Advanced Hydraulics
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Module - 2
Uniform Flows
Lecture - 7
Designs of Channels Using Uniform Flow

Good morning to everyone, we are back into our lecture series on Advanced Hydraulic. We are going through the second module on Uniform Flows.

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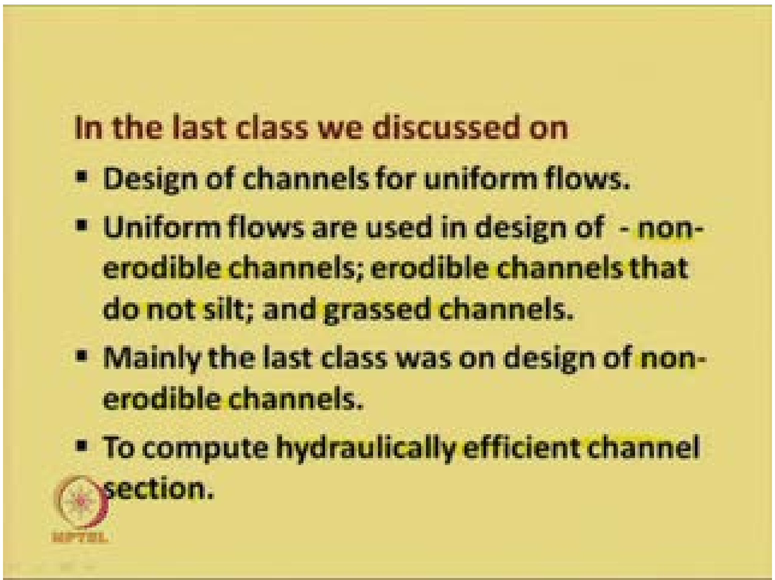

In the last class, we had discussed on the aspects of design of channels for uniform flow, we have suggested that the uniform flow can be used in design of non erodible channels, in the design of non erodible channels, erodible channels. Of course, erodible channels we have suggested that it should not silt. And also the uniform flow can be used in the design of grassed channels.

So, in the last class, actually we studied on the design aspects of non erodible channels, what are the various factors that has to be considered while designing the non erodible channels. We have suggested some of the concepts called hydraulically efficient channel section, other concepts called free board, how to provide free board and all, if you recall them. Today, in today's lecture, what we are going to do is that the topic will be same it will be continued on the design of channels for uniform flow.

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So, this is part 2 of that, we will be discussing on the standard concept of standard lined canal sections, especially in India. The central water commission of India has suggested certain standard lined canal sections, so we will just briefly go through them. Also we will have a brief description on design of erodible channels of course, without silting process. And if time permits we will go through the design of grassed channels or then, if not we will continue the same topic in the next lecture also.

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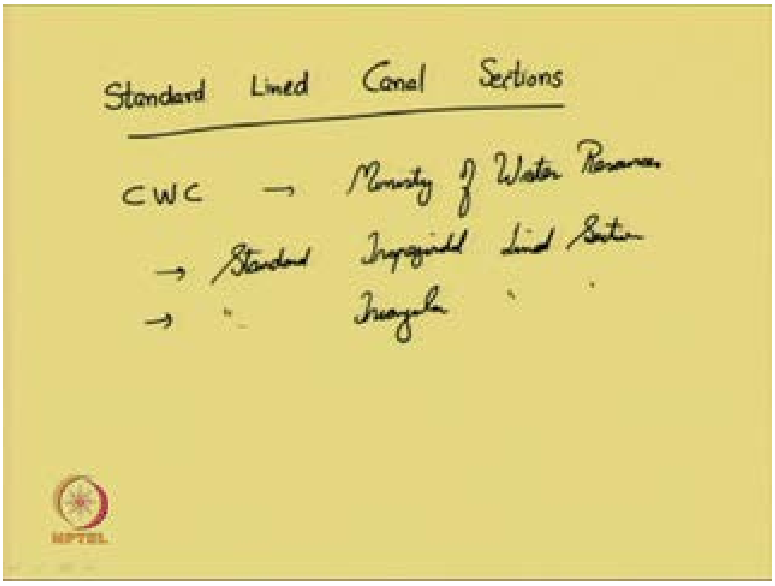

So, as we mentioned today we will be going through the concept of standard standard lined canal sections. So, what do you mean by standard lined canal sections? I hope most of you might have heard about central water commission. This central water commission, it is a part of ministry of water resources in India ministry of water resource in India. So, this commission has many mean authority related to water aspects in our country. So, they have suggested certain guidelines or they have suggested, how to construct canals and all.

There they suggested the concept called standard lined canal sections, they used the standard trapezoidal lined section and the standard triangular lined sections. Like that two types of standard lined canal sections they have suggested. According to their according to them, the most of the channels should be of trapezoidal or the standard trapezoidal shape and standard triangular shape, what is meant by the standard lined canal sections. So, as you as we have mentioned earlier the lined canal section means, it is a non erodible canal section.

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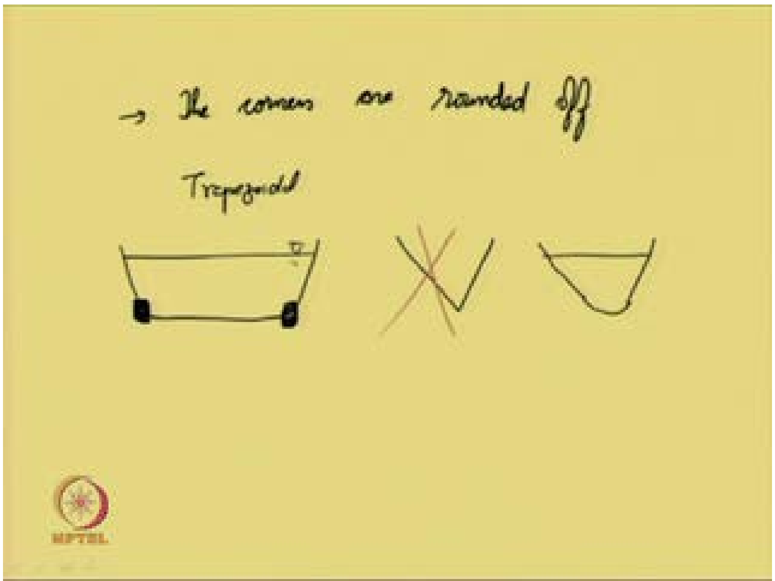

So, this standard lined canal section, for whatever section be, there the corners are rounded off in they are rounded off in your standard lined canal section. So, for example, if it is a trapezoidal section, then you may see that the trapezoid here, the corner will be rounded off like this; and here it will be rounded off like this, like this shape channels you may observe. If it is a triangular rather than like this, they devised it in the form of rounding it off and adopting the channel section like this. So, you can see such type of canal sections or the standard canal sections in various parts of India. So, you will see what are the design aspects of the standard lined canal sections.

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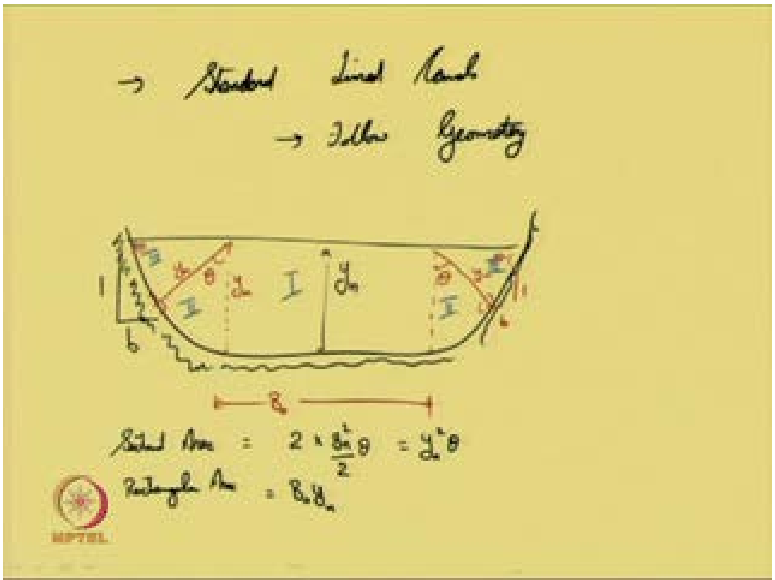

So, the standard canal sections, standard lined canals, they follow certain geometry. So, they have a definite geometry means, they follow some rules of the geometry and it is been designed, the rounding off the corners, as we have seen here rounding off the corners and all, see the rounding off this portion. This is not done arbitrarily, if they have a definite method, means how to round it off, from which portion it has the rounding off has to be started and all, they have a definite theory there and definite geometric principles are used.

We will see for the for example, in the case of trapezoidal channel section in the case of trapezoidal channel section let me just draw the thing, it may be of like this. So, you have your a bed, this trapezoidal channel section is having the side slope, so 1 is to b normal depth y n. Then the rounding off is started in such a way that from here, at this location, if you just mark the straight lines, with using the radius as the same depth as the normal depth. They will construct an arc that will perpendicularly bisect this portion.

So, this is a perpendicular location and this is having the same length as y n, like this here. Now, this angle theta now this theta is a design parameter it is to, while designing the standard lined trapezoidal sections and all, you have to identify what should be the theta value. Definitely for this portion, as you are aware B 0 is the bottom width of the trapezoidal channel, side slopes are given as 1 is to b. So, with these quantities given to you, how will you design the standard trapezoidal section.

So, for this you can now easily devise, means you can easily suggest that, there are mainly three sections of area. One is the main rectangular area, the main rectangular area let me give it as 1. Second there are 2 sectorial areas, let me suggest this as 2 and there are another 2 triangular areas, let me mark this as 3. So, these 3 areas they all come into picture, when you compute the total area of flow section. So, you when you compute the total area of flow section, you have to compute the individual areas of these figures or of these shapes.

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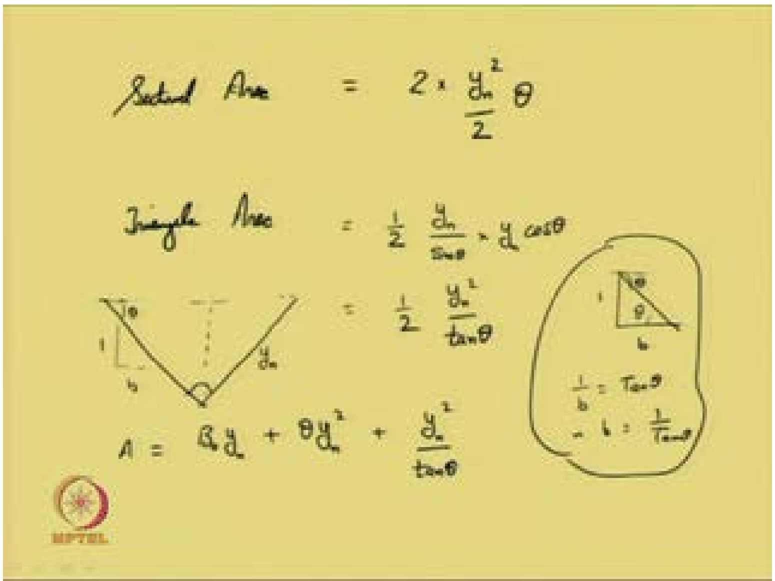

So, for the sectorial area there are two sectorial areas, I can give the area as twice into y n squared by 2 into theta fine theta is a angle theta is the given angle. Now, let me ask you here, in this case, if the angle between the normal depth here and the radius given here that bisects the side slope perpendicularly, if this is theta, what will this angle be, here also this angle. So, you know the property of this geometric property, so this angle will also be same as theta.

So, you can use a same concept here, so when you compute the thing sectional area, you know this is twice y n square by 2 into theta. If you want I can give it in the previous slide itself, so that you will not get confused. So, sectorial area twice into y n square by 2 into theta. So, this is same as y n square by y n square theta, what are the what is the rectangular area, your rectangular area this is nothing but, B naught into y n. So, these 2 areas, now 1 and 2 are already available to you, now means it has been calculated, what about the triangular section triangular portion of the section.

There are 2 triangular portions given as 3 indicated as roman letter 3. So, you can compute them triangular area. For that, let me enlarge it for you for your benefit, if this was the side slope given to you 1 is to b. And this is the portion where the radius of the radius of the curve that bisects perpendicularly with the side slope.

So, at this location, so you have this quantity now. Say this angle is theta, this angle is 90 degrees, this angle is theta, as we have seen through the geometry, this distance is y n.

So, definitely what is this height and what is this distance here. So, you can compute all of them, so the triangular area I can give this as half of see, this is theta, so y n by sin theta that should give you this distance.

So, half into y n by sin theta into then what is this height, this height is y n cos theta right, do I need to elaborate that, so this is half times y n squared by tan theta. So, you can now relate theta, with terms of side slope b, 1 is to b that side slope, that also you will observe that your side slope whichever is given 1 is to b. In this case also, this angle is observed to be theta or subsequently this angle will be theta. Therefore, 1 by b is equal to tan theta or b is equal to 1 by tan theta.

So, this relationship one can remember them, you can use them later on in subsequent cases and all. So, your total area A, will it can be written as B 0 y n plus theta times y n square plus y n square by tan theta.

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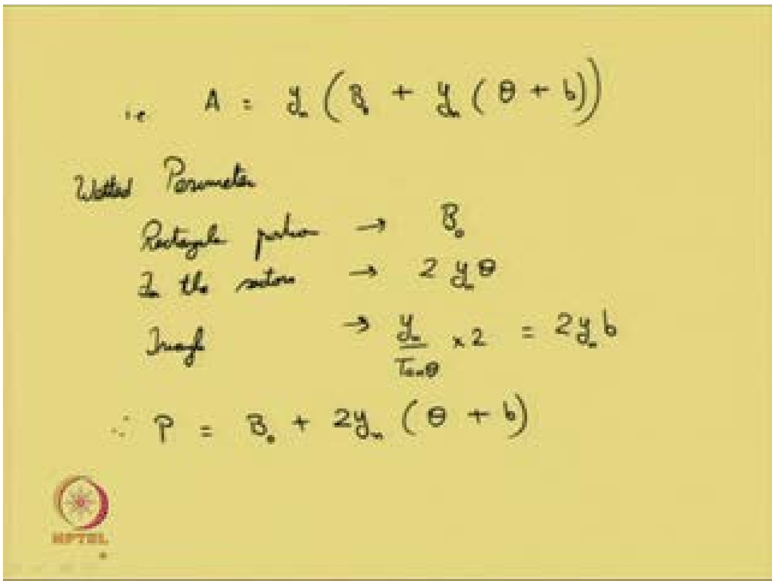

That is A is equal to y n times B 0 plus again y n times theta plus b, we have already shown you, the relationship between theta and small b. What is the vector perimeter of such a section, for the rectangular portion you have the quantity B naught, for the sectors you have the quantity twice y n theta. For the triangular portion, you can give this as y n by tan theta into 2, this is nothing but 2 y n into b. Therefore, your vector perimeter P is equal to B 0 plus 2 y n theta plus b. Like this, one can find the vector perimeter for the standard lined trapezoidal section.

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$$R = \frac{A}{P} = \frac{y_n\left(B_0 + y_n(\theta + b)\right)}{B_0 + 2y_n(\theta + b)}$$

$$Q = \frac{1}{n} A R^{2/3} S_0^{1/2}$$

$$= \frac{1}{n} \frac{\left(B_0 + y_n(\theta + b)\right)^{5/3} y_n^{5/3}}{\left(B_0 + 2y_n(\theta + b)\right)^{2/3}} S_0^{1/2}$$

Your hydraulic radius this is nothing but, A by P, it can be given as y n into B 0 plus y n times theta plus b divided by B 0 plus 2 times y n into theta plus b. So, the discharge using manning's formula that is, 1 by n A R to the power of 2 by 3, S naught to the power of half, you are you want to design a standard lined trapezoidal section. So, the discharge will be given to you, based on that one can compute the quantities here. So, what does this mean here, I can suggest this quantity as 1 by n B 0 plus y n into theta plus b.

This whole quantity raised to 5 by 3 into y n to the power of 5 by 3 B 0 plus 2 y n theta plus b, this whole quantity raised to 2 by 3, S naught to the power of half. So, if discharge is given, you can now easily identify the section factor for the following channel section, for the standard lined channel section.

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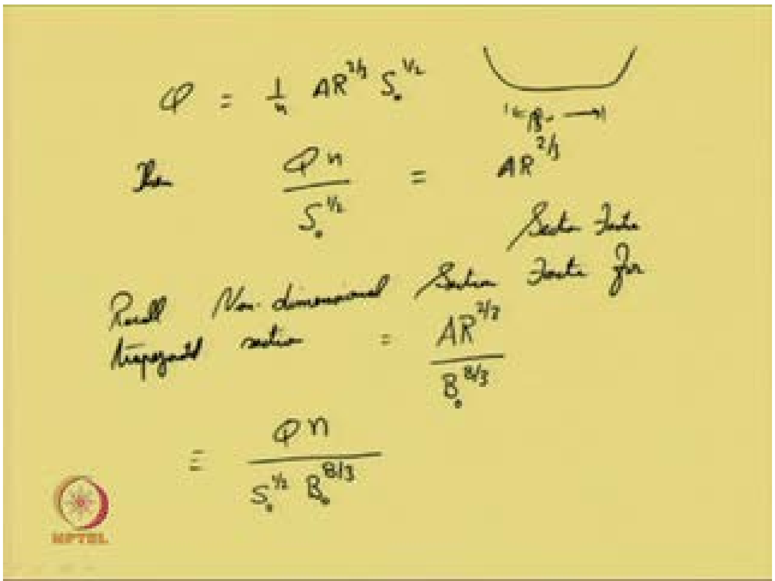

If Q is equal to 1 by n A R to the power of 2 by 3, S naught to the power of half then, the product Q n by S naught to the power of half is equal to A R to the power of 2 by 3 is called the section factor. So, if you recall this section factor, it can be non dimensionalized, if you recall from our earlier lecture, recall non dimensional section factor for trapezoidal sections. So, the non dimensional section factor for trapezoidal section was based on the bottom width of the trapezoidal channel, this bottom width, based on this parameter on has devise the non dimensional quantity.

So, this was given as A R to the power of 2 by 3 by B naught to the power of 8 by 3. Or you can suggest that this is same equivalent to Q times into n divided by S naught to the power of half B naught to the power of 8 by 3, so what is the suggestion here.

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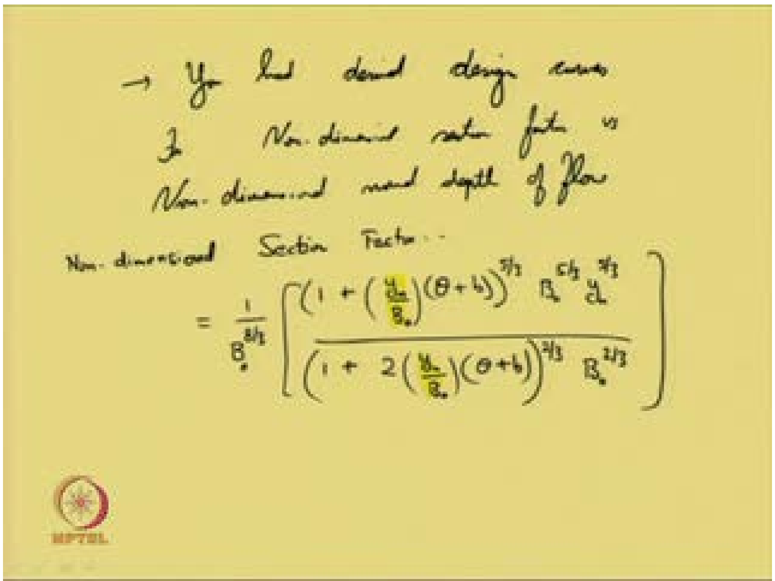

So, once you get the non dimensional section, section factor for the corresponding channel, from you have already designed. If you recall that, you had derived design curves, for non-dimensional section factor versus non dimensional normal depth of flow. So, this process you do it again here, because this is now entirely new type of channel that is the standard lined canal section.

So, you again develop the design curve, how you do that, the non dimensional section factor I can give this as, is equal to 1 by B naught to the power of 8 by 3 the whole quantity. 1 plus y n by B naught into theta plus b. This whole quantity raised to 5 by 3, B naught to the power of 5 by 3, y n to the power of 5 by 3, 1 plus twice y n by B naught theta into theta plus b, this whole quantity raised to 2 by 3 into B naught to the power of 2 by 3.

So, this quantity just rearrange, cancel the terms appropriately, rearrange the things you are now getting the terms in non dimensional form. You see here, this is a non dimensional parameter this is a non dimensional parameter. You will see here that B naught to the power of 5 by 3 is there in the numerator, it is there in the denominator, the whole quantity, this again can be rearranged, I will just write in the next slide.

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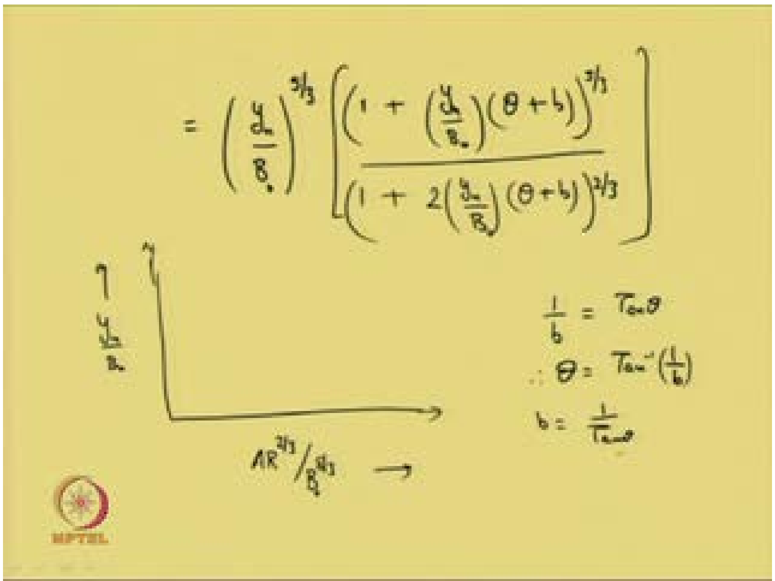

Your non dimensional section factor it can be given as y n by B naught, this whole quantity raised to 5 by 3 into 1 plus y n by B naught theta plus b. This whole quantity raised to 5 by 3, 1 plus twice y n by B naught theta plus b, the whole quantity raised to 2 by 3, like this you will get your non dimensional section factor. So, one can easily draw section factor by b naught to the power of 8 by 3 or I can write this quantity as A R to the power of 2 by 3 A R to the power of 2 by 3 by B naught to the power, this versus y n by B naught.

You can easily now plot for the standard lined trapezoidal section. Again here you will see that both theta and b simultaneously there is no need for you to take it as parameter. If you know b, then you will know what is meant by theta, if you know theta, then you know what is b. So, you can substitute for example, theta or if you recall that 1 by b is equal to tan theta, therefore, theta is equal to tan inverse 1 by b. So, you can substitute wherever theta is coming into picture this tan inverse 1 by b quantity.

Similarly, if you want to use b theta instead of b, you can just do that, b is equal to 1 by tan theta. So, substitute this quantity now, in the entire equation here, expression here, you will get your corresponding things, it is a corresponding way you can obtain the parameters. So, you solve them, that is you now create the design curves, from the design curves, you choose your appropriate non dimensional depth of flow. Subsequently, what is the corresponding area of discharge and all can be easily identified.

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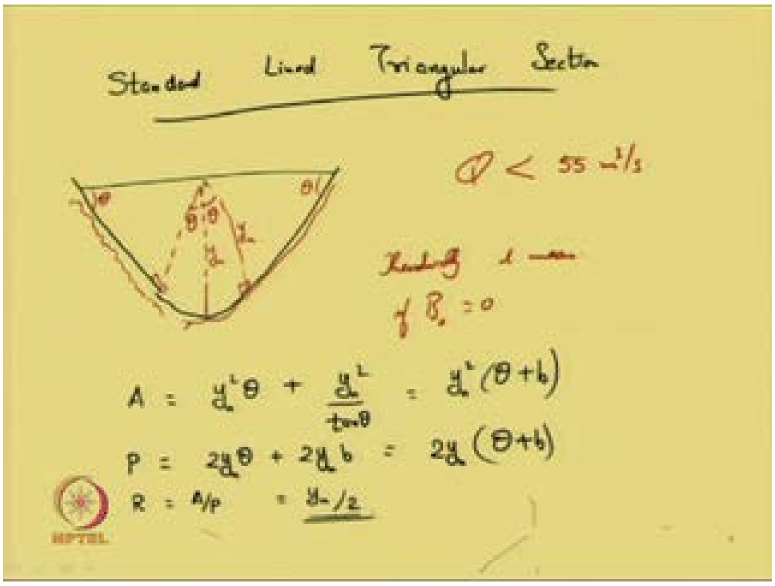

So, the similar concept, now you can use it for standard lined triangular section. So, I am not going to explain it too much here, as is done for trapezoidal section, but however we will just briefly go through them. So, your standard lined triangular section it will be of the following form. So, curve it will be rounded off by a curve. So, let me give this angle as theta, again this angle is theta, the depth of flow is y n, you know this radius will also be y n, this is same as done for the trapezoidal section, this angle will be your theta.

Because, you know this portion is perpendicularly bisecting the side slope of the triangular section. So, therefore, you can give the quantities, geometric quantities like this, geometric parameters in this way, you can subsequently design the triangular section values and all or you can find the corresponding section how, what are the section dimensions and all. Where are the standard lined triangular sections used, so, the CWC ministry of water resource India.

They have suggested that triangular sections standard lined triangular sections have to be used, wherever your discharge Q is less than 55 meter cube per second. So, if it less than 55 cumecs, then you can use the standard lined triangular section, that will be the better way compared to the compared to excavating it in trapezoidal form and all. Of course, in trapezoidal form you will see that you cannot round it off properly, the corner may not be able to be round off using the geometry, as mentioned earlier.

So, you have to use there triangular section that, so theoritically your standard lined triangular section means theoretically it means, in the standard lined trapezoidal section, if B naught is equal to 0; then that will give you the standard lined triangular section. So, you cannot use the non dimensional section factor as was devised for the standard lined trapezoidal section, that cannot be used here. So, what is the vector area, area of the flow in such a section, this is given as y n squared theta plus y n squared by tan theta, if you recall them.

So, in the trapezoidal section there was a rectangular area also coming into picture B 0 into y n, so that portion is not coming here, that is the only difference. So, your computation becomes much, much easier in that way, this is the area your vector perimeter P is equal to twice y n into theta plus twice y n into b, 2 y n theta plus b. So, interestingly what is your hydraulic radius, A by P this is equal to just compute it, I am getting this as y n by 2.

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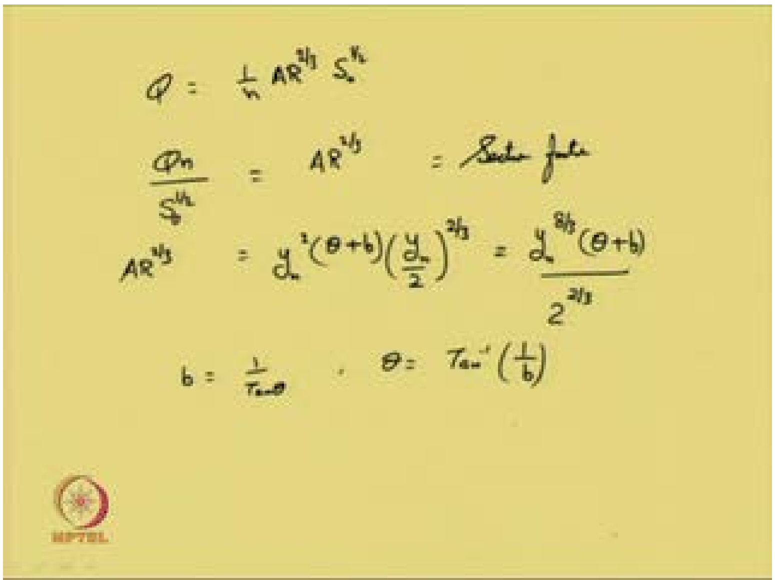

So, now use these quantities, you can subsequently identify the discharge, means you just use the again manning's equation Q is equal to 1 by n A R to the power of 2 by 3 S naught to the power of half. You can identify section factor here, Q n Q into n into n by S naught to the power of half, this will give you the section factor, for trying a standard triangular canal section, section factor that is available here now. So, using the section factor now, you can easily incorporate the design parameters.

Say here, again you will see that A R to the power of 2 by 3 is nothing but, equal to y n squared into theta plus b 2 by 3 this is equal to y n times 8 by 3 into theta plus b by the following numerical value two to the power of 2 by 3. So, you can employ this relationship directly, there is no need non dimensionalize the thing here, you will get section factor versus y n depth directly. Because, here again you know b is equal to 1 by tan theta or theta is equal to tan inverse 1 by b.

So, you can use these two relationships, incorporate it here, you can identify, which theta can be taken here, which b is better suitable here. Though those things is not available through your hydraulic (( )) efficient sections also, you can continue in that way. Next before going into the design of erodible channels, just I want to briefly mention you wide channels.

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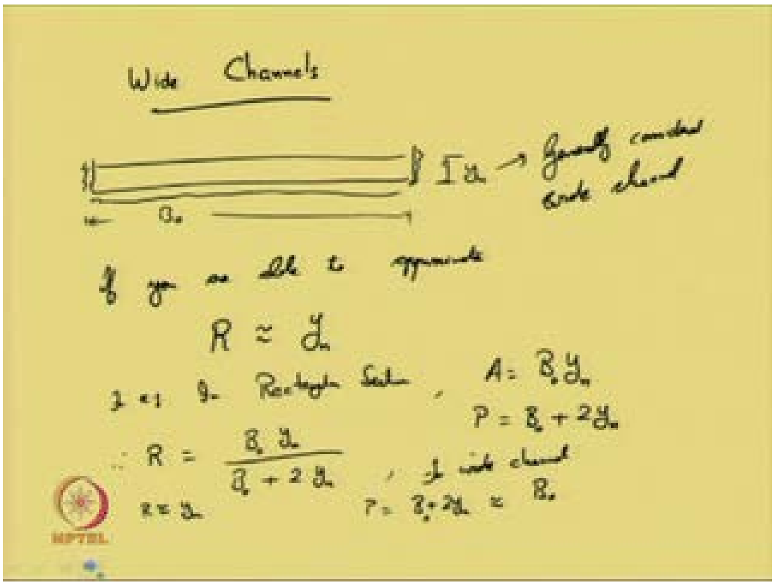

So, generally you may encounter very wide rivers and very wide channels and all. So, what do you mean by wide channels, say if I have a following cross section of a channel. Now, this channel such a type of say cross section, it is generally considered wide channel. So, what is the quantity how you can consider it is wide as a wide channel, so whatever be the shape of the cross section.

Suppose, if you are able to approximate the hydraulic radius same as the normal depth of flow, in any of the section if you are able to approximate it like that then that channel section is called a wide channel section. If you can check in for example, in rectangular section in your rectangular section consider any rectangular section, you want the wide channel section right. So, just redraw them here, a wide rectangular channel section, the depth of flow is y n, width of the channel is B 0.

So, in the rectangular section your area of cross section is equal to B naught y n, your vector perimeter is equal to B naught plus 2 times y n. Therefore, your hydraulic radius R is equal to B naught y n by B naught plus 2 times y n. Now, in this case if you closely observe, for wide channels the summation b plus 2 y n, approximately same as your B 0 itself, this much vector perimeter B 0 length is there. Even if you add two times the normal depth it is not going to change the vector perimeter that much.

So, if that approximation is taken your hydraulic radius becomes same as the normal depth of flow or it is approximated as the normal depth of flow. So, if that criteria is there, then any channel can be considered as, means if wherever the hydraulic radius is approximately same as your normal depth of flow; then those channels can be considered as wide channels. So, wherever in the questions and all if wide channels are been clearly specified, you can take your hydraulic radius directly as the depth of flow and the computations becomes much, much easier.

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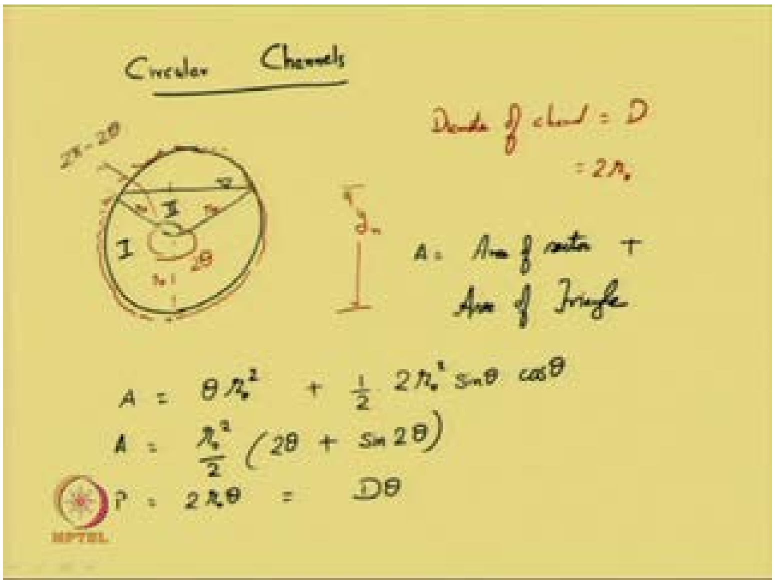

Another thing is circular channels, in one of our beginning lectures, we considered suggested that if a cross section has a circular shape. Then if the section is not fully filled with water, if it is only partially, if it is open to atmospheric pressure, the top surface of the water. Then such the flow in such type of channels can also be considered open channel or the flow in such channels can also be considered as open channel flows; you can apply the theorems of open channel hydraulics in such cases.

Say for example, here in this case, this is the top surface of the water in the closed circular channel. So, to design the circular channel, you can now suggest that say let this outer ankle, let me consider it as twice into theta. Let me consider the outer ankle as twice into theta, your depth of flow is given as y n. Another property is the diameter of channel, this is given as D it can also be considered twice into R naught.

So, this dimension is R naught, so, here in this channel your area of cross section involves area of sector, this I can mark it, this is 1, then area of triangle this is given as 2. So, area of sector plus area of triangle, so what is area of sector. So, as we have just gone through the other standard lined canal sections and all, this is now quite familiar for you. So, this is nothing but, theta times R naught square and what is the area of the triangular, so what is the area of this particular triangle, so this angle is 2 pi minus 2 theta.

So, this is 2 pi minus 2 theta, this angle you can use the geometric principles, now you can suggest that areas. Now, is equal to the area of triangle, is equal to half times twice R naught square sin theta into cos theta. Do I need to explain it here, I hope you are able to understand this angle is, the included angle is 2 pi minus 2 theta, you can means you can make it into half, so the each of the half angles consists of pi minus theta, so each of the half is pi minus theta.

So, you know what will be this angle, this is this distance will be definitely R naught by sin pi minus theta. And sin pi minus theta, what is that, what is sin pi minus theta? it is cos minus cos theta or is it sin theta itself. So, you just tell me now, so you will get the following form. So, this will be R naught means, this area of cross section you will be computing it in the following form.

So, this area I can give this as A is equal to R 0 squared by 2 twice theta, on rearranging the terms you will get it in the following form. The vector perimeter of the circular section this is nothing but twice R naught theta, this is equal to the diameter D given to yo, D into theta.

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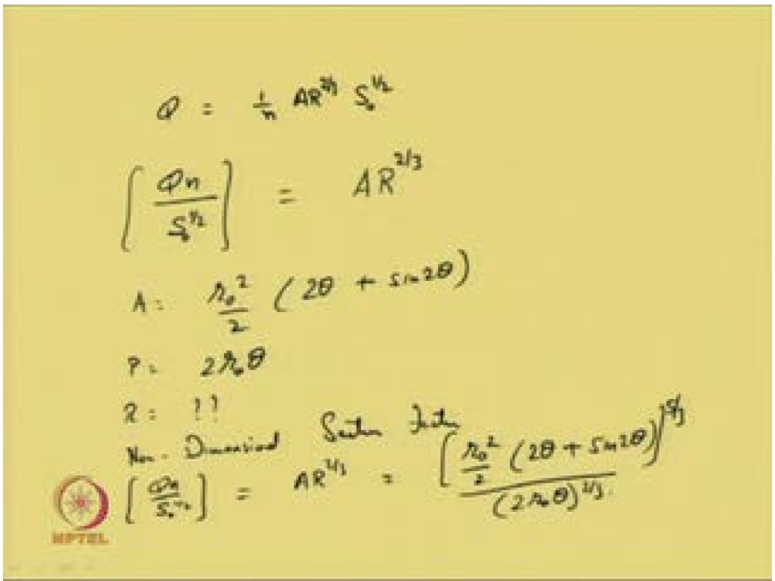

So, again one can use the same manning's formula 1 by n A R to the power of 2 by 3 S naught half. So, for designing the thing, you can take means Q is given to you, based on the material n is available, channel slope based on topography and the various criteria, if is given means, if it is computed already. So, this term is taken and now you are going to compute the section factor.

So, the section factor for the circular channel, here you can again think of the in same thing, A is equal to r 0 squared by 2 twice theta plus sin 2 theta is given, P is equal to 2 r naught theta it is given. So, you compute it, compute R is equal to what, based on that you devise the section factor, you can again form non dimensional section factor here. If required you form the non-dimensional section factor, because you know the depth of flow y n, it is some function of the diameter of the section as well as the angle theta.

So, based on that, you can find the non dimensional section, section factor appropriately then you can design the thing. So, this is given as, say, Q n means the dimensional quantity will be Q n 2 r 0 theta whole to the power 2 by 3 in this quantity to the power of 5 by 3. So, you can non dimensionalize it using D, you can use the D appropriately and subsequently compute the design. Obtain the design curves and subsequently design the circular channel sections.

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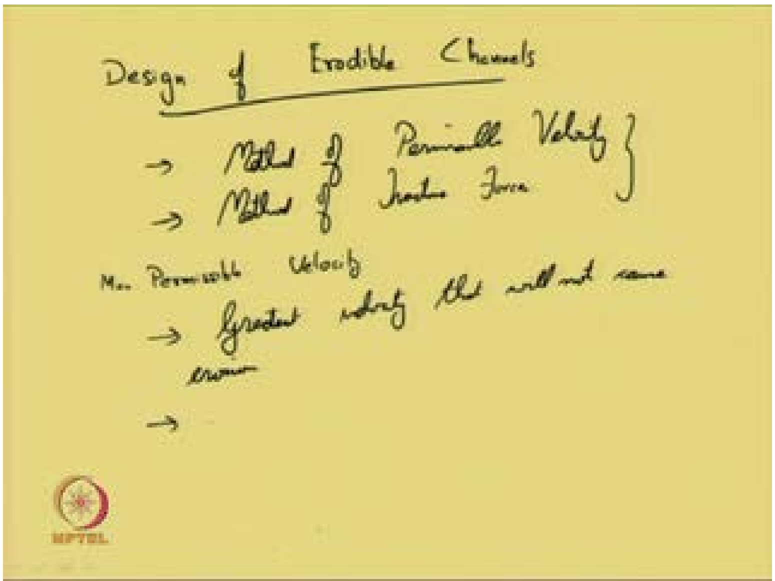

So, as mentioned now we will just start the design of erodible channels. So, we have suggested that the erodible channels which we are going to take into account here is, the channels that do not silt. So, if it is not silting especially the erodible channels, they are very much complex means you cannot means we have to definitely take that the non silting property into account. Then only the uniform flow approximation can be given for the erodible channels, also you require a stable section.

Whenever you design a erodible channel based on the uniform flow approximations, you require a some type of stable section, so that also require certain quantities. So, some of the methods used are method of permissible velocity and method of tractive forces. So, for erodible channels, for designing of erodible channels, these two methods are generally employed. What do you mean by maximum method of permissible velocity, we have suggested yesterday the method minimum permissible velocity.

Similarly, in the erodible channels you require a maximum permissible velocity. There are various type of channels, you use different type of materials, whether if it is sand, whether if it is alluvial soil, whether it is clay, whether it is concrete, whatever be concrete. Of course, you know that it is non erodible, means when you line the channel with concrete and all, it becomes a non erodible. We are talking about the erodible channels.

So, in that case these gravels or whatever natural materials are available the, for each of these materials, it may allow upto a maximum permissible velocity beyond which it cannot bear the force due to that flow. Until that portion, it can bear the force and it will not erode means. So, your maximum permeable velocity it is called your maximum permissible velocity it is called the greatest velocity, it is the greatest velocity that will not cause erosion.

So, for different materials they have different maximum permeable velocities, based on one's experience also we have to judge, which type of materials has to be used or which what should be your permissible velocity and all. So, in this case for example, a newly constructed gravels or gravel channel may have less permissible velocity compared to an old gravel channel. Because, the old channel is already settled and you can have a higher mean velocity, their permissible velocity in design.

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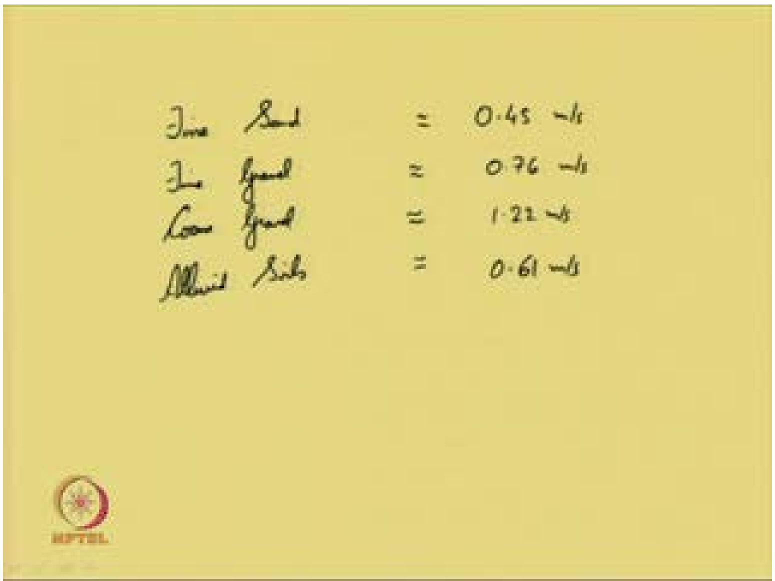

So, the permissible velocity include, just for some of the materials say for fine sand, you have approximately 0.45 meter per second. For fine gravel, you have approximately 0.76 meter per second as the maximum permissible velocity. For your coarse gravel, you have approximately 1.22 meter per second, alluvial soils, you have approximately 0.61 meter per seconds. So, these are some of the guidelines means some of the things already through various experiments and all, it has been designed. You can use them while designing the erodible channels using uniform flow approximations.

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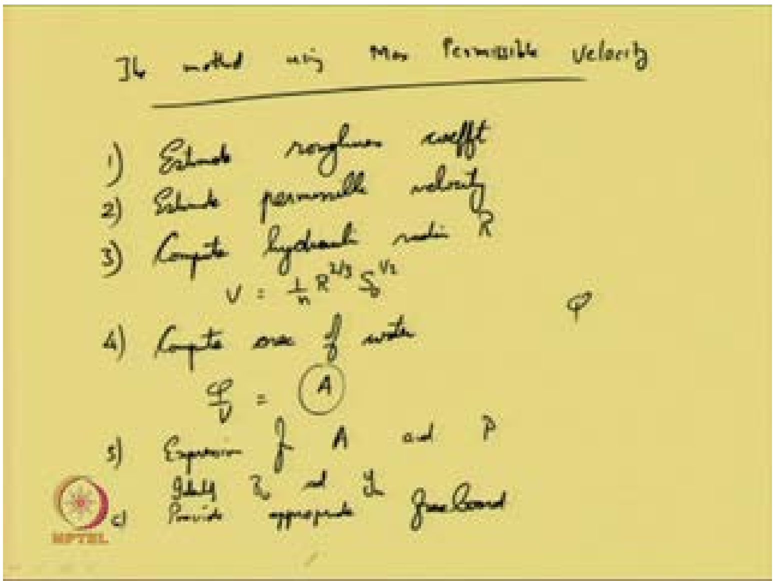

What are the steps, the method for maximum using the method using maximum permissible velocity. So, I can just number them, say first you need to estimate roughness coefficient based on your material chosen. Then you have to estimate permissible velocity for that material, maximum permissible velocity, then you need to compute hydraulic radius R you have to compute hydraulic radius R from your manning's equation.

Say, if V is equal to maximum permissible velocity and if this is a known value to you from this relationship you can easily find your hydraulic radius R. The next step is you have to compute the water area required, what is the area of water in or the cross sectional area of water that you need to compute it, because Q is already given to you. Based on that Q by V is equal to A, like this you can compute a, the area of cross section. Once you compute area of cross section, then you know expressions for A and P.

For example, in trapezoidal section what is the expression for A, what is the expression for P and all, you know that, you use them. Identify for trapezoidal section, identify then what is your bottom width b and normal depth y n, you can use the design curves also here again. Like that, you can design the thing. Also finally, you need to provide appropriate free board. Like this you can use the method of maximum permissible velocity.

Thank you.