Advanced Hydraulics
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Module - 4
Hydraulic Jumps
Lecture - 6
Jump Controls

Good morning to everyone. We are in the fourth module. We are dealing with the course on advanced hydraulics, and in the fourth module we are studying the hydraulic jumps.

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In the last class, we have discussed on the use of hydraulic jumps as an energy dissipator. We also introduced to you the concept of stilling basins. How the jump positions are varied for a fixed tailwater condition. How the fluctuating tailwater conditions can also influence the jump position. What are the different types of jumps that are normally used for energy dissipation. And also, we have briefly introduced to you jumps in sloping channels, that portion we have to continue today; means, we have just introduced to you, how the jump can occur in the sloping channels.

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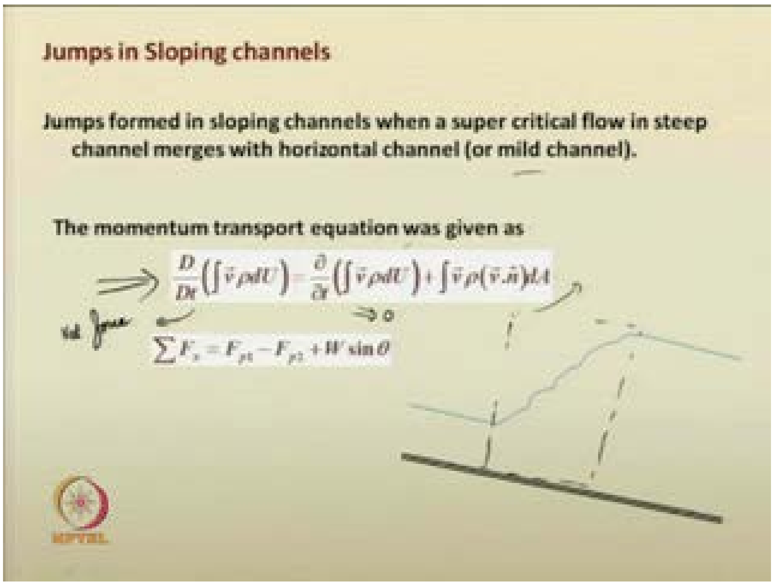

So, in the jumps in the sloping channels, if you recall them, it is a form when a supercritical flow from steep channel merges with horizontal channel, or in the files or it can be a mild channel also. The momentum transport equation was given for a control volume, right. If you recall them, the control was specified, and momentum transport equation was given in the following form.

So, you know that the net, or what, whatever, this is the material derivative of the momentum, this left hand term of this equation; so, it is the material derivative or time derivative of change of momentum. So, the rate of change of momentum is the net force in the system. And, this you know, it is the net outflux of momentum; and this is the change in moments, momentum stored inside the control volume. So, as it is a steady state condition, this portion we are neglecting and considering it as 0, if you recall them, isn't it. So, and this is the net force; so, this portion will give you the net force, that also we have studied.

Now, before continuing with this portion, let me give you briefly the solutions of the last days quiz. It was due to the time constraint, the solutions were not mentioned in that lecture. So, I just briefly describe it.

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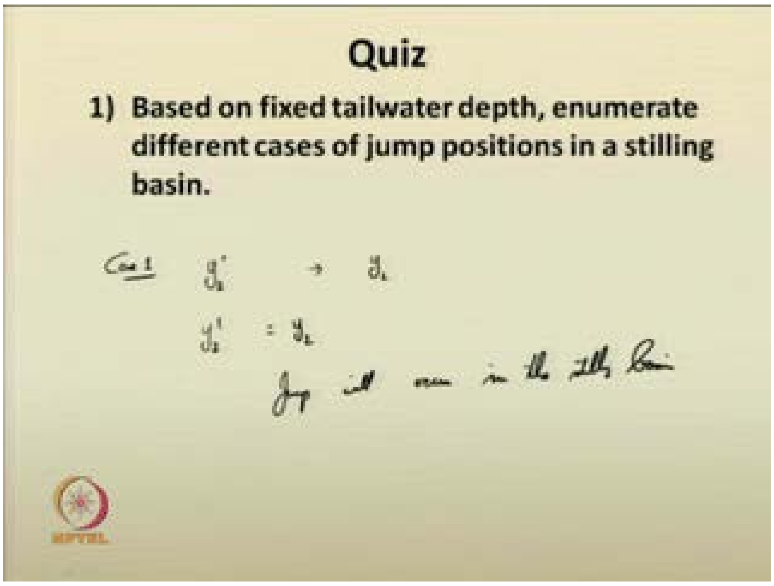

So, the first question asked in the quiz was: Based on the fixed tailwater depth, enumerate the different cases of jump positions in a stilling basin. I hope, you can easily answer them. If, you know that y 2 dash and y 2, the tailwater depth as well as the sequent depth; you have studied that, right. So, based on that, if the tailwater depth and sequent depth are same, if y 2 dash is equal to y 2, then jump will occur in the stilling basin itself. So, this is case 1.

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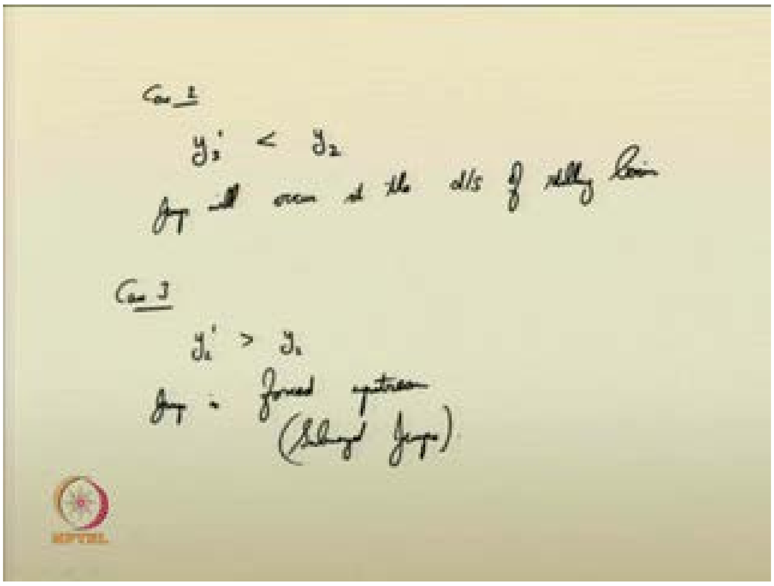

So, case 2. We have studied, when y 2 dash is less than y 2; that is, your tailwater depth is less than your sequent depth, then jump will occur downstream, at the downstream of stilling basin, so that is it will be pushed further. So, it may not even occur in the stilling basin itself. Case 3, which you would like to enumerate is case, so, where the tailwater depth is greater than the sequent depth of the hydraulic jump; then the jump is forced upstream; there may be even cases, where submerged jumps may occur also, right. So, just this, this is the answer for that quiz question.

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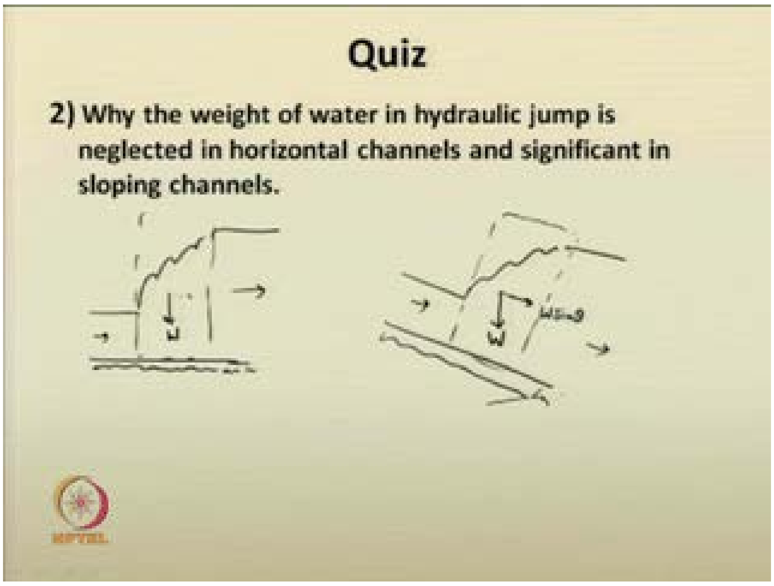

Next question we had asked was: Why the weight of water in hydraulic jump is neglected in horizontal channels, while it is significant in sloping channels. So, you just need to draw the figure horizontal, horizontal channel jump occurring there; just show that in the hydraulic jump the weight of water is acting vertically downwards, the flow is horizontal. So, there is no component of weight in the flow direction.

Whereas in the sloping channel, the same jump occurs; and, if you take the volume, you will see that the weight is acting vertically downwards. However, there is a component w sin theta, that also contributes to the flow, or it is in the direction of flow. Therefore, you cannot neglect weight of water in hydraulic jumps in sloping channels. So, you have seen the solutions of the last days quiz. Now, coming back into the hydraulic jumps in slope, sloping channels.

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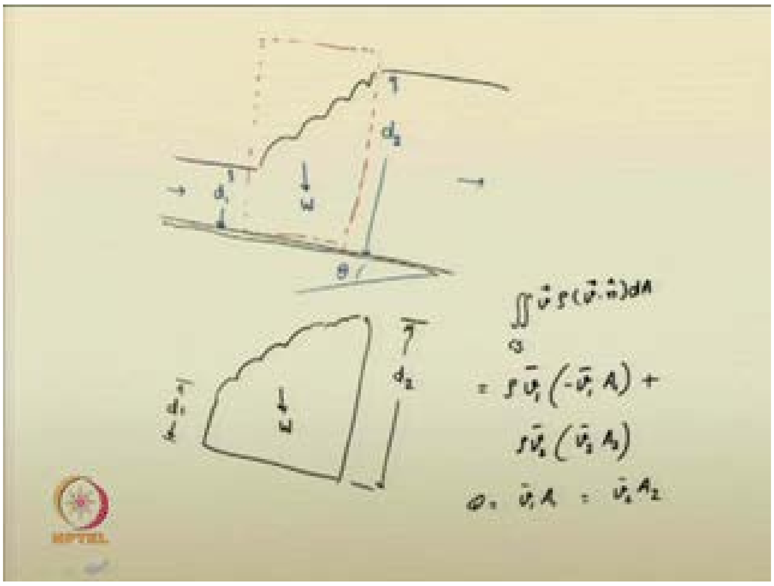

So, as we can see it from a side section, the jump, the weight of the water is significant, as you can see it here. I am just describing a control volume given in the red color here. So, that control volume, if you take into account; so, the control surfaces, I am just taking the control volume. So, here you have depth d 1, here you have depth d 2, right; and, there is weight of water acting downwards.

So, when you applied the momentum transport equation in this control volume, you have seen that the portion across the control surfaces, v rho v dot n d A, this was nothing but, equal to rho into v 1 bar; ok, I can just show it exactly, v 1 bar into, minus v 1 bar A 1, then plus rho v 2 bar; so, bar means the average velocity of that section is being taken; v 2 bar A 2; this was, this you are quite clear. So, from this thing, as the conditions are steady, we suggested v 1 bar A 1 is equal to v 2 bar A 2. So, you can directly substitute these quantities also, if you required.

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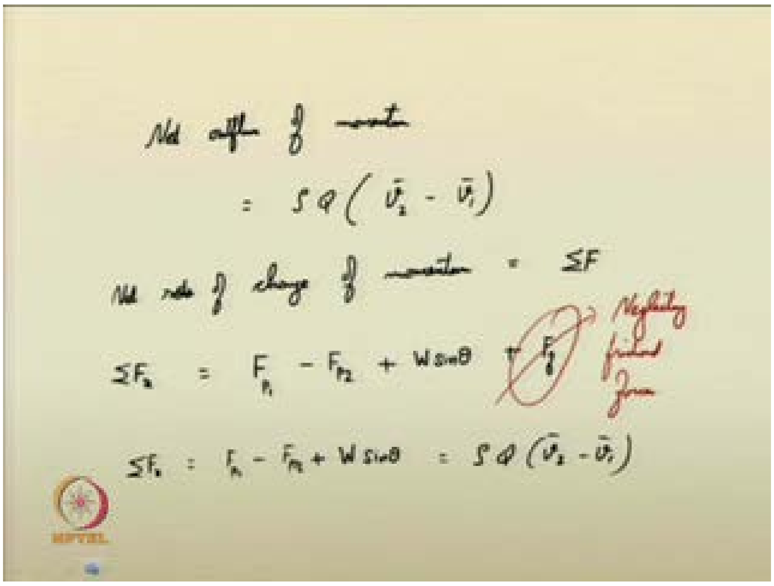

So, I can write, the net outflux of momentum, net outflux of momentum through the control surfaces is nothing but, rho into discharge into, v 2 minus v 1 bar. The net rate of change of momentum is equal to the change of, rate of change of momentum is equal to the net force in the control volume.

For example, in the direction of flow, so in the direction of flow, in the direction of flow, let me consider the net force as sigma F x. Therefore, sigma F x, it consist of, just look into the picture here, it will consist of pressure force that will act on this control volume, pressure force that will act, sorry, on that control surface there, pressure force that acts on the control surface there, here. And, as this is predominantly one dimensional case, we are not considering any flow perpendicular to the screen, whichever you are seeing here; you are considering only a unit width in the perpendicular, in the perpendicular direction to the screen here. So, and the top and bottom boundaries, they are not allowing any flow passing through them.

So, the pressure forces will be on this location, and as well on this location. So, I can give this as F p 1, then F p 2. You have component of weight in this direction, so the net force will be F p 1 minus F p 2, plus W sin theta. Actually, theoretically speaking, frictional force should also have been there; but, you are neglecting frictional force, you are neglecting frictional force for all types of hydraulic jump.

So, we can now suggest sigma F x is equal to F p 1 minus F p 2 plus, W sin theta is equal to rho times discharge into, v 2 minus v 1. Once you get this relationship, now you can easily identify what are the pressure forces- F p 1, F p 2; and, what is the force due to the weight, that also can be taken.

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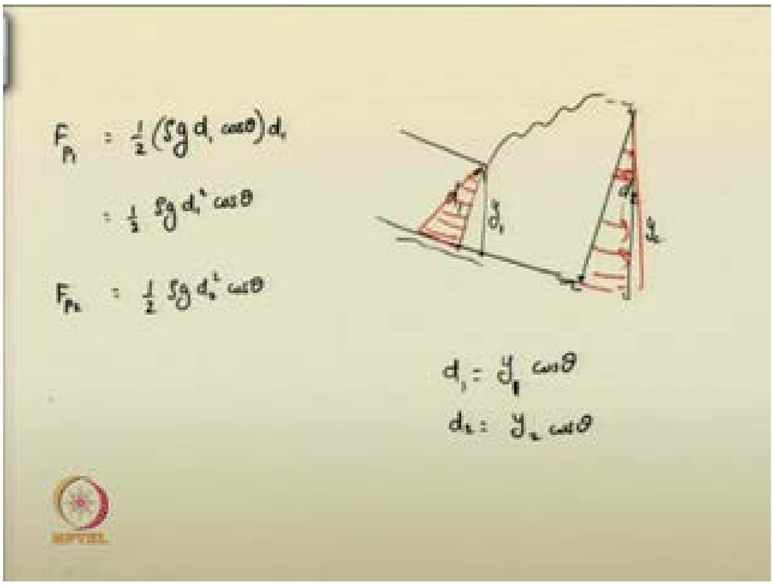

So, what is F p 1? Say, if you have a depth like this; this is depth d 1; the corresponding, from this location, the depth to the bed will be actually vertical depth will be y 1, right. And, it is on this direction, the pressure forces will be acting. So, we have F p 1, the pressure force will be or the pressure distribution can be given as such; and this force is evaluated as F p 1 is equal to half times rho g d 1 cos theta into d 1; so, this is nothing but, equal to half times, rho g d 1 square cos theta.

Similarly, in the upstream, sorry, downstream condition, where the slanting depth is d 2 and vertical depth can be considered as y 2; you know the relationship, d 1 is equal to y 1 cos theta; d 2 is equal to y 2 cos theta; it is simple trigonometrical, this thing, relationship. Pressure force on this boundary, I can just give it as the pressure distribution like this; there also F p 2 is equal to rho g d 2 square cos theta. What is the weight of water? How do you take into account of weight of water?

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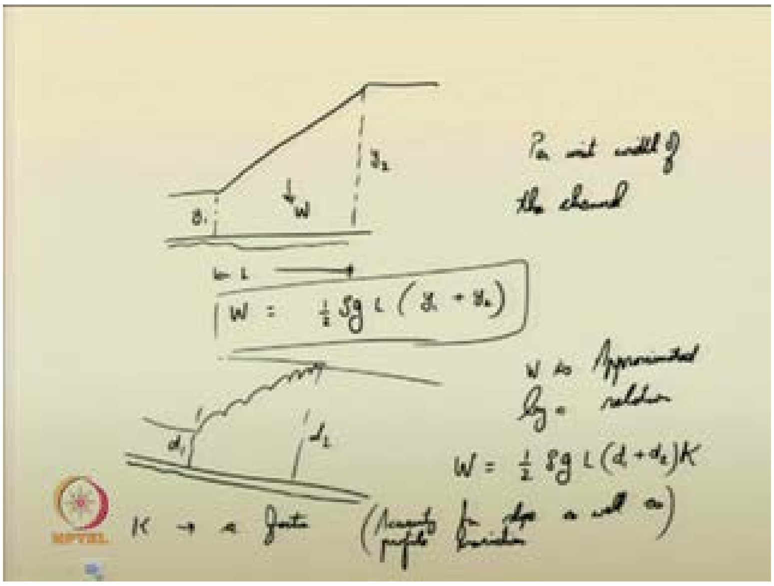

If the jump was in a horizontal channel, if the jump was in a horizontal channel and if the profile, hydraulic jump profile is a straight line, like this, if it is a straight line like this, then it would have been much much easier for you to evaluate the weight of water, right. In such situation, W is nothing but, equal to; here, this is y 1, this is y 2, and say, this is the length of the jump L. So, W is equal to half times; you are taking per unit width of the channel or stream, you are taking the conditions; so, the weight per unit width of the channel or stream, this can be given as half times rho g, L into, y 1 plus y 2. So, this is the theoretical, theoretically possible weight of water for such a ideal situation, where the flow profile is a straight line.

Now, in this sloping channel, we already have a slope; not only that, the jump is not having a straight, means, the hydraulic jump profile is not a straight line. So, taking into account all these factors, taking into account all these factors, we can approximate; W is approximated by a relation. such a way that W is equal to half times rho g, L into d 1 plus d 2; same as the above case, but this will also be multiplied by a factor K; so, K, a factor; it is greater than 1, usually greater than 1; and this factor is being taken so as to account, take it accounting for slope as well as profile variation. So, we are taking a factor like this.

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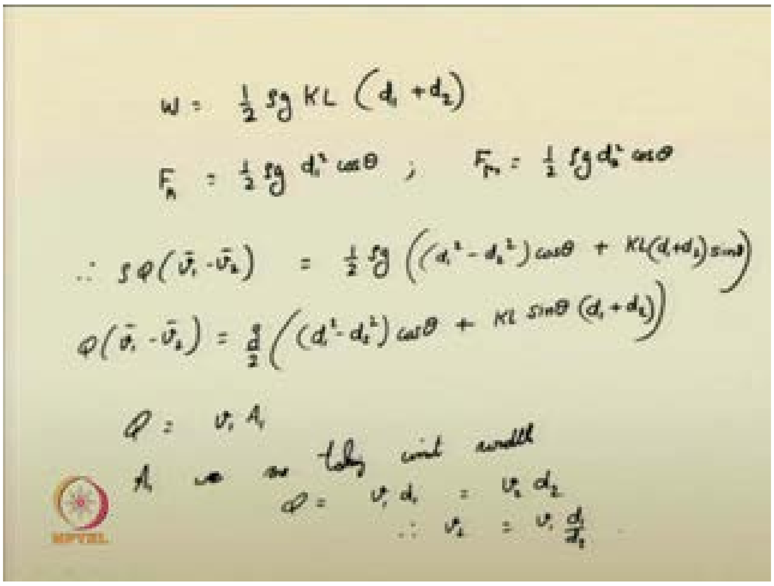

So, we can now write; say, W is equal to half times rho g, K times L into, d 1 plus d 2. So, you also have F p 1 is equal to half times rho g, d 1 square cos theta; F p 2 is equal to half times rho g, d 2 square cos theta. Therefore, going back into the equation, going back into this particular equation, we will be writing it again, rho q v 1 bar minus v 2 bar is nothing but, equal to half times rho g, d 1 square minus d 2 square cos theta, plus K L, d 1 plus d 2, and w sin theta is the component, right; so, K L d 1 plus d 2 sin theta.

So, we can eliminate rho from the equation. We will see Q times v 1 bar minus v 2 bar is equal to, g by 2 d 1 square minus d 2 square cos theta, plus K L sin theta, d 1 plus d 2, like this you can write. So, we have already seen Q, it is function of; Q is nothing but, v 1 into A 1.

Now, as we are taking unit width, we are taking unit width; perpendicular to the screen here, you are taking the unit width, right. So, Q is nothing but, v 1 into d 1; this is also equal to v 2 into d 2. So, what does that mean? You can have easily the relationship v 2; therefore, v 2 is equal to v 1 d 1 by d 2. Why we are writing it like this? Because the pre jump depth and the pre jump conditions are mostly available to you. So, we are determining the post jump situations with respect with the pre jump. Therefore, I am writing, velocity v 2 is equal to v 1 times d 1 by d 2. You can substitute those quantity in the above equation.

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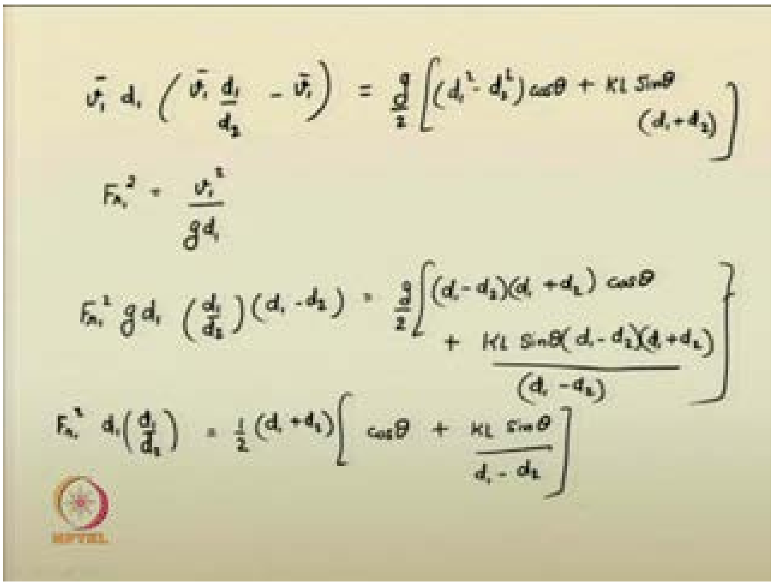

You will see that, this becomes rho, sorry, v 1 bar d 1 into, d 1 by d 2 minus, v 1 bar is equal to g by 2, d 1 square minus d 2 square cos theta plus, K L sin theta into, d 1 plus d 2. Like this we can rearrange them. We can again work it out; you will see that, say, we know the upstream froude number; so, upstream froude number is nothing but, v 1 square by g d 1, right. So, this square root, sorry, the square of the froude number can be described like this.

You can directly substitute this quantity now, in the following equation also. So, you will get F r 1 square, g times d 1 into, d 1 by d 2 into, d 1 minus d 2; this is nothing but, equal to g by 2, d 1 minus d 2 into, d 1 plus d 2 cos theta plus; you can again write it; rearrange the quantities here, K L sin theta, d 1 minus d 2 into, d 1 plus d 2 by, d 1 minus d 2, just for our benefit, so that I can now cancel d 1 minus d 2 everywhere; for that purpose, we have written it like this. So, this equation becomes, F r 1 square d 1 times d 1 by d 2 is equal to, half of d 1 plus d 2, into cos theta plus, K L sin theta by, d 1 minus d 2; like this we can come into derivation there.

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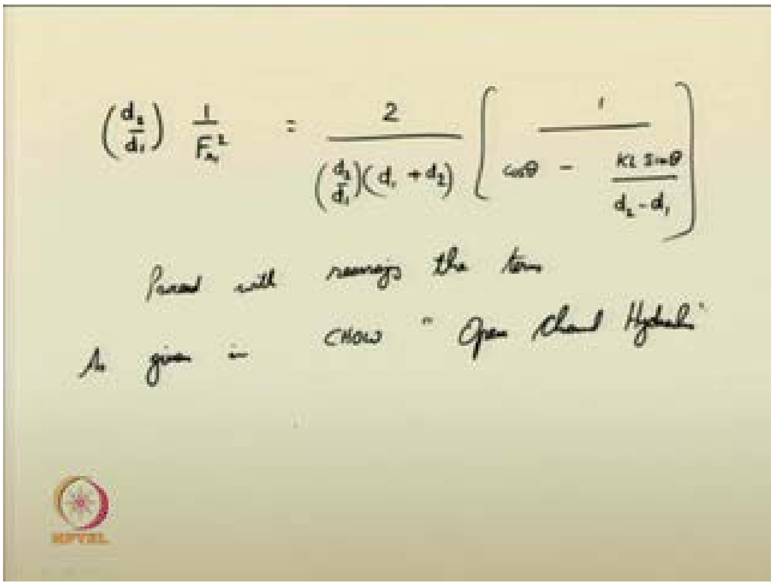

You can again, you can again rearrange the things here. That is, d 2 by d 1 into; you are just taking the inverse of the above relationship, you will get the following form; 2 by, d 2 by d 1 into, d 1 plus d 2 into, 1 by cos theta minus, K L sin theta by d 2 minus d 1. Here, I have just taken it; instead of d 1 minus d 2, d 2 minus d 1; therefore, that negative sign appears in the formulation.

You can further proceed, proceed with rearranging the terms. So, I can just, means, we can follow it. Now, at this stage, we expect you to work it out further. And, as given in Vente Chow's book, Vente Chow's "Open Channel Hydraulics", the above equation can be simplified and it can be written in the following form: d 2 minus d 1 whole cube by, a quantity g, 2 g square plus 1; ok, I will just write it in the next page.

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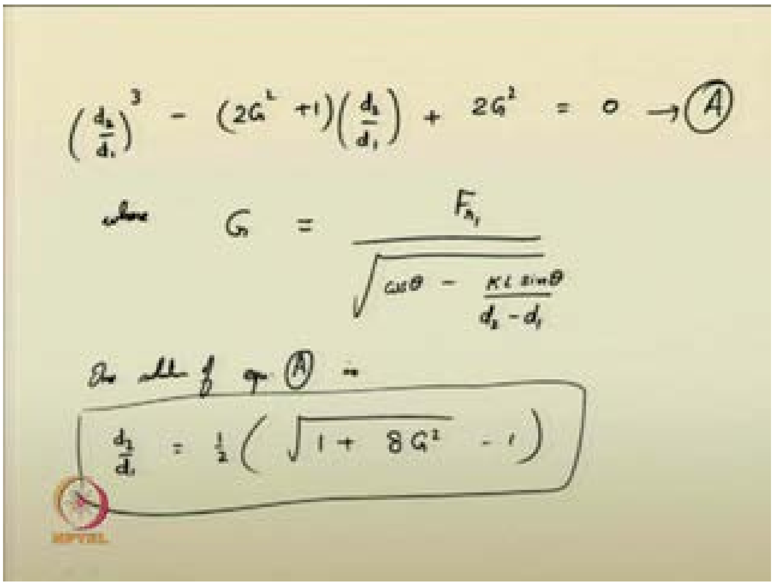

This simplified form, d 2 by d 1, whole cube minus, 2 G square plus 1, d 2 by d 1 plus, twice G square is equal to 0, where the quantity G is nothing but, equal to the upstream froude number divided by the square root of cos theta minus, K L sin theta, d 2 minus d 1. So, if we can define G in this way and if you incorporate, you can see third degree polynomial or an equation with respect to d 2 by d 1, and that can be now easily used.

You will see that one solution of this equation; say, if I name it as A, one solution of equation A is d 2 by d 1 is equal to half of, root of 1 plus 8 times G square minus 1. So, if this is clear, you will see that, you will get a depth ratios for the sloping channels, d 2 by d 1 is equal to, in the following form or so, right. So, this, like this relationship also you will get for the sloping channels.

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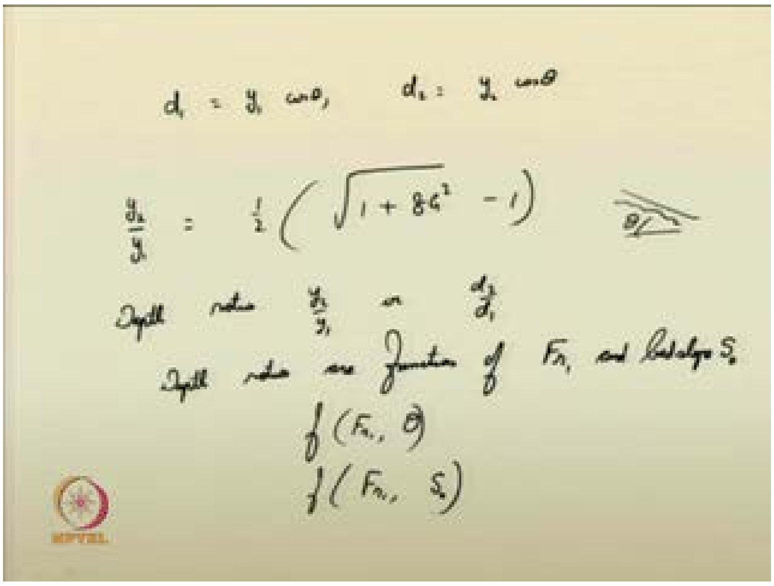

As d 1 is equal to y 1 cos theta, d 2 is equal to y 2 cos theta, the above relationship can be changed to vertical depth, y 2 minus y 1 is equal to half of, root of 1 plus 8 G square minus 1, right. So, you are getting the depth ratios, y 2 by y 1, or d 2 by d 1.

So, this function, that is depth ratios, they are, are functions of the upstream froude number and bed slope; say, you have the bed, channel bed like this and this is theta, so definitely it is a function of theta, right. So, theta, means, that it can represent it in terms of the bed slope S 0. So, we write this as function of F r 1 and theta; either like this function of (F r 1, theta), like this I can write, or I can write function of F r 1 and the bed slope S 0; like this also one can write.

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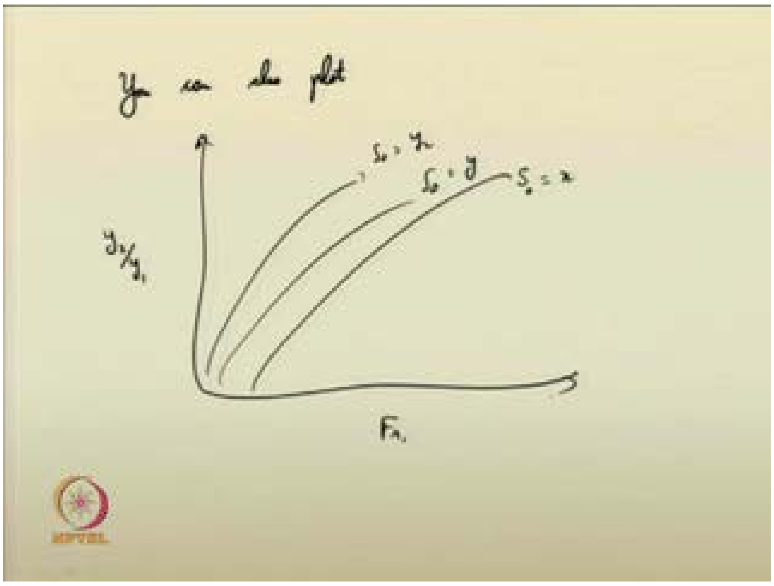

You can also plot, you can also plot; that is F r 1 versus y 2 by y 1; say, like this, different curves you will get for different slopes. Say, S r, S 0 is equal to some magnitude x, S 0 is equal to some magnitude y, S 0 is equal to some magnitude y 2; whatever it be, some magnitude. So, for different slopes, you can plot this thing. And, this standard charts are also available. One can easily go through that chart and also get the sequent depth, if this, for the corresponding slope, that is also quite possible.

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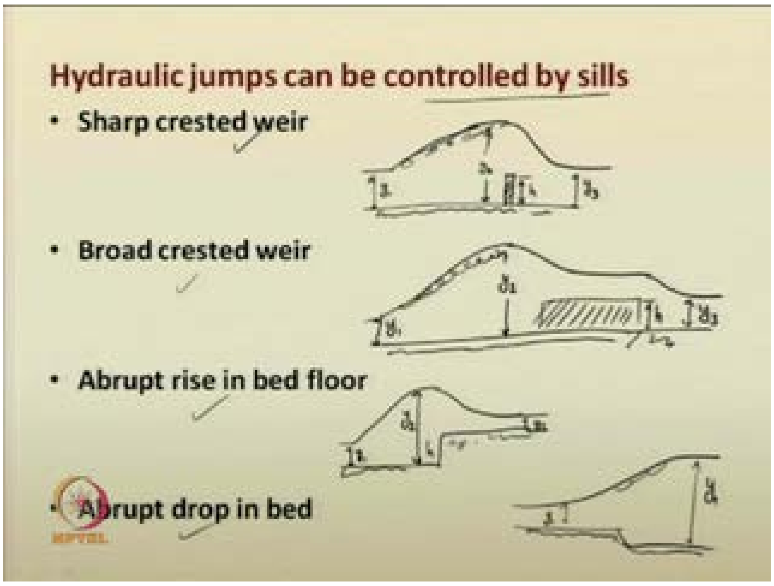

Next, we will discuss on control of jumps. Hydraulic; as we have studied earlier, hydraulic jumps require some certain control, so that it will be held within that stilling basin. Otherwise, you have seen how it can be pushed in the upstream, or it can be pushed downstream, or it can get washed away; so, there various provisions of controlling the hydraulic jumps.

And the jump, one of the important things is, or one of the most commonly used thing is, sills. You can control hydraulic jump by sills. What are the sills? You can use sharp crested weir for controlling the hydraulic jump, you can use the broad crested weir, or you can provide abrupt rise in the bed floor, or you can provide abrupt drop in the bed flow.

How it looks? For example, a sharp crested weir, if I draw the channel longitudinal profile of the thing; so, you are having a hydraulic jump like this with rollers and all, then you see that, you want to control it within this span, so you are providing a sharp crested weir here; so that, the file now looks like this. So, this is the pre jump depth y 1, this depth is the sequent depth of y 1, and this is the tailwater depth; and the height of this sill, this sharp crested weir sill is h.

Similarly, for a broad crested weir also can be employed for controlling the hydraulic jump in, within the specific location; so, if you have a jump, now, by providing a sharp crested weir somewhere here, you may see that flow profile will go like this, and it may come up like this. So, again, this is tailwater depth y 3, this is the prejump depth, this is the sequent depth of the jump, and this is the height of the sill. Similarly, so, we can just provide rollers, so that it is suggesting hydraulic jump; it is not a gradually varied profile, it is rapidly varying profile.

Similarly, if you, you can provide abrupt rise of the bed; say, this same jump can provide abrupt rise; so, it will come like this, and it will go, continue with those thing; the bed will be trice from this location. So, this is y 2, y 1, and this is y 3, so height of the sill is same h. Similarly, abrupt drop in bed; so, we will see, for what all conditions these things are being taken into account. Abrupt drop means in the bed. So, this is the sequent depth, this is the prejump depth. So, we will discuss all those things.

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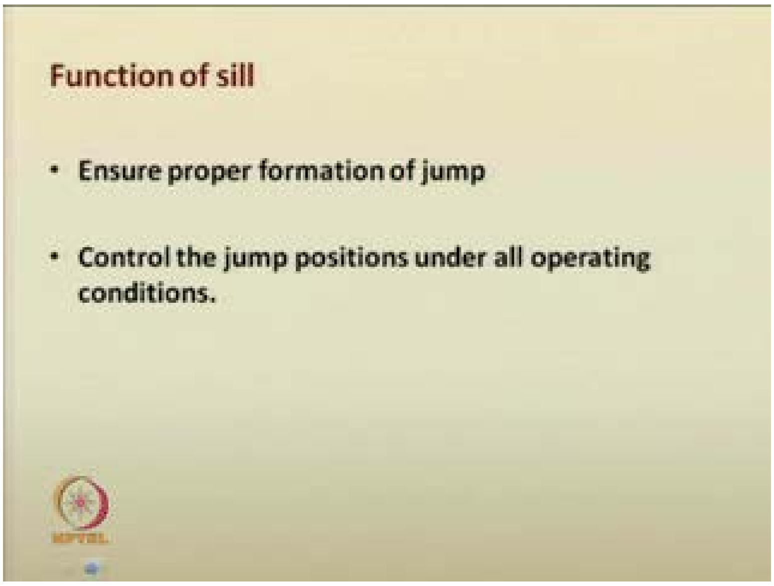

So, what is the function of a sill? Means, the sill has to ensure proper formation of the jump within that stilling basin, and also to control the jump positions under all operating conditions. So, the flow may vary in that; say, say, in that channel, the flow may vary, the amount of discharge may get varied and all. So, you have to ensure that the jump is occurring in that position, particular position itself. So, for those condition also, the jump, control of jumps are required.

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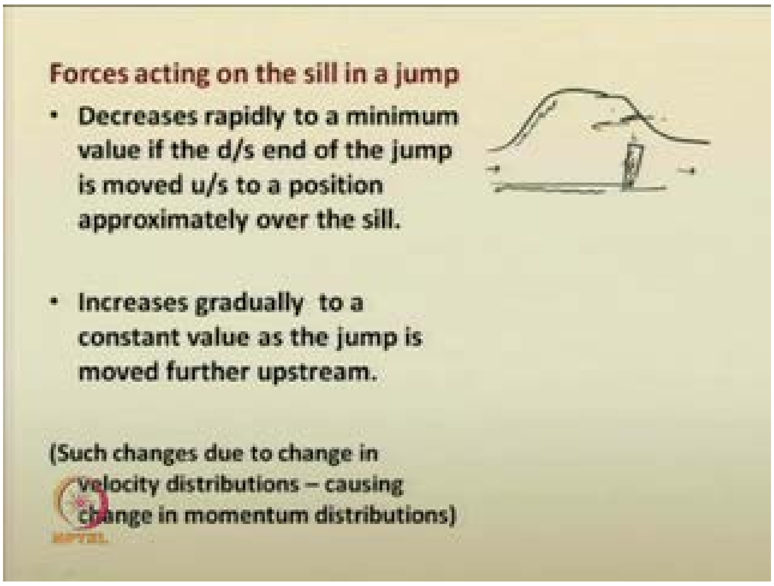

So, what are the various forces? You can see that, the different forces acting on the sill on a jump. So, the forces, it decreases rapidly to a minimum value, if the downstream end of the jump is moved upstream to a position approximately over the sill. For example, if I am providing a weir, sharp crested weir, and you see a jump position is like this, in this case. So, here, what happens is that, whatever force is there; suppose if the jump would have been extended further downstream, and if this is moved in this direction, the jump position is, it will be minimum over the sill. So, the jump position, it should end at the sill, top of the sill; then, the force exerted on the sill will be minimum. Now, if it goes further upstream, the forces may gradually increase. So, that way, one can design the jumps for the, or you can provide proper designs for the control mechanisms.

What are the reasons that cause such changes in force? You know that; the velocity distribution both in the upstream and the downstream conditions, just in the jumps, jump situations, it may not be uniform or it may be quite different, due to various strolling effects and all. So, there will be different momentum distribution as well, that can causes different distribution of forces and all. So, you can, you can describe those theory in that way.

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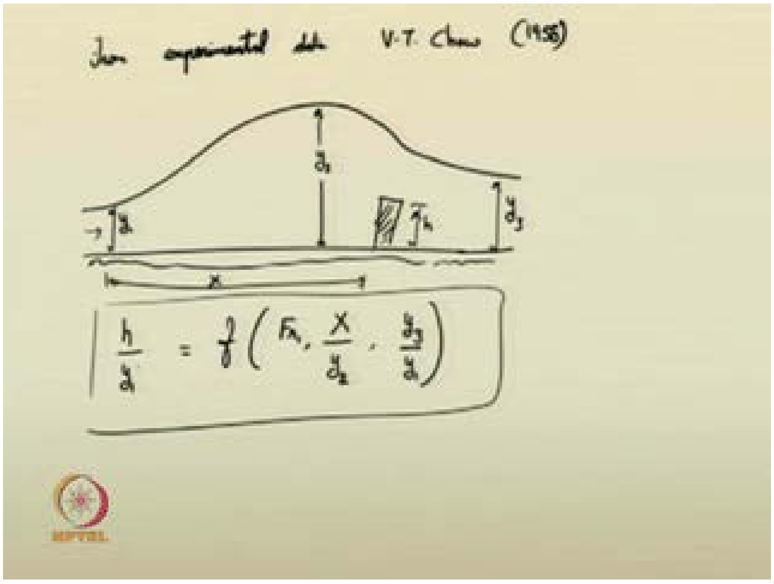

So, from the experimental, from, you, it is quite difficult to theoretically explain; theoretically explain, or quite difficult to theoretically formulate the equations related to control sections and all. So, many experimental studies are done.

So, from the experimental data as given in V.T Chow’s book, V. T. Chow’s, it is a quite old book on “Open Channel Hydraulics”, so very standard book. So, if you refer that book, you will; say, for example, in the case of a sharp crested weir or any case, any sill; not only sharp crested weir, broad crested weir, or abrupt rise, whatever be, so there are the following parameters; that is the height of the sill, the prejump depth, the sequent depth of the jump, and the tailwater depth; following 3, 4 depths are available, or following 4 depths are present in such control mechanisms.

So, from various experimental studies, it has been observed that the ratio, the following ratio that is the height of the sill by the prejump depth, they have considered it as some function; it is some function of the incoming flow froude number. That is the froude number at this incoming section, or at the prejump depths, prejump depth section; ratio of X by y 2, and ratio of y 3 by y 1. What is capital X here? It is the distance from the toe of the jump to, or from the beginning of the jump location to the toe of this sill. So, this distance is called X.

So, like that, from the experiment scientist, it is been observed; means, this particular or this particular means, it is a ratio h by y 1 is always a function of froude number X by y 2, and y 3 by y 1. So, once you incorporate these mechanisms, then the design of this sill will be appropriate; or means, you can design the sills in a better way.

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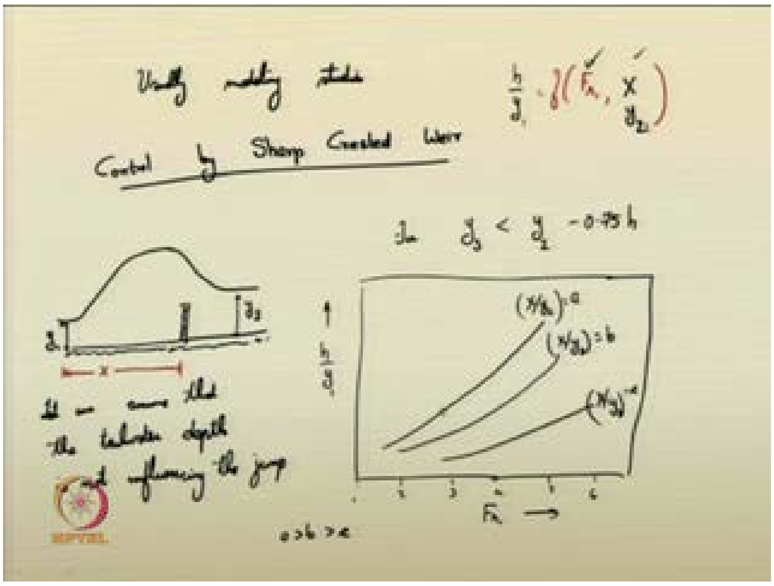

So, usually, we used modeling studies. As we told earlier, the theoretical studies or theoretical explanations are quite difficult. So, using modeling studies, we can define these for various conditions; we can define for sharp crested weir, for broadly crested weir and all; we can define, or we can device charts for designing purposes. So, modeling studies means dimensionless analysis. You use the various dimensions and all. You can obtain the non dimensional forms and all. So, using those mechanisms and all, one can infer the design mechanisms for sills.

For example, control of jump by sharp crested weir; say, if you have sharp crested weir, how do you control the jump? I have the jump here, and I am incorporating a sharp crested weir. So, let us consider this as y 1, y 3. I hope, you all recall that the hydraulic jump portion, whichever we are studying right now, it is in steady state condition. So, and in this particular case, let us assume; let us assume that the tailwater depth is not influencing the jump, the tailwater depth is not influencing the jump.

If we give this assumptions and all, so you will see that for y 3, say, these mechanisms, that is the tailwater will not influence the jump; it can be suggested only for the following cases. That is, when y 3 is less than y 2 minus 0.75 h. This is also empirically, means, they have obtained it through their experimental study. If y 3 increases beyond this thing, then it definitely affects the position of the jump and all.

So, based on this criteria, we can device the following charts; you can see them. So, if y 3 is not influencing the thing, case, then as we suggested h by, in the previous slide, h by y 1 is equal to; so, h by y 1 is equal to function of froude number X by y 2, y 3 by y 1. Now, if y 3 is not influencing the hydraulic jump, then we can easily suggest; your, following this thing is, in this case is, h by y 1 is some function of froude number and y 2 by y 1, because y 3 is not influencing the situation.

Again, how do you define this, a situation? Now y 2, we cannot say it is exactly measureable, or y 1 is a more appropriate term that can be measured; and, for designing, we want to, basically we want to know at what distance from the beginning of the jump should we provide the sill. So, this X is a important parameter that we need to design, isn't it. So, that way, we can now suggest that, following relationship; that is, we can device curves, h by y 1 ratio with respect to the incoming flow froude number following curves; say, froude numbers, it may be 1, 2, 3, 4, 5, 6, like that.

So, we can have various curves for different values of x by y 2. We can have various values for X by y 2, as suggested here. So, X by y 2 is a relation. So, we have, in this case, for sharp crested weir, h by y 1 is ratio of F r 1 and X by y 2. Therefore, this is one particular curve. For another value of X by y 2, you have, say, let me write this as some numerical value a. Say, please note that, it is not a variable; it is just some numerical value a. It can be 1, it can be 2, it can be 3, 4; this is for X by y 2 is equal to, certain quantity, say b; X by y 2 is equal to c.

So, such designs or such chart sheets, if you can prepare, from your experimental or modeling studies and all; definitely here, you should note that a is definitely greater than b, it is greater than c. So, if X by y 2 ratio, if it is small, your curve will be h by y 1 verses F r 1 curve, will be looking like this. If it is little bit greater, it will look like that; for higher values of X by y 2 ratio, it will be looking like this.

So, like these curves you can prepare, and based on that, based on the means, you can now appropriately suggest what could be the height of the sill, given, given the following criteria and all. Say, for a given froude number the, if that froude number is maintained, you can suggest that if the X by y 2 ratio is a, then the h by y 1 ratio should be following thing; one can easily interpret for designing.

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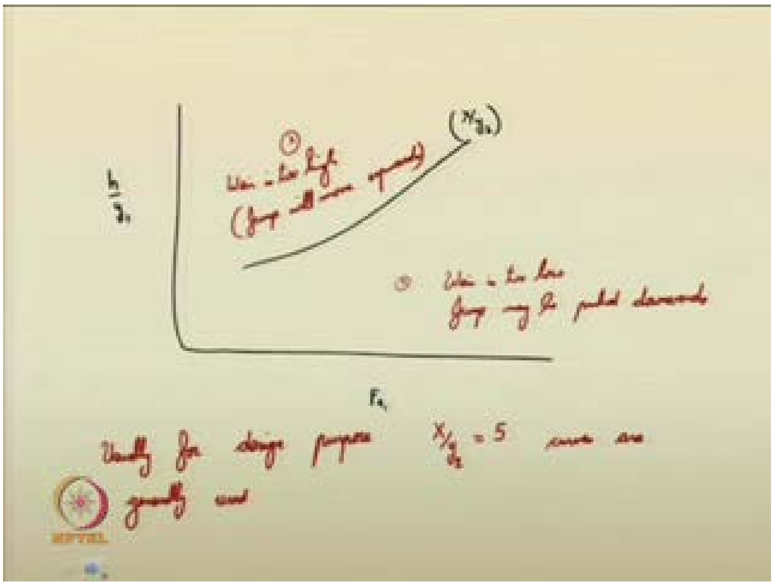

So, again, I am just redrawing the thing here. You can see that, as this is froude number, this is h by y 1 number, and this is the curve for any particular value of X by y 2 ratio. So, in this case, you have, say, points lying above this particular line of x by y 2, you have points lying below, and also on the right of this X by y 2 curve. So, you can have 2 different situations. What does this infer?

So, here, points that lie above this particular curve, it suggest that weir is too high is these locations; so, for such ratios the weir height is, or the height of the sill, sharp crested weir is too high. In this, these cases the weir is too low. So, the jump; weir is too low; so, the jump may be pushed, jump may be pushed downwards; further downstream the jump will be pushed; or it may get washed away also. In this case, the jump will move upwards. So, for the following X by y 2 condition, if you are providing the h by y 1 ratio in the upper cases, so this is what it will happen; that is the meaning of these, such curves and all.

So, usually for design, usually for design purpose, the curve meant for X by y 2 is equal to 5 ratio, whichever curve is developed; that is generally used for the design purpose; here generally used.

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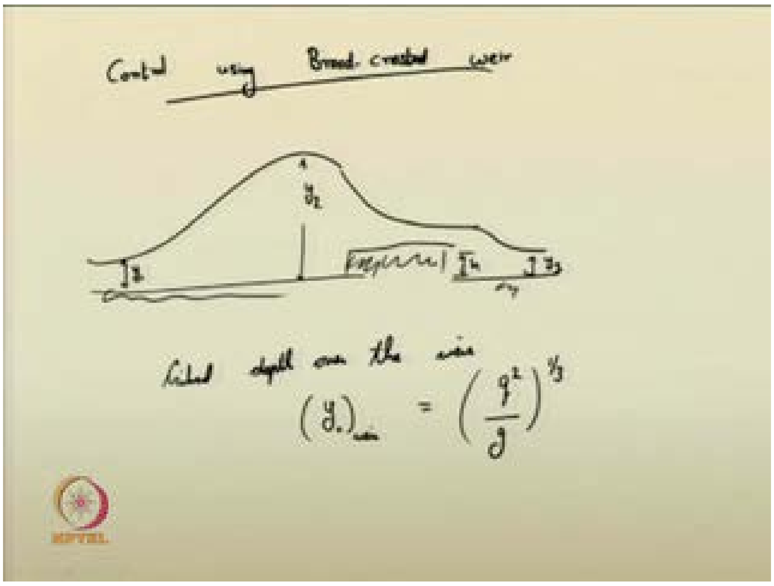

Next, we will see control; there is the, again the control of jump using broad crested weir. So, you have a broad crested weir for the jump. So, you can have different tailwater depth, let us see; again, this is the prejump depth, this is the sequent depth of the prejump, this is the height of the sill, and here let us assume y 3 as the tailwater depth.

So, for these following conditions; or the once criteria or one of the situations that is how the broad crested weir act as a control is that; one thing you have to remember is that the minimum possible flow or the type of flow that can be possible over the weir, it should be at least critical, right; that is, you are having a subcritical flow here, and it will just slow down the; that is, it will just low down and it can reach up to the critical flow, that is the requirement.

So, using the specific energy theorems and all, you can easily device, what should be the depth of flow over the weir, broad crested weir and all. Like that it can be deviced. Again, y 3; so that we cannot, we do not have influence of tailwater depth on the flow, for that criteria, is the thing suggest.

So, you know that critical depth over the weir, this can be given as y c over the weir; this is equal to the discharge per unit width by g whole to the power of 1 by 3. This you, I hope, you can require, as we are all taking the rectangular weir; that is the reason. So, q is discharge per unit width.

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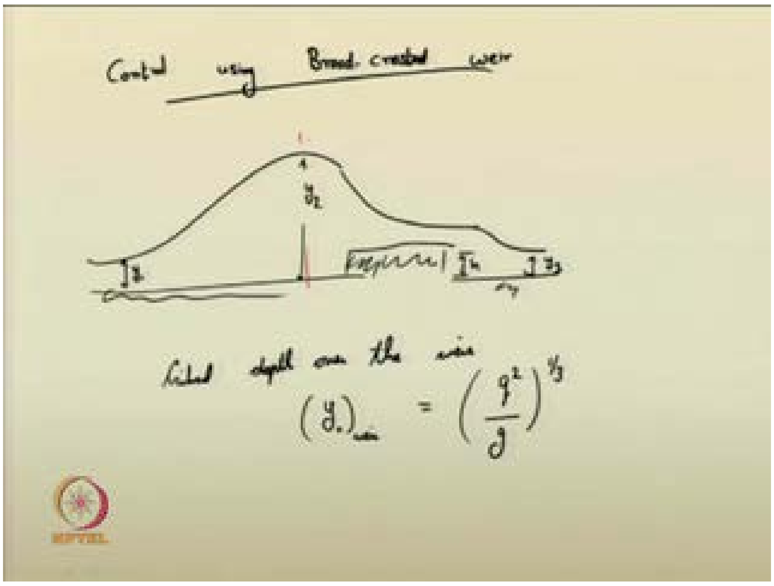

So, applying the conservation, means, was specific energy theorem, just say in this particular situations; say, may be in this following sections.

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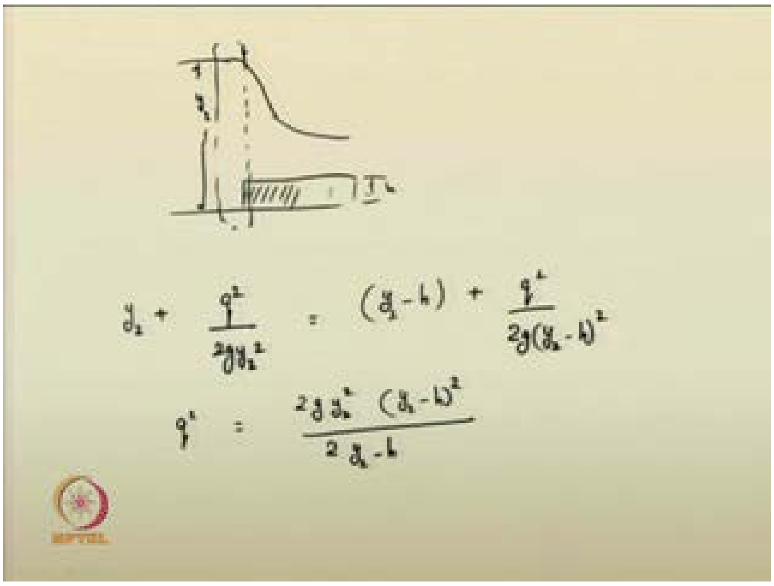

So, using the specific energy at equation for the 2 sections; say, this is your broad crested weir of height h. Then, this is where the jump is coming now. So, for these 2 sections, in these 2 sections, we can suggest; say, here this is y 2. So, between these 2 sections, the energy equation will look like this: y 2 plus q square by 2 g y 2 square is equal to; so, here this is y 2 minus h, y 2 minus h plus, q square by 2 g y 2 minus h whole square.

So, using such specific energy equations, you can now find the relationship of q square; that is, what is the discharge per unit width. So, that you can get it as 2 g y 2 square into, y 2 minus h; you just rearrange the terms, you will get the following relationship, fine.

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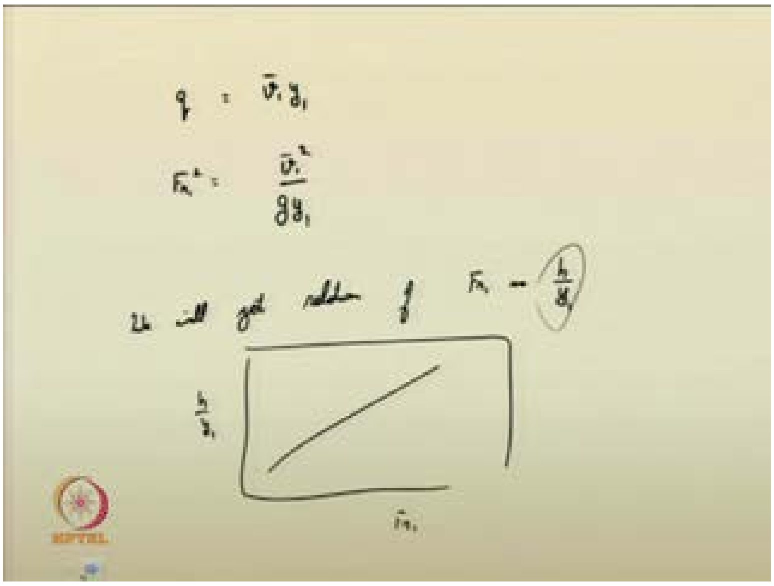

Now, we can also see that q is nothing but, the velocity at section 1, that is prejump depth, at the prejump condition. So, this is a known value to you; velocity is known to you, y 1 is known to you, so that also you can easily, it is available. You also know the froude number at the prejump section, v 1 square by g y 1, is the square of the froude number.

So, you can substitute these quantities in the, this particular equation, fine. And, what we will get is that, we will get relations of froude 1 versus h by y 1. So, if these plots are given to you; so, for different values of froude number, what is this depth ratio, h by y 1 for this condition; if it is plotted, you can design the sill appropriately.

So, you can give such plots now; say h by y 1 for different froude number. You can plot like this. Now, here, you will see that, the, the ratios are only functions of h by y 1 and froude number; or h by y 1 is function of only froude number; we are not taking X by y 2, or even y 3 by y 1 ratios and all. So, that is only for the broad crested weir.

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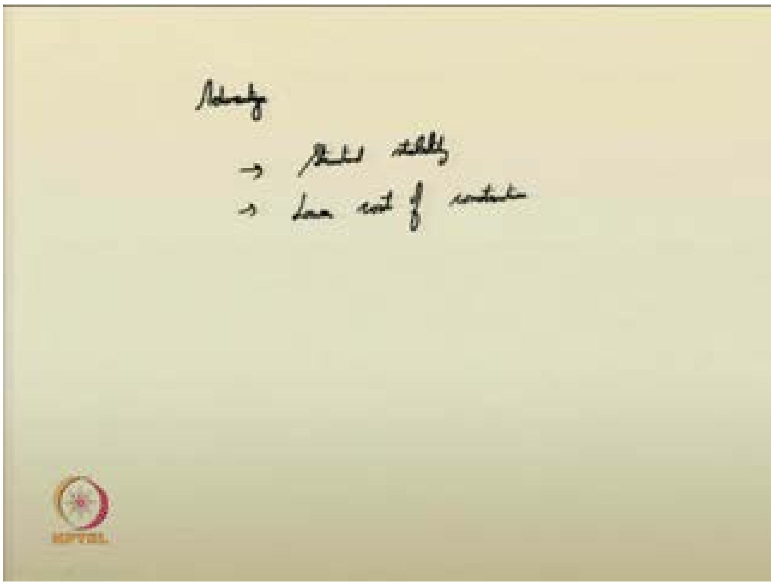

What is the advantage of broad crested weir, advantage of broad crested weir? So, broad crested, they are structurally stable, structural stability and lower cost of construction compared to abrupt rise. So, for these cases, you use broad crested weir. So, that way I was thinking of continuing the other 2 cases of controls; but, however due to time limit we will continue it in the next class. We will have a quick quiz related to the following topic.

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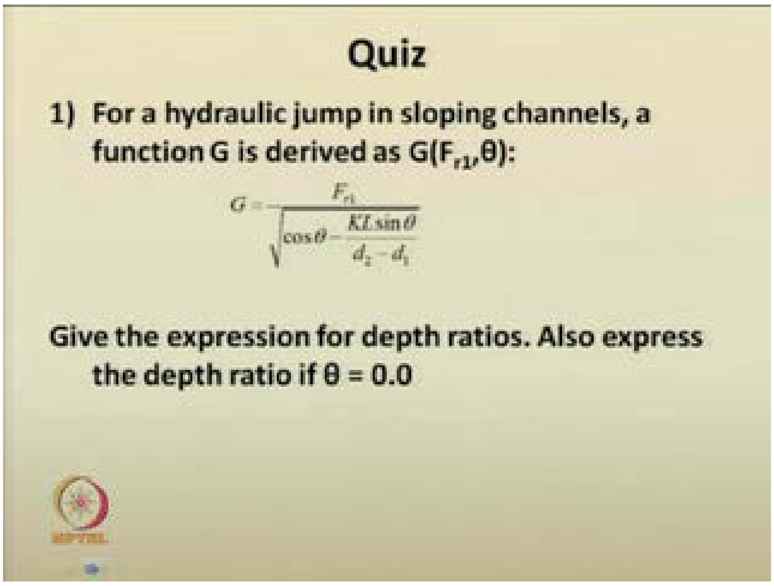

So, the first question is: For a hydraulic jump in a sloping channel, a function G was derived, that is G is function of froude number and theta, if you recall them, so that is G was given in the following form. Give the expression for depth ratios. Also express the depth ratio if theta is equal to 0.

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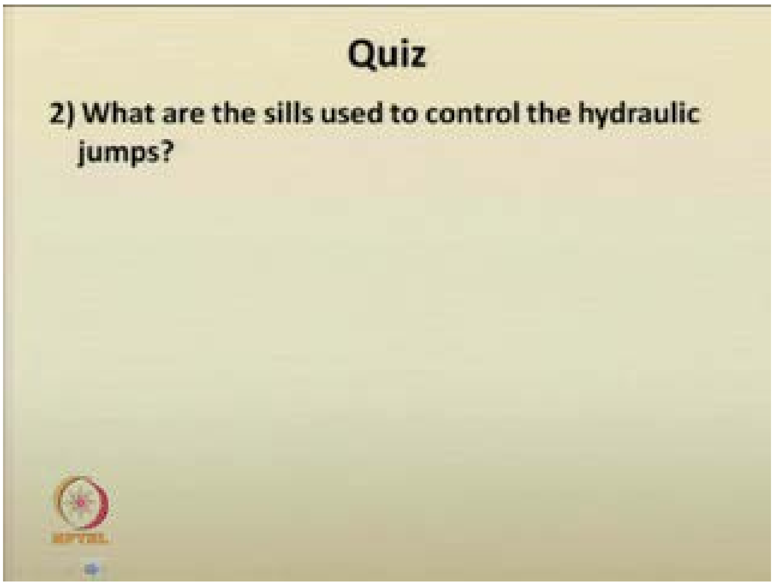

Your second question: What are the sills used to control the hydraulic jumps? What are the different sills you have just; so briefly tell them; no need to describe about them, just give the names.

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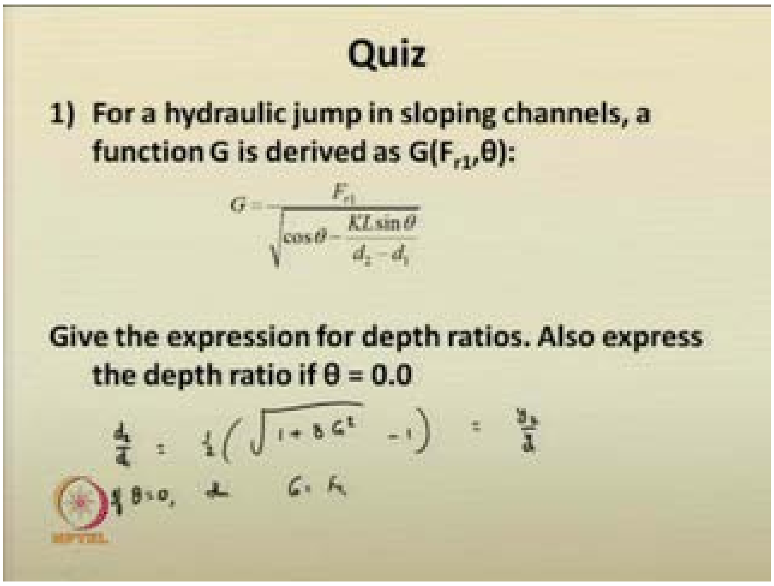

So, the solutions for this case are, you have the depth ratios d 2 by d 1 is equal to half of, root of 1 plus 8 G square minus 1. This is same as the vertical depth ratio, y 2 by y 1 also, right. This is how the depth ratio expression is given to you. So, if theta is equal to 0, then what happens? G is equal to F r 1 itself. So, you will get the depth ratio y 2 by y 1 appropriately.

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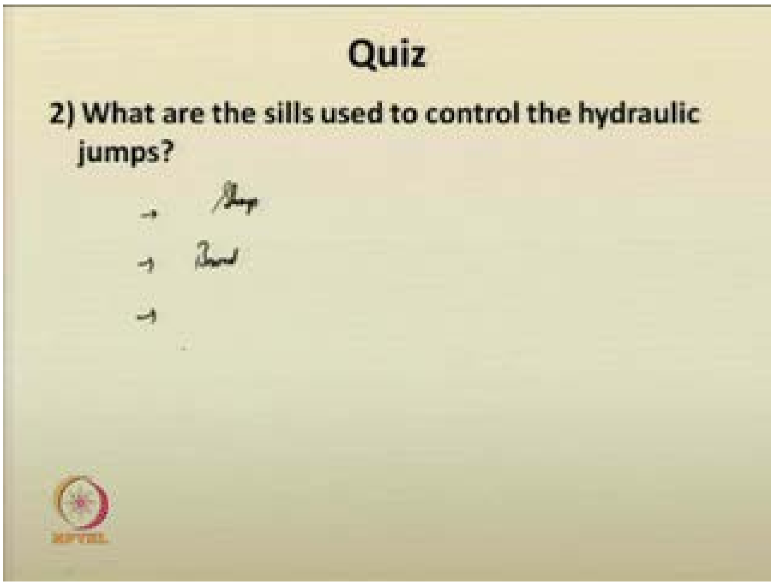

For the next question: What are the sills used to control hydraulic jumps? So, you know the solution for that; broad sharp crested, broad crested, then abrupt rise, abrupt, abrupt rise in the bed, abrupt, lowering of the bed. So, these are the answers for the second question.