Hydraulics

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Module No. # 05
Rapidly Varied Flow
Lecture No. # 03
Canal Design-1

Uniform flow concept will be required in our every step, I mean in most of the time we will be designing the canal by seeing what will be the depth of flow. And in in deciding those depths of flow, in computing those depths of flow, we will be definitely using the concept of uniform flow. And in uniform flow, if we just recall, we studied about the resistance flow formula and in that resistance flow formula we remember that we had resistance parameter, that is say roughness coefficient we call it. So, in Manning's equation, that is say n value and in chassis equation, that can that is that was written as c, chassis coefficient, so that way whatever may be the name, this particular roughness coefficient depend on the roughness of that channel. So, now, when we are going for designing a channel, then this roughness parameter is also very significant that we consider and then we design the canal or channel, ok.

So, these aspects will be coming there and then we studied critical depth or critical flow condition. Of course, critical flow condition will also be required in some part of the design, like that sometimes we may be, we we we may be willing to see that the flow is not supercritical, so that the canal will not be damaged and in those situation, we will be requiring the critical flow concept in design of the channel.

Well, then of course, we studied gradually varied flow and we studied rapidly varied flow. In fact, in canal design, normal canal design, this gradually varied flow and rapidly varied flow concept is not coming directly, but suppose in a canal, we have a barrier upstream or barrier downstream rather than, say there will be some gradually varied flow profile forming.

And in that case, say for normal condition when we are designing a canal, suppose we are getting a particular depth in it, now say we think that there may be some obstruction, downstream and in that case some gradually varied flow profile can be forming and in those situation what will be the additional height that is required over the computed depth of uniform flow? And those things may be required and then similarly rapidly varied flow also we may have to see, where the gradually where the hydraulic jump may be forming and say concept of rapidly varied flow is also required in those situations. Suppose, we are narrowing down the canal to a very small width, then sometimes we need to see whether there will be afflux on the upstream, whether there will be a varying varied flow just near that say constriction, so those aspect also we need to know.

Well, then, when we are talking about design of canal, then we should know that there may be channel when we were discussing about classification of channel, we were mentioning about that part, that is there can be natural channel or there can be artificial channel, well. Now, natural channel is that we are getting in the nature, like river, stream, all those things and in those cases, this concept of canal design or channel design might be coming in some of the issues where, we are designing some hydraulic structure and then there may be some approach channel which is otherwise natural, but we need to maintain some of the conditions, there say it should not be degraded more, that mean there should not be erosion or there should not be say deposition, that sort of condition may come up and in those situation, we will be requiring this concept of canal design in those part.

But in manmade canal, particularly when it is artificial channel, then that means it is a manmade canal, when we are talking about artificial channel, well. That manmade canal that everything depends on how we design the canal and that that is why for artificial channel, this or say artificial channel means we call this as an irrigation canal or say drainage channel. Those are artificial channel and for those situation, the concept of designing channel will be coming in a more, I mean is more required in those cases.

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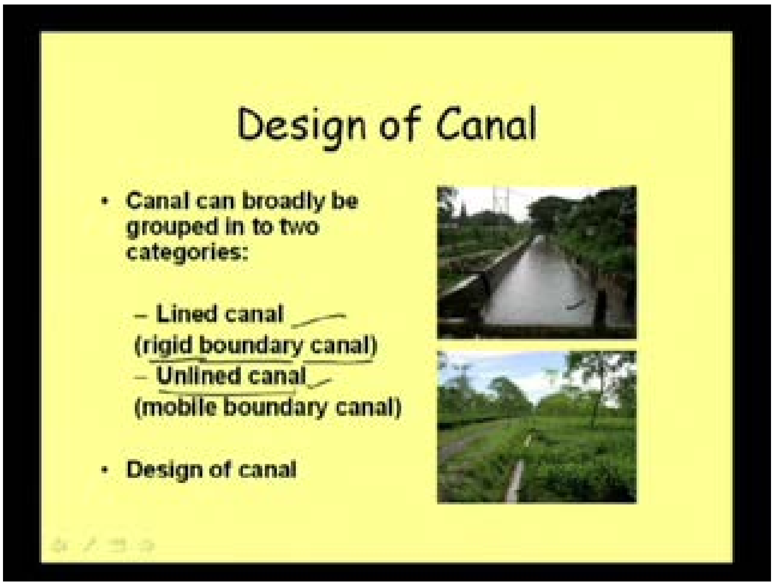

So, let us start with say design of canal and we want to specify at the beginning that canal can be broadly classified into two group, well, again there can be subclasses, but broadly we can classify canal into two group. Say, one is Lined canal like this one, that we are showing here say this is a Lined canal, there are lining, we did discuss about this sort of canal in our very first class itself. So, this sort of canal when we design, then our design concept will be different from that, when we design a channel for a unlined situation, means like that channel or we are showing in the slide here, you can concentrate on to the slide.

So, the canal can be lined canal or it can be unlined canal. Now, when it is lined canal then we call this as a rigid boundary canal, so it is a rigid boundary canal. Now, by lined or by the term lined canal what we are meaning is that, this canal when we are constructing, we are providing some lining to the boundary of the canal. Means to the side, say if the canal is there to the side we are providing some wall and to the bottom also we are providing some wall. Now, those walls can be concrete wall or sometimes we may decide to provide a say wooden boundary also in some cases and in hilly area I have seen that some people are providing bamboo lining also. So that way in some cases some experimental situation we may provide, say plastic also like that, so different type of canal alignment can be there and for if we are trying to carry some very important item, then it can be steel lining also.

Well, so like that canal lining can be of different type and when we are providing those lining we are referring this as a lined canal, well, but another point here we should know that by line canal our objective or design concept is coming like that, that this canal will not be eroded by the flowing water. So, that we are completely avoiding in our thinking of design, that this canal is never going to be eroded and so other requirement will be deciding in the canal design.

So, now, suppose a canal it may not be lined, but suppose it is passing through a very rocky tarring and somehow we are making a may be rectangular or trapezoidal canal through a rocky tarring, then also there will not be any possibility of getting eroded or there will be less possibility of getting eroded. Because it is if it is a very hard rock, of course it will depend on the composition of rock and how much it is susceptible to water erosion or to weathering how much it is susceptible to weathering if it is exposed to water and if it is exposed to atmosphere in tropical country. Particularly if those weathering conditions are different, but, however, in general, when a canal is made on a rocky tarring, we may consider these to be a type that it will never be eroded and in that process the concept of line canal will be applicable although we are not providing an artificial lining to such canal.

Well, then when we are talking about this unlined canal, means we are talking about mobile boundary canal or mobile boundary channel. By mobile boundary what we mean that the channel bed and the side can get eroded, well it can get eroded. Now, when we talk about this situation that it can get eroded, that means it will depends on various parameter, like what is the flow velocity, how much can be the erosion, what is a type of sediment that is the the bed is constituted of and so the bank is. So, that way the type of sediment and the saturation condition all this different aspect will be coming.

Well and again depending on that, particularly depending on the formation through which the canal is passing, suppose sometimes it may be a alluvial formation, right, say alluvial formation means a the bed material are say silt, sand, it is like that and in that case it may be more susceptible to erosion. Again, in some case, the canal may be passing through non-alluvial formation, means say clay formation and in that case, the susceptibility of that to erosion may be less, but again it depends on suppose in upstream there are something because of which the canal can carry or the water flowing through the canal can carry sediment. Then we need to see that this sediment should not get deposited into the canal and the path may not be blocked, so all those issues will be coming. Well, with this understanding then we can have one idea right now, that well as the canal can be of different type, the design concept for these different types of canal will of course be different. Well, so let us see what can be the design concept of lined channel, what can be the design concept of a lined canal?

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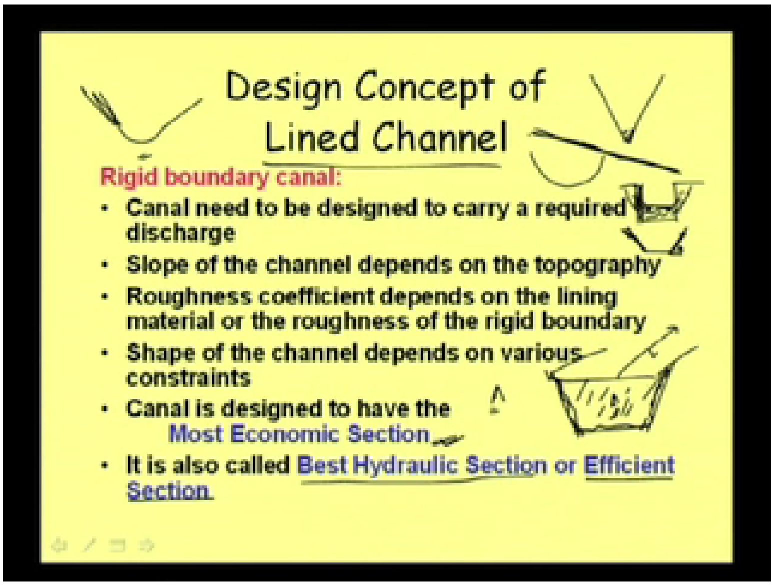

So, first let us talk about rigid boundary canal, means which is not mobile, boundary is rigid means it is a lined canal. Well, so first point that canal design, what we mean by canal design that of course we need to know. That the canal needs to be designed to carry a given amount of discharge, first, from other criteria we should know that what our requirement is. And what is our requirement means, the basic requirement of a canal is that it should carry this much of discharge that is the volume of water that needs to carry. So, we need to design this to carry that sort of discharge. Now, when we are saying that we are designing, means what we are basically doing? Well, so discharge is given and then Slope of the channel, say when we say that this is our design canal, means what we need to give? We need to say this is the bed width of the channel that need to be provided, this is the depth of the canal that need to be provided and of course, we can say that this is the Shape, it can be rectangular, it can be say trapezoidal, it can be triangular, it can be circular, so different type of Shape we may suggest.

So, that way our design may involve all those things and then we can suggest, well, this canal will have to have a slope of this much. But, now, when we talk about the Slope, then we can see that slope of a channel, you can concentrate on the slide, the slope of the channel depends on the topography, well, that means, that slope we have hardly much scope to play with that particular parameter. Say, we need to design a canal in a particular locality or in a particular location to carry discharge from one point to another, then the natural slope or natural topography will guide that what should be these slope, there we can play by a very small amount. Say for example, if I draw this one, say this is the canal and natural topography is suppose like this and then, we may not design a canal like this and then that and in this way, but we can design a canal by filling up some portion here, then cutting some portion here and then filling up, we can design a channel of uniform slope.

So, I mean the marginally we can change the existing natural slope and we can have our desired slope to some extent, but it is not that we can change the slope grossly, well. So, generally when we talk about design of canal, we do not think or we do not consider that we have enough opportunity to manipulate with the slope. So, we will assume that this is the slope or we will take the natural slope as our slope and then we will go or we will proceed for the design.

Well, then another important point that we were discussing that is the roughness coefficient depends on the lining material or the roughness of the rigid boundary. So, we need to see that what sort of lining we are providing and based on that we will be deciding that, well this is our roughness coefficient n. And in some case, well if we are thinking that by providing a particular type of lining our say roughness coefficient decreases and we know that when our Roughness coefficient decreases, then our discharge capacity or discharge carrying capacity of the channel will increase, because Q is equal to 1 by n, then it is coming that a then R to the power 2 by 3, S B to the power half.

So, if we remember that formula 1 by n is there, so if we if if the n value reduces, then thus carrying capacity of that channel increases. So, in some cases, we may have to change the lining also, in fact, for improving the channel carrying capacity many a time this side slope or the I mean slope of the canal, the side of the canal and bed are many a time lined with some finer lining so that we can have better flow through that.

Well, then another aspect is the shape of the channel that depends on various constraint, well, that is of course, I am not writing in a very very elaborately, that it depends on various constraint, now what can be those various constraint, shape of the cannel. Say for some situation we will have to go for trapezoidal channel, why, say if we go for rectangular channel, if we go for rectangular channel, then suppose the channel depth coming is quite significantly high.

And if we make a vertical cut in a particular formation, then that side or the vertical cut may not stand, it there may be slope failure, there may be the failure of the side and so that way this sort of channels when there is a vertical cut, I mean when vertical cut is not possible, we need to go for inclined cut or indirectly this lead to trapezoidal channel. Well, then similarly sometimes we may find that a triangular shape is suppose better, for some consideration say triangular shape is better, but when it is a triangular shape, then we can see that well.

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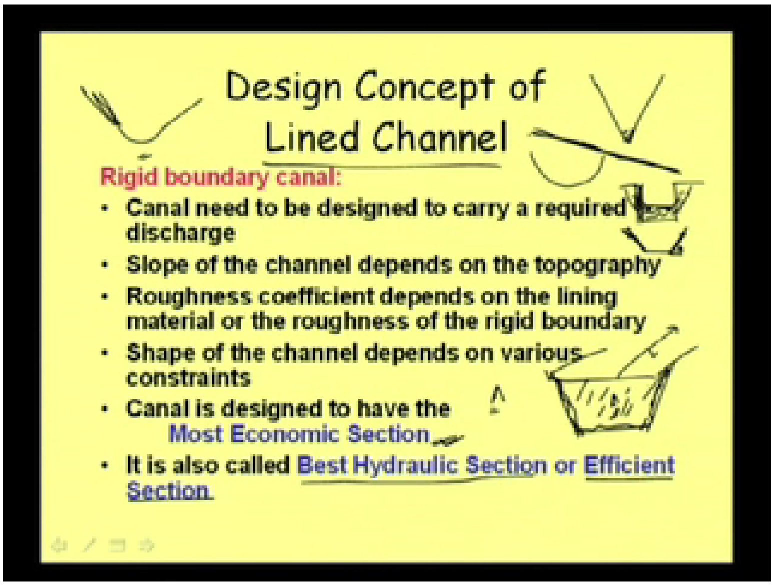

When it is triangular shape, then we can see that thus I need to take the pen, well, say this channel, suppose triangular channel is otherwise better, but we can find that this angle a may be sometimes is very narrow and say if sediment deposition take place in this part, it may be practically difficult to clean those things and that may be one constraint. So, I am just giving one constraint, but there may be several such practical constraints and sometimes say we feel circular canal is better, circular canal if we construct it is most economic or say it is better. But construction of circular canal itself may have lot of practical difficulties, say we are trying to construct in a very interior place and the frame work that is required for constructing a circular canal may not be available there, the labor available or the manpower available rather may not be that may not be having that expertise to make a circular canal.

So, that way there may be different different situation which force us to take a particular shape. And as I was already telling that rectangular channel if we take, suppose this sort of cutting is there and then if this is suppose sandy soil, it will not stand, this will fail. And then if it comes here, if it fails and if it comes here this sediment will block the flow and it will create problem.

And say we are giving lining, then of course the failure chance is less, but to prevent the failure the cost of lining that is required may be much high, rather than that if we give a inclined shape then easily it is otherwise also stable. So, lining is not required to support the soil, but support the soil means support the collapse of soil, erosion, resistant for that purpose we require it, but for to prevent the failure of slope, the thickness of the side is not required. So, this thickness will be less and that way it may be preferred.

So, depending on various constraints we need to decide the shape of the channel, in some cases people are trying with channel of this sort, say this part is circular and then this part is expanding, because this part has cleaning provision and that is why it may be advantageous. So, in some channel, we can go for that sort of shape also, well, so based on all those experience and understanding and the real situation then we need to decide that what will be the shape of the channel, well. So, once we have the Shape of the channel and at the shape of the channel we must mention another point, that is the slope, that slopes well we are saying that it is trapezoidal. Now, depending on the different type of soil the slope of this trapezoidal channel may be this theta, may change.

Well, then, if all these things are there, say we have the discharge, we now know the roughness coefficient, we have decided that our channel should be trapezoidal or rectangular, whatever it is, which is most advantageous and that we will decide. And then we are having the slope of the topography also, so after having all these things in our hand our target will be to design the canal, so that we can achieve the highest economy that is the most economic section we need to design.

So, our channel should be such that it cost is its cost is less and so that sort of channel when we design this is the very basic concept when we follow, then the channel shape whatever we get, we call that as a most economic section and that particular section, most economic section is also called hydraulically efficient section or we call best hydraulic section.

Well, so that way in case of design of line canal, in case of design of line canal our objective is to design the canal as a most economic section or the best hydraulic section, these are actually just the same name and or efficient section, right, different names we follow. But, here we can have some relation, most economic means say if we are providing lining, if we are providing lining to the canal, then our target, if we try to reduce our cost then our target will be that, well our perimeter, because lining means the lining we are providing in the perimeter, this here we are providing the lining. So, if we try to reduce the cost, if we try to reduce the cost, then this length perimeter should be minimum, so that way we are talking this as a most economic section, but now what is the difference between best hydraulic section or efficient section? You see Most economic section is coming because the cost is less, now again if we see, suppose the same area, same area is there and then to minimize the cost we are trying to reduce the length of the perimeter, but in that process we are achieving another objective.

See, the resistance to the flow is coming from the perimeter, if our length of the perimeter is more, resistance to the flow will also be more and when resistance to the flow is more, suppose for the same area if the cross-sectional area is remaining same, cross-sectional area remaining same. If the perimeter is large, then that is weighted perimeter is large, then resistance will be more and as such the discharge will be less and our objective will always be to carry the maximum discharge or say require discharge at minimum perimeter provided area is remaining same.

If we talk about excavation, say excavation will depend on the area, sectional area I am talking about, this is total volume but length is something and with that length and this area if we cut the channel then excavation is coming up, then excavation will depend also on this section of the area. If the the volume of excavation will be that this sectional area multiplied by the length, now, if this area remain a fix, then this excavation a into L that volume will remain same and as such the cost of excavation will remain same. Now, for the same area, if we can have minimum perimeter, then we are always on the beneficial side. From the economic point of view that is the cost of lining and from the flow point of view or hydraulics point of view that is the discharge point of view, the for a same area discharge carrying will be more if perimeter is less. So, that is why we design the canal with this particular concept that is the most economic section or best hydraulic section or efficient section.

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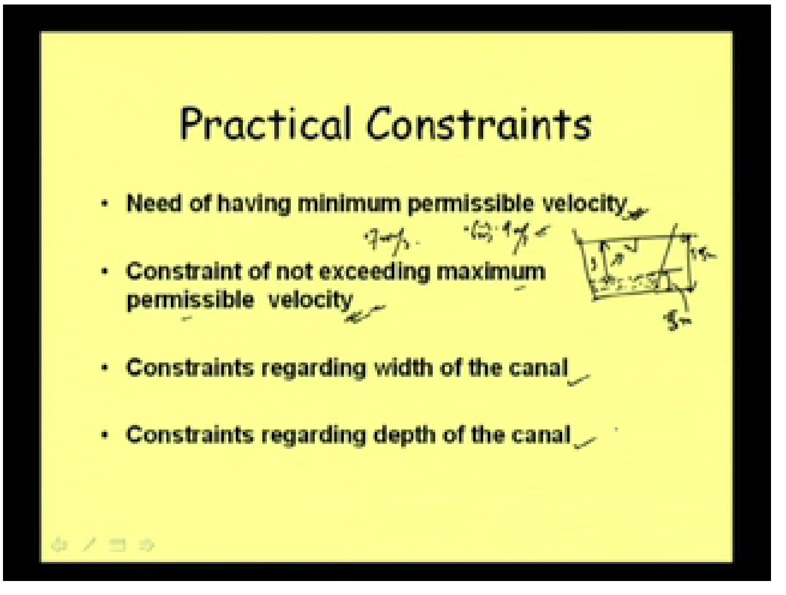

Well, now, but always it may not be possible. Say, now, what will make this best hydraulic section that we will discuss definitely, but it may not always be possible to design the channel or canal as a best hydraulic section. Suppose, for a rectangular channel, if I say that best hydraulic section is that where say bed width is equal to say twice that of the depth, well we will derive that later on, but right now you just take it or let us take it in that way, that suppose we know that for a best hydraulic section the bed width should be twice that of the depth.

Now, well, by that concept to carry a particular discharge, we can have this is the section. Now, we have a slope, there the bed slope, now what is the other constraint that may come, first is that need of having minimum permissible velocity, you can concentrate into the slide that is need of having minimum permissible velocity.

Well, what is mean by that? Well, the canal, when it is lined we know that it will not be eroded, so we are not worried about that, it will not be eroded, so how much velocity is flowing or what is the velocity of flow, we are not that much worried of course, there is always a maximum permissible limit also. But, still say we are less worried about that part, but we are more worried when suppose we are designing a canal and we know that this canal there may be sediment laid in water flowing through the canal, that is water is carrying some sediment from upstream.

So, in many many cases, we find that in a city suppose we are designing a canal and that canal portion may be a lined canal, but in the catchment, say upstream area, there may be lot of hills or there may be say vegetation cover may not be there in the catchment area and because of the during rain suppose lot of sediment may come. So, although our canal is a line canal, but it is carrying sediment laid in water, it is carrying sediment laid in water. And now, if the flow velocity in the canal become very less, than the sediment carried by the water may start settling down in the canal.

And as we know that say this is our canal and from the upstream say a lot of sediments are coming and then sediments are settling down, because the flow velocity is less and for a water its sediment carrying capacity depends on the flow velocity. Well, if it its velocity is high, it can be carry more sediment. Suppose the water are coming from the upstream catchment or the upper catchment where it is coming from a hill on that way, suppose the slope is very high there and the flow velocity is very high, it is eroding the soil and then it is coming and entering the city and in the city, it is finding a drainage canal where the flow is moving, but that flow is carrying lot of sediment that it has carried from upstream.

And once it is in the city, it may be a plain area and if it is a plain area, of course in the city if it is hill that is fine, velocity may be high, but if it is a plain area, then if the velocity drop down, velocity drops below a particular limit, then depending on the size of the sediment it may start settling there. And if it settles then thus carrying capacity of the canal will be reduce, say originally its sectional area was entire sectional area with time, when sediment will start settling there, then its carrying capacity will be reduced grossly and then the objective for which the canal was designed will not be served. So, that way we need to take care that when we are designing a channel, suppose we have done our calculation, we have put the best hydraulic section, then what we need to see that for required discharge, with what velocity the water will be flowing in the best hydraulic section.

Now, in the best hydraulic section, suppose we are finding that with the velocity with which the water is flowing is not sufficient to carry the sediment that it is carrying with it, then definitely we cannot provide the best hydraulic section, because at that point our criteria changes. Well, we tried with best hydraulic section, but it cannot be provided because the water will not be able to carry the sediment and sediment deposition may take place, that will create problem. In fact, in in a in area, in in in a city, I was involved in a drainage design and I could see that this canal, the existing canal could not serve, because say total depth is 1.5 meter, but this depth of sediment that was observed is point 5 meter.

So, originally it was designed for 1.5 meter of depth, but this existing depth is only one meter. So, that way this lead to flash flood a sort of thing, that is the canal cannot carry the required drainage and then we have to see that how it can be, I mean overcome, how this problem can be overcome, so this design was wrong actually. So, so that sort of concept we need to see. Then another point that Constraints of not exceeding maximum permissible velocity this is also one point, of course in line canal, if our lining are strong enough then we can go for high velocity. Again, in some cases, we can go up to 3 meter per second, four meter per second that sort of velocity is also permissible, but if our lining is not that strong enough, say due to economic reason we cannot provide that strong lining and in that case, we will have to be worried about that aspect also, that the velocity should not exceed a particular limit.

And so far this minimum velocity is concerned, it is generally found that .6 meter 2.9 meter per second sort of things and on in an average generally .7 meter per second can be considered this minimum velocity so far is concerned. But maximum velocity we can go to say 4 meter, 5 meter depending on the I mean type of bank lining, but this is one consideration that we need to make, then there may be some other constraints like constraints regarding width of that canal.

Well, recently I was involved in a design aspect of one city called dibrugarh, there design of canal. And then there the drainage canal this was found that with all calculations that how much discharge will be coming from hydrological calculation, that I could see, that the size required for the canal is, say I mean if I go for the best hydraulic section the width become say 4 meter, 5 meter like that. In some places, now it is passing through some already developed area and roads are there, so if we and we need to provide the canal in those portions, because so far the surface terrain condition is there, this is the place where the water will be coming, but now the road size itself is not that large there. So, the you forget about the side canal or the road side canal, so there we may not be able to go for that type of canal which is say four meter wide. Well, in that case, we may have to reduce the width and we may have to increase the depth to carry that discharge.

Of course, while doing those then we need to see whether the flow velocity will be dropping down to a minimum value and whether this will lead to sediment deposition. If so, whether a pumping device is required, all those aspect will be coming. And of course, sometimes even we may think that if this is not possible reducing that part, we may have to make a canal, box canal, which over which the road may be there. So, under the road we may have to have a box canal, so different options are there. Well, but still that sort of constraint may be coming the width of the canal, length, availability and all these things will be coming. And sometimes there is suppose constraints against depth of canal, well that is also another constraint.

Suppose after calculating the best hydraulic section, we have found that the width is 2 meter, depth is one point 5 meter, fine ,well, we tried to put that, but we have seen that below one meter there is a say very important object like say oil pipelines, suppose which is carrying oil. And this cannot be removed, this cannot be lowered at that point somehow and then you cannot provide a depth of 1.5 meter there, so you will have to restrict your width, depth. And similarly, suppose in a particular area we are trying to make a canal, which is of 2 meter depth and then we have found that after 1.5 meter there is a rock strata, well. And then say it is an irrigation canal and we cannot afford to afford to say cut that rock and to because it will be quite expensive, so that way it may not be possible.

So, we may decide that this our best hydraulic section cannot be provided here, rather we will go for a depth of say 1.5 meter, because at 1.5 meter depth the rock strata is there and we cannot go below that. So, that way there may be different practical constraints and that govern the size of the channel, but our effort, our basic design concept for line canal is that we should try for designing it as best hydraulic section, which is the Most economic section as well.

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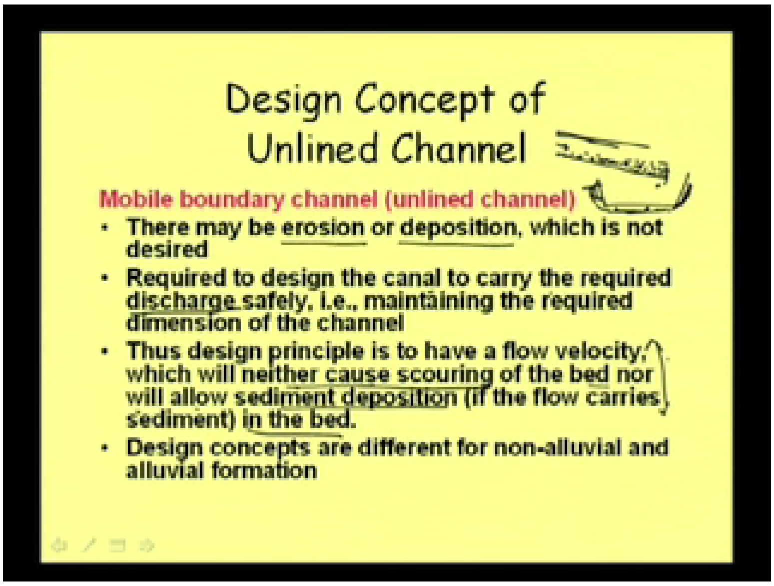

Well, then we will be discussing unlined canal in detail, but before going to the discussion let us discuss some of the issues briefly about unlined channel. Well, we will be discussing that also in detail in different class, but still some of the very fundamentals or required things we will be discussing here. When we talk about design concept of unlined channel, entire concept is different, here we are not talking about best hydraulic section or rather we can say that the most economic section is not the best hydraulic section here.

So, because the entire concept is different here, say there may be erosion or deposition, well when it is a unlined canal, so with flow velocity there can be always erosion of the bed and side bed and side can be eroded and once it is eroded at a particular point, then it is obvious that the canal will be carrying sediment laid in water, once it is eroded, it will be carried by the water. So, from upstream itself it can carry, within that channel itself it can erode and it can erode side and bed and then it can carry the sediment. Once it is carrying the sediment again the velocity is low at some point, it may again deposit the sediment. So, what we can have that, this sort of channel we are very much concerned about that erosion and deposition of sediment in that particular channel, well.

And if erosion occurs and if deposition occur, already we have discussed if deposition occur then the entire carrying capacity decreases and similarly, it has of course far-reaching effects, suppose that channel is of this type and somehow the flow velocity is dropping down and deposition is taking place here. Now, when deposition takes place what happens? Suppose the water was flowing with a particular velocity then when deposition is taking place, flow velocity get retarded in the upstream and when it is retarded, because it is getting some obstruction and it is retarded flow velocity, if it as it is says subcritical flow flowing here.

So, it is retarded, now when it is retarded its sediment carrying capacity further drops down and then further deposition take place. So, that way ultimately the entire channel slope get reduced like that, when say Slope is reducing, again depth is increasing, flow velocity is further decreasing and then sediment deposition is further increasing, and that way it is a progressive process. Due to a progressive process and that is why this is not desired at all, so we should design the channel in a way that there should not be deposition of this kind, similarly, if it erode the channel, then also we are not achieving our target. If it is eroding then it will cause damage to the channel flow, if it is eroding the side, it can get widen. Suppose the channel is like this, was like this and it has eroded this side and bed, then its entire section is changing and we may not get the required depth what was desired and the flow velocity may again change and then again it may sometimes lead to deposition initially erosion.

So, those erosion and deposition erosion will always cause damage to that channel and that is why this erosion and deposition we should not allow or we should design our channel in such a way that this can prevent erosion and deposition, which is not desired at all, well. And that is why it is required to design a canal to carry the required discharge, discharge is always say fixed, we are deciding that our channel is to carry this much of discharge. So, this discharge safely, by safely what we are meaning that maintaining the required dimension of the channel, maintaining the required dimension of the channel means it should not get eroded, neither it there should be deposition, well. So, thus design principle is to have a flow velocity, which will neither cause scouring, means that is erosion of the bed, nor will allow sediment deposition, nor will allow sediment deposition, well in the bed, this is what the design criteria.

So, in our design of line canal, the design criteria was that it should be the best section, most economic section, but here our design criteria is that, in line in in unlined canal the design criteria is that the velocity should be such that there should not be any scouring or neither there should be any deposition of course. In real situation, it may happen that the bed is having some erosion, because the process of flow is like that, it may cause some erosion in the bed. And at the same time it is eroding the water, is eroding some part of the soil and again deposition is taking place in the next movement in that position suppose. So, erosion and deposition process if it is going simultaneously, in that case, it will appear that the channel is neither getting eroded, nor it is getting scoured, but in reality, both process may go parallel.

Well, in some of the design concept of unlined canal it is assumed like that, that we talk about a critical velocity, that this is the critical velocity, well this critical velocity is different from the critical flow concept, that we discussed earlier, that is the minimum energy concept, it is not like that, but we talk about a critical velocity, it is like that which is neither scouring nor depositing or we can say that it is scouring and depositing, but both are in balance condition and that is why it is appeared to be neither scouring and nor I mean depositing, so that sort of concept will be coming.

Again, when we are talking about unlined canal, then the canal that we are designing as unlined it may pass through an alluvial formation or an non-alluvial formation. Well, when it is passing through a non-alluvial formation, means a clay formation and like that, so that sort of formation is less susceptible to erosion and in that case our major criteria are say there should not be deposition or the velocity. Or rather one point is that this alluvial, it is non-alluvial canal and then we can decide that if the velocity is not exceeding that particular limit, which can cause erosion to this unlined canal, non-alluvial unlined canal, that we should not cross that velocity.

So, it is a maximum permissible velocity concept we can follow, that this is the maximum permissible velocity, we should decide the shape and we should design the shape in such a way that we achieve a velocity which is not crossing the maximum permissible velocity. And at the same time the minimum permissible velocity is also there which will not allow a deposition of sediment, but if it is passing through a alluvial formation, if it is passing through a alluvial formation, in that case, we need to go for that critical velocity concept, erosion and deposition both are very much important there and relevant for the design purpose.

And for that actually the theory developed so far is not that much and most of the things are empirical, that is based on the observed observation carried out in different canal, some formula has been derived, that is empirical relations are there of course, semi-empirical theories has also been developed, that is semi-theoretical we can call, well, that way different concept are applied for design of unlined canal.

Well, now, till now we are talking about one term that is most economic section. Well, but what this most economic section is we have not discussed till now, we are giving just one term that is the perimeter should be minimum, but why that we have explained. But if perimeter is minimum, how we can achieve this, how we find that which will what condition will lead to perimeter minimum.

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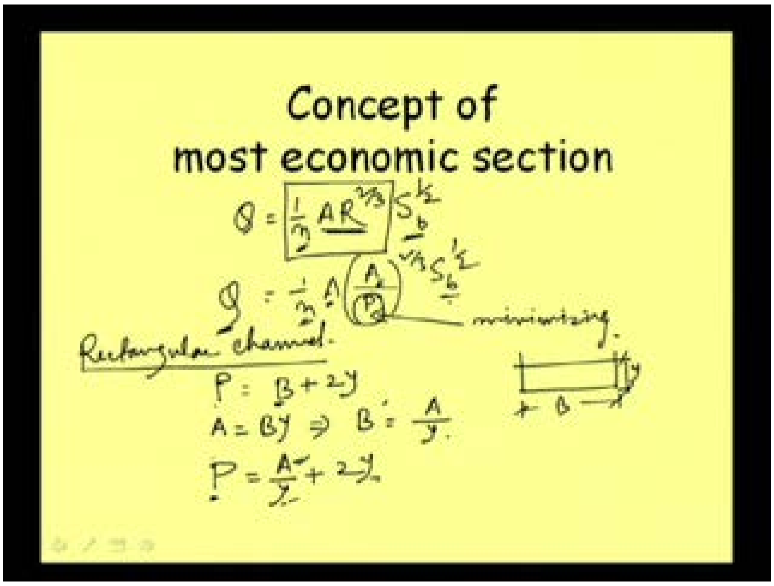

So, let us see that concept of most economic section. Well, we discussed about a term called conveyance, that is Q is equal to say 1 by n A R to the power 2 by 3 then S to the power half. And when we designed canal, we are talking about normally uniform flow, we see that in uniform flow condition what it is. And then of course, when we decide the side, we give some excess height, that is called free board of the canal and that free board is given generally it should not be less than 5 percent of the depth or it should not be more than 30 percent of the depth, it depends on some other criteria based on which we decide that this should be the free board.

So, from our design depth we give some excess depth as free board, well, that will be coming, but normally we use uniform flow formula, so this is what the formula. And here 1 by n A R to the power 2 by 3, that is basically the conveyance k and when our conveyance is more, when our conveyance is more, that means, it can carry more discharge, conveyance more means, literally it means that it can convey more water. So, our target is to maximize the conveyance, maximize the conveyance. Now, when this S B is fix, n is suppose we have decided from the other criteria as discussed, then our target is to minimize this A R to the power 2 by 3 or now, we can write from here say this is equal to 1 by n A, then A by P to the power 2 by 3 and S B to the power half.

Now, as we were talking about other criteria, say area is fixed, means if our area is fixed for a particular lined, volume is fixed now. So, when for that particular area and say we want to maintain a velocity then also we can see that which area is sufficient say discharge is given, we know the discharge by area will also give us the velocity. So, from that point also we can roughly see that our area should be this much or that way also we can decide. Now, area is suppose fixed, then how we can maximize this Q value.

For the given area we can maximize the Q value, our required discharge for a given S B, for a fix A and then our required discharge can be maximized by minimizing the perimeter, by minimizing the perimeter, so that is what our basic concept. And now, we know that say perimeter minimization how we can get, say perimeter expression if we write, suppose for rectangular channel, say let us say for rectangular channel, for rectangular channel this is say B bed width and then this is what is depth y. Now, perimeter is equal to we know that B plus twice y, B plus twice y is the perimeter. Now, of course, we want to minimize this P and for that we want to see that how we can express B, because that our area is important at this point. So, we can see how we can express it that area is equal to B into y, B into y.

So, this implies that B we can express as area by y, well, so B we can write as area by y now. So, P is equal to, P is equal to say we can write it as A by y plus twice y. Now, if we consider P, now we can consider P as a function of rather y, because we are already considering that A we are targeting, that A is fixed and then we are trying to find P as a function of y.

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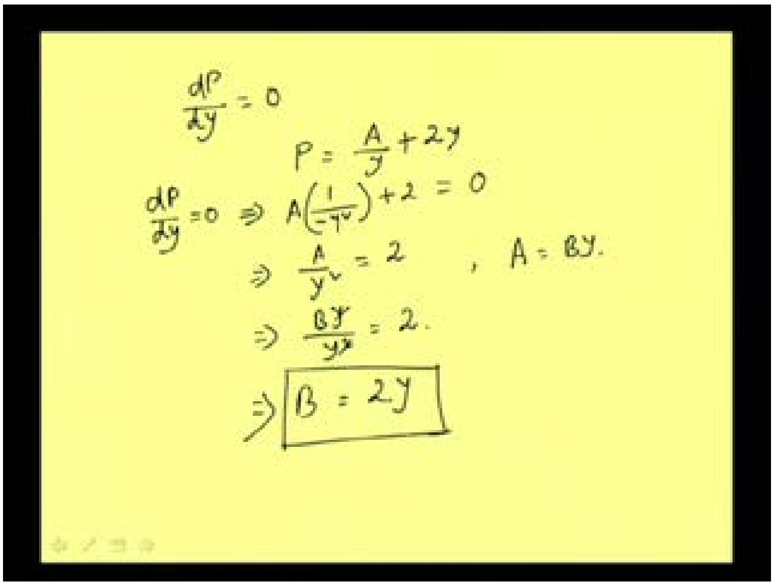

So, how we can have minimum P? If we do say d P d y equal to 0, then this will give us the minimum perimeter, this expression will give us minimum perimeter. So, we can just write that our expression was P is equal to P is equal to A by y plus twice y. Now, if we just use that concept that d P d y is equal to 0 implies that a is fixed, so it is 1 by a, so it will become a into say 1 by minus y square and plus 2 this is equal to 0. So, this will implies that A by y square is equal to 2, A by y square is equal to 2.

Now, again, we know what a is, area is nothing but B into y, so just replacing that what we can write, B y by y is equal to 2, that implies that if we B y by y square that was…, so this and that will go, so B is equal to twice y. Earlier, we were just using the term I was talking about, say our expression is for most efficient section or for most economic section, our relation is that B is equal to twice y, that we were just saying, now we have seen that. If we go by this particular concept for rectangular channel, we are getting that B is equal to twice y is the expression for most economic section.

So, if possible blindly we can give B is equal to twice y, but blindly means if we give blindly without considering the criteria that we have already discussed, the sediment deposition or the practical constraint, it will not go to the side and just design it. Then while going to the side for implementation, we may face lot of difficulties, so we need to design the canal after looking into all the other aspects, but should try to provide the most economic section and this is the condition for rectangular section.

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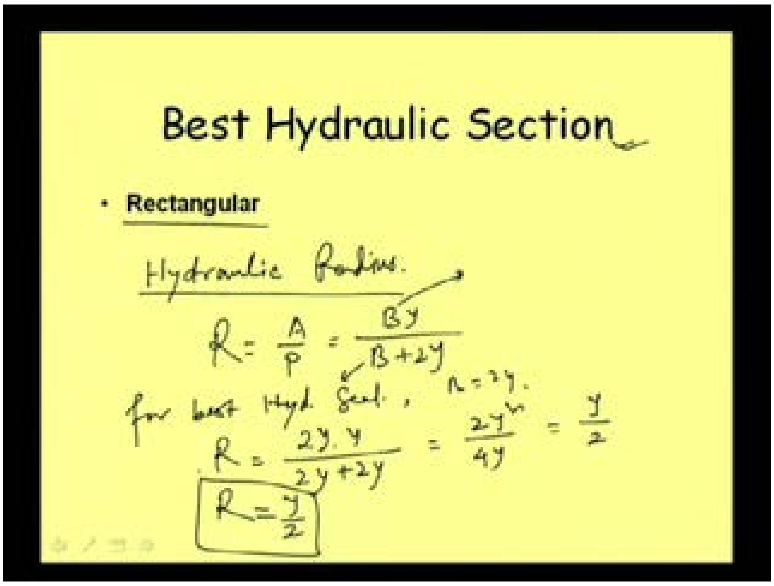

And then we can see that for a most economic section that is also we call as a best hydraulic section. For rectangular section now we can see what the value of say hydraulic radius is, what is the value of hydraulic radius, because why it is required? Say we can we require the for calculating the discharge amount, we require the hydraulic radius also. So, once we can have the hydraulic radius in terms of depth, then also we can do those calculations.

So, let us just see what is the value of hydraulic radius in most economic section that is R is equal to A by P. And now we can write that area is equal to B into y and then perimeter is equal to B plus twice y, but what this B is, what this B is, what this B is, this for best hydraulic section. For best hydraulic section we have we have R is equal to see in place of B, now we can write twice y, because B is equal to twice y, B is equal to twice y. So, we can write B into y into y, then twice y plus twice y, so this will lead to twice y square by four y or this is equal to y by 2. So, R is equal to y by 2 that is what the best hydraulic section and in best hydraulic section hydraulic radius can be considered as R equal to y by two. Well, with this understanding of best hydraulic section, now let us see whether this same concept or the same relation will remain valid for other sort of channel well.

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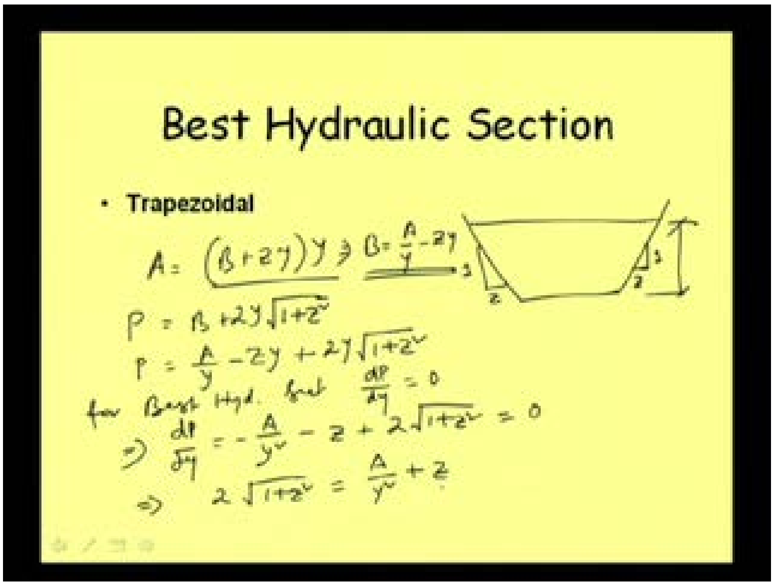

Let us discuss about trapezoidal section, let us discuss about trapezoidal section, well. If we take a trapezoidal section of this sort, say this is j, side slope is z and let us consider this to be symmetrical. Generally when it is manmade, we will generally try to make symmetrical, of course in some case, in hills, we may go for unsymmetrical also, in one side we have Slope, other side we do not have, then we may go for suppose I mean a unsymmetrical channel also, it may require, but normally we try to go for a symmetrical section. Say depth is y, well, now, in case of trapezoidal section, in case of trapezoidal section, we can write that area is equal to say B plus z y into y, that expression we already know and this will lead to this will lead to say B is equal to say A by y minus A by y minus z y.

That's why we are getting the that, that way we are getting the expression for B. And then perimeter, perimeter is equal to you can write B plus twice y root over 1 plus z square. Now, this can be written as P is equal to in place of B we can write A by y minus z y, that means just writing the B value plus twice y root over 1 plus z square. Now, if you just apply the same condition that for best hydraulic section, best hydraulic section d P d y is equal to 0, that implies d P d y is equal to we can write that is minus A by y square, I mean y differentiating. So, it is an a we are considering as constant here, then this will be minus z and then plus 2 root over 1 plus z square.

Well, so this is equal to 0 and this implies that twice root over 1 plus z square, that expression I am writing with an intention here in this side is equal to A by y square plus z. Now, we can again replace the value of a, a we know that a is equal to B plus z y into y, ok.

So, what we can write, that is 2 root over 1 plus z square is equal to that was A by y square, so in place of a we can write now this as B plus z y into y. If we just recall this was a, so we are replacing by this by y square and plus z, so this way we are writing this expression, fine.

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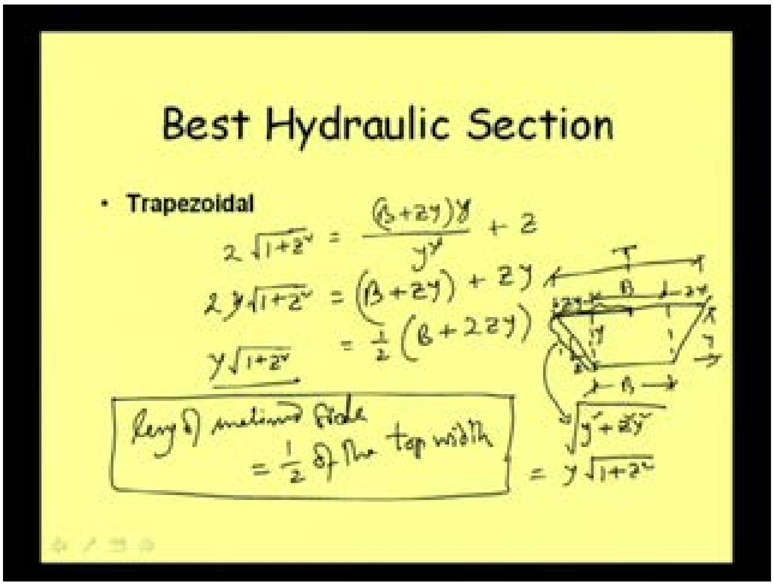

And then, if we multiply this by y, if we multiply this by y, then let us see how we can write, say twice y root over 1 plus z square, twice y root over 1 plus z square is equal to this is already going and then it become B plus z y, B plus z y plus z into y, B plus z y plus z into y or we can write this as say y root over 1 plus z square y root over 1 plus z square is equal to half of say B plus twice z y B plus twice z y.

Now, if I draw the trapezoidal section here, if I draw the trapezoidal section here, this is leading us to one important aspect, say this width is B, fine, this side slope is z, already explained, now this height is y, this depth is y, this depth is y, fine. So, what about this side? Say from here to here this is z y, now so what is the length of this side? What is the length of this side, if this is y, this is z y, then it will be root over, that is simply applying this square plus that square is equal to the diagonal, two perpendicular sides. So, this is, this length is nothing but y square plus say z y z square y square root over…, so we can write this as y root over 1 plus z square, so this part is giving us the side length.

And then we know that this part is B and this is again z y, this is again z y, so what is half of B plus twice z y, B plus twice z y is nothing but the top width t. So, half of B plus twice z y is nothing but say half of the top width, means from here to here, so this length is equal to depth length and this is what the condition for best hydraulic section, we can write that length of inclined side is equal to half of the top width. So, that way this is leading us to this condition, so if a trapezoidal channel we want to make most economy, we will have to design it by following this concept, again we should not forget that there may be lot of practical consideration which may not allow us to have this sort of best hydraulic section.

Well, we have discussed about the design concept of unlined, no, lined canal, we have discussed about the design concept of lined canal. And of course, discussed some of the fundamental aspect of say unlined canal also, and but we are yet to cover that if that channel is suppose it is a lined canal, but it is a triangular, it is circular, what will happen how we will design that part, so that we will be discussing in the next class. And then along with that we will be starting our discussion on unlined canal as well; thank you very much.