Hydraulics

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Module No. # 06
Canal Design
Lecture No. # 01
Canal Design-1

Friends, welcome you all to this class of canal design which well we will be continuing. Today, we started on canal design yesterday and we will be continuing with this class today again. Well, what we were discussing on canal design, let us just recapitulate. We started with the very fundamental concept of design of channel and then at that point we did discuss that channel maybe lined canal or it can be unlined canal.

Well, now, when it is lined canal, then we could see that the problem of scouring or say erosion is not there, as such our design concept is different or rather we try to make the channel in a most economic way. And then, when we talk about unlined canal, then our problem are different, there it can be non-alluvial, the channel I mean I mean within the unlined category itself there can be non-alluvial channel or the channel can be alluvial channel.

Well, when it is non-alluvial channel, then again we could see that problem of erosion is not there up to a certain limit of velocity and problem of sedimentation is of course not there. Because the we consider that in a non-alluvial channel, the sediment carried by the water is less and as such the sedimentation problem is not there. However, the erosion problem as I said that it is not there up to a certain limit, then we should maintain up to that limit of velocity. That means, our design principle become such that we should decide our shape, we should design our shape of the channel, we should design our size of the channel in a way, that the flow velocity does not exceed that permissible limit that is maximum permissible velocity concept coming there.

And when we talk about alluvial channel, when we talk about alluvial channel then the problem can be both scouring, that is the erosion of the bed and bank and the problem can be of sedimentation. So, that way we just need to take care of both the cases and it is very difficult to have analytical solution for such problem. And then, generally people try to have the channel of the size so that a velocity is achieved, which is referred as critical velocity. That critical velocity is that, this velocity or under this velocity that channel will neither be eroded, nor there will be deposition, so or sedimentation. So, that sort of critical velocity how we can have, that is again a very challenging task. And for that purpose generally empirical relations are used, means the equation derived on the basis of lot of observed data of such stable channel that are used and of course, some semi empirical theory are there like tractate force method and that are also applied.

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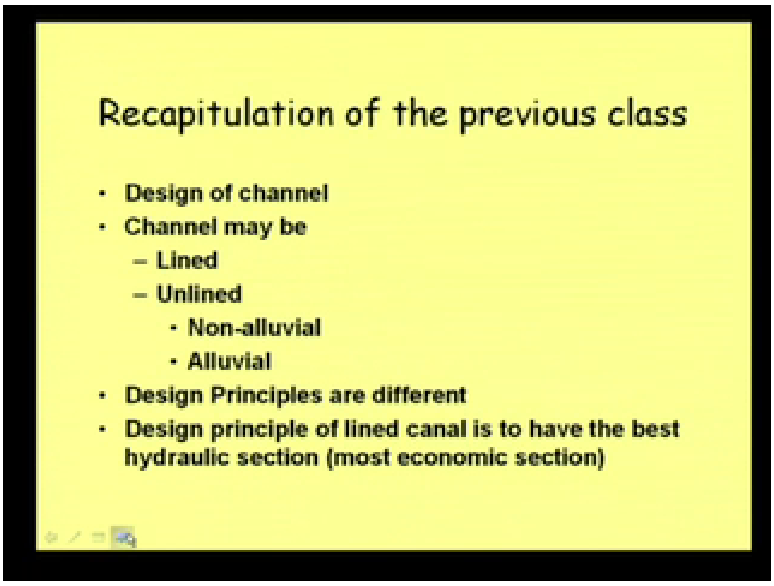

Well and in the last class, we we could see that design Principles are different for different type of channel and design principle will pull for line canal is to have the best hydraulic section. And we started with the design of rectangular channel and then we could complete up to trapezoidal channel. Well, then again we tried to see that in trapezoidal channel the design criteria is that or the Best Hydraulic Section is that one where the length of the side channel, side slope, length of the side slope is equal to half of the top width, that was the condition that we could derive.

And using that condition again we can see that for a trapezoidal channel, when it is the best section, best hydraulic section or most economic section, it is satisfying this particular condition what we have stated, then it can be found that hydraulic radius R for that situation is equal to half of the depth, that is R is equal to y by 2. And the same condition we could see for a rectangular channel as well and in rectangular channel the condition for most efficient section, we are using several terms most efficient section, best hydraulic section or say most economic section.

In fact, all are meaning the same thing that is the perimeter minimum. And for rectangular section we could see that B that is the Bed width is equal to twice that of the depth. So, that was the condition for best hydraulic section and of course, we have already explained what the condition for trapezoidal section is. Now, let us see what will be the condition for triangular section, we will start with that.

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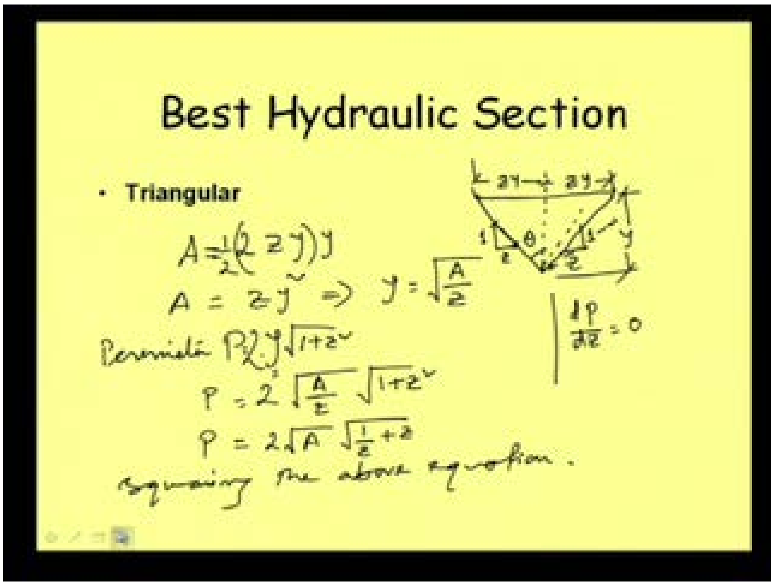

Well, now let me take a triangular section, well say this is a triangular channel and this is the depth of flow and let me just call this angle as theta. And of course, we can just give idea about this theta in terms of the side slope also, that is say z is to 1, it can be written from theta or z is to 1 and depth of flow in triangular section is say y. Now, let us see what is the expression for area? Area is equal to half of the base into altitude, now what this base is basically, as we know that this top width is equal to z into y, this much and again z into y, this much, because depth is 1. And so the stop width we can write as say twice z into y, twice z into y, so our expression for Area is half of the base into altitude. So, this is what the base and altitude is y, what I mean this height is y, so that is equal to z y square and that will lead us to an expression for y is equal to root over A by z.

Well, as now we know that our concept of making a design for most economic section is that we will try to make the perimeter minimum, that is P, if we get an expression for P, we will try to make P minimum and in that case earlier we were doing d P d y that is with the change of y. How the P is varying? And we are trying to see that when d P d y is equal to 0 that will give us the expression for minimum value of P. Now, here we can see of course why we can we could change, but if we change the z, if we flatten the z, we bring the z here, depth will automatically come down or perimeter. So, for a particular, for a given area if we change the z value, depth will come down, if we increase the depth, if we if we reduce the z value, it will be coming like this, rather if we increase the z value it will be coming like this. If we decrease the z value it will be going like this and then the depth of flow will be changing and then perimeter will also be changing, weighted perimeter will also be changing.

So, you can see and for design of a triangular section what we can specify, that suppose we are asked to design a triangular section, then we can specify that well this should be the area and this should be the side slope. Once you specify the side slope, because here B we need not specify, B is not coming at all, so B means Bed width I am talking about, so we need to specify the side slope.

Well, so we can see that when P will be minimum in terms of z also, there is a variation of P perimeter with respect to z we can say. So, we can try to find what is d P d z and that way we can try to equate this to equal to 0, so this way let us see what is the expression for P. And perimeter P let me write the expression for perimeter P, that perimeter P is equal to, say this length is equal to y root over 1 plus z square that means this part is root over, say this length is, if it is 1, it is z root over 1 plus z square.

So, this will be, this total length will be, for 1 depth it is like that, for y it is root over say 1 plus z square and then we will have to multiply it by y, so this is the perimeter and this perimeter, this is only 1 side, but we have perimeter means we have both the sides, this and that, so it will be equal to 2 time of y root over 1 plus z square. And that can be written as 2 times of this y, now will be expressing as root over A by z and then we can write this as root over 1 plus z square, well. And this can be written as again, say if we take this z inside this root sign, then we can write it as twice root over a and root over 1 by z plus z, well.

Now, to have this expression in a simple form, we can square the both sides, so squaring what we can have? Squaring this equation, squaring the above equation what we can have?

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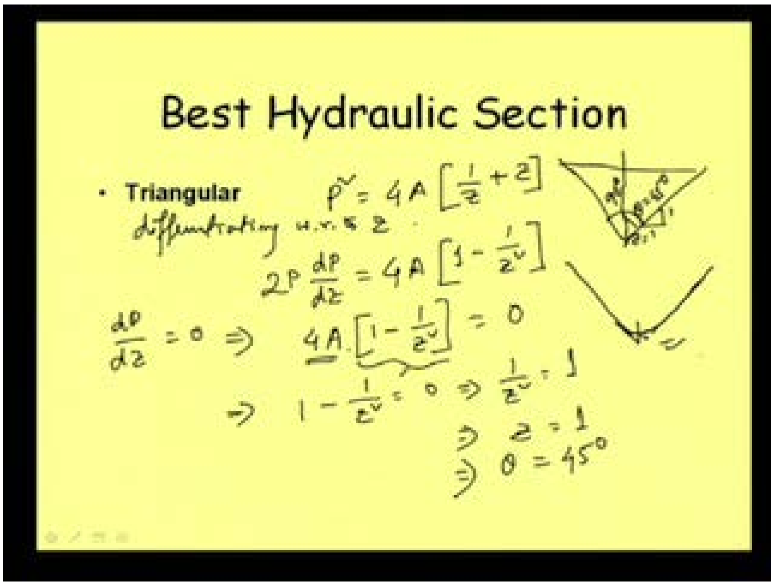

We can write this P square is equal to say 4 A, then 1 by z plus z. Now, we can do differentiation of this equation with respect to z, so differentiating differentiating with respect to z what we will be getting, this is say twice P, then it is d P d z. And our interest is that this should become 0 is equal to 4 A, 4 a and then this expression will become, this is I am writing first d z, d z is equal to 1 and this will become say minus 1 by z square, this will become minus 1 by z square. Well, if d P d z equal to 0, so d P d z equal to 0 implies, now from this expression what we can have, say this is 0 means this left hand side is 0 means, we have that 4 A 1 minus 1 by z square is equal to 0.

And now, in a channel, if area is 0, there will be no flow, so the question cannot be that area, whether area will become 0 or not, this is a product of this and that, so this term cannot become 0 and as such this expression must be equal to 0. And so this implies that 1 minus 1 by z square is equal to 0, this implies 1 by z square is equal to 1 and 1 by z square can be equal to 1 only when z is equal to 1. And z is equal to 1 means what we are getting indirectly, that our z is equal to 1 1, so this z is equal to 1 that means this angle theta, the angle theta must be equal to 45 degrees, so this implies theta is equal to 45 degrees.

So, a rectangular, sorry a triangular section will be the best section when we can have theta is equal to 45 degrees. Or theta 45 degrees means when we talk about the total angle then this is equal to 90 degrees; a 90 degree channel we can say, 90 degree channel means the angle of the triangular section should be 90 degree for this is to be most efficient. And of course, in practical situation, when we propose triangular channel, then it may not be possible to provide exactly a triangular channel and then in many a time it is given like this and this portion is rounded up and then we provide these things like that, but the angle if you extend, this should be say 45 degree and 45 degree like that, well.

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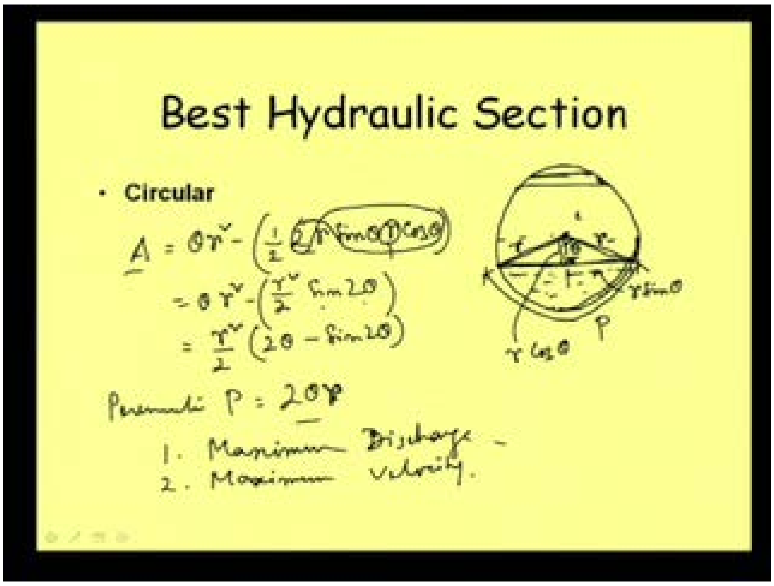

Then, we can go to another type of channel that is circular channel, ok, in Circular channel what will happen? Say, let me draw a circular channel, well, say this is the centre and then say flow is we are considering that flow is up to this level, this is the water at this level. And then this length is equal to radius, means we are suppose the radius of this circle is r, so this is r and in both the direction this will be r. And let me draw a normal in this direction and this angle is theta, well.

Now, you can concentrate into the slide that how we write that area. Area is equal to, well this entire area, our fluid is actually or the water is in this portion, so how we can find this are? We can find the entire area, entire area will be basically say like for a whole circle it is pi r square, that means twice pi is the total angle, so half of the pi r square. And for this sector we know from our very basic geometry that it will be theta into r square, but from that theta into r square we will have to deduct this triangular portion, we will have to deduct this triangular portion.

And this triangular portion what will be the length that we can have that this is R, this is R and this is theta, so what this length is? This length is basically say we can have this is r sin theta and what about this length? It is the height of this is r cos theta. Now, having this we can write that flow area or sectional area of the flow, sectional area of the flow is as theta into r square minus, again we can go to half of base into altitude, so half and base is r sin theta is this portion, so it will be twice r sin theta, twice r sin theta and altitude is r cos theta, so we are writing r cos theta.

Well, this can be written as theta r square minus say r square by 2, r square by 2. And why I am writing this to 2? I am not cancelling at this point, because twice R, twice sign theta, cos theta we can write as sin twice theta, so this part we are clubbing twice sin theta cos theta, sorry I will have to leave this also, twice sin theta cos theta as twice sin theta and then we are having this expression. Well, that can now be written as say r square by 2 and then we can write twice theta, this twice theta, because two we are bringing out minus sign twice theta.

Well, this is what the expression for area. Now, expression for perimeter, here perimeter is this length, here perimeter is this length, so this is about perimeter and as we know that area perimeter or say perimeter of the entire circle is twice pi R that way here the perimeter of this portion will be say twice theta R, here our angle is this 1, ok.

So, perimeter P is equal to twice theta r, so these are some of the fundamental expression that we are getting for area and perimeter for a circular section, well. Now, let us again come back to the concept of best hydraulic section. Now, what we mean by best hydraulic section? Again, the same that is minimum perimeter, minimum perimeter, so but 1 point here is that for circular section the most efficient section is considered from two different angle. Well, that what that two different angle? That is, one point is that we want to maximize the discharge, till now in all the section or in all different type of channel shape we were talking about the best hydraulic section is that which can carry maximum discharge.

And but in case of circular section, we consider from two different aspect, one is that maximum discharge concept, one is maximum discharge and the second is say maximum velocity, maximum velocity, why? That is, in many case this Circular sections are used as … and for different practical purpose sometimes it become necessary. And what more important point is that discharge through this section, if we come to this part or say we are trying to find what the discharge is, then in many a time our objective is to have maximum discharge through the channel and in many a time our objective is to have maximum velocity through the circular section.

So that we can avoid siltation in this channel and so that way and in circular section maximum velocity and maximum discharge is not the same, is not providing us the same value. For say other section, when it is area is constant, we are having that discharge is equal to a into V that way we are getting. When area is constant, when V discharge is maximize, means velocity itself is maximized, but here it is not like that and that is why from two different angles we look into the condition and it is found that from both the point we get little bit different expression for the efficient section.

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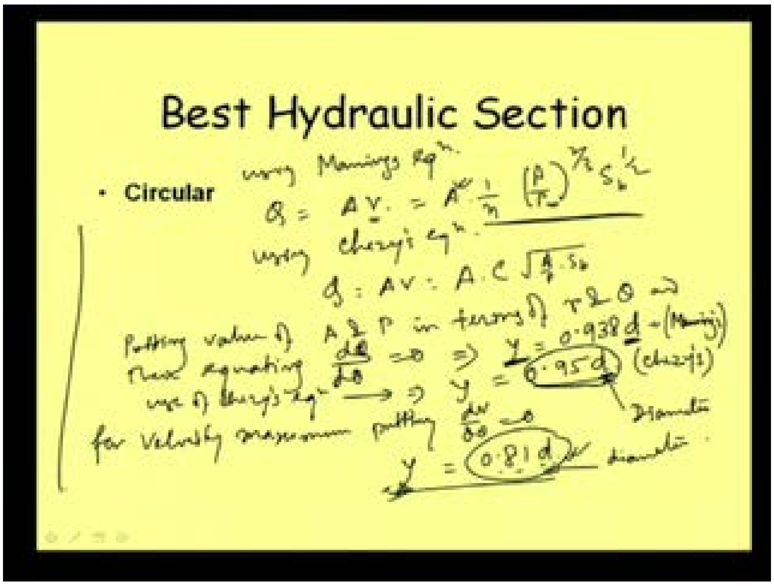

Now, from maximum discharge condition, if we go by the maximum discharge condition, say we will be getting Q is equal to area into velocity and this means that a into 1 by n, this our very popular expression using manning’s equation. Suppose, when we are using manning’s equation, but if we use Chazy equation, say using manning’s equation we can have this. But we use Chazy's equation, if we use Chazy's equation then our expression will be different, then it will be Q is equal to area into V, that will be a into C into root over R or A by B into S B, that we can have expression different, well.

Now, we have expression for this area and the perimeter in terms of theta and r. So, if we put what we need to do, let us just explain, if we put the expression of Area and perimeter in terms of theta and R, now for a given section R is fixed, for a given section R is fixed. So, if we put the expression for area and perimeter, here or here or whatever, wherever it is and then we will be having the expression for Q in terms of our theta, it will it will become a function of theta. And then if you go for d Q d theta, we want to know that which theta will make the depth maximum and once we get the theta, then drawing the theta we can find what can be the depth.

Because, if we refer to this diagram, if this theta is known to us, from this theta we can find where we are actually, where this depth will be that can be found out easily, because from here to here it is radius and so we know that this part is r cos theta, so depth is equal to, depth is equal to say r minus r cos theta, r minus r cos theta. That means this is the depth, this is the depth, so this depth can be found out easily once we can find the theta. So, with that intension putting value of a and P in terms of in terms of r and theta, we can get… and then and then equating and then equating d Q d theta 0, well this is d Q d theta equal to 0, this will implies, this will give us the value of y, this gives us value of y equal to 0.938 into d, this d is the depth of flow.

Well, so y is equal to point 9 3 8 d, but this expression we are getting when we are using manning's equation. So, this is by using manning's equation, this is by using manning's equation, but if it is Chazy's equation, then this will lead to use of Chazy's equation, use of Chazy's equation that will lead to y is equal to 0.95 into the depth, so 0.95 it is by Chazy's equation. Well, here, so difference is not that much, here it is 0.938 means approximately 0.94 and here it is 0.95 d.

So, if we want to have maximum discharge over a channel, which will be referring as a efficient section, that case our target should be to make the depth equal to 0.95 d. And if we feel that generally a a filling may come to our mind that if a circular channel is there and if it is suppose closed channel, then we have a feeling that if the channel flow full, then the discharge will be maximum of course. If it full flow full the concept entirely it is changing, I mean it is becoming a pipe flow system, we are not talking about then this open channel flow, but by open channel flow, if we make the discharge, if we make the depth equal to 0.95d around, 95, 94, 94d, then we get maximum discharge and we should not carry the depth beyond that limit.

But, again then again V can be also expressed as V is equal to this part, V is equal to this part and so putting d V d theta equal to 0, for velocity maximum, for velocity maximum, what we can do, putting d V d theta equal to 0, if we do that then we get that y is equal to 0.81d 0.81 d. And that is important, that is important, by using both the equation this is just likely different, but it is around 0.8 d, that we can say.

Now, this is important from this point, that if our target is to maximize velocity then our depth should be kept less than, depth should be kept less than… Well, this d what we are drawing or writing is diameter. This d is diameter of the channel, this d is diameter of the channel, this d is diameter of the channel, not it is not the 0.938 of d, this depth is y, so this depth is equal to 0.93 time of the diameter, y is equal to 0.95 time of the diameter and this depth is equal to say 0.81 time of the diameter. And we are just calculating this depth and this is what y by y, we are writing this y, this is what ok.

Now, from that point what we are getting that, where we should keep our y for having maximum velocity and maximum discharge, this is quite different. If we try to have maximum velocity, we will have to keep it as 0.8 time of the diameter and if we try to maximize our discharge, then it should be 0.95 time the diameter. And this difference is quite significant, this difference is quite significant, as such this point is important. Well, with this understanding of best hydraulics section for circular channel now we have got what will be the condition for best hydraulic section in case of trapezoidal channel, rectangular channel and triangular channel.

Now, we can try to design our channel using the concept of best hydraulic section for line canal, where the question of erosion is not coming. Of course, the question of deposition can come and as such after designing the section by best hydraulic section concept, we need to verify whether there will be sediment deposition, whether the minimum, it is whether it is above the minimum permissible velocity or it should not go below the minimum permissible velocity that is important point.

And suppose our lining is concrete, then also it should not exceed the value for say 3 meter, second, that should not be exceed, otherwise there will be a problem of course, depending on strength of the concrete we can go for higher velocity also, but normally it should be within that range, otherwise the Maximum Velocity can also cause problems. So, those aspects also we need to check.

With this discussion on line canal now we can start our discussion on unlined canal, which is of course much more complex, actual Design of Channel in Unlined canal is much more complex than a line channel.

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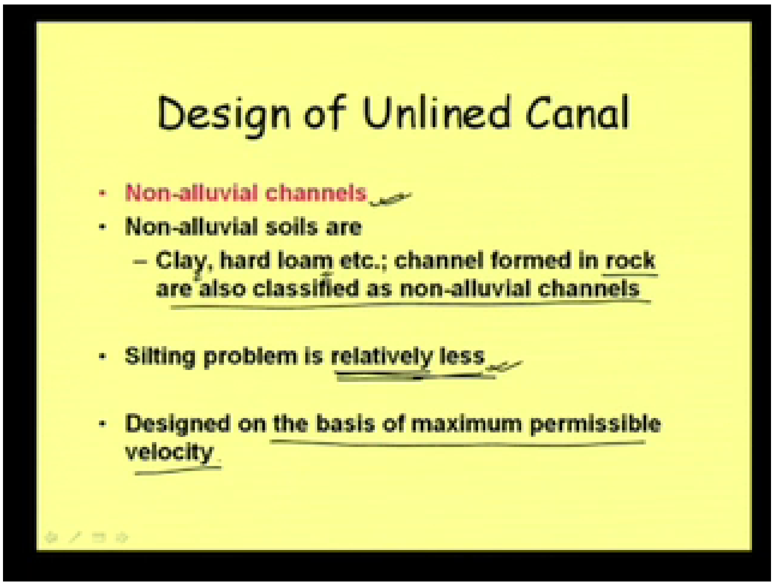

So, again in line channel we can discuss it in two groups, first is that non-alluvial channel and the second is that alluvial channel. Well, first we shall start our discussion with non-alluvial channel, well. So, by what we mean by Non-alluvial channel? When it is say sand and silt, it is forming the formation, the geological formation is suppose of sand and silt, then if we make a channel in that formation like natural rivers are also like that and then what is the river deposition on the side and finally, when we get that sort of land form and that we call as a alluvium, alluvial landform and that sort of channels are called alluvial channel. And Non-alluvial means it is not of silt and sand, so hard loam or say clay more on this sort of formation when we get, that is called non-alluvial channel, well.

And non-alluvial channel in fact if it is on a rock that also we can refer as non-alluvial channel. I mean, when it is not an alluvial channel everything we can refer as alluvial channel. So, this concept can go for even rocks also, so rock is also classified as non-alluvial channel. And as we did discuss that silting problem is relatively less in non-alluvial channel, why relatively less? What we mean by relatively? Because in Alluvial channel we will know that erosion process is quite I mean prominent and that is why there will be… if it is in a alluvial formation, that channel is coming from somewhere upstream and that is also definitely passing through some alluvial formation and then say erosion will be there on the upstream also. So, it will be carrying some sediment.

But if it is a non-alluvial formation, the channel is passing from upstream and there also erosion will not be there if it is designed properly of course. And then as such the sediment problem will not be there, sediment problem means flow of sediment into it should not be there and then flow of sediment deposition problem should not be there. And but as I was giving 1 example in the previous class, that if the water is coming from a upper catchment to such channel, which is otherwise non-alluvial in nature, maybe in hilly portion, but still the due to rain maybe heavy erosion in the hill because of deforestation. And then, all the sediment, final sediment carried by the water will flow through this non I mean not non-alluvial section and in that case, if the velocity drops below a particular limit, there may be a problem of sedimentation.

So, that is why the term relatively less is coming, it can be there, but generally it is less, well. And if we consider this to be less, then we forget about the condition of minimum permissible velocity, then we think about only the condition of maximum permissible velocity. That is the velocity should be below a limit, so that the erosion or scouring of the channel may not occur, well, so design is on the basis of maximum permissible velocity, well.

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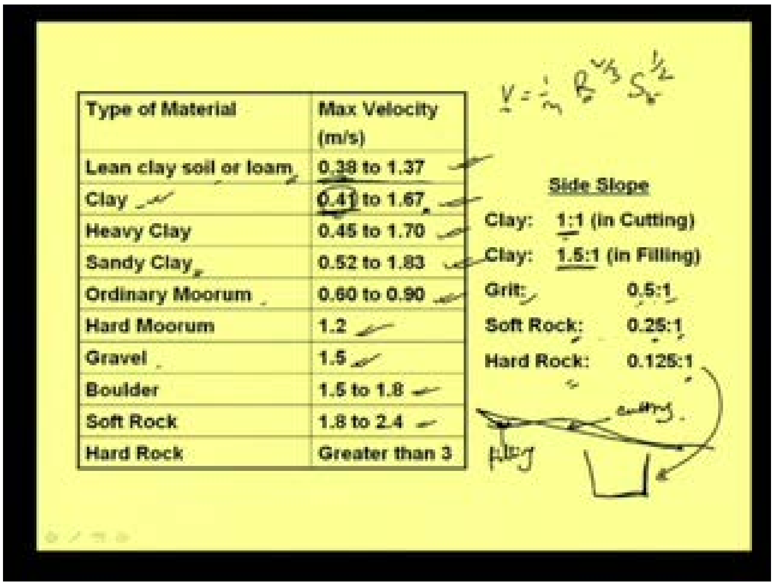

Now, when we talk about maximum permissible velocity, then we must have some idea that well for this particular non-alluvial formation what can be our maximum permissible velocity? Once we know that then it is not a difficult task for us to calculate the velocity, because using uniform flow formula once we decide about a shape, about a size of the channel, once we decide that, then say getting the value of velocity or computing the value of velocity by using manning’s formula say V is equal to 1 by n, then R to the power 2 by 3 S to the power half, this is very common. Once we know the slope of that channel, once we know the dimension of the channel means r will be knowing, known to us.

Then velocity we can compute easily, but what information is required is that which velocity is permissible or which velocity will remain within limit for a particular material and that we can see that this stable is giving us some idea. That is, for lean clay soil or loam, this ran’s from .382 to 1.37. And for clay it is from .41 to 1.67, of course as we can see the ran’s is very high, I mean, so for velocity value is concerned, the ran’s 0.41 and 1.67 is not a very small ran’s and these are in meter per second. So, this ran’s is still quiet large and experience count at that point. Looking into the situation, we should know that what can be the value of this and in fact, sometimes we may have to go for experimentation also to know the exact value.

But, for say design of a small channel section, we may take this value and we can go by this permissible value. And when we are not sure about what will be the maximum value, then we should go for the minimum value, what is being suggested as the maximum Velocity. Because ran's can be from 0.41 to point 1.67 for clay say, so if it is clay, if we do not have much idea, we should be conservative in our design and we should use them 0.41 meter per second as the value.

Because, if we take this higher value then we may not be sure that at lower than that also the clay surface can get eroded. Well, then for heavy clay it will ran's from .45 to 1.7, for sandy clay, when we are coming to sandy clay, then it is ranging from 0.52 to 1.83, then moorum, it is going from .6 to .9. Here ran's is little less, we can be more confidently we can use for hard moorum, in fact it is given as 1.2 more confident. Then Gravel, gravel is given as 1.5 meter per second, boulder, when it is of the size boulder, that is little larger size, then this can be taken up to 1.8, soft Rock 1.8 to 2.4 meter per second and if it is a hard Rock, as I was stating earlier that for cement concrete also we can take up to 3 and for hard rock, also it is 3 meter per second or greater than 3 meter per second, it depends on what type of rock it is.

And of course, the chemical composition of the, sorry, rather mineral composition of the rock matters, because when we are talking here about the strength of a rock, it is always in connection with water. So, it will be in touch with water, then how it gets whether under the action of water that is also important. So, the mineral composition of such hard rock also we need to know, because say today it may remain very hard, but with time it may undergo erosion, I mean, the weather weathering and then due to weathering its strength may reduce and with time it may.

So, that way these are the values, now again this is one point we are getting what is our maximum velocity? Then, before designing we should know one more aspect, say a channel we want to design and then from the topography we are getting the slope, fine. Then what should be the Side Slope of the channel? Whether it is we can go for rectangular, whether we should go for trapezoidal that we do not know at this point well. So, that is also one important aspect that we should know. And from experience and from experiment we can find out this sort of value and these were given as suggestion. Like that for Clay we can go for a slope of one is to one if it is in cutting. What we mean by cutting?

That as I was explaining say suppose natural terrain is like that and we want to make a channel to carry something from say this point to this point water, now it will be difficult to go like that. So, what we will do? We will make average slope like this from here to here. We are filling up this portion and suppose this formation is Clay, say this formation is Clay, then what we will be doing that we will fill up this portion and we will cut this portion, this portion will be say under cutting, this portion is under cutting and this material that we will be getting by cutting that can be filled up here to get filling portion, so this is what the filling.

Now, definitely when we are having a filling portion, here the Clay, although it is the clay material, but we will be in little loose state, although we will be trying to compact that still the initiative condition of clay will be definitely less, will be having less strength than the, will be having more strength filling condition, will be having more strength than the filling condition. So, that way, for the portion where we are having cutting in clay, there we can go for side slope of 1 is to 1, but if in the filling portion we should not go that sort for steep slope, we can go for 1.5 is to 1.

Then of course, when it is greet, then we can go for 0.5 is to 1 and then if it is soft rock, these are we are talking about cutting soft rock, then it is 0.25 is to 1, that is why it is increasing for hard Rock, we are going for 0.125 is to 1. And in fact, for hard rock we can go for 0 slope also, I mean 0 slope means it is vertical one, say 0.125 is also very small, say it will be like this, 0.125 is also like this, means almost vertical, almost vertical say this will be and in some case we can go for vertical cap, well.

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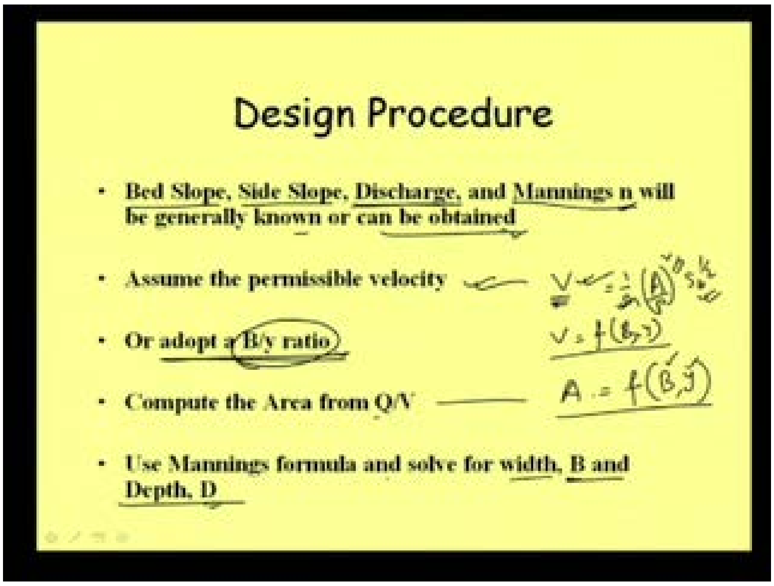

So, these are some information which we can use for design of this canal in non-alluvial channel. And what will be the procedure, design Procedure, say bed slope we will be getting from the topography as I have explained, we have very small scope of manipulating that, of course we can do it as I was showing here, that say this can be, the slope we can have, this slope also by cutting we can have. If we cut this portion we can have this slope, if we have, if we fill up this portion, so slight manipulation is possible, but grossly we cannot change the slope, but still bed slope will be knowing from the say topography.

Then, the side slope, this last slide will give us the side slope, based on the material or based on the formation material we will be deciding our side slope, well. Then the discharge, that we will be getting by hydrological analysis or suppose hydrological analysis means if it is a drainage channel we need to know how surface will be coming. And that way we can decide how much discharge will be there, but if it is a irrigation canal then it will depend on how much water we are releasing from the main source, what is the water requirement of the crop, based on the water requirement of the crop, we will be releasing the water and what is the maximum requirement of the crop, crop water, that we will have to find out and of course, with that we need to aid what will be the loss and other aspects.

So that how much is the maximum discharge we are allowing to flow through the channel or we will be allowing to flow allowing through the channel we need to know. So, by some means we need to have our discharge and that part of course we are not discussing like in this course. And then manning's and that is the roughness parameter, roughness parameter we need to know from characteristic of bed, roughness and characteristic of side roughness. And in many standard book now this manning's roughness value are available, that part we did discuss in our in our discussion regarding uniform flow. So, we are not discussing here again, but we can have this value from standard book and many references are there, so this will be generally known or can be obtained as I have explained.

Then, after having this thing, we will have to assume a permissible velocity, say V is known what should be V or sometimes rather than having that V we can have, rather than having that velocity V we can have or we can adopt a B by y ratio, here that is width to depth ratio. And some suggestions are there some organizations has walked and for a particular discharge what should be the B by y ratio that sort of some table or graphs are available, that also we can use, of course this is more convenient. And then once we have this V and this discharge, we can compute the area, so this area is known.

Then, here we can see that now we can use manning's formula and we can solve for the width B and depth d, because we we need to know design of channel, means we need to know what the bed width is and what the depth of the channel is. So, we can now use manning's formula and we can solve for this bed width and d, because see area is nothing but a function of B and y and this velocity by using manning's formula what we can have that 1 by n, then a A by P rather A by P to the power 2 by 3 and SB to the power half. Now, S B we already know and we are knowing, so V is a function of area and perimeter, then area and perimeters are nothing but it is these are just expression, that this area and perimeter can be expressed in terms of B and y. So, this is also a function of B and y, so we have 2 equation, we have 2 equation and we have 2 unknown B and y. So, these 2 unknown can be solved from these 2 expressions and that way we can have our design dimension, well.

And then, with this now we have that understanding how we can go for design of alluvial section. So, then of course I did not mentioned that if we go by the value of B by y ratio, if we go by the value of B by y ratio, once we have this B by y ratio, then this velocity or area, whatever we calculate, say our B by y ratio is given, so then velocity as it was a function of B and y, B and y or say area, that was a function of B and y.

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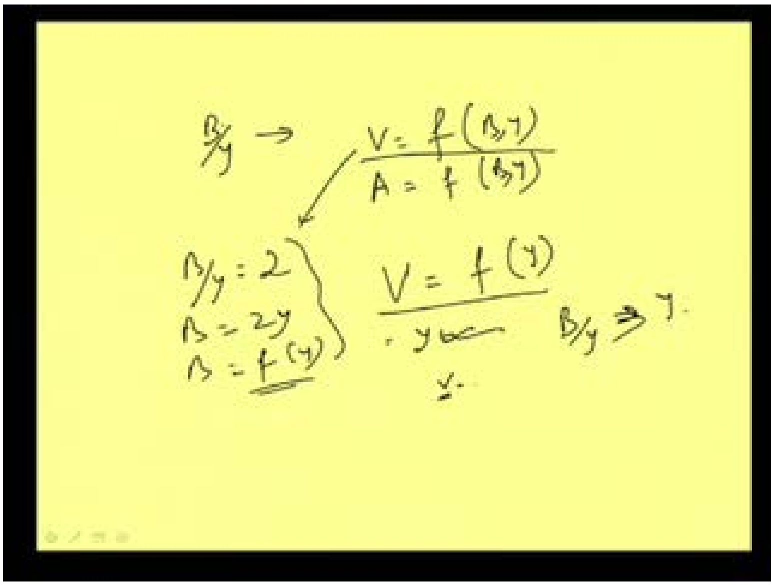

Now, what we can have, velocity this B and y ratio is given, so B itself is a, suppose B by y ratio is B by y ratio is suppose 2, then we can have B is equal to twice y, so B itself is becoming a function of y. So, as such this expression from this relation what will be having, V become a function of y only, V become rather, V become rather function of y only, because B also is becoming a function of y and so from this expression we can calculate directly the depth. And once we can calculate the depth value, this is known, then again from B by y ratio we can calculate the y and this will give us y value.

Well, so the size of the channel will be known, then we can calculate area and we can find out the velocity, we can find out the velocity, we can find out the velocity, but this is also a procedure that we can follow once the B by y ratio is given. But problem, only one problem is that when we are using B by y ratio, then we are getting the velocity, we are not starting from the velocity and once we get the velocity we need to check whether this velocity is below the maximum permissible velocity, otherwise if the velocity is high, we need to adopt another B by y ratio and we should try for solving, well. With this we can now move onto the topic of design of alluvial channel.

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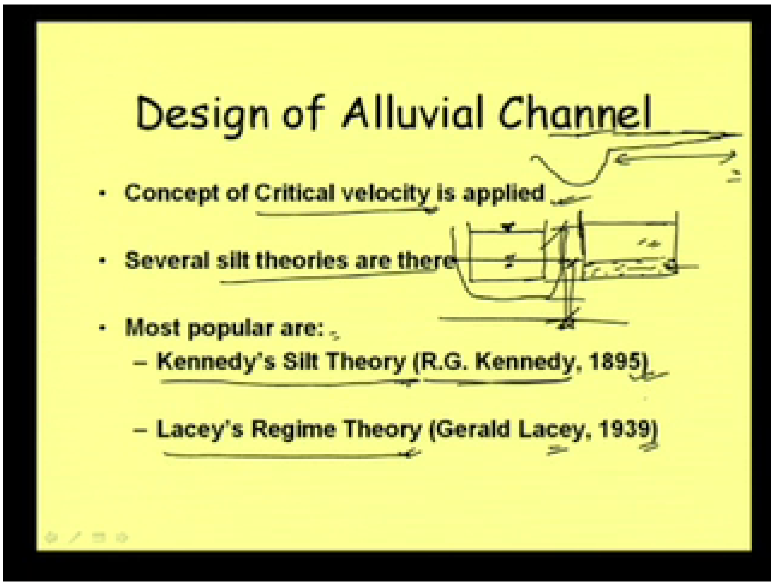

Well we started with design of non-alluvial, we started with design of say line canal, then we have discussed the design of non-alluvial channel and then we can move on to the…, now we can move on to the design of alluvial channel. Well, now, for analyzing or for designing alluvial channel, as we are already explaining that part, that scouring, that it is the erosion and deposition both can be there, so concept of critical velocity is applied for design of alluvial channel. And then when we are using this term critical velocity, I repeat that point, that critical velocity is not the critical velocity that we were discussing when we were discussing critical flow, because we were also telling that when the flow is in critical condition, by critical condition at that time we were meaning that fraud number is, one energy is minimum, so that sort of conditions were there for critical depth.

And the flow velocity at critical condition we referred as critical velocity when it is higher than we talk as super critical, when it is lower than critical velocity, then we talked at sub critical velocity. But that critical velocity is quite different from this that whatever critical velocity that we adopt for design of alluvial channel, well. This critical velocity is that velocity, which will neither cause erosion, nor cause deposition in the channel.

Well and to have that velocity it is very difficult really and then several sealed theories are there and different person started walking, different investigators started walking, engineers started walking on these, because of their practical problem in agricultural field, basically it started with agricultural field. So, they found that in agricultural field when canal were constructed with some expectation that it will be able to carry this much of discharge, then later on it was found that no deposition is taking place in that channel and then, I mean this well, that is of course important, let me just explain it little bit when a canal was designed.

Suppose it was expected that this much area is there, this much area is there, flow area will be there and sediment deposition has taken place, so its capacity has reduced not, now with sectional area remaining is only this much, because of sediment deposition. So, when the capacity reduces, then suppose we expected that this much water will be carried, but it will not be carried, this is one point, well that we could understand. But, if scouring take place or erosion takes place, then what is the problem? Well, if the canal was designed like that and scouring has taken place, so a canal has taken a shape of this one.

Now, with a given discharge, earlier it was expected that the water will be flowing at this level, now we know that in a canal, in a canal, if we expect that this is the water level, then water level, with this water level it can move up to say, there will be a slope here and with this water level, it can it is moving up to certain depth, up to up to certain distance here, depth will gradually come down and it is moving up to certain distance like that.

We can. So, more explicitly this point if we just draw a slope like this and then depth is like that, say here we have, because from a river, let me draw it here, say from a river this depth in this side will always be higher and then generally when we do irrigation, suppose from here we are collecting water and then we are supplying in this side. So to what extent we can go? This canal is moving like this and certain extent we can go and this beside that what is the command of that canal? Command of that canal means to what extent these canal can carry water?

Now, this, if the canal size increases, then the flow depth which was earlier expected to be at this level will come down to this level and once the flow depth come down at certain point, then the distance to which it can travel will also reduce. Because this bed resistance size and everything changes and then it is heat reduces, total heat as we know that it is depth of flow meters, it is z plus depth of flow plus V square by twice g. Here, if it is scouring is occurring, z value is coming down earlier, suppose z value was up to this much, I mean from here say prismatic heat was up to this much level, z plus P by w or z plus…, but now it will be only this much.

So, heat is coming down and when the channel is expanding and velocity will also drop. So, this V square by twice g, that portion is also dropping, so total heat is reducing and when you have less heat, it can flow up to lesser extent, it can flow up to lesser extent. So, the command of the canal is reducing, command means the distance or the area that can be covered by a particular canal is called the command of the canal.

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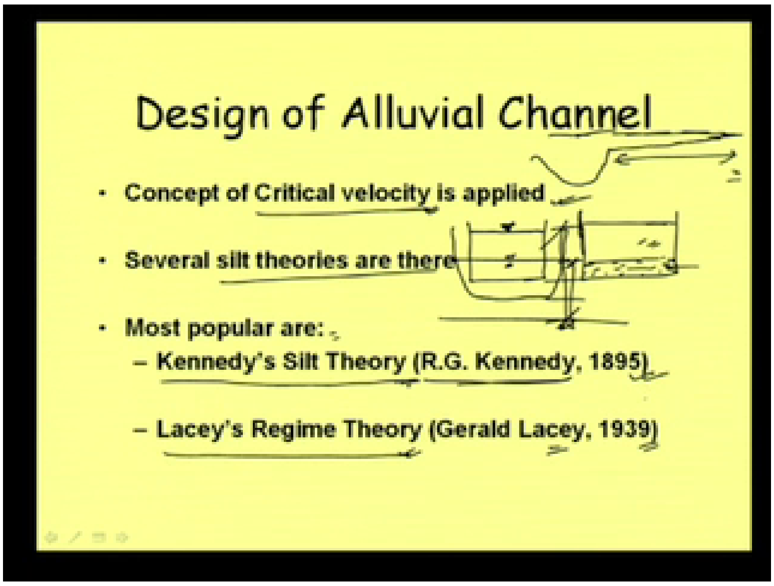

So, as it cannot carry water to far distance, so its command is reducing and so when we expected that, we had an expectation that we will be able to cover this much of area, but once this scouring occurs, we will not be able to cover that area. So, both erosion and deposition has the problem and because of this problem a people have to start thinking that can we have a canal section which will neither be subject to erosion or it will not be subjected to sediment deposition. And that force the investigator and engineers to start thinking on this particular line and several shield theories are therefore developed and most popular of those are say Kennedy's shield theory.

And it was suggested by R.G. Kennedy in 1895, and most interesting point here I would like to mention that again another another shield theory or that is called Lacey's regime theory, that was proposed by Lacey in 1939, after a gap of about 40, more than 40 years, so it was suggested. And both these theory were developed in India, this these are say

Kennedy was also a engineer in that field, in a field that is in a in a irrigation system, that is called upper bi drop canal system. And that was in Punjab, of course this now in Pakistan that place is and now there he was engineer and then he was experiencing this problem that I have explained. And because of this problem he then started observing that if there is I mean if it is possible to have a stable channel that is why his theory is always said as theory of stable channel. And then from the entire canal system, he was trying to find some channel reach, which are remaining stable, of which are not changing, which are not getting affected by erosion and deposition.

So, he first took those channel portion which is actually stable portion and then he tried to observe in those stable portion that what is a secret of that, well and he observed the flow velocity in those channel and then he was trying to see that this flow velocity, at this flow velocity it is remaining stable. Now, then he tried to think that this flow velocity is it related to of course slope is always there and then the slope was very say not that steep slope, these were mild slope at that portion and then he was trying to see that whether this velocity is coming from, whether this velocity can be related to the depth of channel or width of channel like that he was observing and he could let us see that for that portion, this velocity achieving, that velocity is depending on the depth of channel.

The reason he suggested is of course like that, that erosion or scouring take place because of the say when the water is flowing, it has some frictional resistance with the bed and because of that bed resistant there will be Eddie formation, vertical Eddie current and Eddie formation. And then vertical Eddie will be basically lift the sediment and then that is responsible and and and for this phenomenon depth is more responsible, which is more responsible for the eddie formation on the side.

So, and he according to him he observed that this side eddies are not creating that much of problem or not that much of responsible for carrying the sediment and that is and that way he could relate by observing these things. He could plot the velocity and the depth graphically and then he could derive a relation which was quite satisfactory for that portion.

But of course, it was a very side specific study, that was for upper by drop canal region and then the formula he adopted became very popular and it was known as Kennedy's formula. And this was used for design purpose, but when it was applied to some other area, then Kennedy also later could realize that no the width of the channel has something to do with this and this particular for the silt characteristic of the upper by drop canal region only his theory is valid.

For other silt characteristic, because silt will have to the silt characteristic will have to have some important influence on the entire erosion process, so for upper, for other region where the silt characteristic is different, his formula is not giving that stable channel as he expected. So, later on, of course different investigator started working on that and this formula was modified for incorporating all these possible influence of other factors. And still now also this formula is used of course, now a day's Lacey's formula is also used and some other formula like semi empirical or we can call analytical approach of tactics force is also used for design purpose in India. Well, we will be discussing all those in more detail in our next class; thank you very much.