**Fluid Mechanics**
**Prof. Subashisa Dutta**
**Department of Civil Engineering**
**Indian Institute of Technology-Guwahati**

Lec 36: Open Channel Flow III

Good morning all of you. Today let us discuss on open channel flow. This is the last class on open channel flow. As we discuss about the specific energy and today we will solve a few problems as well as we will discuss about hydraulic jump and the best hydraulic cross sections what is required for designing a canal structures. So as I told in previous classes that the mostly we are following it Saint-Gilles and Mela books and some part of Hanif Chaudhary books or the F.M.

White this is as you know it very simple chapters with lot of assumptions we design this open channel flow, flow under a sluice gate, spillway, many civil engineering structures. So we try to design based on this open channel flow. The basic concept what we use is we will talk about that the conservations of mass and energy equations. So these two equations as we consider for the one-dimensional flow that is what we have simplified it one-dimensional incompressible okay steady flow.

So that is the reason it is a very easy to solve it as compared to we have solved many complex problems. But when you simplified it, the flow is one dimensional, incompressible and the steady flow. So that is the reasons we have tried to look at the The basic idea to know it, the flow depth variations in open channels, the velocity variations, how the velocity changes it, how much of energy losses, okay. losses is happening it because of the flow and mostly it is governed by the gravity forces and the frictional forces as I discussed earlier. So we have just two force component the gravity force and frictional force component.

these two course components are there when you talk about a open channel flow. As we discuss about the specific energy and the critical depth, the same concept we will talk about and more details I will today talk how we can use a specific energy which is a graphical representations of energy versus the flow depth of a channel cross section where the datum is considered is a channel bottoms more or less the horizontal channel slopes. In that case we can use a specific energy concept that is to understand how the flow variations will be there and most important again I am to repeat it that subcritical flow okay as we discuss more details subcritical flow that means when you have a flow proud number lesser than 1. So in terms of the flow velocity in terms of the speed of the surface wave you can interpret it what is the conditions comes it when you have a subcritical flow. When you throw a stone to a reverse we have a subcritical flow the wave will be propagates the both upstream as well the downstreams.

Then we have a very the critical flow which will have a the flow proud number is equal to 1 that is the conditions we have when you have a the critical flow that means the flow proud number is equal to 1. Physically if you try to understand it the velocity of the flow is equal to the speed of the surface wave that is what we did it then we have super critical flow where the flow proud numbers is greater than 1. This is what is a recap what we discussed in the last 2 classes. Also we are going to discuss about best hydraulic sections as it comes a simple questions in GATE or engineering service exams that what also will we talk about that. Let us come back to the hydraulic charms how does it forms it.

If you look it that if you have a more or less the horizontal surface okay more or less you have a horizontal surface and you have a sluice gate okay it is a gate operating it. the flow is coming from this side it has a depth okay. After that you can see that flow will be like a jet flow it will happen like this okay. So this is the gate which is we are operating this is what a gate the flow is coming from this side and going out. So we can see that the typically it will have a jet type of flow the flow will be move like a jet type of flow okay.

And you can blow it very simple idea if this y1 is the depth here is y2 is depth if I follow as a steady flow. So the mass conservation equations give me that very basic thing that rho is the density multiplied with the q that is mass inflow is equal to mass outflow that is what is q. In this case if this is the v1 velocity and this is the v2 velocity so I can write it rho v1 y1 and b is a perpendicular depth or the width is equal to rho v2 y2 and b. So b be cancelled out rho as an incompressible flow and the steady flow. So we have a v1 y1 is equal to v2 y2.

What do you mean by that as the depth decreases the velocity is going to increase it okay. That is what a very simple way we can understand it if the depth of the flow is decreases then the velocity increases. As the velocity increases does it go to a supercritical levels or not. as I am operating a gate okay it is going down and going down. So there will be a conditions will come it that this gate will come with a critical flow okay that is what is critical conditions will prevail it beyond that it will go sub critical super critical level.

You look it just to try to understand it the gate I am lowering down So as I get I lowering down my y2 will be lesser and lessers v2 will be larger than the v1 and if I estimate the flow crowd numbers so I am reaching towards to supercritical flow. But that means this will be the conditions we will have a flow crowd number less than 1 this is the conditions what we will have a flow crowd number greater than 1. okay that depending upon the flow velocities okay but mostly if you come to this you can have this subcritical flow you can have a supercritical flow okay but if I will create it a simple the same structures okay there will be a gate there will be a gate this is the channel bottom there will be gate it is a channel bottom is there but here I create a humps create a some sort of a hump by bump type of things I have created. So what will happen it that if I lower the gate the flow will come it here then here it will come it then there will be hydraulic jumps then the flow depth will be maintained like this okay. The flow bed depth will be maintained like this.

See if I take a section here 11, 22 or 33. So these regions I will have a flow which is less than 1, this is the region's flow greater than 1, less than 1. So this is a supercritical flow to subcritical flow. When the flow passes through the supercritical to subcritical with a very limited ranges then there are a lot of turbulent structures created okay. There are a lot of mixings, the turbulent structures are necessary.

created that is what we call hydraulic jump that is what is hydraulic jump there is a energy losses happens it there is a energy losses happen it when flow goes through the supercritical please remember supercritical to subcritical. Supercritical is to subcritical reasons it is creates a jump you can see that is a jump a jump behavior this is the jump we call a hydraulic jump and these the hydraulic jump create a lot of turbulence structures. The noise if you go to just a any spillway or dam structures if you visit it or today you have Google with you, you can just browse it and see that how the hydraulic jump formations happens just downstream of a dam projects okay especially during the monsoon periods. You can see the noise, the turbulence structures all you can see today is okay because you have a lot of sources like Google and YouTube and other sources you can just browse it and see how the hydraulic jump formations are happening which is quite beautiful okay. Sometimes because of hydraulic jumps also there is a rainbow formations happen city which that type of conditions you can see it.

So it is a quite beautiful that way but also it helps engineering also we look at the hydraulic jump because that is a zone we can have a lot of mixings of air mixings or chemical mixings. So engineering also we need to know design it such a way that there should be a hydraulic jump which will be create a good mixings of any chemicals or air bubbles. We try to do it the mixing process with just creating a hydraulic jump okay and bigger hydraulic jumps you can see it and smaller hydraulic jump also happens it in real life you can see when the flow changes from supercritical to subcritical regions. That is the reason we will have a hydraulic jump and also we will have energy losses. We will have energy losses.

So if you look at how do we really analyze a hydraulic jumps. That means if I know the upstream conditions okay very simple way just look at the hydraulic jump part I can just simple way write it it is a jump like this okay it is a jump part here again I am writing a cross section 111 so just to you to coming back to the book levels which is given in the pre-off streams will have the 11 and downstream will be 22. So that means at the 11 I have a y1 flow depth, I have a flow proud numbers, upstream flow proud numbers, I have a velocity. Similar way I have a y2, I have a v2, I have a flow proud numbers at the second level that is what you can look it okay. So if you look at these problems okay that is what is the same concept what I have sketched it that is what is figure is here.

Now if you look at the problems what we are talking about we can always look at that how the things are happening it at this point okay. So that what we can make it how this point is this point is very simple that means I can use a control volume just I have to sketch it as I taught you very detail about control volumes. So just do a control volume how I will analyze a hydraulic jump. So let me I reschedule the problems So what I have the problems it is a very simple problems I have that I have a upstream flow it is a coming it there is a hydraulic jumps then flow is coming here it is it is a steady nature now this is the downstream the flow is coming here and going out here So let me you have a v1 velocity y1 is a flow depth you can compute the flow Froude numbers you can compute the specific energy. Same way you can velocity flow depth flow Froude numbers at upstream and you can also compute specific energy which is a very simple way E equal to y plus v square by 2g.

So we can compute the specific energy at upstream as a downstream because of the hydraulic jump as I emphasized that the energy losses happens. So if I want to draw energy lines or energy gradient line. So how it will come it okay this is y1 depth this will be v1 square by 2g that means this is the locations up to this and I have a let have at this point. So energy line will come like this this is the energy gradient line there will be energy losses. there will be energy losses that what will be reflected in the energy gradient life.

And if I put it the energy losses due to the hydraulic jump is hL okay energy losses due to the hydraulic jump is hL. So very easily I can write it energy conservation E1 is equal to E2 plus hL a very simple thing. So it is very simple things to get it the energy losses okay. If I know the specific energy at upstream specific energy at the downstream just subtracting that I will get the energy losses. How to get the v2 and y2 because upstream conditions we know it v1 y1 flow proud numbers the specific energy but we do not know v2 y2.

If you know the v2 y2 we can compute the flow proud numbers as is a subcritical flow that should be less than 1 and then you can v2 y2 know it we can estimate the specific energy at the downstream levels okay. So then you can compute the energy losses. what way we can solve the problems with us. It is a very simple thing as I have considered this is the control volume I will just apply the two equations with me mass conservation equations and momentum equations. Anyway we are using the energy equations to get this the loss due to the hydraulic job formations.

So I have two equations, I have two unknown So I can estimate that is what very basic things okay more detailed derivations anyway I will show to you but basic thing is that we use the specific energy to know it how much of energy losses is there and once I know this energy loss components okay then I can design the hydraulic jump. So how to get this downstream? the velocity and the flow depth v2 and y2 that is what will be do it with help of mass conservation equations and the linear momentum equations as we used to do it for other conditions for that. Let us come back to the again is a repeating it that the specific energy curve and specific energy curve and hydraulic jump example. How does it comes it okay hydraulic jump let us try to understand that okay. Specific energy curve as I yesterday in the last class we just discussed it that it is a the graphical represents of specific energy versus flow depth.

And when you draw a line the specific energy is equal to the wind which is 1 is to 1 line and since we have derived it the specific energy curve will come like this. okay. So please have a practice to draw the specific energy curve for a particular discharge let be the q, q1. But another discharge if you draw it, it will come at q2, q2 is greater than q1. This is simple things you just interpret it the relationship between the specific energy and discharge and the flow depth you will get this curve natures of u1, u2 are the constant discharge.

I can draw a functional relationship between for a constant discharge mostly this canal and others we design for a constant discharge okay. So for that constant discharge we can have the specific energy versus wind. the relationship that is what is we can draw it okay and as this q2 is greater than q1 your sub the again if I draw a q3 so never interact with each other okay. The q3 will be larger than q2 and q1 so more detail you can go it look at the books of Hanif Choudhary and all but as undergraduate levels let us have a these things Now if you try to make it very interestingly that let me have an upstream flow okay for constant discharge q1 I have a upstream flow okay which is Es1. So that means upstream flow can be subcritical can be supercritical okay can be subcritical can be supercritical.

okay. So upstream flow can have a two alternative depth okay subcritical or the supercritical but as we said it very clearly the hydraulic jumps occurs from the flow from supercritical to subcritical okay. So higher velocity flow to the lower velocity flow that is you can so that way if you look at that so let me I have upstream specific energy Es1 and this is what is crossing it. So being a conditions to have a hydraulic jump formations the point is lies here. So that what I can look it very clearly this point is here okay. But as we know it if there is a hydraulic jump there is a certain energy losses that be the next point will come it here okay which will be HL the energy losses just downstream of this because energy losses happening it will come down any figure will come to towards this part.

So we will have a point this will be the subcritical flow. So that means when you have the hydraulic jumps the flow changes as you know it this is the regions which will have a flow probability number greater than 1 the flow less than 1. So it jumps from subcritical to supercritical so that means this is the directions flowing. and there is a energy losses of HL. So always you can sketch the specific energy diagram try to understand it how the flow moves it when there is a hydraulic jumps drawing the specific energy curve you can find out how these things will come in.

That is what I said it when we constructed the in our civilization the construction of canals and all the things are 4000 years old. So we used to use a simple graphical technique to understand it how much of energy loss is happening it and there are so many hydraulic experiment conducted throughout the world to understand the hydraulic jumps okay. Not only in India this University of Roorkee but our IIT Roorkee presently we known But the hydraulic jump formations and all things a study has been done almost 100 years back. So let me I come back to very basic things as because most of the times we have a rectangular canal drainage lines and all we generally prefer to have a rectangles because it is easy to constructions. The construction is very easy okay to construct a rectangular channels okay.

If that means it is very simple things okay B and you have a flow depth let B H we just try to locate that what is the as you know it the specific energy is minimum at the critical depth. So we need to compute the relationship between the specific energy the minimum specific energy. So basically we are looking it again I am drawing the specific energy curve and drawing So this is what E minimum. We are looking at what is this conditions okay for E minimum versus the yc okay critical depth okay.

This is the yc. What is the relationship with a E minimum for a rectangular channels? It is very easy part okay. If you look at that you just compute the E minimum if you look it that is what will be in terms of yc and vc and just you substitutes the relationship between this charge and yc which we get it from simple from the flow proud numbers is equal to 1 you will get this relationship. It is a very simple things okay flow proud number equal to 1 you will get this relationship if I substitute these the finally what you are getting it that E minimum that means this coordinate will be 1.5 type of yc it is quite easy okay for rectangular channels is many of the times we just use the rectangular channels from drainage systems and as I am discussing about the hydraulic jumps I am not going detail about hydraulic jumps as I just discussed that. But I will just highlight it when you have the hydraulic jump what are the assumptions we put it which is get a some sort of a theoretical value of hydraulic jumps okay.

This is a section 1 1, this is a sections 2 2, okay. So you have again I am putting y1 v1 specific energy y2 v2 specific energy flow power numbers flow power number 2. So we need to do a control volumes to solve this problem. So we need to have a control volume.

So I consider a control volume like this. This is my control volume. So I need to know it what are the assumptions as we did it. First is the pressure distributions here is as it was a hydrostatic conditions okay. The dynamic pressure is close to the hydrostatic pressure distributions okay. So I have the pressure distributions which is assumption is that as close to the hydrostatic pressure distribution.

No doubt there will be velocity distributions as we discuss it but in this case the v1 and v2 in this case we consider the beta 1 and beta 2 momentum flux correction factors close to the 1 okay. Somewhat these approximations are correct for a turbulent flow where the B1 B2 will be close to the 1. Pressures varies hydrostatically that is what I sketch it and the wall shear stress and associated losses okay. The wall shear stress okay at this wall the is equal to the 0 it is quite simplified it okay. Basically we are looking it that the force because of wall stress will be the much much lesser than the pressure generated by the hydrostatic pressure fields okay.

Hydrostatic pressure field it is not a hydrostatic flow is there but the pressure disturbance as close to a flow at the rest conditions okay. So as you have the control volume already you know the beta 1 and beta 2 already you sketch the control volume you know the influx is going out flux you know the mass influx going mass out flux. momentum flux and going out that you know it the linear momentum equation starts about sum of the force is equal to the net momentum out flux. That is the basic equations what we need to use it.

That is what here. So it is a mass conservation equation. okay. Please note that there is no rho and v but it is okay. The flow is incompressible so the density is constant. So we have a relationship as I derive it is the v1 is equal to y2 by y1 v2 or reverse you can always do it.

What you need to have? Sum of the force is equal to that is what is the momentum equations is a net outflux of momentum flux. beta times of mu n v out minus in okay. The negative sign things you just look it. So I compute the hydrostatic pressure distributions and after substituting these you just rearrange the terms. More detailed derivations always you can look it Sinzel Simbala book.

Just rearranging the pressure average what is the pressure component is coming it okay as you know it the pressures will be the average pressures P1 average pressures will be half of rho gy1 because this is a rho gy1 by 2 half of the rho g1 this is a pressure average pressures acting at the section 1 1. similar way sections 2, 2 and if you do a systematic derivations finally I get a relationship with a y2 and y1 this okay. Just for your sake I can just write it y2 is a flow depth at downstreams is a functions of 0.5 – 1 square root of 1 plus 8 flow proud number of off streams is this. So this is the relationship gives us the because in upstreams I know flow depth I know this flow crowd numbers substituting these values because it satisfy the mass conservation equations and the linear moment of equations I can get it this relationship okay.

I can get it this relationship the same way I have to look at the energy dissipations ratio is nothing else the HL by the off streams specific energy. The same way I can get the HL as I explained earlier. I can get the HL functions head losses and then I can just substitute it. So these are very simple thing just arithmetic way you can solve these problems. Now let me I am not going more details because if I go for higher classes you can do it the what type of hydraulic jumps formations happens it and we consider the different type of hydraulic jumps.

But I just want to say that when you have the flow proud numbers okay is a range of the upstream flow proud numbers is range between 4.5 5 to the 9 okay. So flow-prone numbers if I have a the ranging upstream things then there will be a huge energy dissipations okay that is the supercritical regions and the if I have a flow-prone numbers 4.25 to this the energy dissipations will be the about 50 to 70% the flow will be the steady jump formations there.

The jumps will be the remaining at the steady conditions. If you go above the 9 then you will have a strong jump formations. Energy losses will go an order of 70 to 85% okay. That is the basic calculations, a basic idea and we go for classifying the different type of hydrologic germs. But I am not going detail for this undergraduate course level. Now let me solve a very simple problems okay just substituting this values we can solve these problems and if you understand how the hydraulic jumps happens it and how the upstream and downstream links flow characteristics are interrelated you can solve this problem and it is a very simple problem.

The water discharging into a 15 meter wide rectangular horizontal channels okay with a sluice gate we get have undergone a hydraulic jump. The flow depth velocity before the jump is 1 meters and the 10 meter per second is the velocity. So what is given it y1 is given is 1 meter okay. The velocity is given is 10 meter per second. I think B is given here 15 meter but B is not necessary to compute this.

Compute the flow depth, flow proud numbers after the jump that means y2 and v2 head of energy losses or energy dissipation ratio. So as we discuss it you can get this energy losses HL you can get energy losses by specific energy upstream specific energy. The assumptions are the flow is a steady that is okay and quasi steady channel is sufficiently wide there is and effects can be neglected. Density of water as consider 1000 kg per meter cube. Now first we have to check it whether the flow is the supercriticals are not.

What is the flow-proud numbers at the upstream levels? So that is what very simple as the flow-proud numbers is equal to again I am highlighting it velocity of flow by the speed of surface wave. The speed of the surface wave is C0 is out of gy.

So y is here, y1. So we just substitute it. It is greater than 1. So Froude number is greater than 1. So it is supercritical flow. No problem.

As it is expected. So then it will have the hydraulic deformation. we use that linear moment of equations relationship to compute the y2 which is coming around 4 meters okay. With a continuity equations we can get it what will be velocity the v2 and we can again compute the flow proud numbers at the downstream at the sections 2 okay as it is a less than 1 is a subcritical. all these conditions are satisfying it. Their flow is going from subcritical to supercriticals.

The flow crowd numbers you need not to remember it. It is a ratio between the velocity of flow by the speed of surface water wave. The speed of surface water wave having a relationship c0 g into y. y is the flow depth. For y1 depth the speed will be g into y1 for y2 depth that is values C2 will be g y2 that is all.

So these two ratios define the flow crowd numbers. So if you do not remember the flow crowd numbers at least you remember this part okay that is the speed of surface waves okay, speed of surface waves. This is same way estimate the head losses and the dissipation ratio. It is coming at 6.01 and all. This numerical values if you look it that how much of energy losses are happening it and how much of the dissipations which is 0.

28 means about 28% of energy loss is happening it okay. 28.6% of energy losses are happening it because of the formations of hydraulic jump. Second problems is very interesting problems which we have taken from Hanif Chaudhary book. A bridge is planned for 50 meter wide rectangular channels. and carrying a flow of 200 meter cube per second flow depth is 4 meters we reduce the length of the bridge. What is the minimum channel width so that the upstream water level is not influenced by the discharge.

So indirectly it is a talking it that when you are reducing the depth okay that is what again I can sketch it you can understand it this way. okay, the same specific energy. So you can really draw the specific energy for q, small q, discharge per unit width. We can compute this part, okay. So that way I can have this values of q1 constant, q2 constant and q3 constants, okay.

This is specific energy. it is a saying that that let me I have a point is here okay as I am increasing the b though I am increasing the q3. So I am coming to closer to a level where I am reaching to a discharge which will have a E minimum okay that means I am coming to a level where I have a unit discharge corresponding to critical depth. So that is what is reaching it as just track on as I am increasing the B width reducing the B width sorry reducing the B width so my discharge curves is going down and down okay and it will be reached to a point where that discharge meeting with a E minimum after that flow does not occur it. means for that discharge it is a critical depth for that discharge it is a critical depth. So when you are reducing the width of the bridges okay you will come up to the critical depth.

So if you go beyond the critical depth then there will be choke conditions will happen so which we can go try to understand more details in higher classes. So choke conditions will happen it to avoid that we try to maintain that the flow should go at most to the critical flow levels. So that is because it is a rectangular channels you know the specific energy what is coming it for this specific energy already we have relationship with a critical depth which is just so we know the critical depth and for that corresponding discharge for the critical depth also we will get it. The width of the reverse for the BC is will be coming to 15 meters okay that is the width.

So initially with the 50 meters but we can come up to the close to the 14.4 meters okay that is the depth you come with that unless there will be the effect on the upstream water levels. Because of that breeze also can have a upstream effect in terms of more submergence will happen it. To try to avoid that we try to design as a critical depth concept. Mostly I try to say that you can have the specific energy curve to analyze it.

Another thing which we generally talk about in GATE or engineering service exam but today we have a much more sophisticated design softwares are developed.

It is not that easy simple way to design when you design a urban drainage systems or you design a big channel networks which is very complex. It is not like simple way to design a one cross sections. So that is the reason there are lot of design softwares are there to solve the problems. But as curriculum concerns we call it best hydraulic cross section. What is the best hydraulic cross section? It is not best is looking for best anything related to flow, it is related to the economy.

That means if you look at that if I want to construct a channel okay which is I said it channel from a point 1 to point 2 okay have a water flow or any liquid flow from 1 and 2 the points are fixed to carry this water or the liquid from 1 to u. So the slope is more less fixed slope is more less fixed it is we cannot change it the slope more less fixed unless we can put the drops and all but we can have the a point 1 to point 2 we have a constant slope okay. So for the q amount of discharge has to go it okay. So this Q as a design parameters what we are looking it design parameter first is safe right we can have with us okay slope is more less fixed because endpoints are fixed for us. So one is a safe you can have a rectangles we have a trapezoidal you can have semicircles or circular pipes.

So the shapes are can be different type of shapes that is what option with us. What is a relationship with the perimeter and the depth because constant discharge is known for the design discharge. This is what design discharge. So Q is a fixed for us only options with us as a designers okay as I said it nowadays we have a lot of softwares are available to do that but basic concept follows same that if you have a the you have a option for the different shape maybe rectangulars, maybe trapezoidals, maybe the semicircles or circular pipes okay we can have that. Now is coming it that others is that I can have a different perimeters and the flow depth that can have this. If you look at that basically we talk about the construction cost okay which is a directly proportional to directly proportional to the perimeter that is what it happens it.

the cost directly proportional to the perimeter. So that is the reasons we have to we look at the perimeter is P we try to minimize the perimeter. p we try to minimize the perimeter p because the initial cost will reduce it. The minimum p the cost will be the less because length is more less the same. So if you look at that minimum the size of systems is a minimum cost of construction.

Smaller the resistance zones average large average velocity and flow rate okay. The resistance we have to reduce it that means you need to have a concrete channels okay. If you reduce the resistance, your velocity will increase it. The flow carrying capacity will increase it.

That is the reason we are cleaning the drainage system so oftenly. Otherwise it raises. Maximum hydraulic radius which is maximum average flow velocity okay. So basically best hydraulic sections which is that maximum hydraulic radius or minimum wetted parameters for these specific cross sections okay. I just want to repeat it that maximum hydraulic radius will give you a maximum velocity okay. I am not going to that equations but I just want to put it the meaning equations because its the velocity is a proportional to the hydraulic radius okay.

So that is the reasons maximum the velocities is you have a maximum average velocity. So we try to look at the aspect ratios flow depth by the channel depth y by b and we here we are just looking it for a rectangular cross sections what will be the relationship between b and y so that the perimeter should be minimum. okay that is the simple things okay. So we try to look it first a flow area is equal to y into b y and b. Perimeters you can see that b plus 2y and we can write in terms of perimeters b we can remove it and to make these functions minimum so dP by dy is equal to 0 that conditions when you put it you will get it y equal to P by T that is the best conditions in terms of constructions because that is the conditions your perimeter is minimum okay. So y will be the V by 2 that means the y will be the half of the channel width that is the best cross sections for rectangular cross sections what we can same way we can go for trapezoidal cross sections where we can talk about define the area, perimeters then we can again do this differentiation with respect to y then we can get it y is a function of theta, theta is here functions of B and the theta that is what we look it and we also look it that hydraulic radius you can compute the hydraulic radius which is area by the perimeters.

You can just substitute it finally you get it hydraulic radius will be y by 2 and dP by theta is a best the minimum conditions will be theta should be 60 degree and the relationship between y is 3 root 2 by 2 by b okay that is the best condition. Same way I am not going details you can go for a circular channels you can look this how to do this these are a simple things with a considering a 2 theta and geometrically compute the area, compute the perimeters then you make it the dq by d theta is equal to 0 okay. And you try to solve it and dp by d theta and you try to get a relationship between maximum velocity conditions and that is what we do in heat and trial methods. More details I am not going it is all details are there in Senzel Simbala book. You can go it similar way you can talk about a triangular channels in most of the times a low flow velocity we need a triangular channels like urban drainage.

So we can find out the relationship between hydraulic radius and the flow depth. if you are making it economical channels dp by dm okay this m is representing here. So we will get a relationship the same conditions okay getting the area getting the perimeters getting the hydraulic radius and you try to look it what is the conditions come it for dp dp that theta is 45 degree is a best conditions here. okay and m equal to the one conditions that is best hydraulic cross section. Now I will just look at one example from Sinjal Simbala book.

What is transport with a discharge is given open channels, line, the slope is there. Determining the best cross section if the shape of the channel is rectangular and trapezoidal okay. If you look at this condition okay you can highlight the assumptions okay. flow is steady, uniform and all these conditions okay. And you can just substitute basic case of a rectangular cases and use the Manning's equations to get this velocity and b and y components okay as you know it the flow velocities okay.

similar way we can do for trapezoidal cross sections with help of Manning s equations okay. I have not gone very detailed about Manning s equations but you can have Manning s equations and finally you get it what will be the B value for best cross section hydraulic cross section which is necessary as it will be the minimum construction cost. with this let me complete it to for this open channel flow you have to remember very simple things. One is the speed of surface water wave which is a function with g and the flow depth that is what you should remember it from this class and the flow proud numbers is v by c0 okay that is what is basic concept we discussed a lot. This is the concept also specific energy concept what we have introduced it and the critical depth also we have introduced how we can but you need not to remember much except this one with this let me I thank my students group who is really the help for me to develop this very interesting illustrative with a lot of examples of demonstrating this how to solve simple problems or complex problems for this. Thank you.