Soil and Water Conservation Engineering
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Lecture – 42
Drop Inlet Spillway (Contd.)

(Refer Slide Time: 00:22)

Hello, good afternoon all. So, this is the 4th lecture of Drop Inlet Spillway. So, here we are going to cover the basic spillway design. And the in the last lecture, we are going to solve a problem based on this design aspect. So, these are the two points to be cover.

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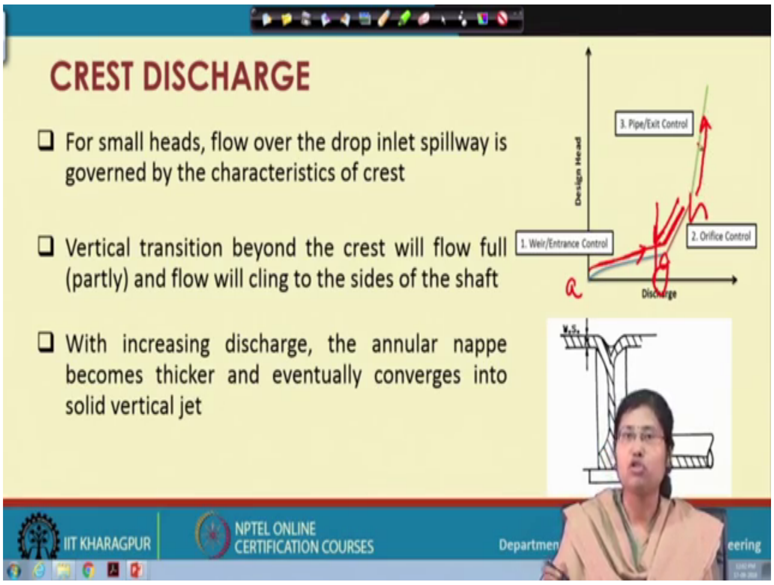

So, first I different we going to cover the different component of the design; so, first one is the crest discharge. So, crest discharge this is the design head and suppose the discharge, so this graphical representation is given here. So, the first part, so this part until this the weir or entrance or as you remember in couple of slides ago, we discussed about when the control one prevails. So, weir or control flow prevails.

And in the second condition two, as you remember in the discharge characteristics curve of the drop inlet spillway structure. So, here the orifice the second part the orifice control prevails. And so this was in that graph, so a to g was the weir or entrance control, and then g to h was orifice control, and the last part is pipe or exit control, where the full pipe flow prevails.

So, for small head the flow over the drop inlet spillway is generally governed by characteristics of the crest. So, the vertical transition beyond the crest will flow full either fully or the partially and the flow will cling to the side of the shaft. So, it can cling at the side of the shaft. And however, with increasing discharge the annular nappe becomes thicker and it eventually converges into a solid jet. So, this way here, it can shows particularly, how the flow can takes place in the crest design.

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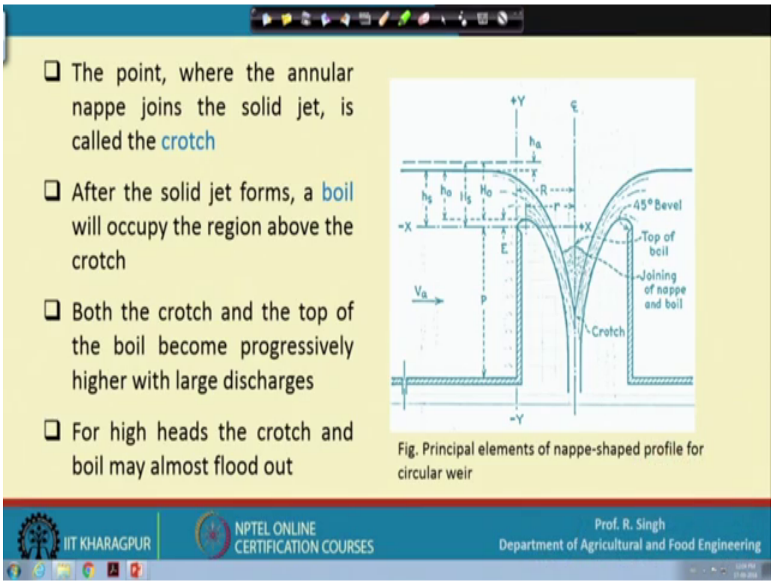

So, this is the principal elements of the nappe shaped profile or the circular weir. The point where the annular nappe, so this part this is the annular nappe joins the solid jet. So, here the point where the annular nappe joins the solid jet here so, this point at the bottom is called the crotch. So, this particular point is called crotch ok.

And after the solid jet forms, so once the solid jet forms here. So, it can create a structure called boil, so which will occupy the region above the crotch. So, crotch is formed at the bottom and solid jet, because of the flow of continuous flow of water, and the water solid jet forms at the top. So, this part is called a boil. And both crotch and the top of the boil become progressively higher with larger discharge. So, once the discharge is higher. So, the both crotch and boil become higher here. And for high head the crotch and boil will almost flood out. So, this is the principal elements of the structure here.

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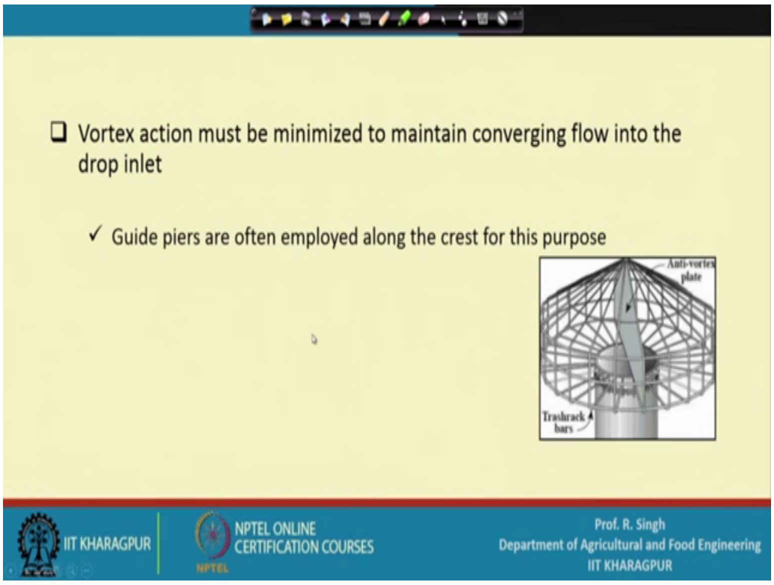

Now, the vortex action in the flow can be minimized to maintain the converging flow into the drop inlet. So, to minimize the vortex action generally a guide piers or antibiotics plate are provided at along the crest.

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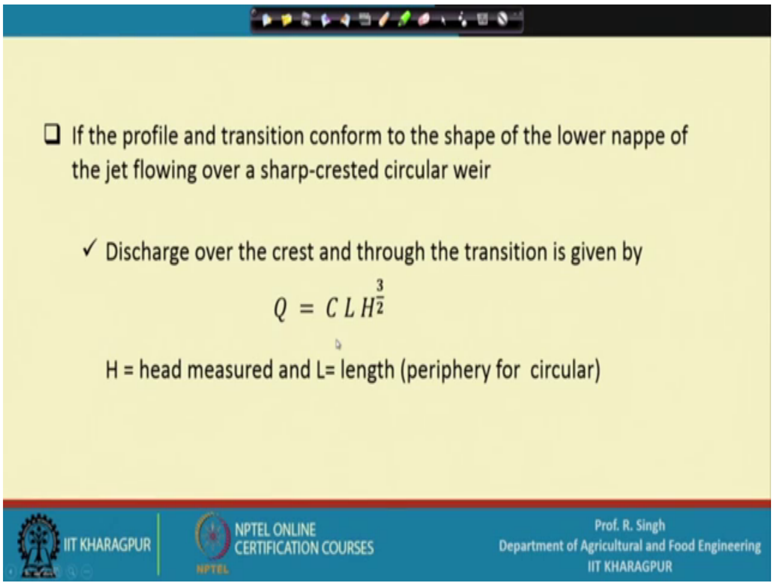

If the profile and transition conform to the shape of the lower nappe of the jet, then the discharge is generally governed by the equation of flow of water through weir. So, discharge is a function of C L, where C is the coefficient, L is the length. Here length is nothing but a perimeter or the periphery in case of the circular shape of the weir and H is the head measured.

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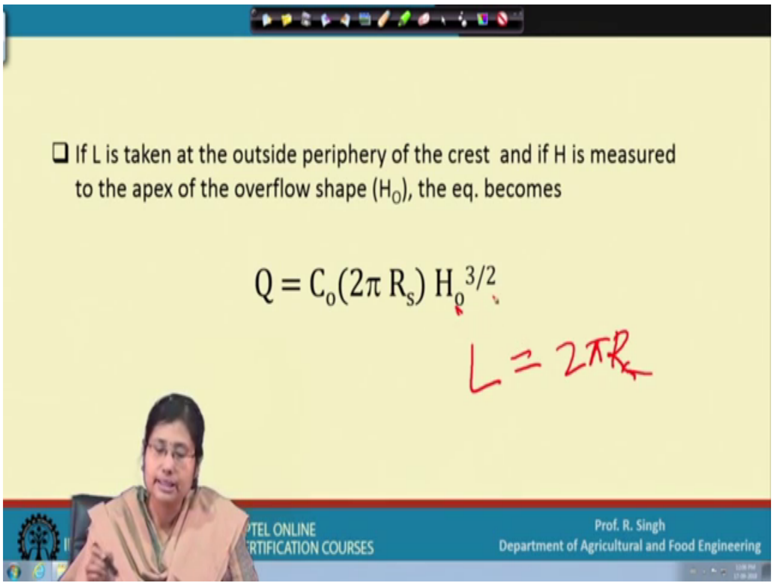

Now, L is in general taken at the outset periphery of the crest and if H is measured to the apex of the overflow shape, then equation become so since it is a circular periphery. So, here we measure the perimeter of the circular pipe R is the radius of that pipe and H 0, since it is the overflow shape at the outlet. And it is H 0 and 3 by 2, so this is nothing but flow through the weir.

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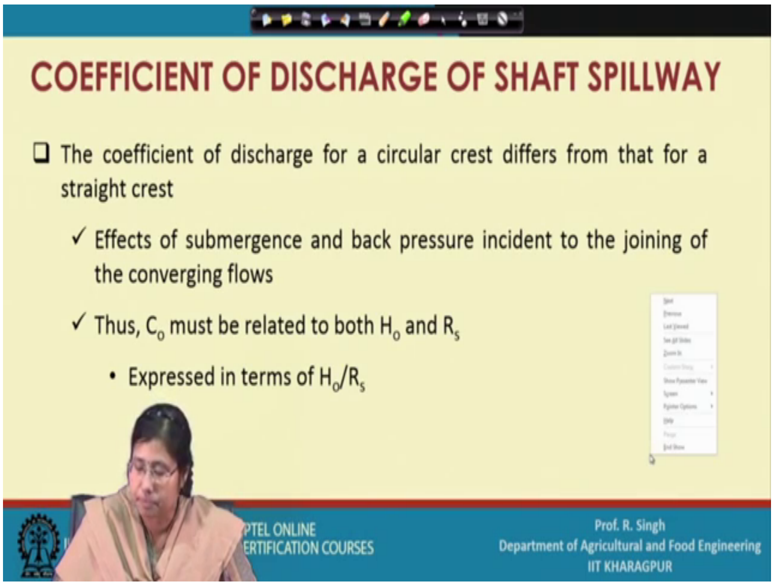

Now, the coefficient of discharge of the circular crest differs from that of the straight crest. So, here in this case the effect of submergence and back pressure incident to the joining of the converging flows. Thus, C 0 must be related to both H 0 and R s. So, this coefficient is expressed in terms of the function of H 0 by R s.

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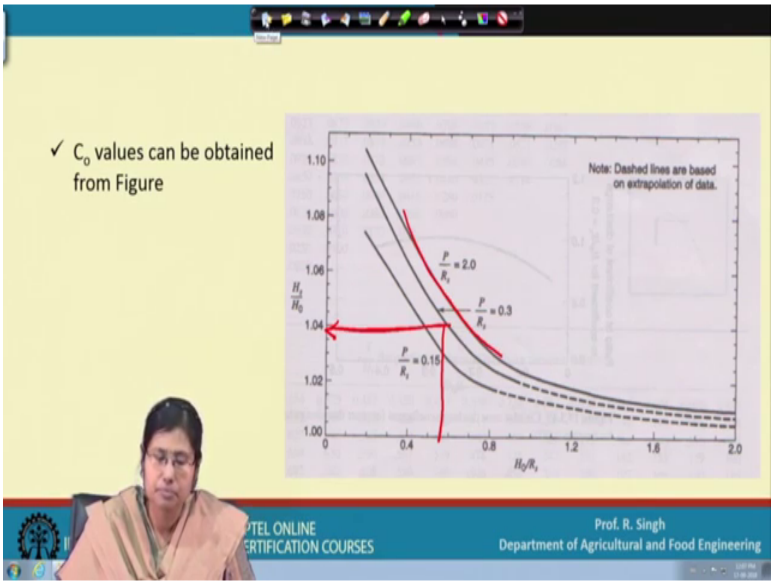

So, there is a different graphs are given at various values of P divided by R s. So, there is a graph of H s by H 0 versus H 0 by R s is provided. So, at different point, so you can determine based upon the H value of H 0 by R s, for a assumed value of P by R s, the H s by H 0 value. So, this is the actual point, and the dotted lines are shows the extrapolated lines of the plot.

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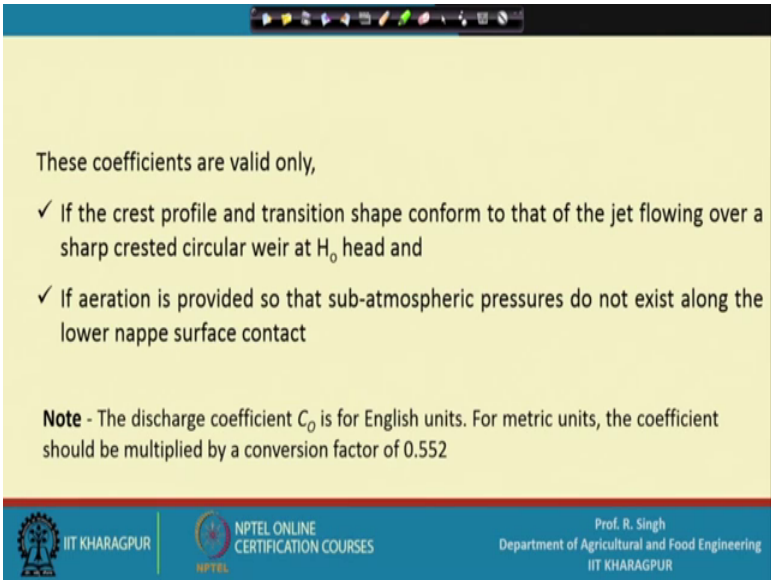

So, these coefficients are only valid if the crest profile and the transition shape conform to that of the jet flowing over a sharp crested circular weir at H 0 head. And if aeration is provided, so that sub-atmospheric pressure do not exist along the lower nappe surface contact. So, the discharge coefficient C 0, are all in English unit. And so to convert it into the metric unit, the coefficient should be multiplied by a conversion factor 0.552.

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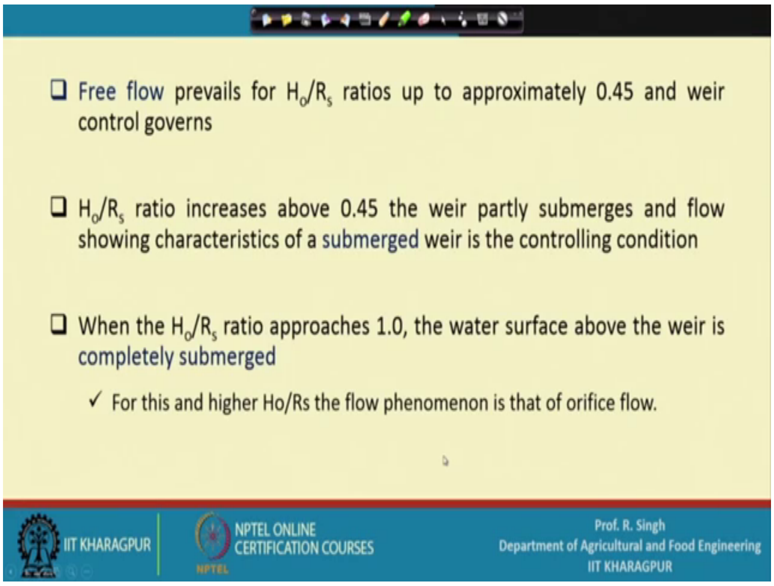

So, free flow in the weir prevails for H 0 by R s ratios up to approximately 0.45 and a weir control governs in this case, so beyond that the flow become turbulent. And H 0 by

R s ratio increases above 0.45, the weir is now partly submerge and the flow showing characteristics of the submerged weir is now un control condition. So, when the H 0 by R s ratio approaches 1, the water surface above the weir is now completely submerged. For this the higher H 0 by R s the flow phenomena is now become an orifice flow. So, based upon the ratio between H 0 by R s different flow conditions prevails.

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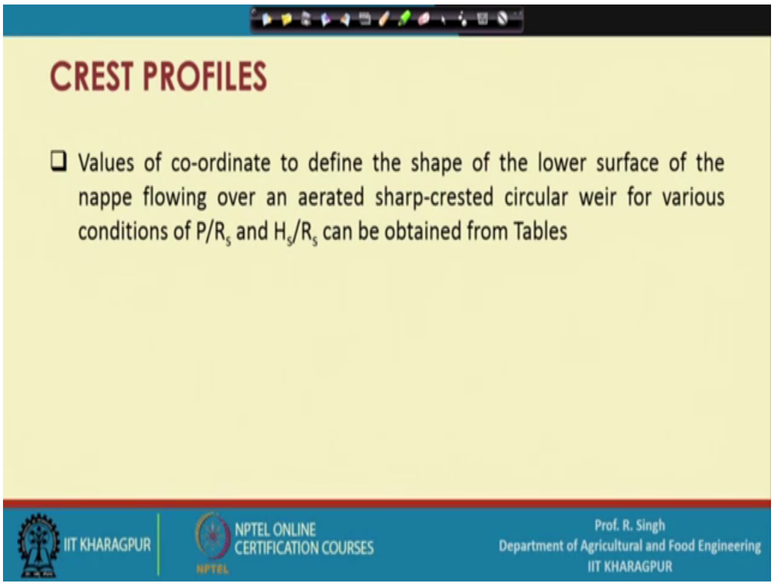

Now, crest profile how you plot the crest profile, the values of the co-ordinate to define the shape of the lower surface of the nappe flowing over an aerated sharp-crested circular weir for various condition of P by R s and H 0 by R s. H s by R s can be obtained from tables, so these values are given. Then H 0 by R is now can be interpolated from this given values.

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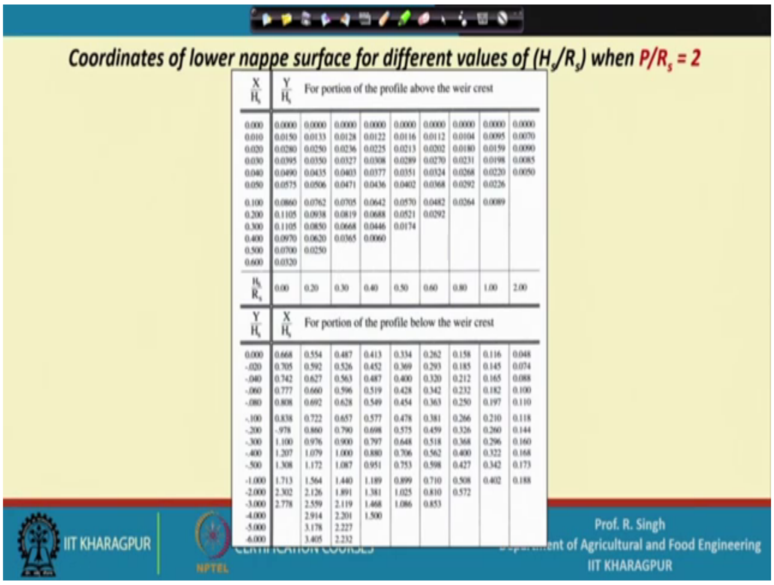

For portion of the profile above the weir crest (Y/H_s)

X/H_s \ H_s/R_s	0.00	0.20	0.30	0.40	0.50	0.60	0.80	1.00	2.00
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								

For portion of the profile below the weir crest (X/H_s)

Y/H_s \ H_s/R_s	0.00	0.20	0.30	0.40	0.50	0.60	0.80	1.00	2.00
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, now you can see the X and Y are the lower nappe surface for different values of H s by R s. So, you can see the extra different values of H s by R s is given at the bottom of the table, and for different P by R s value, so when the P by R s is 2. And so, different values of H s by R s is given and from this, suppose you have a value of P by R s as 2. And your value of H s by R s is lying between 1 and 2, then you can get a X and Y co-ordinates of this nappe from interpolating this tables, so this is when the condition is P by R s is 2.

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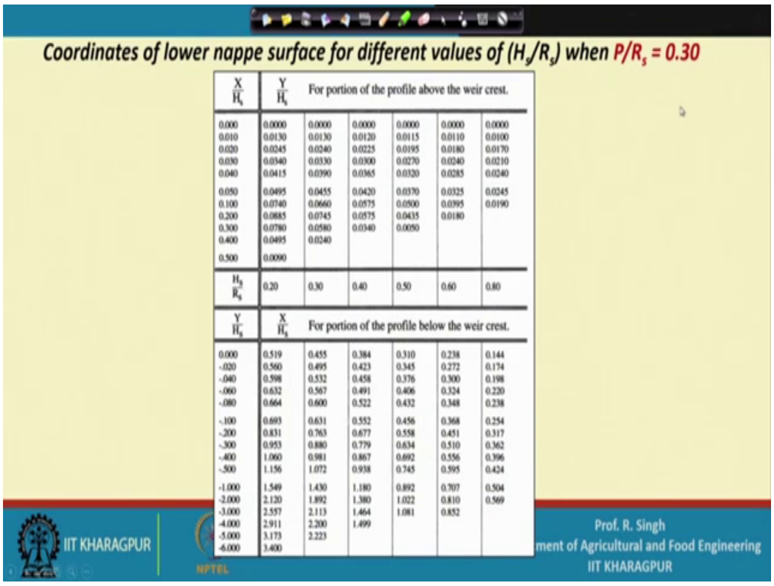

For portion of the profile above the weir crest. (Y/H_s)

X/H_s \ H_s/R_s	0.20	0.30	0.40	0.50	0.60	0.80
0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.010	0.0130	0.0130	0.0120	0.0115	0.0110	0.0100
0.020	0.0245	0.0240	0.0225	0.0195	0.0180	0.0170
0.030	0.0340	0.0330	0.0300	0.0270	0.0240	0.0210
0.040	0.0415	0.0390	0.0365	0.0320	0.0285	0.0240
0.050	0.0495	0.0455	0.0420	0.0370	0.0325	0.0245
0.100	0.0740	0.0660	0.0575	0.0500	0.0395	0.0190
0.200	0.0885	0.0745	0.0575	0.0435	0.0180	
0.300	0.0780	0.0580	0.0340	0.0050		
0.400	0.0495	0.0240				
0.500	0.0090					

For portion of the profile below the weir crest. (X/H_s)

Y/H_s \ H_s/R_s	0.20	0.30	0.40	0.50	0.60	0.80
0.000	0.519	0.455	0.384	0.310	0.238	0.144
-.020	0.560	0.495	0.423	0.345	0.272	0.174
-.040	0.598	0.532	0.458	0.376	0.300	0.198
-.060	0.632	0.567	0.491	0.406	0.324	0.220
-.080	0.664	0.600	0.522	0.432	0.348	0.238
-.100	0.693	0.631	0.552	0.456	0.368	0.254
-.200	0.831	0.763	0.677	0.558	0.451	0.317
-.300	0.953	0.880	0.779	0.634	0.510	0.362
-.400	1.060	0.981	0.867	0.692	0.556	0.396
-.500	1.156	1.072	0.938	0.745	0.595	0.424
-1.000	1.549	1.430	1.180	0.892	0.707	0.504
-2.000	2.120	1.892	1.380	1.022	0.810	0.569
-3.000	2.557	2.113	1.464	1.081	0.852	
-4.000	2.911	2.200	1.499			
-5.000	3.173	2.223				
-6.000	3.400					

Now, when this is a point 3, then a different table coordinates of lower nappe surface for different tables are provided. So, when it is the value is little less.

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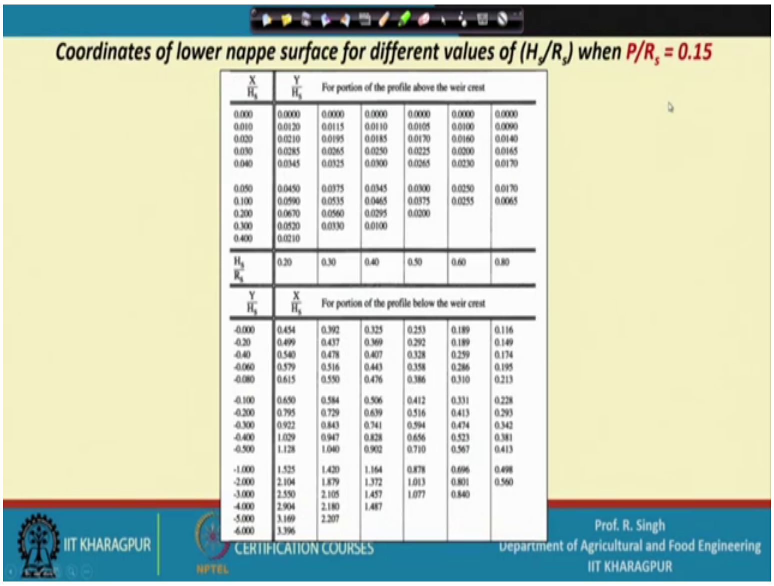

$\frac{X}{H_s}$	$\frac{Y}{H_s}$ For portion of the profile above the weir crest					
0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.010	0.0120	0.0115	0.0110	0.0105	0.0100	0.0090
0.020	0.0210	0.0195	0.0185	0.0170	0.0160	0.0140
0.030	0.0285	0.0265	0.0250	0.0225	0.0200	0.0165
0.040	0.0345	0.0325	0.0300	0.0265	0.0230	0.0170
0.050	0.0450	0.0375	0.0345	0.0300	0.0250	0.0170
0.100	0.0590	0.0535	0.0465	0.0375	0.0255	0.0065
0.200	0.0670	0.0560	0.0295	0.0200		
0.300	0.0520	0.0330	0.0100			
0.400	0.0210					
$\frac{H_s}{R_s}$	0.20	0.30	0.40	0.50	0.60	0.80
$\frac{Y}{H_s}$	$\frac{X}{H_s}$ For portion of the profile below the weir crest					
-0.000	0.454	0.392	0.325	0.253	0.189	0.116
-0.20	0.499	0.437	0.369	0.292	0.189	0.149
-0.40	0.540	0.478	0.407	0.328	0.259	0.174
-0.060	0.579	0.516	0.443	0.358	0.286	0.195
-0.080	0.615	0.550	0.476	0.386	0.310	0.213
-0.100	0.650	0.584	0.506	0.412	0.331	0.228
-0.200	0.795	0.729	0.639	0.516	0.413	0.293
-0.300	0.922	0.843	0.741	0.594	0.474	0.342
-0.400	1.029	0.947	0.828	0.656	0.523	0.381
-0.500	1.128	1.040	0.902	0.710	0.567	0.413
-1.000	1.525	1.420	1.164	0.878	0.696	0.498
-2.000	2.104	1.879	1.372	1.013	0.801	0.560
-3.000	2.550	2.105	1.457	1.077	0.840	
-4.000	2.904	2.180	1.487			
-5.000	3.169	2.207				
-6.000	3.396					

And this is again if the value is still less, so this is a for different values of H s by R s that X and Y co-ordinates are given.

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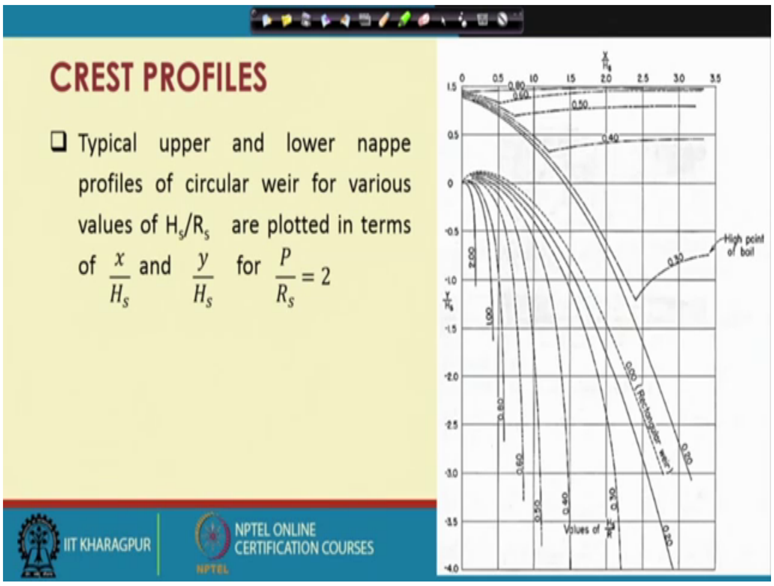

Now, the crest profile; typical upper and lower nappe profile for circular weir for various values of H s by R s are plotted in terms of the x and y co-ordinate. And this is for different P by R s this can be plotted for different assumed values of x and y.

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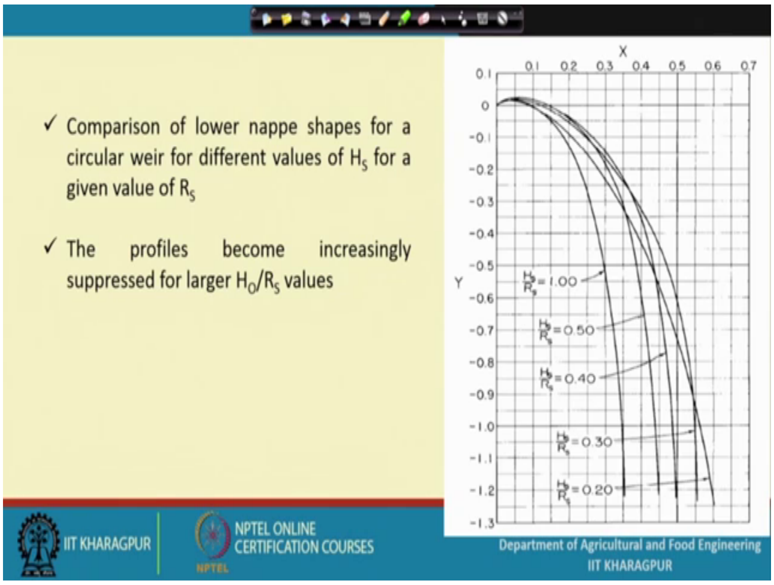

The comparison of lower nappe shapes for a circular weir for different values for H s for a given values of R s is given. The profile become increasingly suppressed for larger values. As you can see for lower values these are starting here, but it is suppressed, when the values of H s by R s are increasing.

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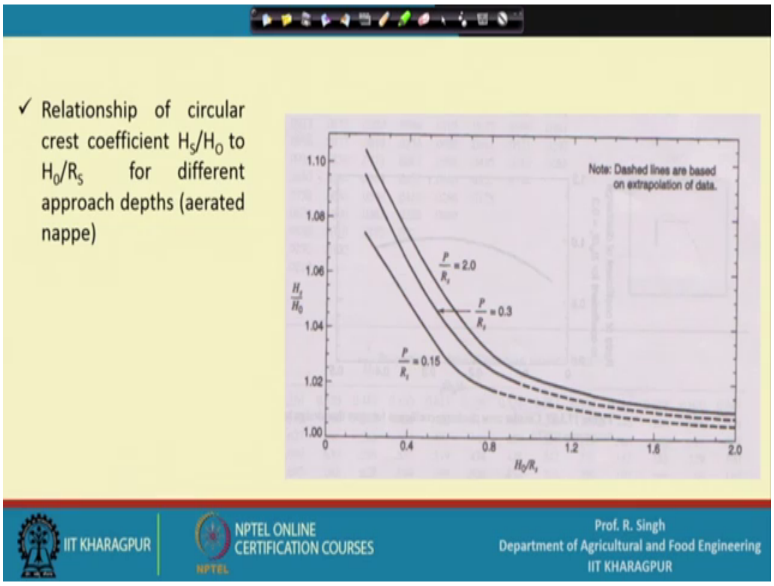

The relationship of again the relationship between the circular crest coefficient. So, these are the circular crest coefficient to different H s by R s and differrent H s by H 0 is provided for different value of P by R s in case of the aerated nappe. And again here the dash lines are extrapolated lines. And from this you can derive the coefficient circular crest coefficient.

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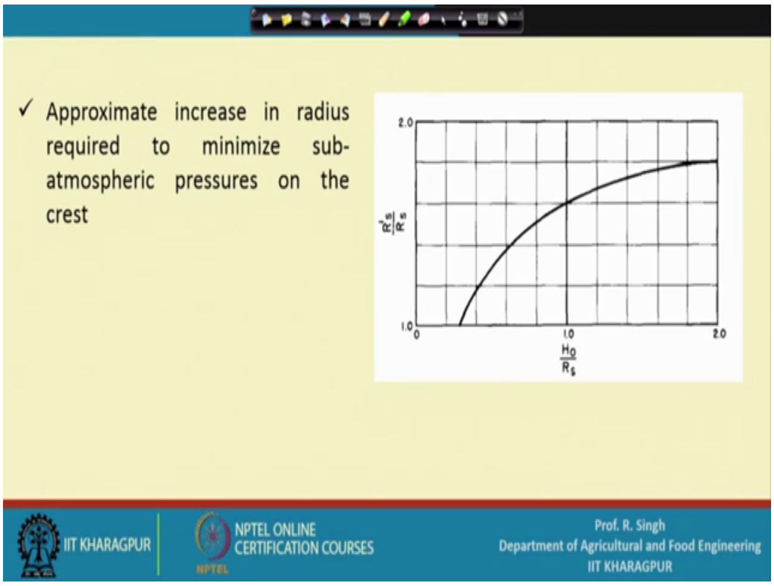

Now, the approximate increase in radius required to minimize the sub-atmospheric pressure of the crest are again determined from this graph. So, at different values of H 0 by R s, you can get the approximate increase in radius, where R s is the actual radius and R dash s is the increase radius. So, this is the point of intersection. So, if this is a value of your H 0 by R s, so you can get this valve in here. And based on this fraction, you can take into account approximate increase in radius to minimize the sub-atmospheric pressure inside the flow of the drop inlet spillway.

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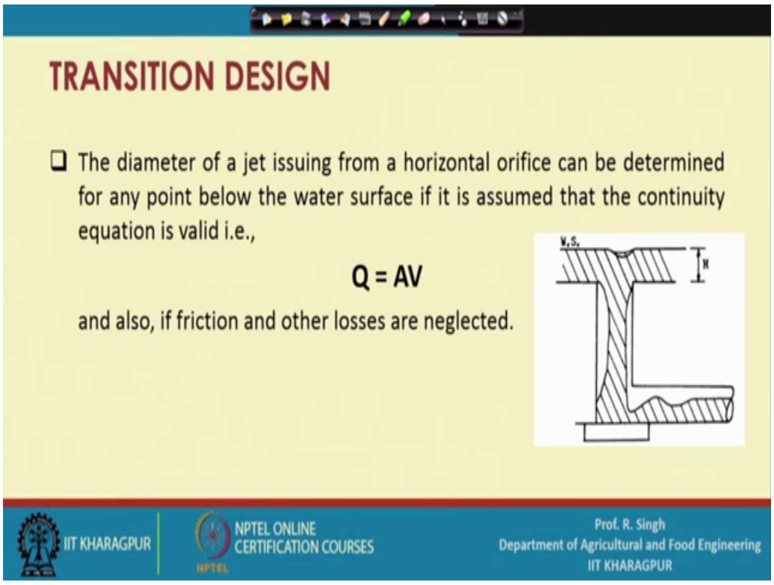

Now, coming to transition design; the diameter of a jet issuing from a horizontal orifice can be determined for any point below the water surface, if it is assumed that a continuity equation is still valid. So, in this case all the frictional and other losses are neglected, only the it is assumed that the continuity of equation is valid in this case.

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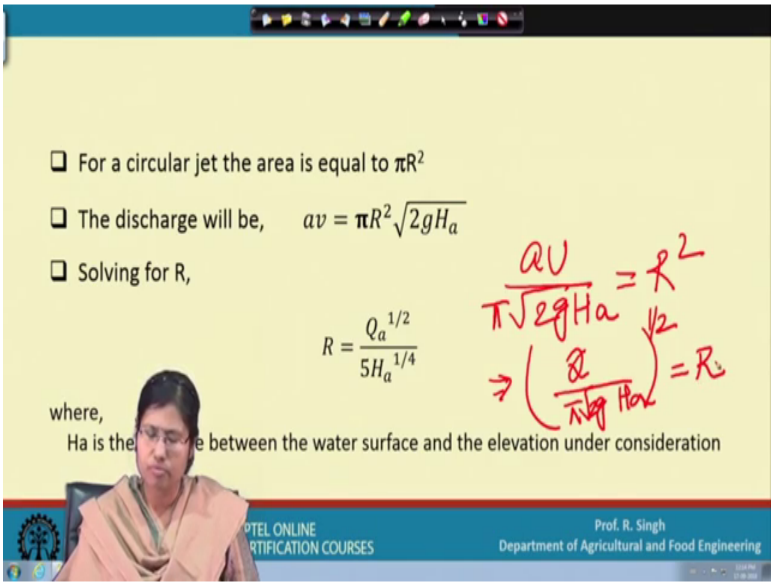

So, since most of the cases the circular jet area is assumed, so that is why, so discharge is a function of area and a velocity. So, this is the velocity of head. So, solving for different values of R, so this empirical equation follows ok. So, where H a is nothing but the discharge between so if you solve this, which will roughly or approximately will take that form, and you can get this equation. So, H a here is the distance between the water surface and the elevation under consideration.

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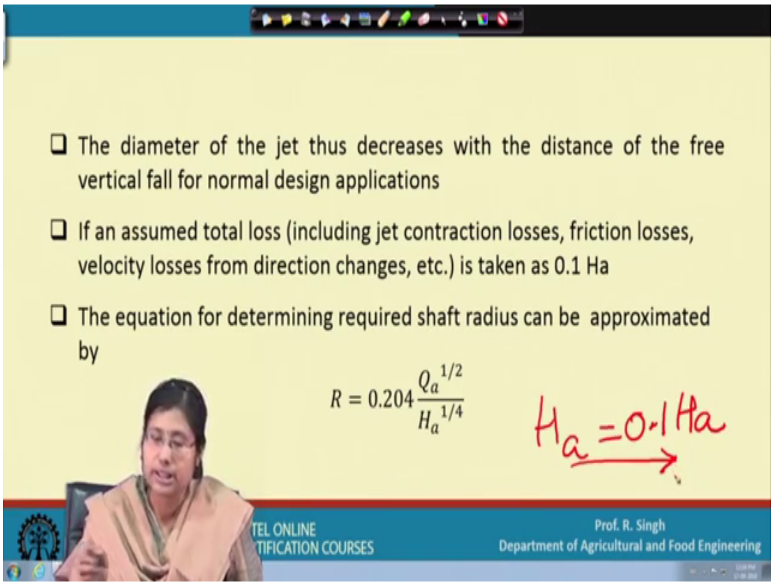

So, now you assume that the diameter of the jet in thus decreases with the distance of the free vertical fall for normal design application. If an assumed total head loss like means including that jet contraction losses, frictional losses, and velocity losses from the direction changes, then you take that is equal to the 0.1 H a. Then the equation is modified and determining required for the shaft radius. Now, the shaft radius can be approximated using this equation, so after taking H a. So, this equation is particularly valid, if H a is taken as 0.1 of H a, so including all kind of losses like contraction, losses frictional losses, velocity losses from direction changes etcetera.

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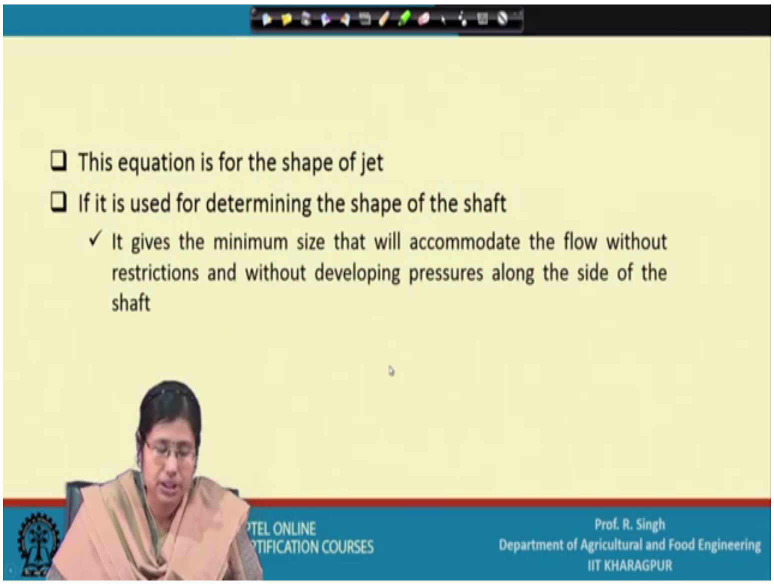

So, this equation is for the shape of the jet. So, if it is used for determining the shape of the shaft, then it will give the minimum size that will accommodate the flow without restriction and without developing any pressure along the side of the shaft.

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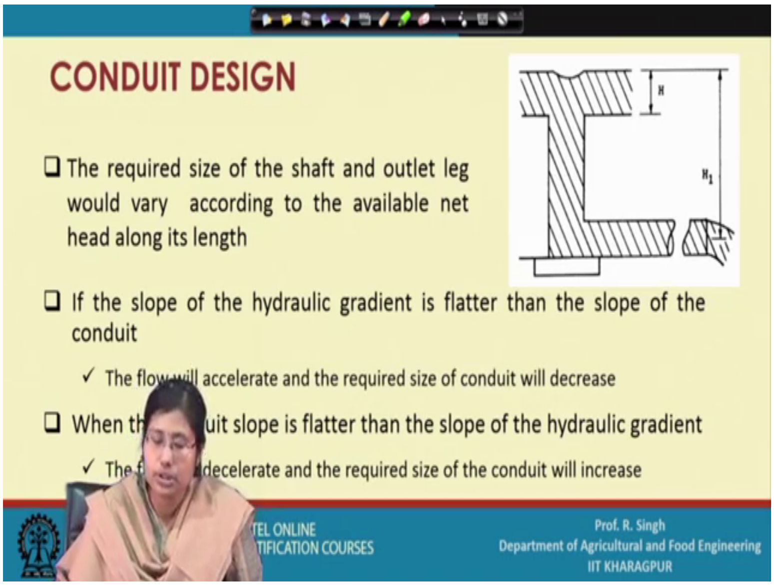

Now, coming to conduit design; the required size of the shaft and outlet leg would vary according to the available net head along with its length. If the slope of the hydraulic gradient is flatter than the slope of the conduit, the flow will accelerate and the required size of the conduct will decrease. When the conduit slope is flatter than the slope of the hydraulic gradient, the flow will decelerate and the required size of the conduit will increase. So, these two cases are opposite and vice versa to each other.

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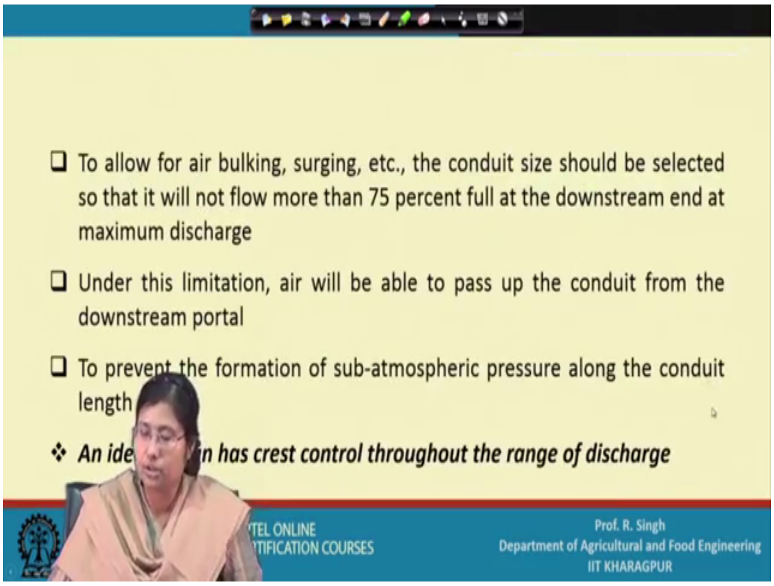

Now, in our design we also take care of the bulking, and surging, etcetera. So, to allow air bulking, surging, so these kind of losses the conduit size should be selected, so that it will not flow more than 75 percent full at downstream end at maximum discharge point. So, we only consider the 75 percent of the flow pipe flow full pipe flow.

So, under this limitation, air will be able to pass from the conduit at the downstream portal. To prevent the formation of sub-atmospheric pressure along the conduit length also this 75 percent flow condition is assumed. Now, an ideal design has the crest control throughout a different range of the discharge. So, this ends the basic design principle. And in the next lecture, we are going to solve a problem based on this design.

Thank you.