Hydraulics

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Module No. # 01

Introduction to Open Channel Flow

Lecture No. # 02

Open Channel Hydraulic Part-1

Friends, we did discuss a lot in our introductory class itself on open channel flow, because in the subject hydraulic engineering or in the science of hydraulics, this open channel flow forms a very very important component. Well, when we see in our day to day life, say flow when we talk about flow, what sort of flow we see that, it can be flow in a river or we see the flow in the channels may be, I mean in the drains or in cultivation field also we see flow in the irrigation track canal. So, that way when all this sort flow we see, all these are basically open channel flow, and of course, in our day to day life, when we talk about flow, we see another kind of flow, that is, say in our household water distribution system itself many place we get water from the pipe. So, that is the pipe network system we sees a flow occurs through pipe also.

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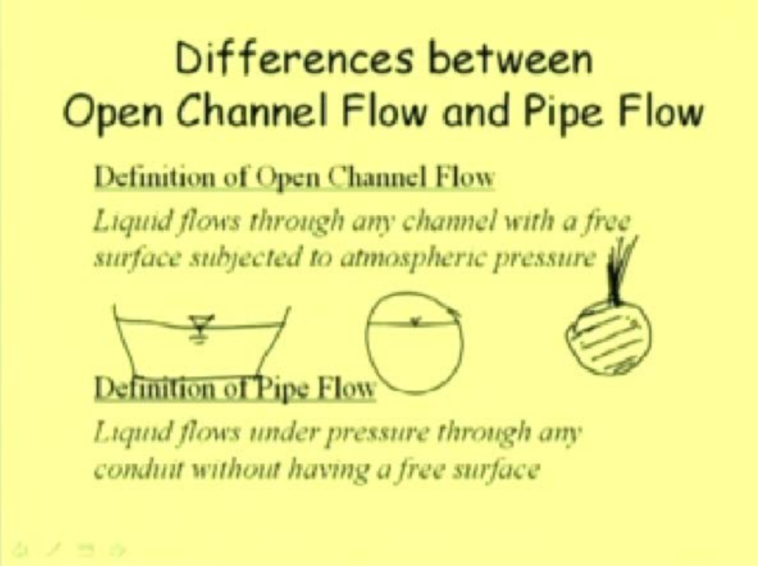

Well so, for going into open channel flow in more detail, let us start it with discussing few issues regarding the differences between the open channel flow and the pipe flow, but when we are talking here as the differences between open channel flow and pipe flow, definitely we are not talking about the physical difference between open channel flow and pipe flow; that means, that we are not talking that when a channel is or when a flow is occurring through a channel it is, open channel flow or when a flow is moving through a conduit or pipe, it is a pipe flow. Well, that is the very basic requirement, but there is more than that. We are trying to discuss the hydraulics; the difference in hydraulics characteristic of open channel flow and the pipe flow.

To start with, the definition of open channel flow in our introductory class also we gave this definition, that is, liquid flow through any channel with a free surface subjected to atmospheric pressure. Then we call that as an open channel flow. Well, just to explain it in a little better way say, if I draw a channel here just to explain it in a more detail, say this is a channel which is carrying water up to this much depth, then what we mean by that, if free surface subjected to atmospheric pressure, what we mean by that?

So, this particular channel is carrying water up to this much depth and this surface is subjected to atmospheric pressure. So, pressure at this level is basically atmospheric pressure. So, we indicate it by a tick point here that, this surface is subjected to atmospheric pressure and that sort of flow we call as open channel flow.

Now, again to go little bit more detail into this particular aspect, suppose in our day to day life, we are finding that sometimes in the road construction, we use in a culvert; many a time we place a hemp pipe that is to carry the water from one side to other side below the road we put a hemp pipe, and through that hemp pipe we see that water is flowing. Suppose this is hemp pipe of that type and water is flowing like this up to this much depth. Now, in our general concept when we say by our general understanding that open channel definitely it is a hemp pipe.

So, it may not be understood as a open channel, but when the water is flowing up to this much level, then we need to see whether this surface is subjected to atmospheric pressure or not now definitely. When this surface is connected to the atmosphere and it has access to atmosphere, then the pressure, existing pressure prevailing on the surface is also atmospheric pressure.

So, this sort of flow although it is flowing through a conduit, but this will refer as a open channel flow. So, that is why I told it is not basically the structure through which the flow is occurring, but here, we are trying to discuss the open channel flow and pipe flow on the basis of very basic hydraulic characteristic the difference between these two.

Well, then if we talk about the definition of pipe flow, what is the difference between open channel flow and pipe flow? So, this definition states that, when the liquid flows under pressure, when the liquid flows under pressure, this is important, through any conduit without having a free surface. So, when water is flowing through a pipe, when water is flowing through a pipe, and it is completely full; it is completely full with water.

So, there is no free surface and the water is subjected to pressure mode and atmospheric pressure and then it is referred as pipe flow. It is different from the atmospheric pressure Now, say if water is flowing like that, it is very clear to almost all of us that water if it is flowing through a pipe, then if you make a small rupture here, what happens?

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Yes

If we see, if we make a small rupture here, then what will happen? That water will just move into the atmosphere like this. Well, why it moves in this form? Why it moves in this form, because the pressure inside the pipe is more than the pressure outside the pipe. Outside the pipe we have atmospheric pressure and inside pressure is higher. So, that is why it is moving out like this. Now, if you a put pipe, water would start rising into the pipe. So, that way this is what the very basic difference between open channel flow and the pipe flow.

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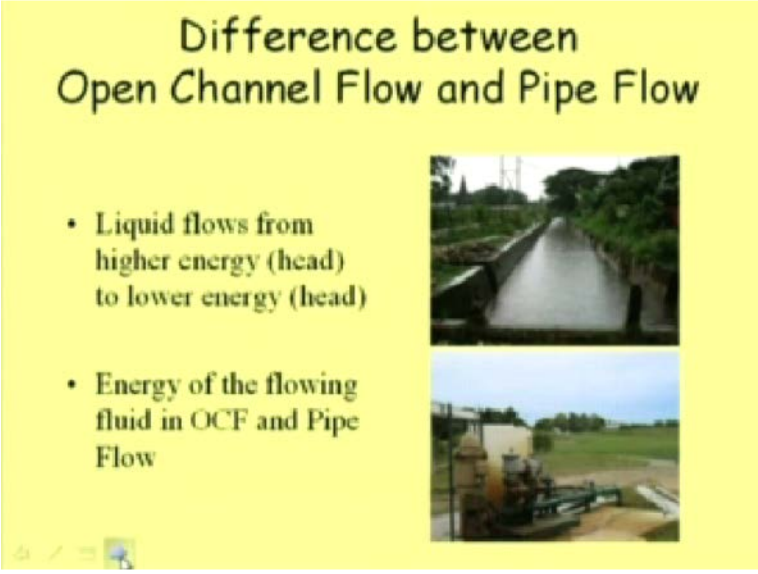

Well, now let me go one step more into this particular aspect, that is, again we are discussing only the difference between open channel flow and the pipe flow. So, in both the cases, we are talking about flow. Now, when the flow will occur, that is important. So, flow will occur only when the energy level on the upstream side, suppose whatever it is a channel or a pipe, when the energy level on the upstream side of the pipe or the channel is more, then the energy level on the downstream side of the channel or the pipe, then only the flow is occurring, and during the process of this flow, some energy get lost; that is also another aspect now.

So, many a time we to understand the flow process from the concept of energy balance or understanding that what is happening to the energy of the entire flow system. So, how to just visualize the energy and how to take this different component of energy because energy is comprising of different component. Say in a channel when the flow is occurring, it is a very common understanding that, if one end of the channel is at higher elevation, then other end of the channel is at lower elevation. Then the water will flow from higher elevation to the lower elevation.

Well, this is of course, much more complicacy is there but just taking as a simple example; that means, because of the elevation level, it gains some energy, water gains some energy. Then again, when we talk about pipe, then many a time we see that through pipe, water is flowing from even lower level to the higher level. We do pumping from say a tank remaining at a lower level to a tank remaining at a higher level.

So, in that case, we use some palm to generate some extra energy at the lower level, so that the energy level at the lower side become more than the energy level at the higher side and then only the water start flowing from the lower level to the higher level. Well that means that extra energy we are generating in the form of pressure. So, in the energy, we have pressure; pressure has something to do then in the energy again the position or the elevation level has something to do, and that way when the water is flowing, that velocity if it is flowing with a very high velocity, it will contain more energy; if it is flowing with a very low velocity, it will contain low energy.

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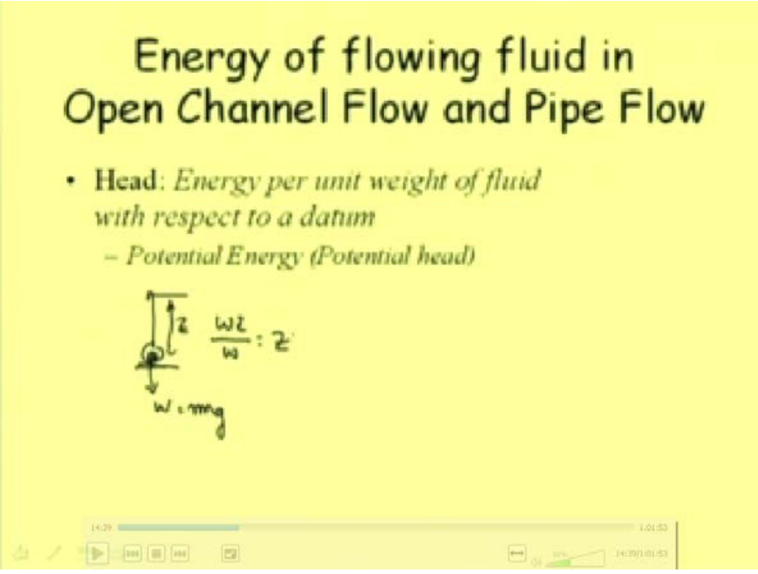

So, that way when we talk about energy, let us see how we can find out the differences between the energy in pipe flow as well as the energy in open channel flow, and before going to the difference, let us see we, we, use a term that we call as head, that is, say energy we call that energy head of flowing fluid in open channel flow and the pipe flow. Now, when we say that head it means, what is the difference between head and energy? Many a time because we will be using this terms. Sometimes we are using this terms head; sometimes we are talking that it is energy.

So, what is difference between these two terms? Basically, the head refers to that energy per unit weight of fluid. Of course, when we say it is energy, it will have to be with respect to a datum, it will have to be with respect to a datum. That way energy per unit weight of fluid with respect to a datum is referred as head. Well, now, first it is there are different, it remains in different forms energy in the fluid can remain in different forms. So, one of that is potential energy or we call potential head.

Well, that is a very common understanding that say may be and may not be fluid any, any, object if we take, suppose it has a weight, now that weight if we are raising for a distance of say z a object we are taking and that we are raising for a distance of z suppose like that, then say this how much work we are doing basically? Its weight means this is the force w and this is what basically we express as, if suppose mass of the body is m, then it is being attracted by a force of acceleration g. Then this m g is basically the weight.

So, this weight we are taking up, up, to a distance z. So, we have done a work of w into z, and if this both the falls from this part to that level, suppose our datum is this one, if this both the falls from this level to that level, then also it will be working the same thing that this weight w which is actually the force and the z distance. So, this will be the weight.

So, w into z will be the work done. Well, then that is why we call that it has when, when, a particular body is at a height of z, then it has the capacity of doing work of this much and energy is nothing but the work done. Now, this is the energy if we talk in terms of per unit weight, then it become say this divided by w; so, this is becoming z. So, potential energy of fluid also say, when it is flowing in a channel, then at what height it is flowing with reference to a particular datum? That height we call as a potential head or potential energy.

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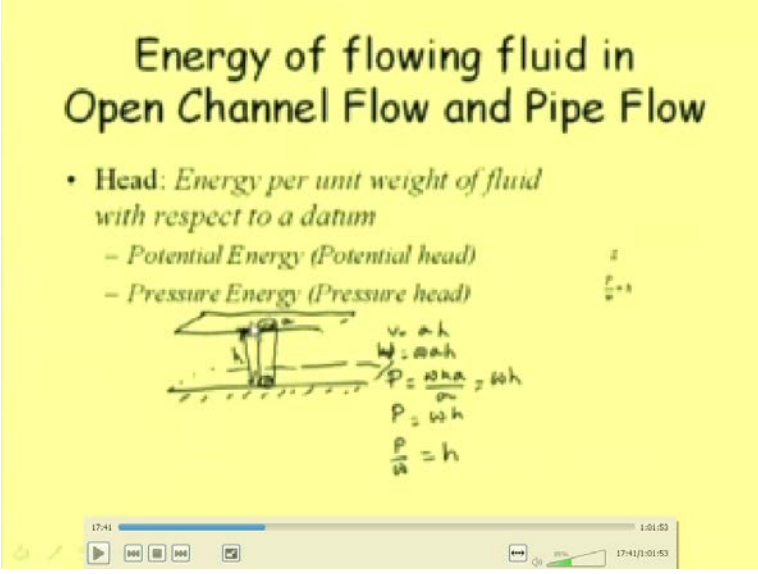

Well then, so this z is the potential energy. Well, then, let me just talk about the another form of energy. That is what we call as the pressure energy. When we see that suppose let me consider this water is flowing up to this much of depth, and then, if I considered, well let me take a surface, say this is the water surface and it is flowing in a channel like this. Now, if I considered a water column of area say a, this cross-sectional area a and a, this is say channel bed, this is channel bed, and then, if this is the height, if this is the height, then what is the pressure exerted on this particular subject, surface? That is, the normal pressure exerted on this particular surface.

If a is the area, h is the height, then volume will be the volume is equal to a into h; this is the volume, and then, what will be the weight? So, weight is equal to, if the unit weight of this particular fluid is w, then this weight is equal to w into a into h and this weight is nothing but the force acting at this point normal to the surface. Well, this is the force. So, when pressure we talk about, pressure is nothing but the force per unit area. So, force per unit area means if we divided by the area, then pressure become equal to, equal to w h a divided by a. So, it is equal to w into h.

So, what we are getting the pressure is equal to w into h. This is the unit weight of water. Now, when we say that pressure per unit weight again, then we divided by w. So, what we are getting that P by w is equal to h. So, this h we refer as, we refer this h as the head of water, that is the pressure head, pressure, energy or pressure head. Well, then, we can talk about, well that is what P by w is equal to h, then we can talk about another form of energy that the fluid derive due to its flow, I mean that it has a flow, it is flowing with some velocity, and because of that flowing velocity, it is acquiring some energy. We all know about the kinetic energy and that kinetic energy is another form of energy that the flowing fluid has.

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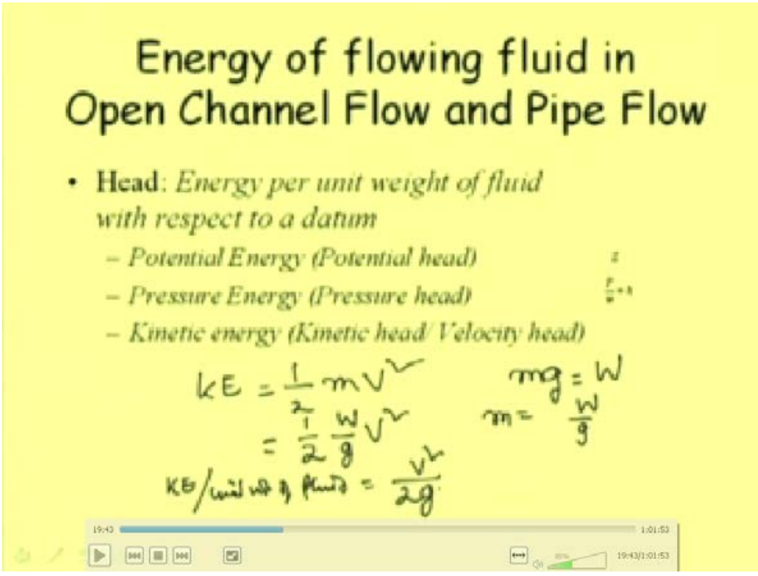

So, that is what the kinetic energy that we also call as kinetic head or the velocity head. Well, when we say kinetic energy. We are starting from that level, that is, we know that kinetic energy is equal to say half m v square. This v means velocity; this v stands for velocity. So, kinetic energy is equal to half. Then this m is mass into velocity square. Well, now again, if it is for one unit of weight, I mean if the weight is w, then say we know that m g is mass into acceleration is equal to the weight.

So, we can write this mass as say w by g this implies that mass is equal to w by g, and that way we can write this as half of w by g into v square. Well now, if we talk this kinetic energy in terms of per unit weight; that means, we will have to divided by the weight w, and so, kinetic energy head when we talk about, this become say kinetic energy per unit weight. If weight of fluid, if I just write it, then it will become equal to say v square by twice g, v square by twice g. So, that is what our the third form of energy that we have that is the kinetic energy v square by twice g.

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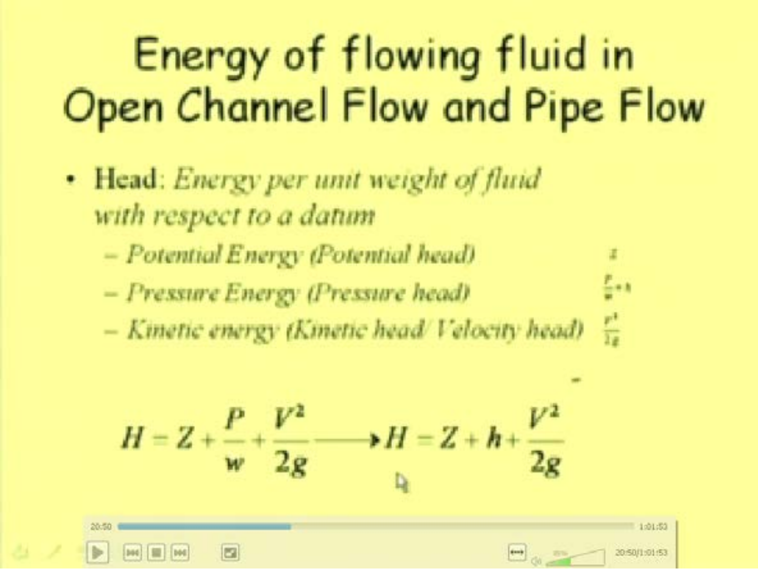

Well, then, in a flowing fluid combining these three different forms of energy, we can say that the total energy that exist in the flow is H we are writing because we are talking about head; we are not writing here as energy rather we are writing here at H because it is the head and that is equal to Z plus P by w plus V square by twice g - where w is the unit weight of water; g is the acceleration due to gravity, and this expression, that is, H is equal to Z plus P by w plus V square by twice g here, this P by w this head in case of open channel flow, we can write this as H as we did explain already that P by w is nothing but the H.

So, this is what the energy form in a particular channel, and based on these energy, we try to see that what are the energy difference between one level and other level, and that way, we need to know that how much is the difference in energy or what is the, say slope of the change of energy. Well rather than saying it like that, let me explain it by drawing a diagram again.

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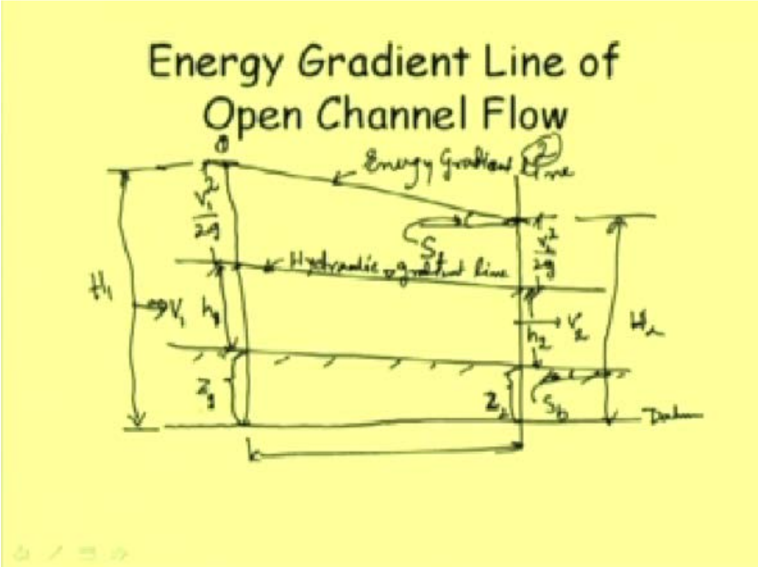

So, there are, there is a term that we call as energy gradient line, and this energy gradient line in case of open channel flow, it will be different form the energy gradient line of pipe flow. Of course, basic concept is same, but we must understand that how we draw this things. Say in open channel flow if we just consider, this is what the channel, say this is the bed of the channel, this is the bed of the channel, and this bed might be having will be having some slope well that is not important right just right at this movement, but well suppose the slope is, still I am indicating that slope is S b means say bed slope is S b well.

Now, to just see what are the energy of this particular channel and say depth of flow is this much, depth of flow is this much, and at a particular level here section, let me take a section here. Now, as I was telling that when we say about energy, we need to say this energy always with respect to a particular datum. Well, let the datum be this one, let the datum be this one. So, this is what the datum.

Now, the energy first we are talking about this particular flow n with respect to this datum up to this much, up to this bed level. This is what is the potential energy because the flow is moving above this point at this height above this particular datum. So, this is coming as the potential energy. So, let me write it at z 1 say this is the section I am talking about and this is say z 1, and then, what is our pressure energy? That pressure energy as we have already discussed it is nothing but equal to this particular depth of flow, this particular depth of flow say h.

That we can express in the form of P by w also, but here, in open channel flow, we write it as h. So, this is what the pressure head. This is the potential head; this is the pressure head, and then, the water in this particular section is suppose flowing with a velocity v 1. Then because of this flowing velocity, it will be having some kinetic energy, say this much is the kinetic energy we are just drawing it in the form of a graph, say up to this much it is the water level, and beyond this, what we are drawing.

This is say we are graphically representing the total things here is the potential energy; here is the pressure energy; then here we are just graphically representing the height as say for this velocity v 1, it will be having v square by v 1 square by twice g from here to here. So, like that, we are having three component of energy at a particular section. Let me refer this section as say one.

Then at another section downstream, then at another section downstream, say here, let me take another section two, section two, and here also this z is say z 2, z 2, and this height is, height rather depth I am talking about this depth is h 2 and say water is going out from this point with a velocity v 2. So, the kinetic energy or kinetic head at this point is suppose this much v 2 square by twice g is this much. So, this is the head, total head in the section two; this is the total head in the section one. Now the line, so what is the difference in head?

So, if I say this is the total head, then I can show that it is what is h 1, and from here to here, say head is h 2, and the line joining the head at this point and at this point this line, we refer as energy gradient line means what is the slope of the energy? That is what the energy at this level minus energy at this level, and if we just divided by this distance between this two point, then what we will be getting that this slope is, this slope is representing the energy slope and we write in open channel flow this as s f energy slope. So, we will be using two terms in most of our future work, that is, the bed slope we will be referring. Then sometimes we will be talking about the energy slope. So, by energy slope, we means the slope of the energy line well and this energy line is called the energy gradient line, energy gradient line.

And then there is another term, there is another term. If we just do not talk about this kinetic head, that is the v square by twice g, then the line joining the other two energy; that means, say this potential energy and the pressure energy that is the z 1 plus h 1; well let me put here one here z 1 plus h 1, if we join, if we just add this two, then we get here two point again and the line joining this two point we refer as hydraulic gradient line, because see when you do not have a difference between this two point, then the water will not flow. When water flow, then only this velocity is coming.

So, flow is starting because of the difference in this hydraulic head and that is we call as a hydraulic gradient line, and in open channel flow, this surface itself is the hydraulic gradient line. So, we say that this is hydraulic gradient line well. So, what the energy concept we have seen or we have got in the open channel flow is that, if we considered this as a datum and say this is the channel bed with a slope S b, then up to the channel bed from the datum it is the potential energy.

Then from the bed to the surface of the water level, that is what the pressure energy, and then, above the surface of the water, then we get the kinetic energy and the line joining the energy level at a upstream point and at a downstream point is call energy gradient line and the line joining this total z 1 plus h at a upstream point and downstream point that is call hydraulic gradient line. Now, how it differs from the pipe flow, how it differs from the pipe flow, well.

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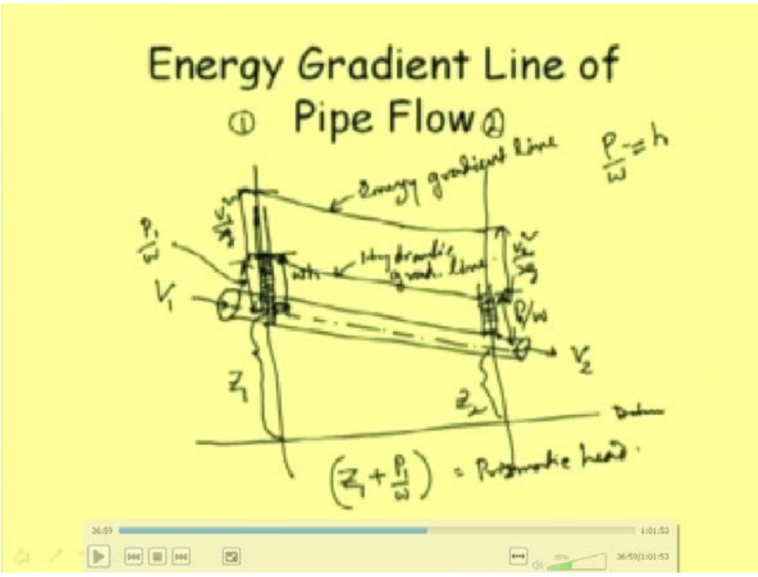

So, let me draw again the same thing that is the energy gradient line in case of pipe flow, in case of pipe flow. Here, say our datum is this one, our datum is this one. Then say a pipe is in this level pipe is like that, and water is flowing through this point; it is going out from this point; it is entering here with a velocity v 1; it is going out from here with the velocity v 2. Now, what will be again if I take two section say, here one section, here another section, section one and section two.

Now, what will be the elevation head for this particular pipe? In open channel flow, it was cleared that we could take this as the distance from the datum to the bed of the channel, but here it is a pipe whether we should take this up to this point or this point or to the center line. Yes, we take it up to the center line say, if this is the center line of the pipe, then we consider up to the center line that it is the z 1, that is, the elevation head. Then, well, here what will be the pressure head? Well, I can say that if the pressure existing here is p; at this point say pressure existing is p, then the pressure head will be, if p is the pressure, then pressure head will be p by w as we did, we have seen already, but well, let me explain it in a another way say, here if we put a small pipe, here if we put a small pipe, which we call as a piezometer, then if the pressure here at this point is p, then to what height the water will rise or whether water will rise to a height.

First point is that if we put a piezometer here, then putting an opening here. Then pressure here is p, and from the top, initially the pressure is atmospheric pressure. So, pressure here is more than the pressure from the top side. So, water will be flowing in this direction rather water will be rising like this. So, when water is rising up to a certain distance, then what will be the pressure exerted? What will be the pressure inside and outside?

From the topside, it will be at this height this column of water is exerting a pressure at this level; this column of water is exerting a pressure at this level and that will be again equal to the height of this particular column, and of course, if we say area, then area multiplied by height this will be the volume; then multiplied by the say unit weight, this will be the force; then divided by the area will become the pressure, and so, the pressure from the top will be again h divided by h into w; h into w will be the pressure exerted from the top.

Then it will keep on rising till the situation is like that; that means pressure at this point is p and the pressure from that topside is also equal to p, and that means pressure from the topside as we are writing this is equal to w into h - unit weight of water multiplied by h. So, this is what the pressure from the topside. Now, when this two become equal, when this p become equal to w h, then this water stop flowing.

So, that is why pressure at a particular point in pipe flow, pressure at a particular point in pipe flow, we can find out by putting a piezometer, by inserting a piezometer here and just observing that to what height the water is rising, and that way we can see that when we talk in terms of head, then this p by w. So, p by w is equal to the h. So, that way we are finding that this is what the pressure head, and this height we can write as, this height we can write as, of course this level should be same, we can write this as p by w. This is what the pressure head.

Then this is flowing with a velocity also. So, finally, there will be some more energy on the top of this particular line and that energy is suppose up to this much we are talking that, this is what the v square by twice z. This is same as the open channel flow. So, similarly, here also we will be getting say z 2. Then if we insert a piezometer here, up to a certain extent the water will be going and this is nothing but p by w, and then, there will be a velocity head, that will be equal to v square by twice z, that will be equal to v square by twice z.

If I am writing this for section two, I will put a suffix two everywhere p 2 by w, then z 2 here; it is z 1 here; it is v 1 and here; it is say p 1 by w, and then, the line joining this energy point and this energy point will be the energy gradient line, this will be the energy gradient line.

Well, and the line joining this point and that point is the hydraulic gradient line, and again, here say this z 1 plus p 1 by w this together we call as piezometric head, and in case of pipe flow, this is of course important and we, we, will be doing some other works in our later part of this course with this sort of things, and then, this is called hydraulic gradient line, this is called hydraulic gradient line. So, how we see or how we just measure the energy in pipe flow and energy in open channel flow perhaps this picture, this two, this slides could make it little bit clear, and of course when we will be moving ahead, then a few more things we will be finding in this differences.

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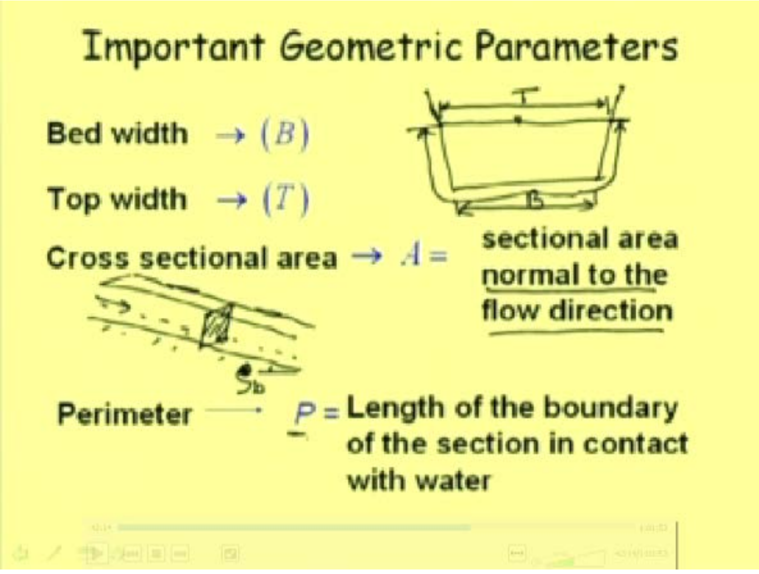

Well and after discussing this, that is, after trying to we have, we have, tried to understand what is open channel flow first. With the understanding that, what is each difference with the pipe flow. Then we would like to discuss that some of the important geometric parameters, some of the important geometric parameters, of open channel flow. Well, by geometric parameter, what we mean that when we have a channel, when we have this channel like this, then we will be referring by these common symbols as you can see that, when we say that bed width, bed width of the channel, this is of course very common and we know that this is what the bed width B and then many a time for many calculation we will be requiring apart from the bed width say what is the top width.

Now, this point there may be some confusion, because when we say this is the channel, then by top width whether we will be and suppose our water is up to this much level, water is up to this much level. Now, by top width, I mean whether we will be understanding the distance from this point to that point or we will be understanding the distance from this point to that point what we basically refer. Well, in open channel flow, when we say top width, we refer to the distance from here to here, that is, what is the top width of the flow cross section.

This is what the top width not the actual top width of the open channel well, and that is why after that we are talking about cross-sectional area, that is why we are talking about cross-sectional area A. So, in any object cross section is a very common things that we always understand that this what the cross section is and but still we want to define it like that the cross section means it is the sectional area normal to the flow direction, normal to the flow direction.

Well, what we mean by cross-sectional area say, if this is a channel and if I draw the section, if I, if I, draw the width of the flow also here, let me draw it like that, and then, by cross-sectional area, what we are meaning that if I make a section. So, flow is occurring in this direction. So, if I make a section normal to the flow, normal to the flow, this is what is the cross-sectional area of flow. Why it is important, because some may take this section as perpendicular, as I mean vertical; it is by cross-sectional area. Basically we do not mean the vertical section. We mean the section normal to the flow direction.

So, that is why I am emphasizing this point normal to the flow direction. Of course, when our slope of the channel is very small, say this bed slope of the channel is very small, then if this theta is very small or theta rather we did use the symbol S b, this S b the bed slope is very small, then this cross-sectional area and the vertical section become almost equal. So, many a time we, for simply, to simplify the situation, we make this sort of assumption also. Then we talk about another geometric parameter that is what perimeter.

So, perimeter p it refers to the length of the boundary of the section in contact with water. So, perimeter of the open channel by that we mean the length of the, this cross section which is in contact with water means from here to here. Then from this length and then we are going up to this much. Again here also we are not considering. When we are saying that perimeter of that section, we are not considering the portion which is lying above the water level; up to the point where it is actually in touch with water. So, that is what we refer as perimeter. So, I hope that we could make this clear what we mean really by sectional area or cross-sectional area and what we mean by perimeter.

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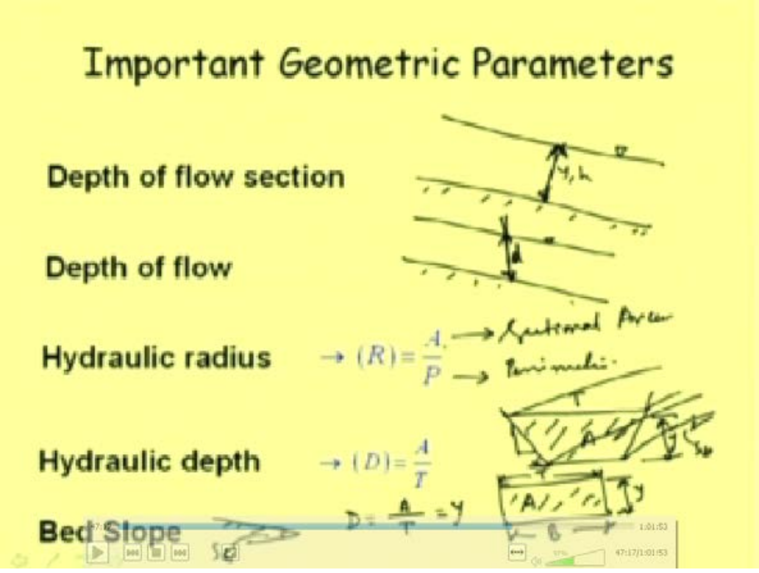

Well, this two terms are important, because in this slide, we will be showing that how these two parameter are used to define some of the important parameter of, I mean open channel flow. Well, depth of flow section, again before going to these terms, let me discuss the depth of flow section. As I was telling this depth of flow section means say as flow section we means always it is normal to the bed.

So, if the bed is like this, then this, this, depth is the depth of flow section, and generally we refer it as y or h or this sort of things, and then, when we say depth of flow, but many a time this two term we use almost meaning the same thing, but in reality, when we say depth of flow, then say if this is the channel like that same channel and then this is the flow surface, then by depth of flow we mean, say at any point, if we observe, then this vertical depth is the depth of flow; vertical depth is the depth of flow say small d I am writing here vertical depth. So, that way there is a difference between this two term also - the depth of flow section and depth of flow.

Well, let me come to another hydraulic parameter of open channel flow. That is called hydraulic radius, and this hydraulic radius will be using in most of our calculation and this is very important parameter. By hydraulic radius what we mean that it is the ratio of the sectional area, that a is the sectional area and the perimeter, sectional area and the perimeter.

So, this ratio forms the hydraulic radius, and then, along with hydraulic radius we have another term. That is called hydraulic depth; that is called hydraulic depth. Well, by hydraulic depth, what we mean that, it is the ratio of sectional area to the top width of the section, not the bed width. You see, if it is a trapezoidal channel, if a channel is of this shape, then say this is the top width and this is the sectional area a. Then our hydraulic radius D is equal to, sorry, not hydraulic radius, hydraulic depth, hydraulic depth D is equal to this sectional area divided by the top width.

Of course, if it is a rectangular shape, if the channel is of rectangular type, then our top width and the bed width, that this we do not refer as bottom width, we call it as a bed width. So, this top width and bottom width is same, and the sectional area is say a. Then again hydraulic depth D is equal to A by T. If we write, this became equal to, if a is this much and t is this much, and if we say that depth of the channel or depth of the flow section is y, then this hydraulic depth become equal to the y.

So, if the channel is of rectangular type, then our hydraulic depth m the depth it become the same, but when it is of trapezoidal type, then this hydraulic depth refer to the sectional area divided by the top width, and depth of flow is of course this one and these two value will be different.

Well, then another important parameter is bed slope, another important parameter is bed slope. That we have already explained the slope of the bed. The slope of the bed is referred to as bed slope and that also we will be using for many of our analysis, and when we say slope, if the channel is of this type say trapezium it is in the shape of a trapezium like that, then two terms will be coming - one term is that the slope of this side, that is we refer as side slope, that is we refer as side slope this slope, and then this bed slope means along the direction of the flow when we talk about what the slope is. That is what we referred as bed slope.

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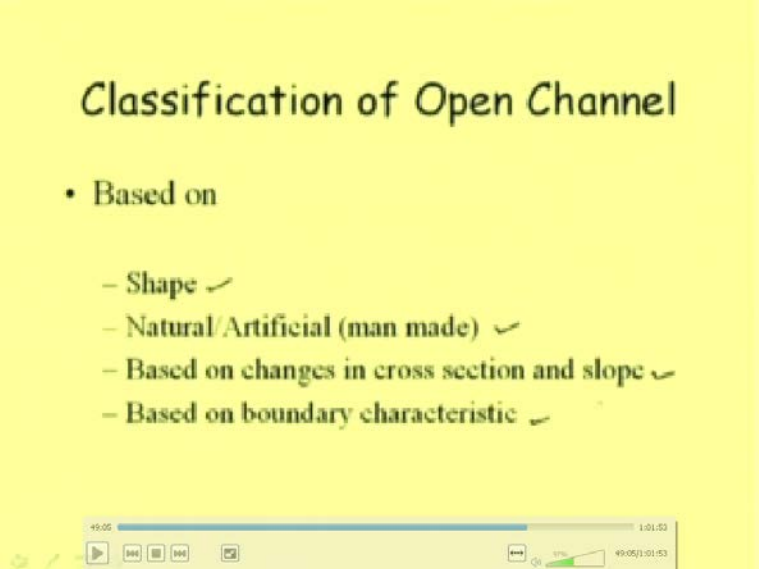

So, that way, in this sort of flow we will be having two slope - one is bed slope and another is side slope. This angle we referred as the side slope well. With this introduction of some of the parameters of open channel flow, some of the geometric parameters of open channel flow, let me go to the next step, that is, let me go for classifying the open channel, that is, classification of open channel.

Well, this classification of open channel we can again do in different basis, on the basis of different aspect. For example, we can classify the open channel say based on shape, based on shape, what shape? What is the shape of the channel? Then again sometimes we call a channel as natural artificial and it has something to do with our analysis also. So, that way we classify it in that way also.

Well, then another important aspect in most of our hydraulic calculation we use like that we, we a, we use a concept of classifying the channel in terms of it changes in the cross section and the changes in the slope. In a channel, the cross section we are observing in a channel; we have already explained what the cross section is, but the cross section along the channel reach may change. Similarly, the slope in the channel may change. I will come to that. So, based on this also we classify. Again sometimes we classify based on the boundary characteristic of the channel. So, that way on different basis, we classify the channel in different way.

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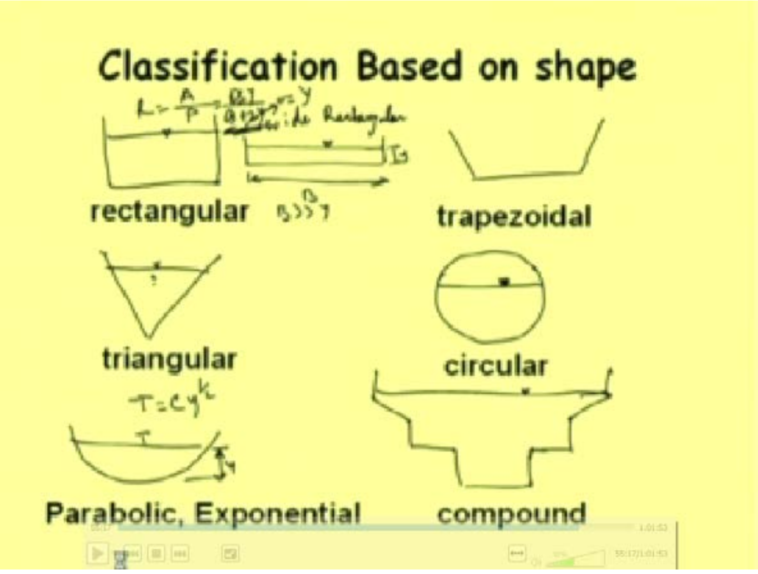

Well, then, let me first start with the classification based on shape. Already I have explained what we mean by rectangular channel, that is, when the shape is just rectangular simple like this, then we refer to as rectangular channel well. Then when we say rectangular channel, why we need to say this, I mean it is though it is very simple, but sometimes we can have a channel another name. That is called wide rectangular channel. Well, rectangular channel is very clear to all of us, but then, what we mean by wide rectangular channel? What we mean by wide rectangular channel?

When the depth of flow is very less, depth of flow is very less in comparison to the width of the channel, in comparison to the width of the channel; that means, when say b is much greater than y, then we call this as wide rectangular channel. So, along with the rectangular channel, I like to say that this is wide rectangular channel, wide rectangular channel, and why we consider this as a wide rectangular channel, because for many of our calculation, like say we are using I mean the hydraulic radius. Say for example, hydraulic radius we are using. Then hydraulic radius is say as we have already explained it. This is what the area, sorry, hydraulic radius R is equal to area by perimeter.

So, in case of a rectangular channel, this area is nothing but B into y and perimeter will be equal to B plus twice y. Now, in many of our calculation, we wish to simply the expression for this term and this B plus twice y this term. Say for very wide channel, for very wide channel, may be a river whose width is suppose 100 meter and say whose depth is say only 2 meter or 1 meter something like that. Then B by twice y term will be say if it is 100, if it is just 1 meter or so, then it will be 100 plus 2 will make it 102, and this is suppose 2 meter; y is 1 meter, then this B is 100.

So, this will be 100; value is 100 meter square and this is 102. Now, this 100 by 102 will give us some numerical value of this hydraulic radius rather than using 100 by 102. If we use 100 by 100 simply, then the value will not differ much. That is why in case of wide rectangular channel, if this B is very very large than y, then we can consider this perimeter though perimeter is actually equal to B plus twice y. We can consider this as equal to B; that means this part we can neglect as compared to B, and then, this B and B would get cancel and then hydraulic radius become equal to y. So, that way based on our conceptualization of the particular channel, our expression we can simplify, and in many of our work, it is advantageous.

Well, then when we talk about trapezoidal channel, when we talk about trapezoidal channel, this has already been explained that this is what the trapezoidal channel. Triangular channel, if the channel is of v shape like that, that we refer as a triangular channel, and for some of our hydraulic activity, we need this triangular channel also. Then of course circular channel, well circular channel, what we mean by circular channel that it can be of the type that basically shape is circle, shape is circle.

The flow is suppose this much depth and it does not matter. If I close this one this top or if I keep it open, it does not matter, but this will be a circular open channel. Even if it close as I have explained already, if the surface is subjected to atmospheric pressure, it will be a circular open channel. Then parabolic or exponential channel say when we talk about parabolic channel like this, then say this is my top width. Then I can express this top width in terms of y; this is top width is equal to some constant and y to the power half. This is parabolic, and then, say this top width if I express in terms of y to the power n. Say this exponent is not half. If it is half, we call it as parabolic. If it is suppose n, then we can call it as exponential channel. It can have any value.

So, in general, we call it as exponential and this is a particular case. Then we can have channel which is referred as compound channel like that. A channel just like this or this is a simple channel, and then, if we have a channel like this, if we have a channel like this well and it not necessarily that this should be a vertical line like this. That can be of this type also; it can be of this type also and water is suppose flowing like this here, and this sort of channel, when it is a combination of different type of channel, then we refer this as a compound channel well.

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So, like that based on the shape we classify open channel into different classes, and then, again based on whether it is natural or artificial, it is very much known to all of us that a channel existing in the nature we call natural; a channel that we are constructing we refer as artificial channel. Then which is more important is the based on change in slope and cross section.

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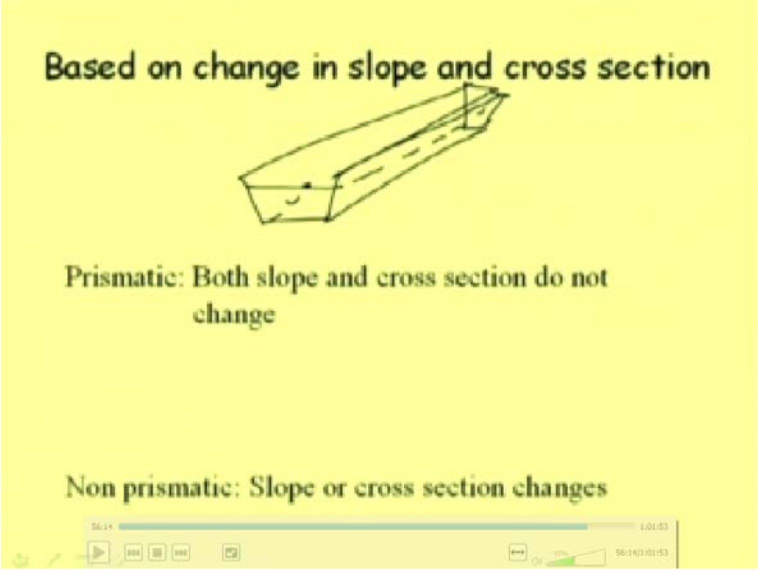

So, if a channel is carrying water and say its cross section here is like this and it is carrying water up to this much depth and this channel is of this type and its cross section here is like this, and say this cross section here and here if it is not changing if it is not changing of course, in my diagram it is, it is, appearing that it is changing, but it is a long distance. That is why it is narrowing down. So, if it is not changing, then we call this as a prismatic channel.

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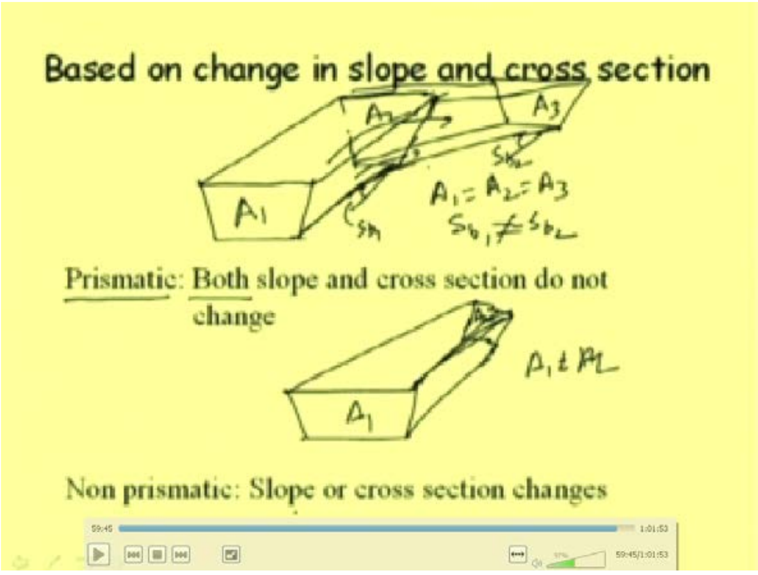

Well, based on the change in slope and cross section, we can classify the channel again into two different part. Say if I draw a channel here, say this is the channel and well. Suppose this is the cross-sectional area here and this cross-sectional shape rather shape is like that, and it is maintaining the same cross-sectional shape; if I move like this, it is maintaining the same cross-sectional shape, say up to certain distance like that, and then, if this cross section is not changing, well this is one issue, then suppose the slope of that channel, this bed slope S b, this is also not changing.

So, when in a channel the cross section as well as the slope of the channel is not changing, it is remaining same. Here whatever is the slope; here also it is the same slope. So, that way we call this as a prismatic channel. So, this prismatic channel when both slope and cross section do not change, but please remember, it is both slope and cross section. If suppose cross section is remaining same, suppose up to this much it was same, then the slope has change like this, and then, we are having again a channel here say the cross section is same. Here whatever cross section we have, we have the same cross section, but the slope has changed at this point water is flowing like this; water is moving and it is flowing like that.

So, this channel although the cross section say A 1, A 2 and A 3 all may be same A 1 equal to A 2 equal to A 3, but the slope S b here is different and slope S b here is different, but S b 1 is not equal to S b 2. Then from here to here, we cannot call this channel as prismatic channel. So, a channel to be said as prismatic both slope and cross section must not change, and of course, in a natural situation or even in manmade case also, we do not get a complete channel as a prismatic channel, but for our analysis, what we make that, from here to here, from one part to one part, a channel reach that from here to here, we refer as a say prismatic section. Then from here to here, from one point to another point, again a prismatic section like that.

And then non-prismatic means when either slope or cross section changes, if any one of these change, then we call this as a non-prismatic channel like that. If the channel is having this section here and then suppose it has narrow down like that, if it is narrow down like that and then we are having a section of this sort here, well this sort here. Then it is say A 1 and A 2; it is not equal A 1; it is not equal to A 2. Then also it is a non-prismatic channel; then also it is a non-prismatic channel. Of course, in between if slope channel, then also it is non-prismatic.

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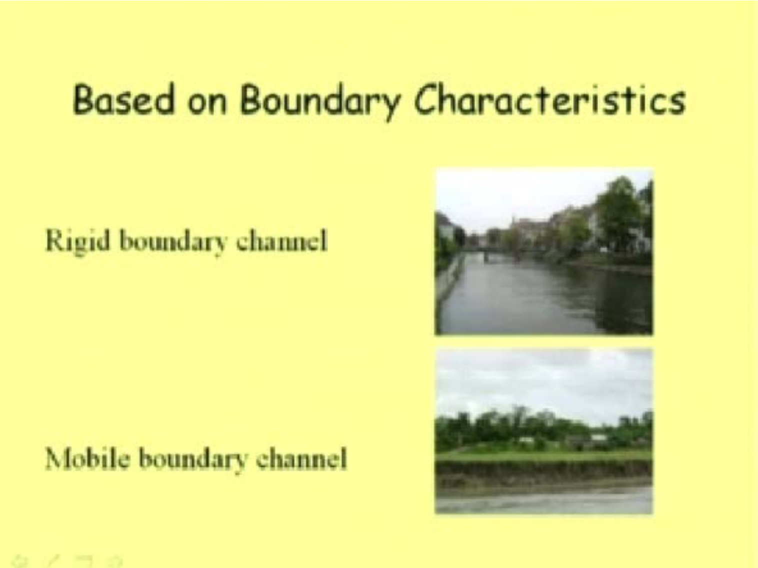

So, both slope and cross section must remain same. Well there is another classification, and then, based on the boundary characteristic, say if we classify we, if a channel is having a proper boundary, then it is referred to as rigid channel boundary which is say non-erodible, and then, if the channel is of this type, then we refer this as a mobile boundary channel; then we refer this as a mobile boundary channel.

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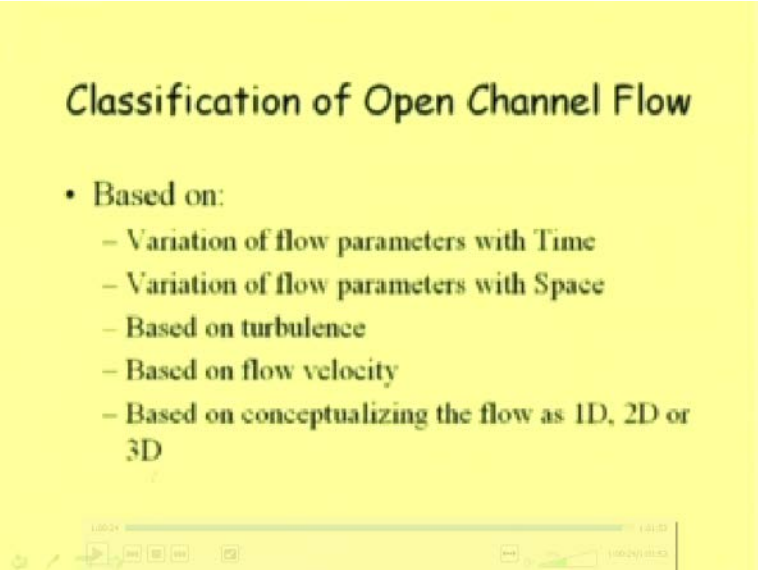

So, this two way also we can classify. Well, today we will not go to the next slide where we intent to discuss classification of open channel flow. Well till now, that means what we have done is the classification of open channel; up to this much only we have done. We have not done classification of open channel flow. So, I hope that we will be able to take in the much better way, that is, what is the classification of open channel flow in the next class.

So, today we have seen that how this open channel flow differs from the pipe flow first, and then, we have seen how the energy in open channel flow and pipe flow is calculated, and then, we have gone into the classification of open channel flow based on different basis. Well, thank you very much for listening to the very first and basic issues of open channel flow and I hope we will be able to go ahead with more of this open channel flow in a much better way in the next class. Thank you very much.