Hydraulics

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Module No. # 05

Rapidly Varied flow

Lecture No. # 02

Flow over hump and channel contraction

To provide the culvert width equal to the width of the channel, we are probably contracting at that point; similarly, in the bridge also bridge are normally made narrow than actual width of the channel. So, in that sort of situation for providing sluice gate also we narrow down the channel width, then we provide for a particular portion the gates for all those situations, there is a contraction of the channel and for that situation how the flow behave.

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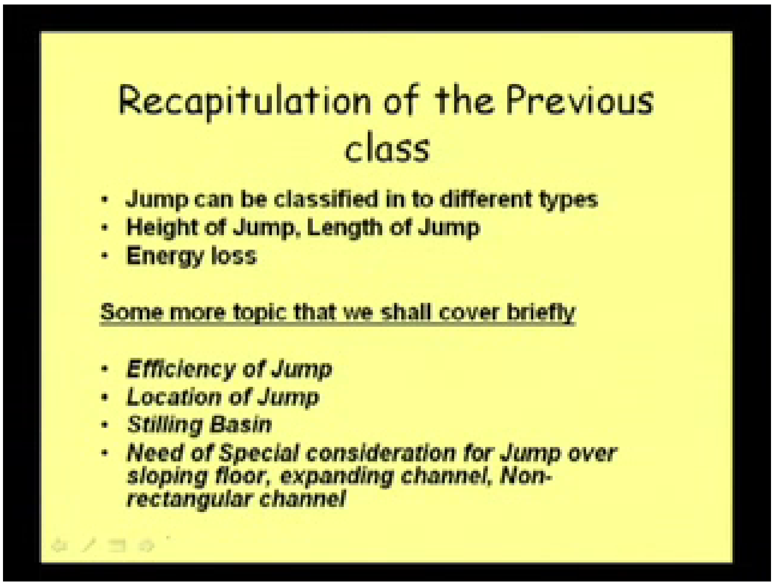

Well, let us first see what we did we did in last class, we covered that jump, how the jump can be classified that we could see, then we were discussing about height of jump and about length of jump. How we should I mean measure this height and length of jump? We should try to do it as precisely as possible and it is difficult in laboratory also.

And then, we were starting a discussion about the energy loss, how the energy gradient line suddenly drop in the hydraulic jump portion and on the upstream of hydraulic jump, if we neglect other loss, then head loss is neglected or quite insignificant, at the downstream of hydraulic jump also head loss is insignificant. If we consider this to be that frictional loss and other things are negligible, but in the portion of hydraulic jump, in the portion of hydraulic jump all forms of loss will be coming and that way the significant loss of energy will be there and hydraulic gradient line will drop suddenly at that point.

Well, we will start with that today, then of course, we will be discussing on efficiency of jump by what, when we are talking about a particular device, because jump is now we can say it is a device that we use for our various hydraulic design, in our hydraulic structure for various purpose. Then what is its efficiency, when we talk this as a device, then we need to know what its efficiency is so that we will discuss, then location of jump we have discussed to some extent that will again review just briefly. Then stilling basin I did mention in the last class, but still in the previous class I did mention and that again will just see.

And then we should know one point that, what we are discussing here or what we are discussing in this particular class is not all about hydraulic channel, there are some other issues that are related to hydraulic jump and we should know our limitation that we have studied up to this much and we need to study something more about that, that we will do.

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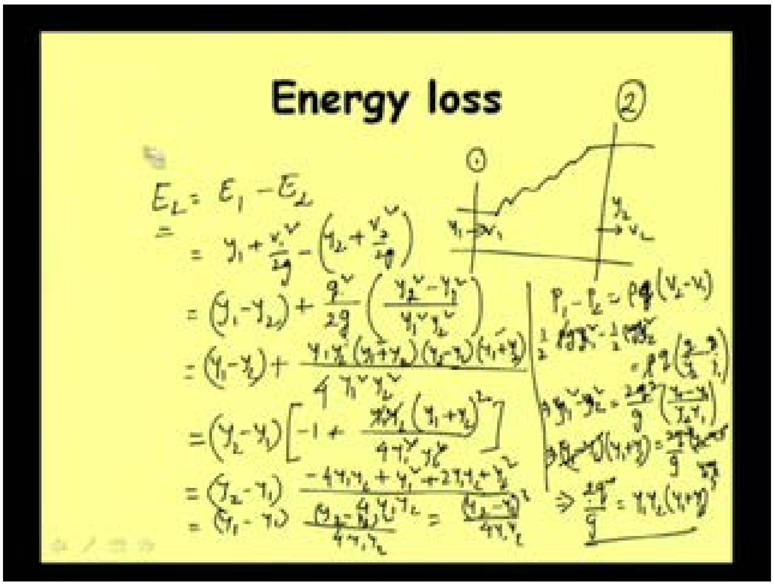

So, how we can calculate the energy loss, let us see that first. Say this is the hydraulic jump and this is our upstream section 1 and this is downstream section 2 and we are just giving this as y 1 and y 2 and say velocity is V 1 and here it is V 2 (Refer Slide Time: 03:55). Again, if we consider this as a rectangular section, then our expression become simple; otherwise, of course we can always find for different section also just to have in a simple form. Say in rectangular section, what we can do?

Say, energy loss E L is equal to E 1 minus E 2 and E 1 minus E 2 is nothing but, say y 1 plus V 1 square by twice g minus y 2 plus V 2 square by twice g or that we can write as y 1 minus y 2. So, for V square by twice g is concern, that we can write as say V square is nothing but, q square divided by y square. So, what we can write q square by say let me write this twice g here and then this expression can be written as say y 1 square minus y 2 square minus y 1 square divided by y 1 square y 2 square; just writing V 1 square minus V 2 square that if we bring it in this form, then it become 1 by y 1 square minus 1 by y 2 square and that if we just summarize, we can write it in this form (Refer Slide Time:05:30).

Well, now this particular expression q square by twice g if we recall our earlier discussion, for that we can write in a different way, that is say we were writing in this expression starting from this one say P 1 minus P 2 is equal to rho q, then V 2 minus V 1 that is our very basic momentum equation neglecting the other friction loss. And then considering this as rectangular, we can write half of say rho g h 1 square minus half of rho g h 2 square and this is equal to rho q that q part as we are of course, we are talking about unit weight, here we are writing h 1 square B, we are neglecting because B is prismatic and that is why here also we can talk about unit weight, so we can write q directly. So, that will be actually we can write rho and then q is equal to say V 1 and y 1. So, we can write V 1 y 1 and this we can write as...

Our target is to obtain q, so let me keep q here and we can write it as q remaining here, this V 1 we can write as q by y 2 minus q by y 1. Now, this part we can write as rho will get cancel g will be going there, 2 we can write here. So, we can write it as say h 1 square minus h 2 square, this is equal to twice q by g and then this q bringing out we can write q square by g and then that will be say y 2 y 1 and this is y 1 minus y 2 well, here we are using y.

So, this h should be actually y, then what we can have that is equal to y 1 minus y 2 into y 1 plus y 2; this is equal to twice q square by g and y 1 minus y 2 divided by y 1 y 2, now this we can say that this y 1 minus y 2 and y 1 minus y 2 will get cancel. So, this will imply that twice q square by g is equal to y 1 y 2, that y 1 y 2 here it is y 1 y 2 y 1 y 2 into y 1 plus y 2.

So, using this relation twice q square by g is equal to this is the relation that y 1 y 2 into y 1 plus y 2. Now, here we have a term q square by twice g, but this term is twice q square by g. So, just replacing that part what we can write say, y 1 minus y 2 plus in this will be y 1 square y 2 square and then this as 2 is here, to have another 2 there we have to multiply it by 4 and divide it by 4.

So, we can write it as 4 here and then this will become twice q square by g and we can replace this by y 1 y 2 and y 1 plus y 2 and this term we can write in the form that y 2 minus y 1 into y 1 plus y 2, y 2 plus y 1 or y 1 plus y 2 the same thing. Now, from here if we bring y 2 minus y 1 common, y 2 minus y 1 if we bring common, then this term will become say minus 1 plus 4 y 1 square y 2 square and then this part we are bringing y 2 minus y 1. So, it is remaining as y 1 y 2 and y 1 plus y 2 whole square y 1 plus y 2 whole square this y 1 plus y 2 and this is y 1 plus y 2 whole square.

So, now by simplifying that, this y 1 y 2 and this square term will go. So, what we can write that is y 2 minus y 1 and this expression will be say 4 y 1 y 2, this will be minus 4 y

1 y 2 plus y 1 square, this if we break then plus twice y 1 y 2 plus y 2 square. And ultimately if you simplify that part, then this is becoming y 2 minus y 1 and then this part is y 1 square plus y 2 square and this 4 y minus 4 y 1 plus 2 y 1 y 2.

So, this will become minus 2 y 1 y 2. So, this expression will become y 1 minus y 2 whole square divided by 4 y 1 y 2 and that is equal to y 1 y 2 minus y 1, yeah this you can write y 2 minus y 1, y 2 minus y 1 whole cube this square and that one. We are writing y 1 minus y 2 whole square, y 2 minus y 1 whole square same thing. So, y 2 minus y 1 whole cube divided by 4 y 1 y 2. So, this expression is very popular expression for finding energy loss.

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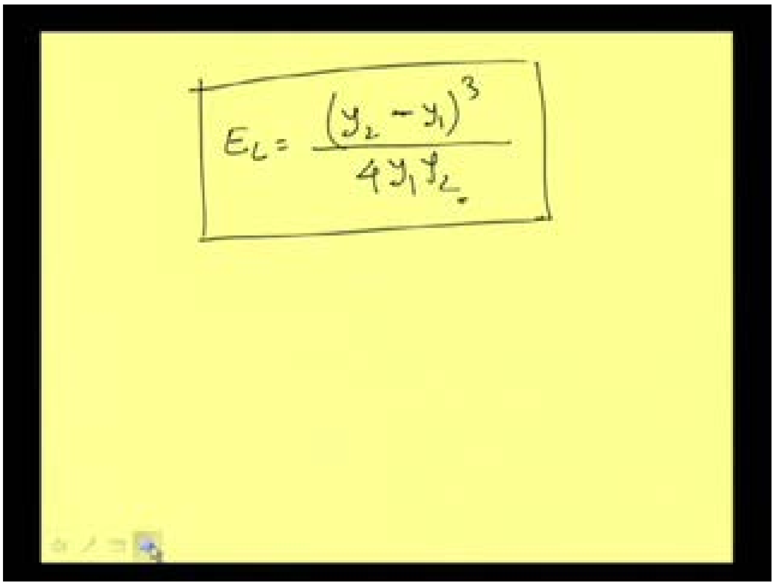

Let me write down here, now that energy loss is equal to we can write or if we have space on next page let me see, we can write energy loss E L is equal to we can write y 2 minus y 1 whole cube divided by 4 y 1 y 2, where y 1 is the depth before jump and y 2 is the depth after jump, all these are the sequent depth of hydraulic jump. So, this is one of the important expressions for finding energy loss.

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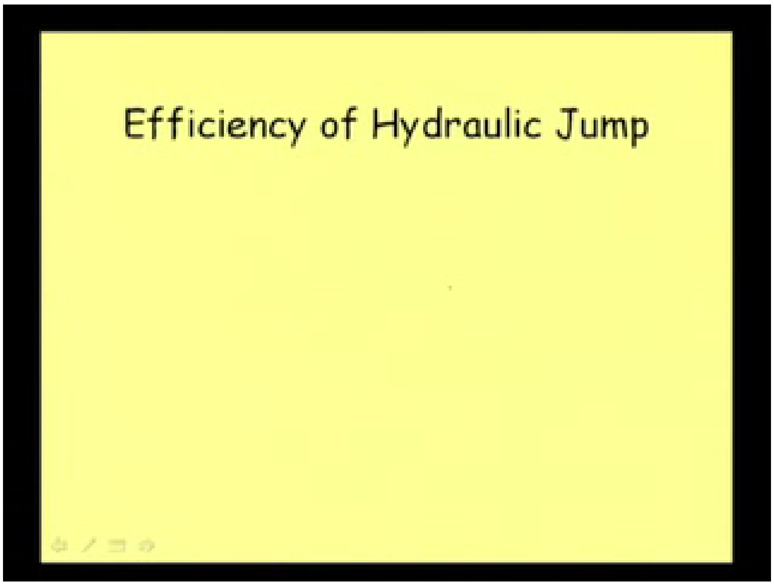

Well, then what is efficiency of hydraulic jump? As hydraulic jump is been formed for, in many case we do it for dissipating energy, so let us see how we observe or how we view the efficiency of that particular device.

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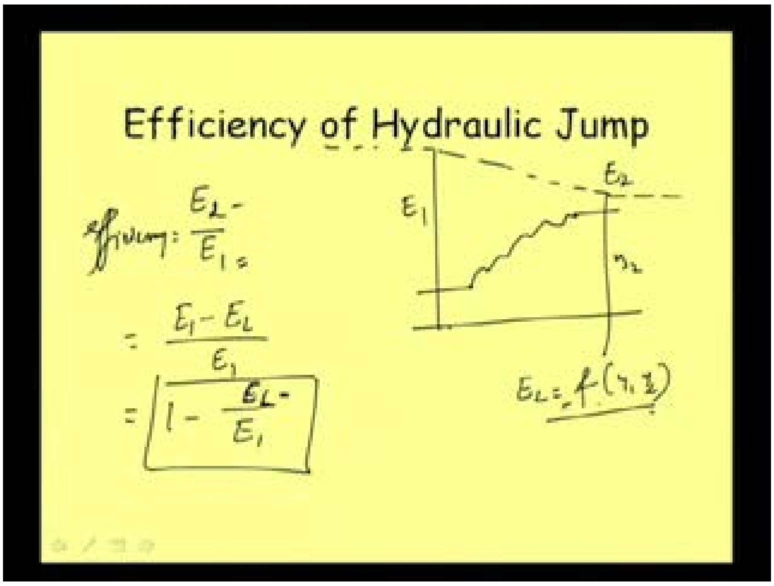

Well, if E 2 is the energy after the hydraulic jump, that is here say y 2 and this energy level here is E 2 and energy level here is E 1, say if I draw the energy gradient line, then it is going like this (Refer Slide Time:13:03). So, this E 2 is the energy here and E 1 is the energy here, then the ratio of E 2 by E 1, E 2 by E 1 that is basically called as efficiency of hydraulic jump. Now, if we just write it in terms of energy loss, then what we can do? This expression say efficiency, we can write efficiency is equal to this one now, how we can write this.

If we calculate the energy loss that means, how we why we are writing all these expression, say energy loss we can directly calculate as a function of y 1, y 2 directly. So, we may not calculate this E 2. So, without calculating E 2 if we just calculate E 1, then also we can write this is equal to say E 1 and this E 2 can be written as E 1 minus energy loss or we can write 1 minus say E L by E 1. So, that way also we can calculate the efficiency of hydraulic jump, this is one expression and this is one expression, I mean if you are not calculating or if we are not calculating the E 2 then, we can and we are calculating suppose energy loss directly from this one, then we can calculate it in this way.

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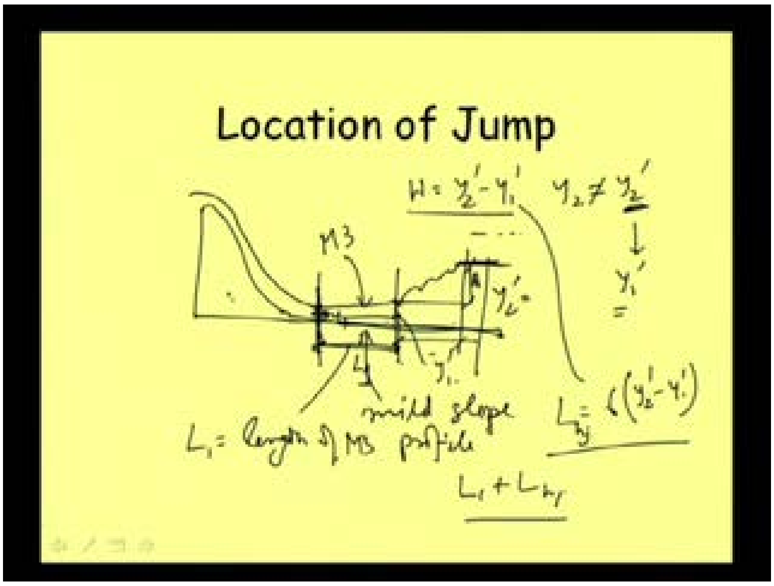

Well, then another topic that is of importance is location of hydraulic jump. As we have discussed location of hydraulic jump say on the downstream of a on the downstream of a say, then where the hydraulic jump will be occurring that is very important, that we have already discussed. And if the tail water depth we can control, if this tail water depth we can control somehow, suppose its low, tail water depth is low means, it is getting repelled and its jump some piece is occurring here. So, location of hydraulic jump where it will occur, how we can determine? Say, we are having this y 2 dash tail water depth we have, first we need to see if this flow is super critical.

At upstream flow if it is super critical, then only hydraulic jump will be forming and at downstream of course, we have to have sub critical flow. Now, if the corresponding is suppose y 1 is this one, then we can calculate the sequent depth y 2. Now, if we find that y 2 is not equal to y 2 dash, that is the existing tail water depth and which is most commonly I mean encountered situation, that calculated y 2 will not be equal to the existing tail water depth y 2 dash. If the y 2 dash is less than suppose this y 2, then we need to find out where it will be located. So, how we can do this, that is say we know this y 2 dash and so from this y 2 dash, we can calculate indirectly what is our y 1 dash, that is this particular depth we can find out y 1 dash.

And now this y 1 dash and this y 1 between these two depth this profile if this is a mild slope if this is a mild slope, then this profile will be M 3 this profile will be M 3. And then our understanding of computing gradually varied flow profile is now coming into play; that is we know that in this M 3 profile our upstream depth is y 1 and downstream depth is y 1 dash. So, from here to here now we can compute the M 3 profile and this will give us the length of M 3 profile, this length of M 3 profile now we can calculate, this is the length of M 3 profile.

Of course, if our channel is horizontal, then we are not talking about M 3 profile and in that case, we are getting H 3 profile. So, whatever profile we are getting, but with our knowledge of gradually varied flow, we can compute that particular profile and then we will know the length of that particular profile. Suppose this length of that particular profile is say L 1. So, this L 1 once we know, then from this point where we are observing the y 1, then we need to get this L 1 and this will give us the location of this hydraulic channel.

Then what will be the length of hydraulic jump? Now, that also we know from the height, if height is this one say height of this hydraulic jump is equal to now y 2 dash minus y 1 dash. So, length will be equal to say six times of this y 2 minus y 1. So, this will give us the length of that hydraulic jump, length of hydraulic jump; this is equal to say six time of y 2 dash minus y 1 dash height of (( )). So, that way we are getting this length also. So, from this point to what extent the jump will be to tell the phenomenon of jump will be that we can say that L 1 plus L, so that way we can know location of a hydraulic jump.

Well, just knowing the location may not help us in our practical purpose. So, what we need to do is that, as we were discussing earlier, if the jump is getting repelled by significant length, then the work that we need to carry out for protecting the bed from this high speed super critical flow, we need to spend lot of money cost is involved here. And that way we need to do something so that we can contain the hydraulic jump just on the foot of this, I mean say spillway or just on the downstream of this spillway so that we can avoid taking protective measure for a very long distance and we can contain the jump here.

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For that purpose, we use certain devices and that is called say stilling basin. In fact, for different fraud number, different types of stilling basin has been suggested, different types of stilling basin has been suggested for different value of fraud number and that way in this particular course, we are not going into detail of those things.

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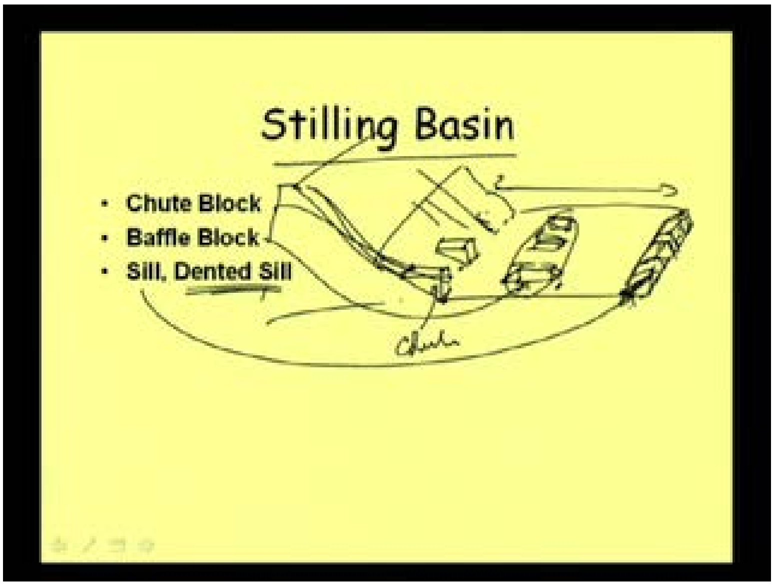

But, basically in those stilling basin, what is there? Say it will be a basin of this sort and here, we provide some say like this, if I draw it in a 3-dimensional view, we can draw it in this form that, at this end we provide a height like this (Refer Slide Time: 20:45).

At this end we provide a height like this and then here, we are providing some block of this sort, we are providing some block of this sort. Well and some more blocks are there of course, and these blocks are called chute blocks, these blocks are called chute blocks. That means that, I can put an arrow, then in between again we can provide some baffle block. This we can provide some baffle block like this and of course, this shape can be different, this shape can be different, like that you can have some baffle block place here and several baffle block we can place, now well I am not drawing that in detail.

And then at end we are providing some sill like this and this is called sill and these are in between whatever block we are providing, that we are calling as baffle block, my diagram is not that proper here. But any way, these are some concrete block that we are providing to abstract the flow and then flow is moving, there are cross current forming and that way this energy get dissipate here and this sill actually, here the water depth rises and that way it helps in forming the hydraulic jump within this portion within this portion, so that portion is called stilling basin.

And what is dented sill? Sometimes we do not provide a continuous one and with some gap we provide say one sill is up to this much, then another sill is there is gap some portion, some portion we leave. So, that way when we leave some portion, then we call this as a dented sill like that; say this portion is sill, this portion is sill, again this portion is sill like that and some gap are there, some opening are there here.

So, this sort of sill are called dented sill and now in some for very low fraud number, we may not be requiring this baffle block, we may not be requiring this chute block and then say with increase fraud number, I mean this combination of these things we can change. In some of the stilling basin for dissipating high energy, we need all these and in some of the stilling basin we do not require all these.

So, that way this stilling basin is one device which is used for dissipating or which is used for definitely for dissipating energy, but main purpose is that energy will otherwise also get dissipated, but here we are trying to contain the hydraulic jump very near to the downstream of this structure. Suppose, this is our dam or something which is here, so and water is coming like this and this we want that we want that I mean the hydraulic jump to form in this part. So, this is one stilling basin details of that, of course we are not discussing in this particular class.

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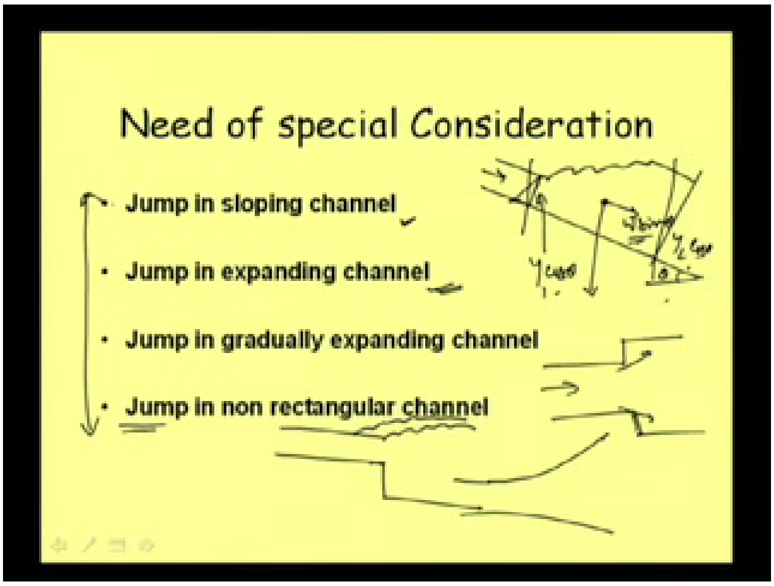

And then, we need to give special consideration to some of the issues like that, when we are talking about a jump in sloping channel, when we are talking about a jump in sloping channel like this, then if we measure the depth in this direction y, then actual flow cross section in this direction. So, this will be y cos theta, y 1 cos theta and depth will also be y

2 cos theta, because our basic concern is that, we are measuring the pressure in the direction of flow. Similarly, when we are neglecting this W sine theta, W sine theta if the slope is quite significant, theta is significant then we cannot neglect this W sine theta. So, W sine theta will be playing its role that is weight of the fluid is coming here and similarly, this depth we need to consider as y 1 cos theta, y 2 cos theta and that way we will be getting a different expression.

Now, details of that we are not doing here, but at the same time we should be aware of the fact that, the relation that we are using y 2 by y 1 is equal to half of root over 1 plus 8 f 1 square minus 1. That particular relation is of course valid for rectangular, but for a situation where our slope is almost 0 and we are neglecting the slope. If slope is there our expression will be different, in place of f we will be having another term capital G which is popularly used and then this will involve these term this involve these term.

Well, then if the channel is in a if the jump is occurring in expanding channel, in expanding channel this expansion can be say it can be like that, it can be like that when the jump is occurring in expanding channel like that, then also this I mean expression that I am using or we are using that are till now will not be directly valid there, will be some other terms coming.

Similarly, expansion may not be that sharp it can be a gradual expansion like this channel in a gradual expansion, well then sometimes this hydraulic jump can occur in a situation, where we are just dropping the channel bed; suppose the flow is coming and jump is occurring from this part and depending on this depth, jump can occur from this level. So that, for those entire different situation, we can have hydraulic jump and the equation that we are using will not be directly applicable.

So, for those situation we should go for further study in this particular topic, well not very critical or not very not it is nothing like that, it is very difficult but, but any way we should be aware that their expression will be little different. Then jump on non rectangular channel that we have of course discussed that, if it is not a rectangular one, if it is a trapezoidal one, then this Ballenger's momentum equation will not be valid. And in that case, we need to start from specific force equating specific force at upstream and downstream side and some graphical solutions are there, some empirical solutions are there, I mean observed and then some equations has been derived.

But of course, those are applicable for some limited situation, but these things are existing and otherwise using a computer, we can just use the trial and error procedure for calculating the depth of downstream based on the depth on upstream or either way it can be based on the condition that, specific force at upstream and specific force at downstream are equal. Well, so this sort of understanding is required, so that with our limited knowledge on the hydraulic jump what we have done we may not end up doing mistake in using those equations directly in this different sort of situation.

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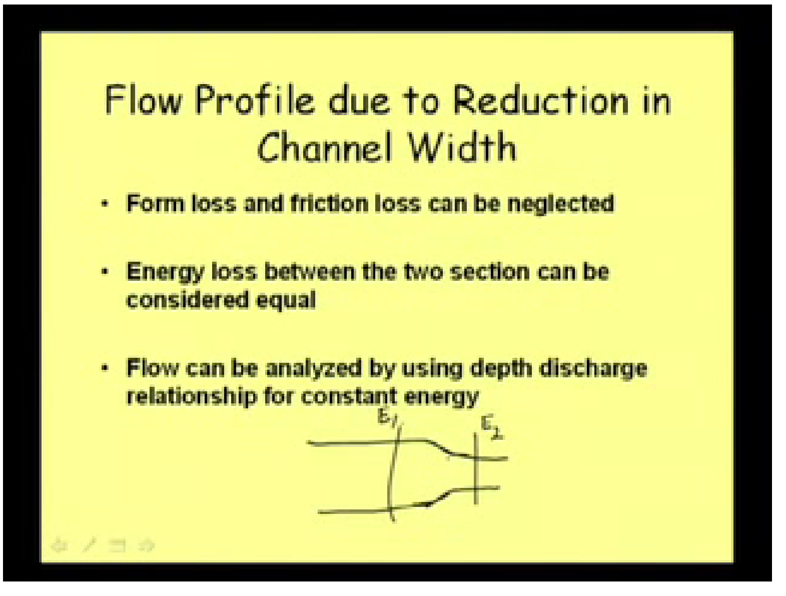

Well then, let us start our discussion on a topic, that is when flow in a channel pass through in narrow section, when the flow passes through a narrow section that is channel width is reduced, when channel width is reduced, how we can how the flow profile will change and what sort of care we should take in those situation.

Well, now if our channel is changing like this with some smoothness here, I am drawing the top view and in plain view of course, it will be suppose slope is not changing or neither bed is changing, say the same slope is there and then well let me not draw this one right now, slope and other things are not changing now that must, but the width is contracting. Now, in this situation the friction loss as this portion is very small, as this portion is very small the friction loss within this portion can be neglected and that is why once we neglect this friction loss and of course, form loss can be considered neglected if it is smoothly changing.

And then the energy loss between this upstream say, this is E 1 and energy at E 2 can be considered to be equal that is energy loss between this upstream and downstream section is negligible. Now, when we consider the energy loss to be negligible, then we can analyze this sort of flow by using our equation, if we remember that when we did discuss about specific force, then we were talking about specific force diagram and we were talking about specific energy diagram and also we were talking about depth discharge diagram. And that depth discharge diagram if we recall, that we could get a curve, which was for a particular level of energy, for one energy level we got one depth discharge curve how it is varying. So, those curves we can use and using those curves, we can analyze the flow in this situation. Of course, there our basic assumption is that, energy loss we are neglecting between these two sections.

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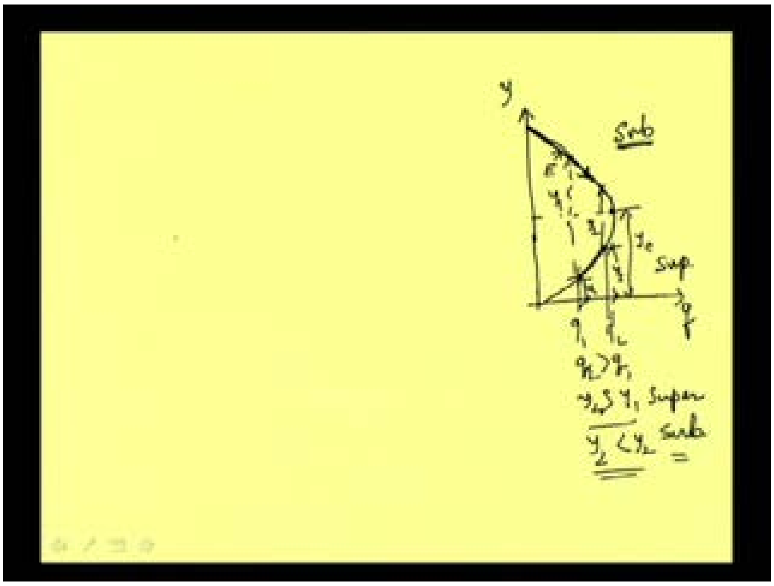

Well, now let us see first, let us draw that particular curve say, if we talk about rectangular channel, then we can write it as unit discharge q. And suppose we are putting the unit discharge q here and depth y in this direction, then what we mean by depth discharge diagram that it is coming like this? It is coming like this; this is the depth discharge diagram. And this line we are getting for a particular energy level E, say this is for energy E, specific energy E for that I mean along with this line our energy is remaining same, when energy remain same then with the increase of depth discharge is changing or we can say when discharge unit discharge is changing, then depth are changing, again this point is critical depth, this point is critical depth.

So, once we know the critical depth then we know one more one more point that, depth above critical depth is sub critical and this is super critical. Then we know another point that well with the change of unit discharge depth is changing, that is of course obvious, but if the flow is in sub critical zone, then with the increase of unit discharge, you can see that curve shows with the increase of unit discharge, depth is decreasing, depth is decreasing whenever q is increasing in this direction, depth is decreasing.

And if you are in super critical region, then with the increase of unit discharge your depth is increasing say q 1 is this one, q 2 is this one, when q 1 is greater than q 2, when q 1 is greater than sorry q 2 is greater than q 1, q 2 is greater than q 1 then we can see that this is y 1 and this is y 2. So, what we can see that q 2 greater than q 1 means, y 2 less than y 1 y 2 less oh sorry y 2 greater than y 1 in case of super critical flow, y 2 greater than y 1 in case of super critical flow. Here q 2 is increasing y 2 is also increasing, but if I extend this line to sub critical zone, then we can see that for sub critical zone, this is the y 1 and this is y 2. So, y 2 is less than y 2 for sub critical zone now with this understanding.

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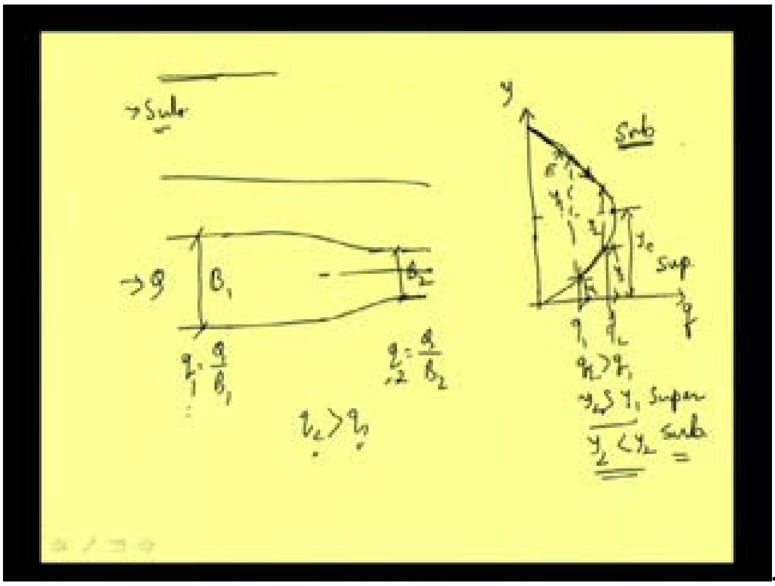

Then now, we can try to analyze the situation when our flow is changing through a when our flow is passing through a width or contraction, channel contraction. Say here our B is B 1 and here B is B 2 well and q coming is q fine. So, unit discharge q at this point is q by B 1 and at this point is q is equal to I can write it as q 1, this is as q 2, this is equal to q by B 2.

So, as B 2 is less, so q 2 is greater than q 1. So, what we are having that q 2 is greater than q 1, well now what about the flow depth if the channel is like this and suppose a sub critical flow is coming from this side, a sub critical flow is approaching. So, it is coming like that and in this narrow portion, in this narrow portion normally we have a feeling that when our depth is say when our width is reducing, width of the channel is reducing then depth will increase because width is reducing, q remaining same we are a feeling that depth will increase, but this is not true for the situation.

You can see that q 2 is greater than q 1, so we are and we are in sub critical region. So, if our energy loss is negligible or we neglect the energy loss in this portion, then what we will be having that when q 1 is when our say in this diagram of course, our q 1 is smaller. So, q 1 will be this one, let me draw another curve this was just to explain the understanding of this particular curve, now if we just use the value.

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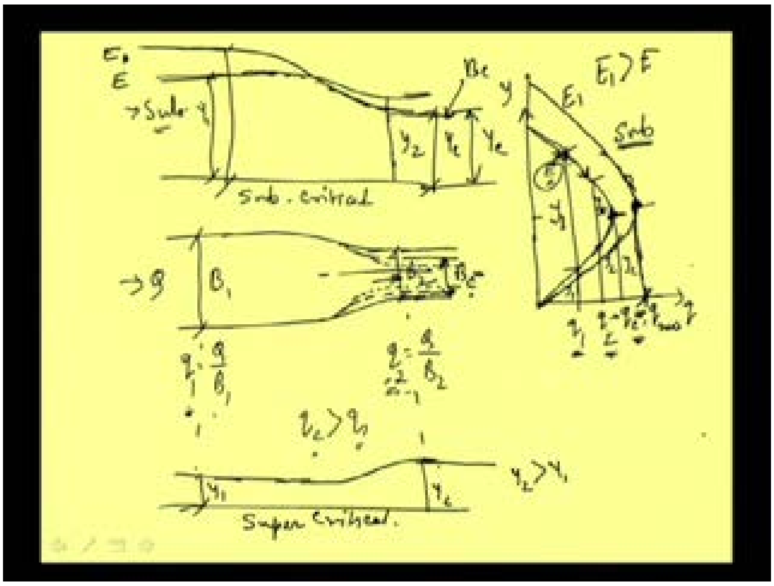

Now, if we just use the value here, say this is my y 1 where q is this one; q is this one we are talking about sub critical flow. So, this is the y 1 this is the y 1 and this is the y 2; q 1 is this one and q 2 is this one well. So, for this sort of situation, we can see when discharge q 1 I mean unit discharge q 1 here is less than the unit discharge q 2. That means, it is the situation of this kind, you can refer the diagram q 1 is less than q 2, q 1 is changing from q 1 to q 2; when q 2 is increasing depth is changing from y 1 to y 2 that is depth is reducing from y 1 to y 2.

So, if our flow depth here is coming as a depth y 1, here at this section the depth will be reducing like that, depth will be reducing like that. So, it will be coming as of course, smooth curve and depth will be reducing like that. So, this depth will be y 2 and that sort of situation we will be getting when we contract this channel and this is for of course, sub critical flow, this is for sub critical flow.

Now, if the flow is super critical, then what will happen? Now, you can see that in super critical suppose other things remaining same, say if the flow coming is super critical. Let me draw it here just below this one, say flow coming here in this section is super critical. So, it is coming like this and in super critical flow out for q 1 the depth is y 1 this one and for q 2 depth here is y 2. So, what we can see that when our q 2 is increasing q 2 is increasing, y 2 is also increasing y 2 is also increasing and that way for super critical flow if depth here is y 1, then depth will gradually, not gradually whether at this point it will rise, it will be moving like this and this corresponding depth will be y 2 and y 2 is greater than y 1.

So, this is just a reverse in sub critical flow, the depth is falling down and in super critical flow, in super critical flow the depth is I mean depth is rising, that is one phenomenon what we can see. Now, say another situation we can have here is that, suppose we are reducing the B and we are reducing it to a point such that this B 2 is corresponding to the critical depth, what we mean by that? When we are reducing the B, with the reduction of B our q is increasing, as you can see q is increasing and then for a particular B value, this q will become q c, our q will become q c; that means, we are arriving at this point, depth is coming down and depth is coming down and we are getting a depth which is critical depth this is our y c. So, we are getting critical depth at this point. So, we can reduce it up to a particular B value, so that we can get a critical depth here, fine.

Now, the point is that well, we can get critical depth by reducing it to a certain width, but if we reduce our width beyond that value, what will happen beyond that value? Suppose we are reducing it further, say we are reducing it further now beyond B c, if we reduce what will happen? Well, it is coming down and then for B c value, for B c value this correspond to depth y c, for this is for B c, bed width is equal to B c, we are getting this y c and then if you reduce it further then our q will increase more. But, in this particular curve, which is for energy level E, we cannot have a point or we cannot have a higher discharge then this q c, this is the maximum possible discharge that can pass through this particular section with energy E.

So, but our discharge is more than that, our discharge is more than that, then how this will negotiate, but in the real field it will definitely stop, it will definitely not stop, it will not stop, it will like keep on flowing. But, something else will happen, as this energy level is not sufficient to push the flow through this small narrow width. So, what will happen? Energy level water will start impounding on the upstream side so that, the energy level increases. So, in fact, this indirectly will allow the water to impound upstream which will make the energy level higher at the upstream and that higher energy level will push the water through this narrow portion. Diagrammatically or graphically what we can say that, for a higher energy level we will be getting another curve for a higher energy level, we are getting another curve like this.

And this line is another depth discharge diagram that we are getting, another depth discharge diagram. Let me draw this depth discharge diagram, what is requiring me to rub all this part that is because we are putting, we are reducing the depth further. So, this energy level will be increasing from E to say E 1 and E 1 is higher than E and at this higher energy level, what will happen and to what extent it will raise? Because it is rising just to push the water through this point and it can push the water when the depth, at this narrow portion is again critical, up to critical that is the maximum discharge possible here is critical at critical section.

So, if our B has been narrowed down, further to have the discharge of this much q new q suppose, new q then our upstream will be rising. So, this will remain there and the upstream will be rising like that, upstream will be rising in this way. And this rise will make the energy level to increase here say energy level will be E 1, earlier the energy level was E here, earlier the energy level at this point was E here, it will be E 1 and in fact, this high energy level will push the water, but depth here will remain critical, depth here will remain again critical, well.

So, that way we are getting again critical depth here, but this critical depth and this critical depth there is a difference, but we are getting critical depth here and at critical flow or we can say the flow condition will be critical at this point, but upstream it will rise. So, that is actually one of the very important phenomenon which creates problem in our engineering activity because as we were discussing many a times, we require to narrow down, we require to narrow down the I mean width of the channel, but if we reduce the width up to a certain point, we can get critical depth; but if we reduce beyond that level, well depth here or flow condition there will remain critical, but upstream side will be rising, that is it will impound water in the upstream side and that creates problem.

Say flow velocity here will be reducing and then there may be flooding on the upstream that f floods will create different type of calculate different type of problems. And if you want to avoid this sort of f floods, suppose in a city drainage system if you are talking about say, in the main drain just you imagine say in the main drain, well let me draw a diagram here, say this critical width of contraction, here we are talking about we have already discussed that part.

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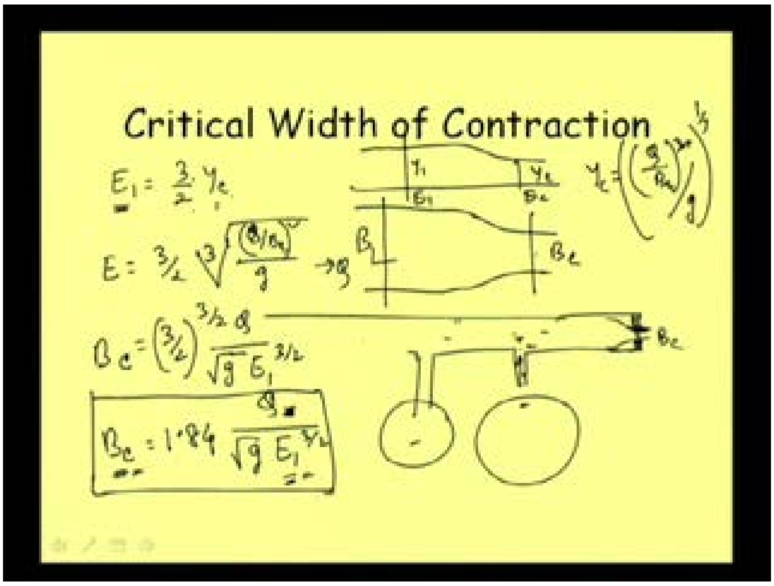

Say the main drain is going like that and there is lot of sub drain or I mean sub channel which is contributing water to this main drain. Suppose we are talking about city drain, these are feeder channel, there may be feeder channel from different part buildings are they are and that way.

Now, say in this part somehow we have a bridge and we are narrowing down that width, now if we narrow down this which will obstruct in that part, we are keeping this much opening and bridge is there. Why we narrow down the bridge because to reduce the construction and sometimes suppose we are putting a sluice gate that way also we may reduce the width because, if we try to cover entire portion by sluice gate that is not possible, I mean huge gate will be there operation cost will be there. So, we really do not want that bigger size also. So, we reduce this size and then flow will be moving like this flow is moving like this; that means it is just like the narrow section that we are making.

And now, if this width goes narrower than the critical B c, if this width goes narrower than the critical B c, then it will start impounding water in this level. Now, if I draw the section say here, the water level will be rising, now when water level is rising in this part then, say feeder channel is supplying water to this one drainage. So, when water level here will be rising, then there will be no gradient from this side to that side because water level here will be more then the water level here and this water flow will also stop that way this part will be having drainage congestion in this part.

So, for designing a gate at the downstream, suppose we are planning that we will pump the water or do something, then when we are in or in normal situation we will keep it opening, then while designing this sort of opening, we need to take care, otherwise floods will be there on upstream and this may cause drainage congestion in other part. And just to see that mathematically how we can calculate the B c value.

Well, again let me take this situation that, we had one point that E 1 energy at this point is equal to 3 by 2 of y c. If we remember point that, when we were discussing our critical depth, when we were discussing our critical depth, then minimum energy E 1 at critical condition we can express these as 3 by 2 of y c and of course, we are writing E 1 because at the contacted portion, at the contacted portion, well let me just take this diagram here. At the contacted portion, we are getting critical flow condition, at the contacted portion we are getting critical flow condition; here we are having critical flow condition because our bed width is B c.

And at the upstream we are not having critical flow condition, but we are assuming one point that the energy at upstream E 1, that depth is y 1 and energy level suppose E 1 that energy and energy at this level is same, because we are from our diagram itself we are considering that energy loss is not significant. So, we can write E 1 is equal to 3 by 2 of y c, now what is y c? That y c we already know that y c is nothing but, Q by B c that is the unit width and square divided by g that is Q square by g whole to the power one third, Q square by g whole to the power one third and that is why what we can write that E 1 is equal to 3 by 2 and cube root I am writing here and this is equal to say Q by B whole square because our known item is Q.

So, I am writing it in this form our interested or we are interested in computing this B c. So, I am writing this as Q by B form. So, it is Q by B c whole square divided by g and then this expression can lead ask to one relation that is making Q and then suppose we can make E cube, then we can remove this part, then it will be 3 by 2 cube.

So, from that we can separate out B c and this way if we you simplify this expression will be getting B c is equal to 3 by 2 whole to the power 3 by 2, 3 by 2 whole to the power 3 by 2 and then it is q divided by root over g and E 1 to the power 3 by 2 E 1 to the power 3 by 2. So, we can get this expression and further simplifying this expression, we can write that B c is equal to 3 by 2, to the power 3 by 2 that will become 1.84, then 1.84 q divided by root over into E 1 to the power 3 by 2.

Again, what that E 1 is? That energy E 1 is equal to y 1 plus V 1 square by twice g, now at upstream if we measure the y 1, we can always get these values and of course, in some cases by neglecting the approach velocity, we can simplify this expression further. That means, further if we neglect the approach velocity V square by twice g will become zero and then we can take this as a y 1 that sort of simplifications are also done, but basically this is the expression for calculating B c.

So, when we know the width of section here, upstream V is known V 1, and then we can calculate knowing the V 1 is as we know the Q, we know the y. So, we can calculate E 1 and then we can see q is known. So, we can calculate all this part and then we can see what should be our B c and if you want to have critical flow condition here, we should make the flow, make the width equal to B c then only we can get critical flow condition.

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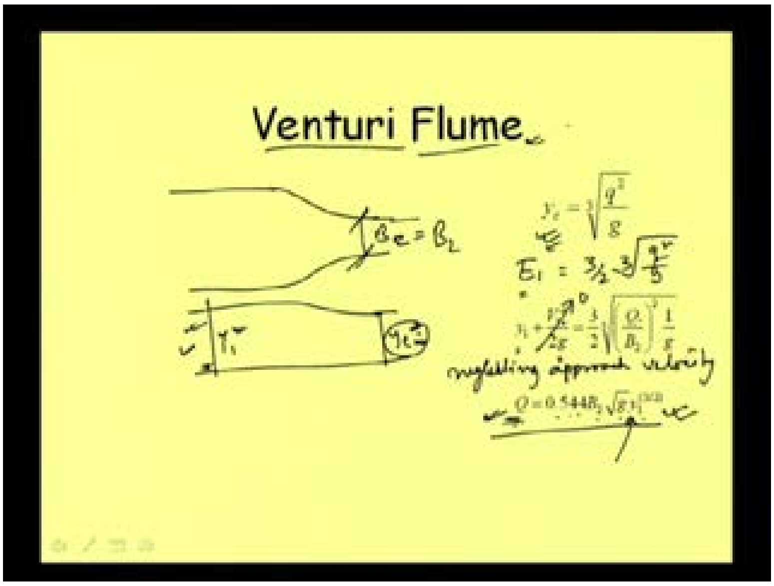

Well, then using this particular principle that when we have critical bed with here, then we have critical flow velocity here and critical depth here, we have y c here based on that. We can device one flow measuring device that we call as a venture flume, what is the advantage of this? Suppose we narrow down, we know this y 1 and we narrow down this width sufficiently. So, that this width sufficiently, we narrow down this width sufficiently to form critical condition of flow at this narrow point.

Now, once we assure that it is critical flow, and then we can find out the discharge based on the depth of flow at upstream. Now, more important point is that to form critical depth here, we know that critical B c, but we can if we further reduce this width, if we further reduce this width, still the flow depth here will remain critical, upstream will only rise and for measuring device, if upstream is rising we do not have any problem; we want to get the discharge based on the measurement, that we will be conducting at upstream point. As such what is that we know this relation that critical depth is equal to q square by g and whole to the one power cube root of V square by g.

Now, what we can do at upstream? At upstream the energy E 1 is equal to 3 by 2, again we can write cube root of q square by g that expression and then already we have written in the last page. So, the similarly we can write that E 1 is equal to say y 1 plus V 1 square by twice g and 3 by 2 cube root of this q square I am writing as q by B 2 whole square by 1 by g, B 2 means this B c we are talking at the section two B 2. So now here, neglecting if we neglect this approach velocity, because depth will be raising sufficiently, so velocity with which flow is approaching is almost negligible. So, neglecting approach velocity, approach velocity what we can have that is q this time will become 0 and then by just rewriting this expression, we can have a form that q is equal to 0.554 B 2 g y 1 to the power 3 y 2, well. So, with this expression once we know the y 1 value at upstream, then we can have what the discharge is flowing.

So, in a channel in irrigation canal, if we can have a readymade system of the type, that well by that we will narrow down the particular portion or we can have a permanent section, where the section is being narrowed down, then just by observing the flow depth at upstream, not in the narrow portion, just at upstream if you observe the flow, then we will be in a position to say what discharge is flowing and that is what is called venture flowing and this is used for flow measurement.

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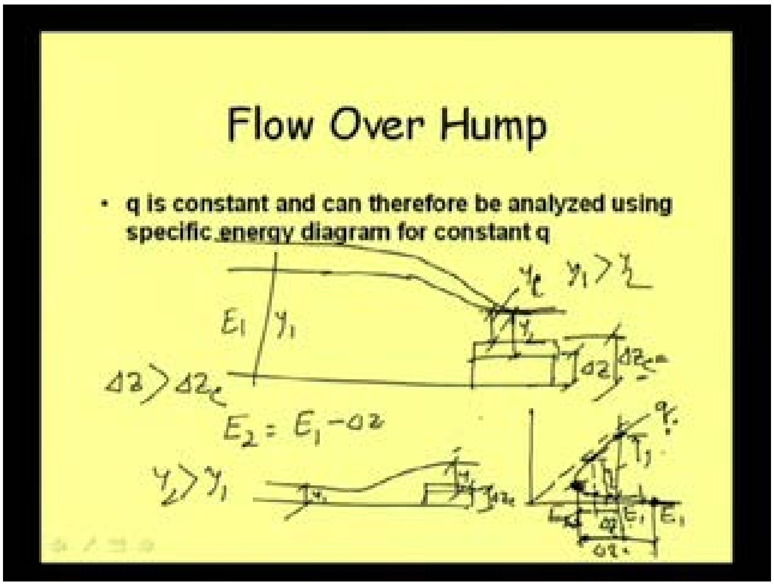

Well, then like this narrow down, sometimes we can have a situation where this depth is raised not depth rather the width is raised, suppose the bed is raised by delta z amount, delta z amount then a sub critical flow is coming then what will happen to this one? Say this is E 1 energy and at this point say what we can write that E 1 or E 2 is equal to E 1 minus delta z, otherwise there is no energy loss that is why we are using, as here we can use the relation, our specific energy diagram.

Here you can use our specific energy diagram, this one; here we can see that at this point suppose our energy level is E 1 at this point and here hump is there, so with respect to that if we measure the energy it will be say this minus delta z. So, if we reduce the energy by delta z amount, delta z amount if you reduce the energy by delta z amount, then what will happen? Originally if our depth was this much if it is sub critical flow, then it will come to this one. So, if y 1 is the depth here, then y 2 will be the depth here.

So, depth is coming down. So, over the hump also depth will be coming down like this, but, if it is super critical flow, if depth was initially this much, then it will be rising like that. So, for super critical flow, depth will be rising, if it is a super critical flow coming then a hump is there, then depth here is y 1, then depth here will be y 2 and then y 2 will be greater than y 1 and here if it is y 1, this is y 2, in case of sub critical flow y 1 is greater than y 2.

So, that way in case of hump also we can get this sort of this sort of relationship and here why we are using this specific energy diagram because this diagram is for a constant q and our q is not changing here, there is a width of the bed is not changing. So, we are using a constant q and then we can use this specific energy diagram to have these things. Now here, if the z is raised to a higher depth, suppose up to this much if it is increased to delta z c, if it is increased to a critical depth delta z c, then our flow depth will become critical z is coming here. So, E 1 will be coming down to E minimum that is we are having minimum energy or we are having critical flow condition, then flow here will become flow depth here will become say y c.

Then the condition is that, if we further reduce this one, if we further reduce this one, then what will happen? If we further reduce this particular level, then this energy level because you cannot accommodate delta z here less than that. So, what will happen? Our this delta z will have to come here, that means, total length will be increasing whether energy level of upstream will have to come up and with the increase level only it can accommodate the delta g, which is delta z which is higher than the critical delta z c.

So, if delta z is greater than delta z c that is hump height is greater than the critical delta z c, then depth here will remain again critical because after accommodating this part again we are coming to critical depth. So, depth here will remain critical, but the upstream level will rise.

So, it is almost similar to the case of narrowing down, but of course, concept is little different and we are analyzing this from the point of specific energy diagram for constant discharge. Of course, in case of super critical flow, in case of super critical flow also we will be getting up to critical depth it is fine, if it is increased to delta z c it is fine, but if it is increased further, then it will not in case of super critical flow. In case of sub critical flow, we are talking about that this depth is like that, in case of super critical flow when we are talking about this situation, then when delta z is increased beyond these things then, it will lead to formation of sub critical flow in this part and hydraulic jump will occur. So, in case of super critical flow, a hydraulic jump will occur and we cannot analyze this flow by using this particular diagram, rather the flow will be hydraulic jump is coming, so the flow situation is changing.

Well, with this one here, we can conclude our discussion on flow over hump and flow over a narrow channel portion. And we have seen how in critical flow and in sub critical flow, the flow can be of different type. For particular situation, we can analyze it with the help of one curve and in a different situation that is the discharge diagram, in case of narrow down and in case of hump, we can analyze that by using the specific energy diagram. Thank you very much.