elevation. So, here the in elevation at a throat is positive and the pressure head at the throat. So, this has to be negative. So, we are deducting this velocity head at the conduit assuming the pipe is 75 percent full. So, you will have to deduct it, because this is a head loss, the frictional losses at the conduit.

So, this is also you have to deduct and the depth at the outlet. So, you assume that, this is a circular cross section. So, the depth at the outlet is nothing but that equation 1072 D. So, the invert elevation. So, throat elevation was 31 meter and a velocity head at throat. So, this was the invert elevation minus the 31 here and why we are dividing it 1.1, because the Ha was assume to be calculated as 0.1 H a.

So, considering all losses so, that is why you are dividing by 1.1 and this is the velocity head and this is a frictional head loss at the conduit and this is the depth at the outlet given by this equation. So, this comes out to be 15.27.

(Refer Slide Time: 22:05)



Now, the invert elevation was given in the design problem is 16 meter, which is very close to 15.27 meter.

So, this in this case the design was accepted. So, the calculated invert elevation is very close to the given invert elevation of 16 meter. Now a water surface profile through the conduit should be computed. So, in case if the calculated outlet invert elevation comes, lower than the established elevation. So, suppose the, our invert calculated, invert elevation is comes in the problem is 15.27 meter, which is around 16 meter.

We will consider the higher side is lower than the established elevation, that is given in the problem suppose the established elevation is 20 feet or 18 meter then the conduit diameter is to be increased. So, in that case you have to increase the diameter, say the assume diameter was 2.5. Now you increase the next higher diameter size like 2.8 meter and then repeat the calculation steps until the desired invert elevation is achieved. So, in this way the design problem goes.

Thank you.