Hydraulics
Prof. Dr. Arup Kumar Sarma
Department of Civil Engineering
Indian Institute of Technology, Guwahati

Module No. # 06
Canal Design
Lecture No. # 03
Design of Alluvial Channel-2

Canal and it will create problem. So, that was the problem in the design of, say line canal. When we talked about design of unlined canal, then again, there may be two different types of formation through which the channel is moving. One can be non-alluvial and other can be alluvial. So, when it is alluvial channel or first let us talk about when it is non-alluvial channel, then the question of getting eroded, this will be coming when the velocity exceed a high level. There is always a maximum permissible velocity. We should not allow the velocity to be higher than that maximum permissible velocity.

So, that was the design consideration because the problem of sedimentation is little less than the problem of scouring in case of non-alluvial channel, but in case of alluvial channel, of course, we did discuss about that earlier. In case of alluvial channel, the problem is much more than the design of non-alluvial channel because in alluvial channel, as you can see that there is a problem of scouring of the channel by the flowing fluid as well as, there is the problem of sediment deposition in the channel.

If sediment get deposited, then also there are problem. If sediment, suppose if the channel gets scoured off, then also there is a problem as such the very design principle is that we should try to have a velocity which is of the type that non-silting, non-scouring. Of course, in true sense, it is very difficult to get a velocity of that type. In reality, there will be scouring to some extent. There will be sedimentation to some extent and it will be in a balance position. Apparently, it will be appearing like that this velocity is causing no scouring or nor it is causing any deposition. That particular velocity, we call as critical velocity.

Here, we should again remember when, here we should again recall that we did discuss about critical velocity when we were discussing critical flow condition. That critical velocity is different from this critical velocity. For designing of this alluvial channel, we have different method, say one is Kennedy's method and another is Lacey's regime theory principle. So, these two methods also we did discuss in our last class. Kennedy's method, we completed almost and Lacey`s theory, we were discussing the very basic steps, but the equation that were developed by Lacey's were discussed. So, let us start today with the steps that are involved in design of channel that is alluvial channel by Lacey's method.

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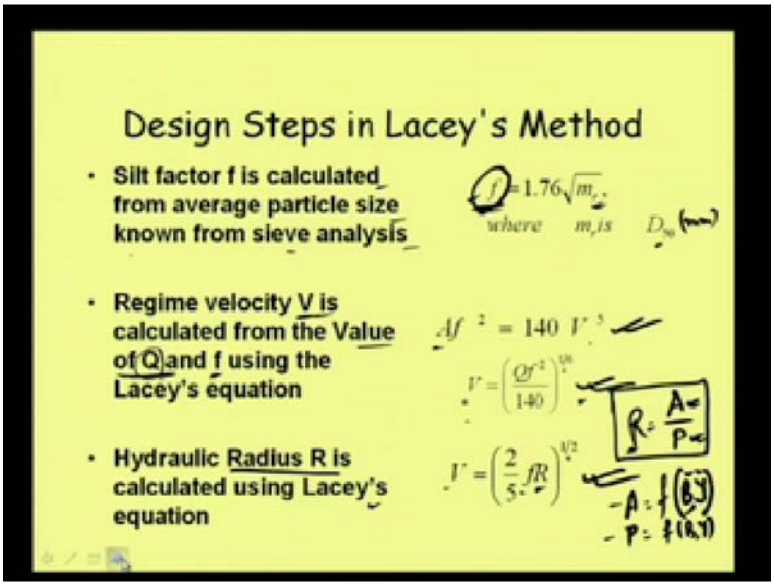

So, we can concentrate into the slide that unlike Kennedy's method, the lacey's method is different from the fact that he gave emphasis on the parameter silt. That is because the erosion depends on the silt and the sedimentation will also depends on the silt size. So, he gave more important to that point and as such, he defined a term called silt factor. That silt factor was used in most of his equation and that silt factor f, we need to know. Then, he gave one relationship for this silt factor which we can find out in terms of mR by mR.

What we mean is, that it is the D50 size of the sediment that is the sediment by which the channel is composed of and the sediment which is coming in because we are discussing earlier itself that when we talk about regime channel, then we consider that sediment that is flowing into the channel that is the sediment charge. We call silt charge that is flowing into rough channel and the silt with which the channel is being formed are of the same quality.

So, we are talking about D50, means both the silt. Well, then this is the D50 side that is the size of, if we carry out Sieve analysis, then the 50 percent finer than a particular diameter, we will be getting particular silt size and that we refer as D50. This is in millimeter. So, we can call that where mR is D50 and it is in millimeter. So, that way we can get the f size. So, first f is that silt factor and f is calculated from average particle size known from Sieve analysis. So, that will be our first step and we should be very much careful in determining this f value because all other relation will depend on these f values.

Then, the second step that regime velocity V regime velocity. V means, we mean that, that is the velocity when that channel will be in regime condition and in Lacey's theory by regime condition we mean that channel has reached the regime condition. That means, there will be no further erosion, no further deposition and it will remain as it is. That is the very basic principle of Regime theory.

Of Lacey's and that Regime velocity at that condition, what will be the velocity that we can find out? This is calculated from the value of Q discharge we will have to know. So, because generally, when we talk about design of channel, we need to design that channel to carry a particular discharge. So, that Q, we will have to know from other hydrological study or if it is irrigation canal, then depending on the discharge to be supplied to the agricultural field.

So, that way, we need to know the discharge. So, from that known value of discharge and already that we have come to know, what this f value is from the known value of f. Using these two values, we can find out what velocity is the regime velocity by using this formula. In fact, when we were discussing in last class, we were talking about this particular formula which was given by Lacey's. From this formula itself, we can have this relation because if we multiply this by V, in fact, I did show in the last class also that if we multiply by the V, this A into V become Q and this become V to the power 6. That way, V, we are getting as Qf square by 140 to the power one sixth.

So, that way we can get the V value. Now, once we get the regime velocity V, then for design of channel, we need to know what will be the hydraulic radius because this V and Q based on Q, we can have the V. From that again, we can have area, but then what will be the hydraulic radius. That is also important for design purpose. So, hydraulic radius is then calculated. Hydraulic radius is calculated using Lacey's equation. This particular equation that we did discuss in our last class that is V is equal to 2 by 5fR to the power half. Well, from this we know V, we know f.

So, we can have what is hydraulic radius. If somehow, it is not in memory, then it is nothing, but A by P. So, that we need to find out and A is nothing, but it is a function of bed width B and Y. Of course, if it is a trapezoidal channel, then side slope z is also coming here. Of course, the z in Lacey's theory, we keep a fix value that is 0.5 is to 1 is normally kept that is for regime condition. It is considered that z will be 0.5 is to 1. So, by that z we move. So, that is why I am writing this as A is equal to a function of B and Y and P is also a function of B and Y.

So, we have two unknown and we are getting one relation which is giving us actually the value of A by P. If somehow, we can get the value of A and P separately, then our task is over in a sense because now we will be having two equations. If you can have A and P, we will be having two equations of B and Y and two equations. So, from those two equations, we can solve for two unknown B and Y. So, now, let us see how we can have that.

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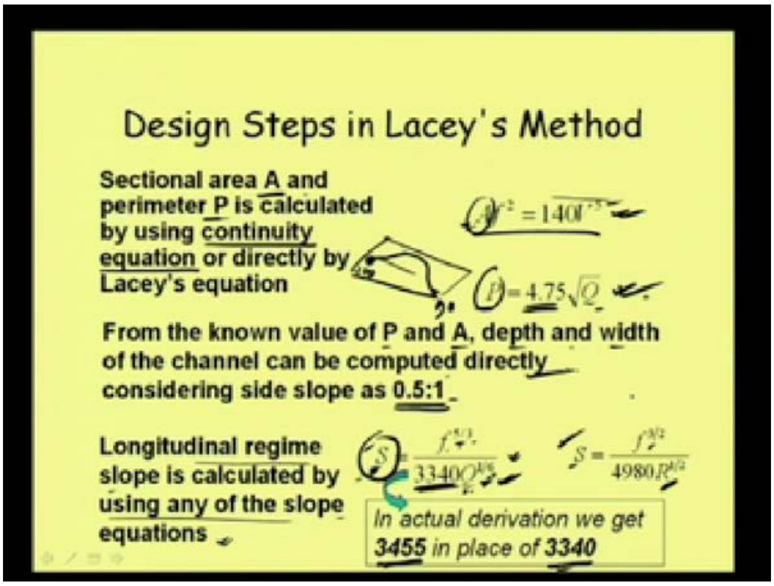

So, sectional area A, we have R with us. The sectional area A and the perimeter R is calculated by using continuity equation or directly by Lacey's equation because Q is equal to area into velocity. So, already we have got the velocity term. So, we know Q. So, we can find area directly or we can use this sort of equation also. This is also one equation that is given by Lacey that is Af square is equal to 140V to the power 5.

In fact, these are all related equations. So, if we use this equation, then also we can find out what the area is or from continuity equation, we can find what the area is. That we can calculate directly. Then, P, we can calculate by using this particular equation. P is equal to 4.75 root over Q. So, Q is known, that is why we can find out P. Now, here I want to emphasize one point that these co-efficient that we are writing here that is P is equal to say 4.75, that value is actually this equation, rather itself is a derived equation. Original equations were given by Lacey's and from that, we derived this equation. So, this co-efficient 4.75 is not exactly 4.75 and that is why, there are some, say round off made in this part. Another important point that originally these formulas were developed in FPS system and then, it was converted to say, as our meter secondary system. So, that way, in this conversion also, we always introduce some amount of error.

So, anyway, but still when we are doing our design purpose, say finally, we are getting our design section. I mean why this is not that important again? I would like to say that point because suppose, practically we are designing a channel and we are getting our channel dimension as, say width is suppose 3.39 or 3.38 something like that, then people will prefer to have a width in practical condition.

If we go to the field to make a channel of width 3.38 or something like that, it is very difficult. So, what will be made? It will be made say 3.5 rather than making 3.38 or 3.39 or 3.34 even. So, people can go for 3.5 meter. So, that way, always we will be rounding up our design dimension at the end. So, if we round off here, itself by small amount that is not making that much harm or that is not making gross difference in our ultimate result, then we use this equation. So, P is equal to 4.75 root over Q is the equation which is used for calculating the perimeter.

Now, after calculating the perimeter, after having the area, what we can have now that from the known value of P and A, this depth and width of the channel can be computed directly. So, that is one advantage. Directly means, here again we need to know one point that we are calculating it directly considering side slope as 0.5 is to 1 which is generally taken from the concept of regime channel and that was suggested. So, by taking this as 0.5 is to 1, we can calculate our dimension of the channel.

So, what is the advantage or computational advantage in this particular method? Till now what we have done in Kennedy's theory. If we remember, we have to go for trial and error procedure that is we get a velocity say, non-silting, non-scouring velocity by Kennedy's theory that is V is equal to say 0.55, then depth to the power 0.64. So, from that sort of equation, we got a critical velocity.

Of course, then later on, he introduced a co-efficient NA multiplying co-efficient N again which take care of about that, I mean silt size. So, that way we were getting that velocity. Then, based on that velocity, we calculate the dimension of the channel and after getting the dimension of the channel, getting the slope of the terrain, we calculate what the actual velocity will be by using uniform flow formula.

Then, these velocities that is, the uniform flow velocity, what we are getting in actual? After getting the size dimension of the channel, we can calculate for a given discharge. What will be the velocity? So, that velocity and the critical velocity that is the non-silting, non-scouring velocity, we need to compare. If these two are matching, then only we consider that our design is, otherwise we need to repeat. We should consider another depth, another critical velocity we will be getting. Then, that trial and error procedure, we need to continue.

Then, as in some cases, when B by Y ratio was given for that particular discharge and then, we can in that case adjust our slope, but that is also by trial and error procedure. Here, in Lacey's theory, that trial and error procedure is not required. That is why it is directly we can calculate. That is one advantage of Lacey's equations.

Then of course, after designing the size, we need to know that what will be the regime slope because as we did discuss in the last class, that a channel adjust a channel when once we allow a particular amount of discharge to flow through it. It will be adjusting its depth, it will be adjusting its width as well as it will be adjusting its slope and it will be adjusting a slope in a way that it will be in regime condition, for a particular depth for a particular width and for a particular slope. So, slope is also important here.

That is why for Lacey`s design, we need to calculate what the regime slope is. That regime slope, we can calculate that longitudinal regime slope is calculated by using the slope equation S is equal to f to the power 5 by 3. Again, it is a function of f. That is the silt factor f to the power 5 by 3 divided by 3340 Q to the power 1 sixth. Of course, here I want to mention one important observation that is, this is also a derived equation, this S. That expression what we are getting is also a derived equation and if we derive it from the equation that we are using here, say this one or the previous equations that we were using all these equations. Of course, you can refer to the equations that we did discuss in our last class.

So, when we put all those equations, we manipulate with all those equations and we try to get an expression for this slope in terms of Q. Then, the actual derivation we get the value 3455, but the value in place of 3455, this equation in this, the equation of slope, people normally use the value 3340. They used to use these values rather 3340. Now, when we calculate, when we derive it with the value or the co-efficient for other equations that we are getting in case system and then, we try to get the value, we get 3455 but still people are using this value because with this value, people could get, I mean good result earlier. There is another point that as I did mention. Due to unit conversion, we are rounding of these equations. Now, what we are using? There are some differences in the co-efficient and then, when we use these values, then these values may have some difference.

Of course, one point if we notice here, then it is that Q to the power one sixth and then, we are dividing by 3340. It is a very large number. In fact, 3340 and f value is a very small value and that is to the power 5 by 3 is there. So, now, when we talk about the slope in place of 3340, if we use 3455, the difference will not be the value of S. Ultimately, the differential value of S will not be that much large, but still I mean, some student or in fact, sometimes people get confused that when we derive, we get 3455, but in the equation, it is written as 3340.

Many books are following this 3340 equation and many books are using or rather some books as mentioned this point that 3455 are around 3450. So, there should not be much confusion about that part because these are derived equation and this co-efficient can always have some influence on that what co-efficient we are using and rounding off the co-efficient. Then, conversion of unit, all those things are playing its role there. Then, similarly from this Q, we can calculate the regime slope. Similarly, by using the hydraulics radius R, what we have already obtained using that hydraulic radius R, also we can calculate the slope.

So, both the equations will give us same value of slope. Then, this slope we need to have. Now, the problem is that in the terrain, if we do not have that slope, suppose in the terrain the condition is like that we cannot have that slope, then there is a problem. We need to manipulate that. What we need to do? Say, if it is a very steep one, then we have to flatten it down or we may have to take the channel. Suppose, in this direction the slope is very steep, then we can suppose, let me draw a slope. Suppose, this is say, from here to here. This is the slope in the three-dimensional view. Let me draw it like that. Say, this is the slope and this slope is much more, of course, if it is very high or very low, then it is difficult to manipulate, but to some extent we can manipulate like that.

Say, if this is very large than this one, we can just fill it up and we can reduce the slope. This is one way. Another way is that if you take the channel like this, then our slope will be reduced. Slope will be flattened, because from the elevation, here suppose it is 100, here suppose it is 90, then the difference of elevation is 10 meter. Suppose, from here to here distance, if you go by a straight path our distance, our slope will be more. If we go by a curve path, if we increase our length, then slope of this channel will be reduced. Of course, making a curvilinear channel and a longer channel will be costlier. So, in many a time, we need to compromise with this particular value. We may not achieve this value in practical situation, but still we should try our level best. So, that we can have all this value as suggested by the formula and so that we can really have a regime channel.

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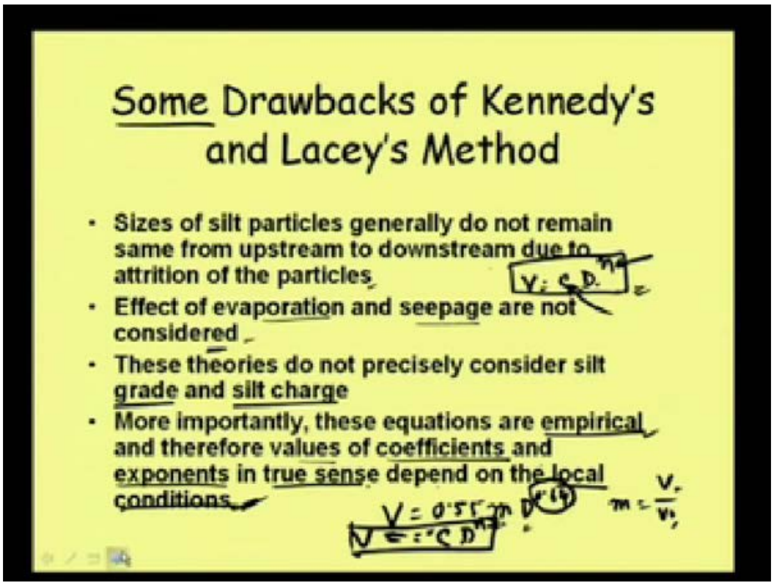

Well, then after that let us see, we have discussed this Kennedys method where we considered a critical velocity. Then, we have discussed about Lacey's method also where we have seen that how using the principle of regime channel, we go for design of channel, but in these methods, definitely we have lots of drawback. In fact, if we use Kennedy's method, if we use Lacey's method, our design dimensions are different. So, now, people get confused that which should be used. That of course, will depend on experience and in a particular region, suppose one formula design by one relation is giving better result, then we should go for that particular method. The more the information we have, when we want to take care of the silt value, then more the information we have about the silt factor. Then, we should use that. We should go for the formula which is considering more. That is Silt factor value and that is the Lacey's theory.

Well, still what are the limitations it has or what are the drawbacks it has? Well, drawbacks can be many, but we are putting here or we will be discussing some of the drawbacks which are important. Say, size of silt particles, generally do not remain same from upstream to downstream due to attrition of the particle. Here, we are talking about a silt grade. Say, D50 or say silt size. Now, that silt size is even, in fact, if D50 is remaining same, but the distribution of silt in a mass, if we collect the distribution of silt size means the gradation of silt that may not remain same because when the silt is flowing from upstream to downstream, there is a attrition. There is an aberration of the silt particles. Each silt is getting, say in touch.

Then, there will be aberration attrition and that way, the size will be reducing gradually. I mean if we see in large dimension, say in a river that will be making our point more clear in the large dimension. If we see in a river, say at upstream, when we are in hill portion, the silt I mean this. Then, we do not call it as silt, but the bed materials are say large size bolder and then when these are rolling down because of attrition aberration, these are disintegrated. Then, when we are coming to the plane side, then even in upstream, our sediment size will be little larger. Then, as we are coming further downstream, our sediment size is getting reduced. Finally, it will be coming to, when it is going near the sea in river; it will be very fine silt.

So, like that the this is sediment size gradually reduces now when our in a canal system if the canal is of quite longer dimension then silt what is entering and what is going out there will be definitely different not only silt entering and going out the bed material that is forming at the upstream and at downstream this will gradually it will change, but we are considering for the design purpose we are considering one silt grade and still we are not taking that silt grade very precisely we are taking that just d 50 size for having the f value. So, this is one of the drawbacks.

Then, another is that effect of say evaporation. Seepage is not considered. That can sometimes become significant in some of the canal system that we are considering. This is the discharge, but in some canal system, when it is wide enough, the evaporation is quite significant. Then, suppose it is carrying some sediment evaporation, loss is there. So, sedimentation sediment concentration will decrease.

Similarly, another loss that if the formation is quite permeable, then there may be huge seepage loss that is by seepage from the canal, the water may percolate into the ground. Then, also discharge is reducing and then when discharge is reducing, this water was carrying some sediment. So, when discharge is reducing, sediment is not reducing. So, sediment will be getting deposited some point somewhere or rather we can say that sediment concentration is increasing. So, those aspects we are not considering at all in the regime purpose. Then, these theories do not precisely consider silt grade and silt charge.

Well, silt grade as I have already explained. By silt grade, what we mean? The gradation of silt we should know. Say, well graded silt means that is in that silt, there are say silt size. Well distributed means starting from smaller to bigger dimension. It is there and if it is poorly graded or uniformly graded, means all silts are of almost of similar dimension and this is for a strength purpose, it is not good. In fact, these silt grade we are not considering precisely, rather we are putting only one value that is D50 to represent the silt size and our silt grade.

That is why that we are not considering it in a very precise way. Then, silt charge that is not considered in this equation, say we are talking about discharge and we are considering one point that silt charge that is coming into the channel and the silt which is forming the bed is of the same size. Fine but how much silt is coming, that is basically we are talking as silt charge. So, what is the silt concentration or the silt load in the channel that is not at all considered in the entire design procedure? Well, of course, later on some design procedure has been suggested where that silt charge is considered directly, exclusively considered. So, this is one drawback of these two methods.

Then, more importantly, these equations are empirical. As you know that Kennedy derived this equation based on his observation of some stable ways in upper wide canal region where, say it has a particular silt size. Then, climate condition and all those things are there. It is for upper wide of canal region, but for a different region that formula may not be applicable because silt size may be different and other factors may be different. So, these equations are empirical means based on the observed data. Therefore, the values of co-efficient and exponents, if we remember that there are in all equation. There are some co-efficient, there are some exponent.

So, values of these co-efficient and exponents are definitely not universal. So, in true sense, these depend on the local condition. It is very important. If I write the Kennedy's equation say V is equal to 0.55, I can put m also here which take cares of the silt. Well, then D to the power 0.64 in this equation when originally it was suggested. Of course, this is again in our meter unit and MKS system, but originally, it was suggested in FPS system. Then, there were also some rounding off this value.

Well, now in presently used equation is this one, but here say to take care of the silt part that is to take care of the influence of different location, this m was introduced where m is nothing, but say V by V0, where V is the velocity. That is the critical velocity non-silting, non-scouring velocity of the region and then, V0 is the critical velocity or non-silting, non-scouring velocity of upper bed of canal region.

Now, if silt size of that particular location is larger, then value of m is greater than 1. If silt size is smaller than the upper canal region, then m value will be less than 1. Well, that is taking care of silt factor, but this is not enough. People observe that with change in silt size and with change in location, this exponent is also changing. In fact, in India for Godavari region, different river valley experiments were conducted and it was found that for critical velocity, for stable section like Kennedy's formula of course, the format is same that is some co-efficient dim, then its depth to the power say NV is equal to. So, this is the general form and this format remaining same, but for different region of India, this co-efficient C and this N were determined and it was found that these values vary.

So, this is of course, important. That is why we can say that Kennedy's formula is basically V is equal to say C1 co-efficient we are using. Then, D to the power N, this is the general form. Now, in this general form, this N and C if we determine our self by observing some stable reach of our region that is of a particular region and that equation will be more reliable for that particular region rather than using this Kennedy's equation directly. Of course, the basis of this form is obtained from Kennedy's formula.

Similarly, in Lacey's equation also, we have several co-efficient and several exponents. So, we should take care of those value and these are empirical. In fact, they hardly have a very strong analytical basis. Of course, that the V was related to D that has some analytical basis. When he observed that he found that this erosion is occurring because of the vertical which is more prominent along the depth, only width is not that important. So, that way we tried to relate this thing, but still later on himself realized that no B by D ratio should be given. He has influence on that way. These equations have that sort of limitation. Analytical basis is not there.

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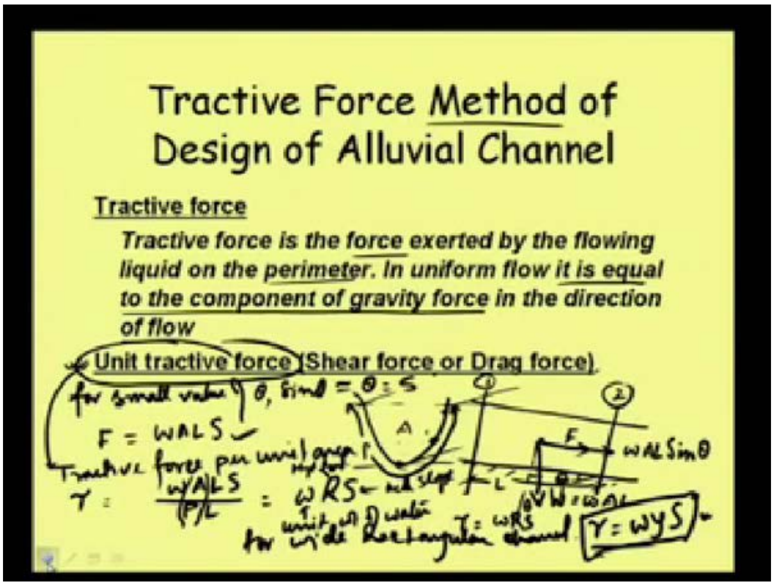

That is why later on people tried to develop one method. Now days, this method is used for design of alluvial channel. In fact, in Indian court also suggest this method that is the Tractive force method of design of alluvial channel.

So, after covering this Kennedy’s and Lacey’s theory of design of alluvial channel, now we will be moving onto design of alluvial channel using Tractive force method. Well, now we need to know what basically Tractive force is. So, Tractive force is the force exerted by the flowing liquid on the perimeter. Perimeter means, basically why it is being written as perimeter or why I am writing it as perimeter. Say, we should not say that it is exerted by the fluid on the sediment or soil because sometimes the perimeter may be consisting of something else, but still the flowing fluid will be exerting a force, drag force on the side of the channel. If sediment is there, if soil is there, if it is am unlined canal, we are talking about of course, alluvial channel. Then, in alluvial channel, the drag force will be exerted on the soil particle. So, that is called as Tractive force.

Now, what that force? That means, when a fluid is flowing through a channel, then what is the drag force or from where it is coming? That is basically the force that is governing the flow or the force due to which the fluid is moving. That is nothing, but the component of gravity force acting in the direction of fluid. So, we can say that in uniform flow, it is equal to the component of gravity force in the direction of flow.

So, that is what the Tractive force, but for the design purpose or for developing the concept of design of alluvial channel by Tractive force, we need to know about another term that is called Unit Tractive force. That Unit Tractive force is also called Sheer force or Drag force. Unit Tractive force means Tractive force per unit area. When we talk about force per unit area, we use the term pressure normally or say stress, but in case of Tractive force, we are using the term popularly it is being used and we are using the term that is the Unit Tractive force. Of course, we can call, that is why this as a Sheer force or say we can call it as a Drag force also.

Now, if we recall our earlier discussion itself in uniform flow, then we have this sort of analysis, say in a channel this is the bed and then, water is flowing like that. Let us consider, say this portion and well, let me draw say this is the section; this is the section and then sectional area. Of course, we are considering uniform flow. So, wherever we are taking the section is in meter, but if the channel is non-prismatic, it is better to take the section from the central part. So, that it represents both side in a well represented way.

Now, say this is area and this is the perimeter. Perimeter is the entire side length. This is the perimeter and say, weight of this is W. Weight of this fluid is W. Well, W means if I represent this W to write the total weight and say, unit weight of the fluid. If I write as say small w unit weight. Sometimes, we are using the term gamma also, gamma w to represent unit weight. Well, in different book, these different symbols are used. We should not get confused by these symbols. We should know the very physical meaning of this one. So, it is the unit weight of water if we write, then unit weight multiplied by the volume of this fluid. We are talking about the fluid volume between section 1 and 2.

So, what is this volume of the fluid? If the area is A and if we take length of this portion, say l length of this portion as l, then what will be the volume of this one? It is A multiplied by length. This is what the weight. Now, what is the force that is acting in the direction of flow? Well, now if I draw a perpendicular line, then this angle is theta perpendicular to the bed because the slope is theta. If I get this angle here, this also theta, so if this is theta and if it is WA into l, then this force will be that is which is basically because the flow movement is in this direction. So, this force will be equal to WAl into sine theta.

Now, for very small value of theta, generally this canal system in agricultural field when we design, then these are normally not having very steep slope when we talk about plain area. Then, this theta, of course, this slope always remains generally small because we are talking about this part. We are doing for design of alluvial channel and in that case, in alluvial channel, it will be normally in the river valley. That way, the slope will not be very high, but of course, if we talk about agriculture in hill somewhere there and in that case this soil will not be alluvial and as such we are not talking about design of this sort of canal. Well, that design concept will be different because the soil will not be alluvial channel at that point.

So, for small value of theta, what we can have WAl sine theta. This for small value of theta, we can have sine theta is approximately equal to theta. What this theta is? Theta is nothing, but the bed slope S. So, what we can have if this force is written as f that f is equal to WA l and S. Now, this is what the Tractive force as per definition. The force exerted by the flowing fluid. This is the force which is driving. So, this force is taking the water. So, this is the force exerted by the flowing fluid. Now, what is Unit Tractive force? The force exerted per unit area. So, what the total area? Total area means here we are concerned about because drag force, we are talking about exerted on the perimeter of the channel.

So, perimeter means, if we talk about the surface that over which it is being applied. So, the total length will be total surface area will be this perimeter into the length. If I talk about the channel, it is basically going like that. So, this perimeter into the length, this length is same as that what I am drawing. So, this is the total surface area. So, Tractive force, say per unit area which is nothing, but the Unit Tractive force that we are talking about. This will be equal to say WALS divided by what is the surface area. That will be P into lP. This is the surface area perimeter length and then, if you open it, this is the surface area P into l. So, that we generally write as tau Tractive stress tau or that tau is equal to we can write, so A by P. That can be written as Rl and l would get cancel. So, this is equal to WR and S where W is the unit weight of water. What is R? We know hydraulic radius. So, I am not writing it here and then, S is bed slope and R is hydraulic radius.

So, we are getting that tau is equal to WRS is our relation. Now, for a very wide channel, if our channel is quite wide or canal is quite wide, then as we know for wide rectangular channel, this R can be represented with least error as depth Y. So, that we did discuss earlier. So, this tau channel for wide rectangular channel, tau can be written as WY into S. So, this is a very important relation and will be used for a basic equation, rather for design of channel by Tractive force method.

Now, let us proceed with this idea that tau is equal to WYS. This is the Sheer stress. Of course, it will not be exactly equal to WYS. What that sheer stress? That is also important now. We are having the sheer force and then, we are dividing it by the entire area as if the value what we are getting is say equal in all the surface area. We are considering that it is the average sheer stress because sheer stress actually may be different.

Suppose, when the water is flowing. This water is flowing through the entire section and it is well understood that sheer stress exerted at this point and may be at this point. At this point may not be equal that will be definitely different, but these values we are getting by dividing the total sheer force by the entire surface length. That is why we are considering this as average sheer stress. Actual sheer stress will of course be less than that and will be having some variation. So, now one more important point is average stress just we are getting, but for design purpose, we should know distribution of this sheer stress whether it will be really uniformly distributed over the surface or it will be distributed in a different way. So, we are talking about distribution of sheer stress.

Sheer stress means Tractive force we are talking about and this Tractive force means again we are talking about Tractive force per unit area that is Unit Tractive force. So, distribution of Tractive force in case of wide channel is of course uniform. If you are getting a very wide channel, then as we are writing here that tau is equal to WYS, perhaps you can use this relation and we can consider that it is uniform anywhere, everywhere.

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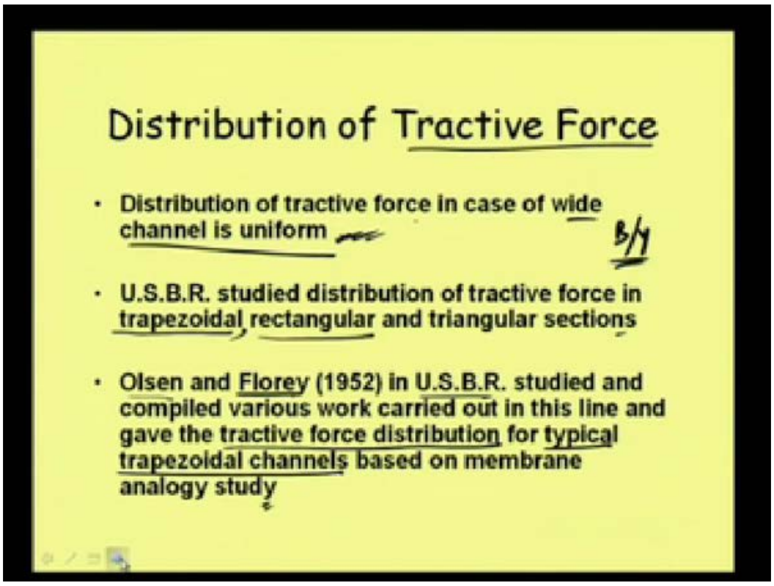

Generally, all channels are not that wide. Wide means how wide that point is there that how much wide the channel is, that is obtained by the value of B by Y. It is always related. Say a bed width. If the bed width is 10 meter and the depth is say 0.5 meter that can be considered as wide because D is significantly larger than depth Y, but the same 10 meter, only that can be considered as wide because B is significantly larger than depth Y. The same 10 meter wide channel, a channel with bed width 10 meter, but suppose if its depth is 3 meter or 4 meter, then we cannot consider these as a wide.

So, wide not necessarily mean only the V value. This basically means what is the B by Y ratio. B should be much larger than Y. Sufficiently larger than Y. In that case only, we can consider R to be equal to Y for wide rectangular channel, otherwise not. R means hydraulic radius is equal to the depth, that we consider when B is much larger than the Y value. So, we should be very much careful.

If someone asks a question that a 20 meter wide channel, can we consider it as a wide rectangular channel? That is not the right question. We will have to ask that if B by Y ratio is this much, can we consider this as a wide rectangular channel. So, that part we should be careful, but for wide channel, this Tractive force distribution is generally when this ratio is becoming say 10 and more. If that it is becoming, we consider this as a wide channel. For this wide channel, we can consider this to be uniform Tractive force. Distribution can be considered uniform.

Now, United State Board of reclamation. So, they studied the distribution of Tractive force in trapezoidal channel in rectangular channel and in triangular section. In fact, they conducted lot of experimental studies and to have this value. You do not have any other way out than to carryout experimentation. They of course, conducted some other study using, say numerical technique also, but their basis was experimental. Then, they conducted lot of experiments to have idea on distribution of this Tractive force.

Here, the name of Olsen and Florey in 1952, they are important. Of course, they are not alone. Along with them, other engineers were working and they compiled their study as well as study conducted by other people. That all study conducted in USBR that were compiled and they gave the Tractive force distribution for typical trapezoidal channels based on membrane analogy study. I do not want to go into detail of that particular study here right now, but we need to know that based on their study, they gave a distribution of Tractive force. That distribution means how actually Tractive stress will be varying along the perimeter. So, they gave that distribution.

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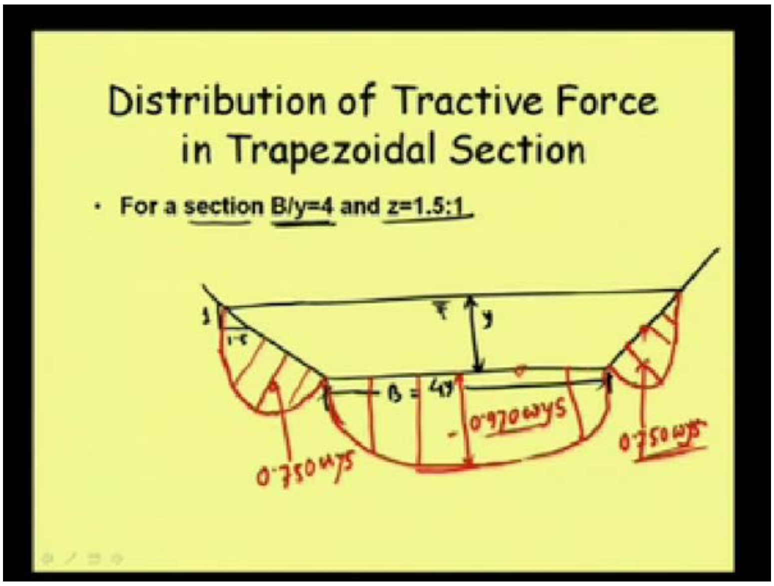

Let us see how this distribution occurs and of course, they did it for different type of channel, different type of trapezoidal channel means say trapezoidal channel with side slope something. I mean may be 1 is to 1.5. They conducted some experiment with side slope 1 is to 2. They conducted some experiment with rectangular channel. So, like that they conducted several experimentations. Then, for all those different slide slopes, again they considered, what is the B by Y ratio?

As we were discussing that is very important factor. So, for say B by ratio 5, then say 10, 6, 7 for different 1, 2, you will be studying from 1 to 10. They conducted different experiments and then, they got those values. Let us see, how these variation occurs? They gave, I am just drawing one that is and which is available in different books also. That is for a section B by Y ratio is 4 and Z is equal to 1.5 is to 1 by horizontal 1 vertical. So, that channel if we draw, it is like that.

So, this slide slope is like this, say it is 1.5 and this is 1. Well, then this width, if the depth is say Y. Let me take little proportion. It is because B by Y is one fourth. So, if this depth is y, then width is equal to 4 times of the Y. This is the bed width and this is nothing, but our actually B value. B is equal to 4Y. So, for that particular channel, if we draw the sheer stress distribution, then we can see that at the bed, the distribution is more or less uniform. It goes like this. Distribution is more or less uniform. Well, we take a different color, so that it becomes more distinct. So, this is the channel and the distribution is more or less uniform. Say, it is like that and this maximum value of this particular distribution is obtained as 0.970 into WYS.

Now, what it means? Say, every point we have sheer stress. We are plotting say graphically we are plotting the sheer stress. Whatever sheer stress value here we are getting, we are plotting it. Finally, we are getting the graph. This is nothing, but graph of sheer stress at different point. Well, at different point we are getting, say at this point, the sheer stress value is this much. At this point, sheer stress value is this much like that. At different point, we are getting sheer stress value and then maximum value what we are getting at this point is 0.970 WYS. W means this is omega YS unit weight of water. So, this distribution says that although, in our analyses earlier we were getting, if we refer to this one that is we are getting sheer stress is equal to WYS, but here we are getting it as say, 0.970 WYS. Of course, almost equal to WYS, but it is 0.97 almost equal to 1, so at bed we are getting.

Now, what about the side inside sheer stress distribution is not like that. Obviously, this part of soil or the surface here, the depth is and that is why the sheer stress will also be less, but here it is increasing and sheer stress distribution is less. That is why the sheer stress will also be less, but here it is increasing and sheer stress distribution is, if I plot the graph, it will be maximum somewhere here. It will be 0 here, and then, here we will be having some value. Then, as such the distribution will be like this, sheer stress distribution will be like this. If I plot it, plot the value and the maximum will be somewhere here and that maximum sheer stress at the side that is equal to 0.750 WYS. Writing upto say three decimal place, we can write like this. So, similar distribution will be getting here also.

So, this is not uniform and that value is also say 0.750 WYS. Now, say we have some idea at how the sheer stress is getting distributed on the side of the channel. For design purpose, we are concerned about the maximum sheer stress to which the channel is getting subjected that is if we need to make our channel safe, then we should see that at this point, this is the sheer stress that is getting exerted. On the other side, this is the sheer stress. It is being subjected. Now, whether we will be going for this sheer stress for design purpose or this sheer stress which one.

Again, there is another point that bed material, if we just imagine on the point that when the material is on the bed that sheer stress required to move off, this particle will be more than the sheer stress required to move this particle from this particular point because this is in rest. It has its weight, say submerged condition. So, it has submerged weight. It has some friction. So, the force must be sufficient to move this particle by overcoming those forces. Here also it is there, but it is in the slope. So, its weight of the particle is here and it has a component in this direction. That will also try to move it in this direction. So, that way this sheer stress required for moving is also less here.

Then, of course, we will be coming to that discussion in detail in our next class, but we should know one point, that the sheer stress required to move this particle is less here and that is why, initially design in stated form and the side sheer stress consideration, static stress consideration and then we check whether it is safe for bottom or not. Well, now this is what I have drawn for only one size of the channel. Only one size of the channel. That is for b by y ratio is 4 is to 1. But the channel conductor experiment for different time. And then for our excel design purpose also. Say only with this, we cannot say that this is enough for our design purpose. There may be channel and say if you go for b by y ratio with very large, then sometimes it may not be the channel which we require.

And then it may be quite large for required section. So, say depending on the discharge, they need to be carried. Depending on the discharge they need to be carried. Our b by y ratio may be small if the discharge is less or the b by y ratio will also be large. So that way, finally this I mean, USBR showing the distribution and these are all we are talking as, say this we can write as tau s maximum. So maximum sheer stress at the side. And this we can write as sat tau b max. That is out of all stress this is the maximum. And for different b by y ratio, they gave some graphical plot. For a side sheer stress and for a bead sheer stress. For a bead sheer stress and for a side sheer stress, they give a graphical representation for all this different b by y ratio.

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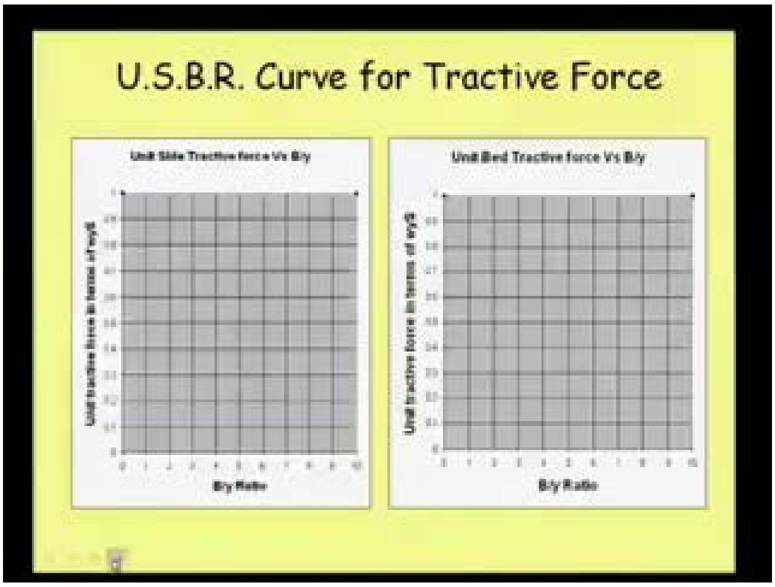

And just the format of the graph is like that. Say these are popularly known as U.S.B.R Curve for Tractive Force development for a tractive force analysis. So, they plot it b by y ratio in this x axis and then on the y axis they gave unit tractive force in terms of say w, y s. That means, this will, suppose it is 0.6, it means suppose for a particular b by y ratio 2, there will be some curve. We are not having that curve. In the next class, we will be drawing those curves. How this curve comes and finally you will be seeing that how this curves helps for getting the value of side tractive force and that is suppose for a particular point if, we are getting say, 2 b by y ratio, we are getting a point here. Then this will indicate, the sheer stress of the side will be 0.6 wys. And similarly, for say tractive force at the bead also, they gave less series of curve.

And using those series of curve, we can have the tractive force for different size of channel and again for different side slope. Channel may be of different b by y ratio, as well as channel will be having different side slope. Those different side slope and different b by y ratio, now with these curves we will be able to have our tractive stress, unit tractive force and then based on that we will be able to design. Of course, for this required is the permissible tractive stress. What we are getting is the tractive force exited by the flowing fluid. But you need to know that how much stress tractive force you can bear. That is called permissible tractive force or unit tractive for. So those we will be discussing and based on that, how the channel can be designed by using tractive force matter, design states that will be discussed in the next class. Thank you very much.