Hydraulics

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Module - 2
Uniform Flow
Lecture - 5

Uniform Flow in Mobile Boundary Channel

Friends welcome you all to this class of uniform flow in mobile boundary channel. In the last few classes we have discussed about uniform flow, various aspects of uniform flow, but all those that we made those discussions were on rigid boundary channel, that means, when the channel boundary is fix by boundary here we mean that either the bed or the bank I mean everything is fix, so on in that context only we were discussing uniform flow.

Now, today class we will be basically concentrating on the issue that if the channel boundary is not fix, it is mobile like say in a river, it can happen particularly when the river is flowing through a alluvial soil with say fine sand or may be little coarser sand, but still suppose the water can erode that sand, then there can be change in the bed form; and then similarly, suppose, if we talk about manmade canal also say in irrigation canal, we can have sometimes due to economy we may not it may not be possible to provide a lining to all those channels. In field level channel it may not be possible.

Suppose, for irrigation in the main canal it may be possible to provide a lining, but say the minor canal or the distributaries or that is going into the field which is ultimately carrying the water it may not be possible to provide a lining; and if the soil type is of the type that it get eroded or the water can erode it, then this makes a different cases of uniform flow, basic concept is same, but I mean we need to see whether all the theories that we applied for rigid boundary channel, all the formula whether we can apply those as it is or we need to consider some special issues in that.

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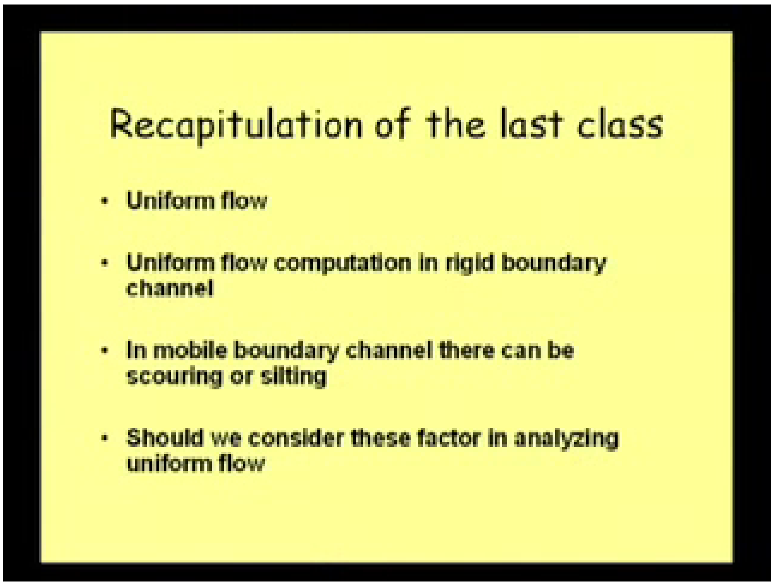

Well, before going to this we have done in the last class, say, uniform flow that we have discussed very clearly. Well, let us recapitulate what we did in our last class. Well, we studied uniform flow. That already I have explained the how uniform flow occur and all these things we have studied in the last few classes; then of course we did uniform flow computation in rigid boundary channel, and then we also studied that mobile boundary channel there can be scouring and silting, this when mobile boundary channel is there in our very introductory class and in subsequent classes also we have discussed that there can be scouring, there can be silting.

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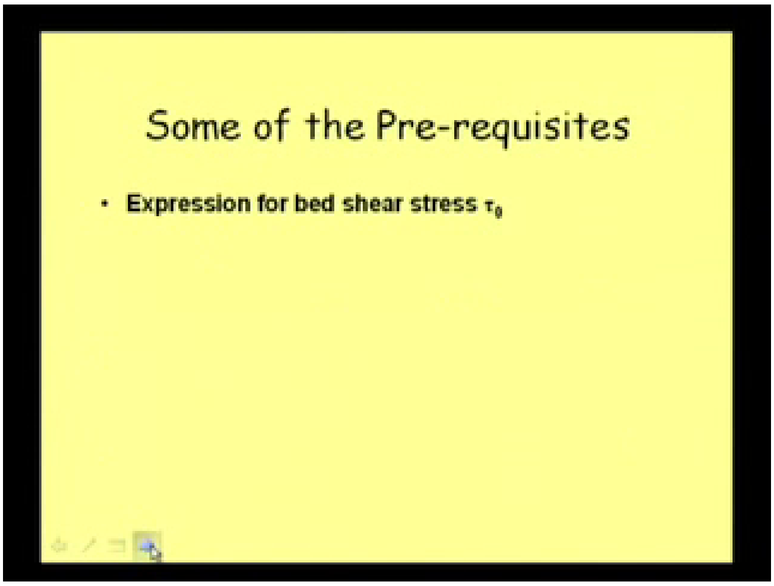

Now, our point is that should we consider these factors in analyzing uniform flow. Well, now, before going to various expression, various relation of a forces, and that influences the flow in mobile boundary channel, we need to know some of the fundamental relation that when the water flow, then how the water exert force on the bed or what sort of stresses can develop in the bed. And that is why what I feel that some of the pre requisite that I feel that is necessary before studying the mobile boundary channel, we will be discussing first; well, then one of that is that expression for the bed shear stress tau 0, now you can concentrate to the slide that we generally use the symbol this tau 0 for the bed shear stress.

Well, now, what can be the expression for this tau 0, bed shear stress means, when the flow is moving, then how much shear stress the flow is exerting on the bed, and then for that in uniform flow how we can have the expression for this tau 0 well.

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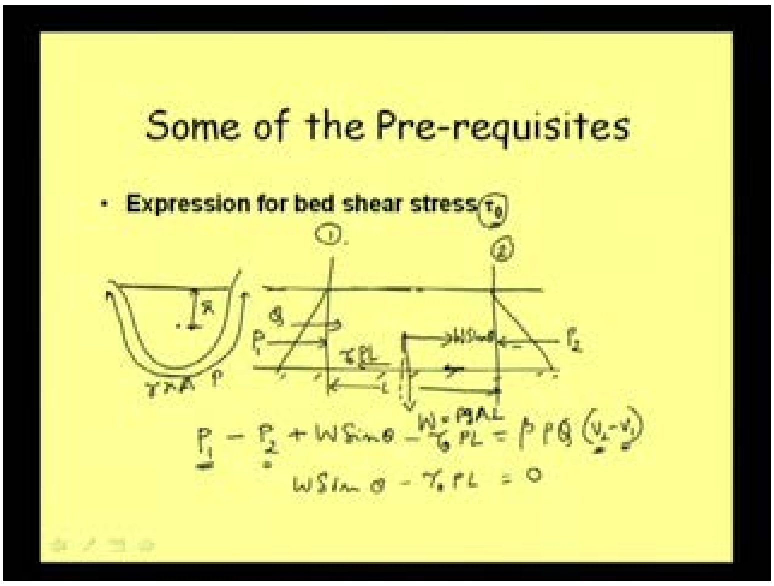

Now, let me take a simple channel like this, and say uniform flow is flowing; now, we are concerned about uniform flow, channel section may be anything like that, but it is flowing uniform flow; now, if we take two section, if we take two section, 1 and 2, 1 and 2, and we recall the expression for our momentum, and whether if we write the momentum equation. Then we can write that what are the forces acting on these water, what are the forces acting on this section the water between the existing between the section 1 and 2;. Well, that we can write first, say, the force the pressure force working in this direction; and if say x bar is the distance up to the center then this pressure force we can write that gamma into x bar or sometimes we write this as rho g in to x bar, that is the pressure at that point multiplied by the area multiplied by the area we get the pressure force, that way some pressure force is acting from this side.

And another pressure force I mean in this body, the pressure force on the from the downstream side that will be say P 2 and weight of the liquid that is W, and then component of this weight which is acting in this direction, that is in the direction of flow is W sin theta. In fact, this sort of forces we have written several time; now, normally we used to write earlier that this force that is the resisting force that is acting on the…, that is opposing the flow as, say, f; now, here we will be writing it in a different term, that is say tau 0.

If tau 0 is the shear stress if tau 0 is the shear stress, then if we consider the tau 0 is the shear average, shear stress means, shear stress in the bed at different point in reality it can be different, but say we are assuming, and on the side also it can be different. But let us assume that, this is this can be considered uniform shear stress; and then if this is the perimeter, and if this is the length if this is the length, then we can write that shear stress at or this force resisting force is equal to total surface area is equal to perimeter multiplied by the length and multiplied by the shear stress. So this is the shear stress which is generated here and is opposing actually frictional resistance, when the flow is moving always we know that opposing force will be just be sufficient to just obstruct the flow, and that way the this tau 0 is we are writing that bed shear stress, and it will be the four generated will be proportional to this tau 0, and it will be equal to rho into L.

Well, now, this force what we can write, say, total force, and suppose, the Q is the discharge moving Q is the discharge moving in this direction, then we can write the equations as say P1 is the force from this direction then minus P 2 is the force from that direction this direction, and then plus W sin theta then minus tau 0 into P into L, these are the forces that are acting here, and this is equal to rate of change of momentum; now, we know that when we talk about momentum, we need to put the momentum coefficient when we are writing this in terms of average velocity. So, Q we are writing say as a into V or whatever it is, so we will be using the momentum coefficient P, and let us write it as Q is the discharge flowing, then multiplied by rho is the mass, and the change in velocity say V 2 minus V 1; so, ultimately this expression is giving us the rate of change of momentum, and that way these are the applied force and these are the rate of change of momentum.

Now, this expression we have written earlier also just to refresh our mind and to write it in the form of tau 0 we are writing it again. Well, now, this is the case of uniform flow this is the case of uniform flow; now, when we talk about uniform flow our depth is same; suppose, whatever depth we are having here, whatever depth is here, these two are same means section 1 and 2 depth are same. Now, if this depth are same, and if the channel is prismatic, that is this section, and that section we are having that is section 1 and 2 our sectional area is also same. Then this pressure force from the upstream side and pressure force from the downstream side, these two will be equal this two will be equal; and similarly, we know that in uniform flow this V 2, that is the velocity at the section 2 and the V 1 that is the velocity at the section one will be again equal. Well, that way what we can see that if this V 2 and V 1 are equal to 0 in uniform flow, so this will become 0, and then if this P 1 P 2 are also equal, then we can simply write that w sin theta W sin theta minus say tau 0 into P L equal to 0 or this two we can just equate like this, that is say W sin theta is equal to tau 0 into P into L.

Now, what is this weight? The weight is already we were drawing several times, this weight is nothing but if the unit weight of the fluid is say w or sometimes we write it as rho g, rho g is the unit weight of the fluid, sectional area is say a, and length is L, then this is the total weight of the fluid.

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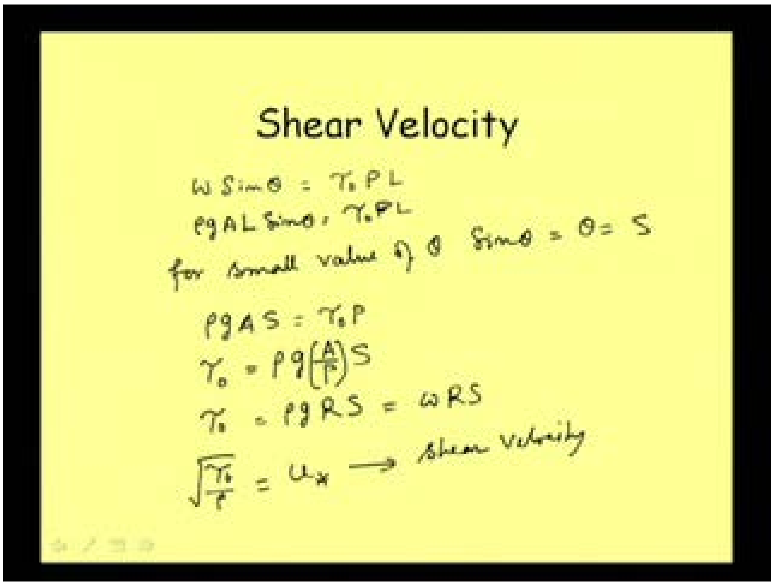

And then that is why here we can write it as W, we can write it as rho g A into L and sin theta this is equal to tau 0 into P into L tau 0 into p into L; now, this sin theta again for small value of theta for small value of theta, what we can do for small value of theta, we can always write sin theta equal to tan theta equal to theta, so that means, this is equal to the slope S fine; and then this equation you can again write in the form that rho g L and L would get cancel, so A into S is equal to tau 0 into P. So, from this what we can write that our basic objective is to get this tau 0.

So, tau 0 is equal to we can write rho g then A by P into S, now this by P term A by P term we know that it is nothing but the hydraulic radius of the open channel, so we can write the tau 0 is equal to rho g R into S, and many a time this rho g we can write as W R S - W means this is unit weight unit weight; sometimes it is written as gamma also. So, any symbol can be used W R S, so that is what our tau 0 expression for the shear stress; and then using this expression for shear stress. Now this is the very basic expression which will be using for finding, that is if the stress is more than certain value then there will be erosion if the stress is less than certain value then there may not be erosion or scouring, and this shear stress again we can write it, we can express a different value like that is tau 0 by rho tau 0 by rho.

And then if we take a square root of that if we take a square root of that, this particular expression is said as u star is written as u star, what this is it is called shear velocity shear velocity; you can see this root over tau 0 by rho means we are getting root over g and root over R S; now, again the velocity formula also we know that root over R S comes, so it is in the similar form and then its unit is also similar to velocities, so it is called shear velocity. So, with this first introduction to shear velocity, now we can go to another important parameter or another important understanding of the sheer force; now shear force or shear stress on the bed is one issue.

Then again another issue is that, whether the bed is smooth or rough, means, when the erosion process start that is in the mobile boundary channel suppose the erosion process is starting, then there may be some undulation in the bed; and otherwise also, of course, it is a general in general term also there will be some roughness in the bed; now, that roughness how much it is rough whether it is smooth that is very relative terms, that is very relative term, say, one can say this is rough, another can for another person it may be smooth; and when we come in the context of water say in a river bed there may be some undulation, and then suppose depth of flow is very high.

Now, for that high depth of flow a smaller undulation may not be considered as rough, but say for a small depth the same undulation of the bed may be considered as rough; similarly, suppose boundary river is there, that is the size of the bolder, and that size of the bolder whether we call these as a rough bed or a smooth bed; well, there also again that question come; if basically the point is coming in the form that, if that roughness is not creating turbulence in the main flow that roughness is not going into the turbulent zone and creating turbulence, then we refer this as a smooth.

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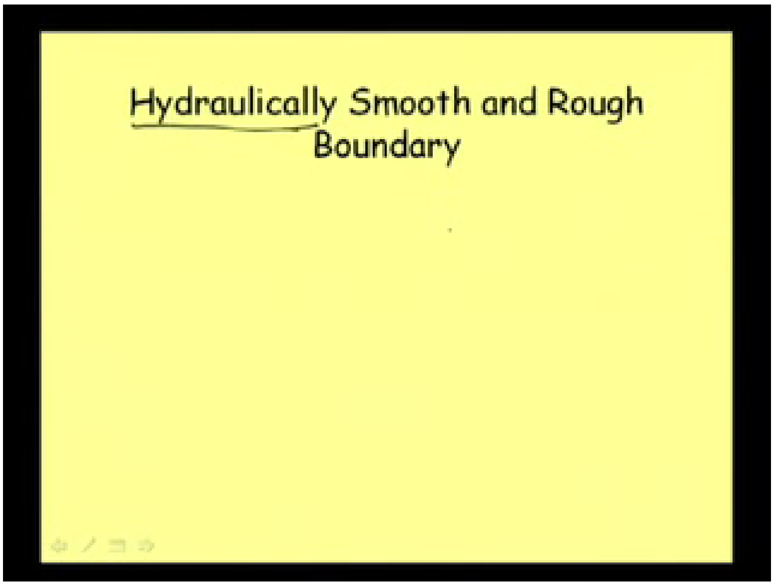

So, I mean there is a specific definition of smooth and rough boundary when we talk in terms of hydraulics. So, we call that as a hydraulically smooth and rough boundary well. So, we can now concentrate into the slide again, we will be just drawing how we can define this hydraulically smooth and rough boundary.

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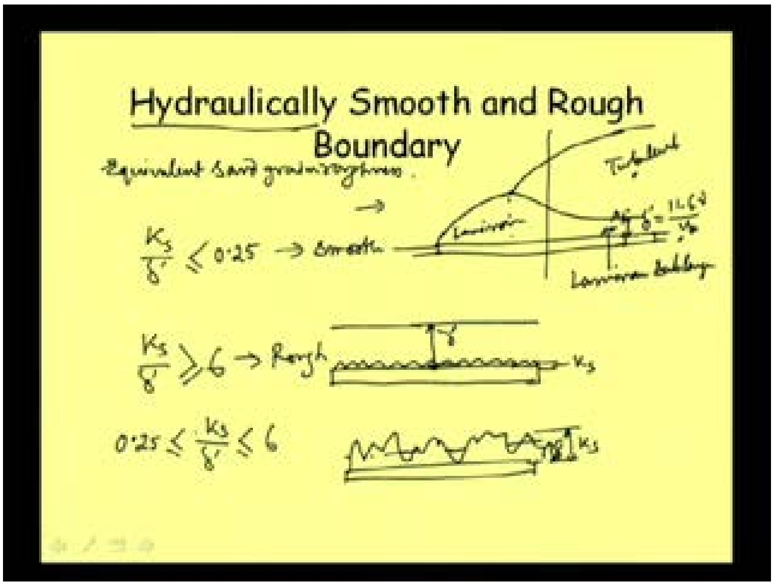

Well, that basically when we studied, probably you have studied already or we have seen in our fluid mechanics also that when a flow is coming from this side, and say it is moving over a boundary, now in channel, of course, this is always a boundary I mean our bed itself is a boundary. So, when it is moving over a boundary, then the flow get retarded near the boundary and so the zone where the flow is getting retarded is increasing like that, say, in this portion the flow is retarded, and then it is going up to certain extent, then in this portion the flow as it is getting retarded, and the flow will be laminar in this portion, and then it is moving like this; that means, this is extending the zone of influence that is extending, and then here the flow may be turbulent, flow will be turbulent; and then but still we get a layer here below which, that means, in this portion the flow is still laminar.

So, that layer which is suppose a flow is turbulent, in general flow is turbulent, but under the turbulent flow there is a layer which is again continuing as a laminar, so, that suppose depth if I write as delta dash, then it is called laminar sub layer, so this layer is called laminar sub layer. Now, in open channel flow say let us consider there is a up to infinite extent there is the channel bed and it is coming from this side also there is a continuation of the channel bed, so we are concerned about this part only, that is we know that there is a laminar sub layer, there is a laminar sub layer; and of course, this expression for laminar sub layer is also given by different experimental study and this is can be written as u star like that 11.6 u star; well, this laminar sub layer has something to do with the roughness.

Now, let me draw one boundary, say this, now this boundary may have some roughness, this boundary may have some roughness, again as we understand that when we talk about a roughness in a boundary, it is very difficult to say or very difficult to define that say roughness if I write as some value K, suppose roughness is or we can use a suffix K s it is a surface roughness K, then definitely the roughness at different area will be different, and exactly defining a diameter or dimension of that roughness is very difficult, and that is why we use a term that is called equivalent sand grain roughness; this roughness can be expressed in terms of equivalent sand grain roughness K s.

Well, what we mean by equivalent sand grain roughness equivalent sand grain roughness, that information is also required. In fact, Nicholas says he conducted experiments, so Nicholas says conducted experiment with different material with different material say he did used different material, and say making pipe, and then he found the, he was observing how this material is behaving say may be head loss how it is how the head loss is occurring there, and then he did use different sand grain, collected different sand grain, and say of uniform size sand grain he was collecting, and then he took the similar diameter pipe, and then the inside of the pipes were coated by different type of sand grain, means, different sizes of sand grain, say, one pipe is being coated with a very fine sand grain, another pipe is coated with a little coarser sand grain; and so, that way now for those pipe where it was coated for those pipe which were coated rather with known sand grain, that are that that are known, that is this pipe is coated with this sand grain means, its roughness is the diameter of that particular sand grain, and diameter of that particular sand grain is known; now, he conducted experiment with those pipe, and the pipe of different material, then he found that yes this material is behaving similarly to the material to the pipe coated with a particular size of sand grain.

So, now, he has two things in his hand, one is a particular material of the pipe, another is a pipe coated with a particular size of sand grain which are behaving in the same way. So, then for that particular material suppose steel for the steel he has a sin is hand with a particular type of sand grain, so he said that this has sand grain roughness of this much well. So, that way for different materials sand grain roughness were given, and then for a for a particular material we can considered this K s, of course, on principle or in general we can say that this is a roughness or suppose for some material there can be where we may not have this sort of value.

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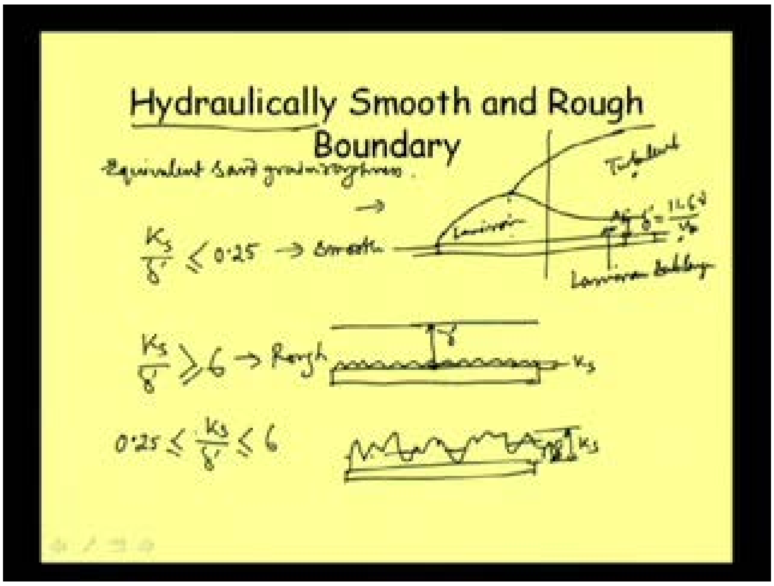

Now, this is the roughness, you take it like that, this is the roughness; and see the laminar sub layer depth is suppose here, here is the laminar sub layer depth say this is the laminar sub layer we generally go from the average height average of this thing, so the laminar sub layer height and depth and this say delta dash; now, if this K s is very very small as compared to this laminar sub layer depth, then we call this as a smooth; now, again in engineering if we say very very small these are sometimes become big, so we need to express it in terms of some definite value.

Well, that definite value definite value was given as if K s divided by say delta dash, if this is less than equal to 0.25 means delta dash is say 4 time greater than K s; if it is less than equal to 0.25, then we call that particular surface as smooth surface that particular surface as smooth surface; well, that means, there is another point important point that it is not only the flow depth, but a depth of laminar sub layer, and this depth of laminar sub layer will depend on this u star that is shear velocity, so that way and viscosity of this fluid

So, this entire factor will influence, and finally we are getting that a particular surface can be considered as rough for a situation; and for another situation the same surface can behave as a smooth also, so it is always dependent; now, this if this is the value, then we can call this as a smooth boundary smooth boundary; smooth means, hydraulically smooth; and then if we have that value that K s by delta dash, say, another case here, say, roughness are very large, and this is our roughness K s.

And then if I calculate the say delta, this is smaller than this delta dash, delta dash is smaller than this, that means, the roughness will move into the or rather roughness will penetrate through the laminar sub layer, and then it will go to this turbulent layer, this part is turbulent, this part is turbulent, this part is of course laminar, this part is laminar, and this is going laminar; and that laminar portion which is remaining below turbulent we are naming as laminar sub layer. Well, so, this roughness when it is moving or when it is going inside the turbulent then this will influence this sort of flow.

When the roughness is going like that, then this is influencing this sort of flow; otherwise, if it is stop going into the turbulent zone, then whatever rough it may be it is not influencing this flow, so that way this flow will be behaving as if it is moving over a smooth surface, and that is why we call this as a smooth. Now, when this is when this value is greater than equal to 6 greater than equal to 6, that is K s is 6 time larger than the delta dash, laminar sub layer depth, then we call this as a rough, we call this as a rough. Well, so, we have got the smooth hydraulically smooth boundary and hydraulically rough boundary, then in between there can be always transition like that, if it is point 0.25 less than equal to say we can write K s by delta dash, and it is less than equal to 6, then in between this part we will call that the boundary is in transition; now, why we are talking about all this rough, smooth, and what is our basic objective. Basically, we will start with some derivation of equation, and these in these derivation we will have to use some approximation or some theory that has come from observed value, and say those relation will give us some relation which are valid only for smooth not some relation which are valid only for rough, so we need to know what is basically smooth and rough and on which these things will be valid, and because of that we are starting with this an just introducing what is hydraulically smooth and hydraulically rough boundary.

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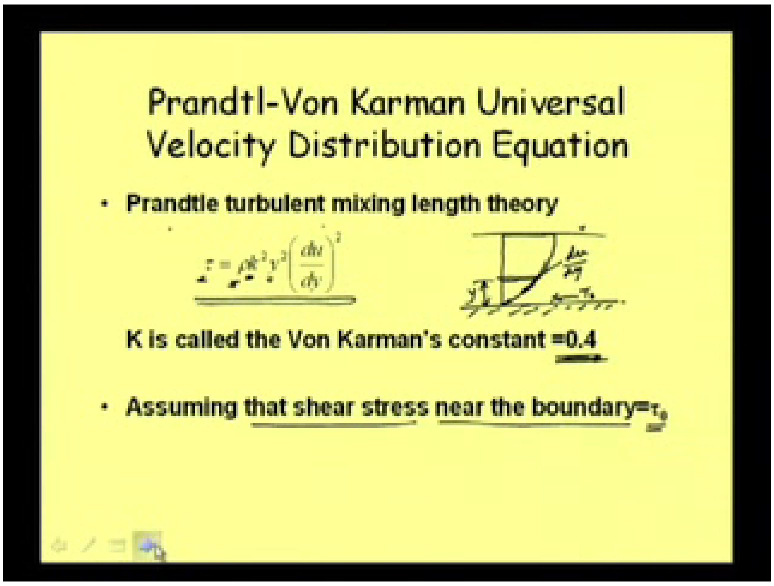

Well, already we have defined that; then we need to know another fundamental another fundamental relationship which relate which relate the shear stress tau shear stress tau, we were talking about bed shear stress which we were writing as tau 0, well, but there may be a situation that we need to know we need to know the bed shear stress, but exactly at bed, what is happening, it may not be possible; and sometimes our say boundary material or the bed material size is little larger or say we need to actually consider, say, if it is the bed if it is the bed then say boundary materials are actually like this; and then we need to consider shear stress to move this particular shear stress is acting at this surface. So, it is not really acting at this point, but it is acting at some height that height is nothing but equal to the diameter of that particular. So, that way we need to consider those things and for understanding all those we need to know this Prandtl von Karman universal velocity distribution equation.

Well, now, say we need to start from one relation that we call as a Prandtl turbulent mixing length theory; well, we will not go into much detail of these things how it is coming. But we will start with taking this expression as it is, that is if a in a channel in a channel say this is the surface, and then this velocity distribution we are interested, how this is actually velocity distribution is occurring, and very near to bed say at any level here at any level, so the u is changing and at depth y say rate of change of this is d u d y d u d y.

So, rate of change of velocity with respect to y we are just writing like this, and then shear stress at any level, this is we are not mentioning this shear stress to be the shear stress in the bed; it is valid that shear stress at any level can be expressed at as say shear stress at any level is equal to rho that is the density of the fluid, then K square, this constant is called von Karman’s constant. And then it is y square means K square y square is the depth from the bed y square and d u d y whole square.

So, that expression we are taking directly; and Von Karman found that after experimenting in a in this particular phenomenon he found that this K can be expressed as a constant value, this K can be expressed as a constant value, that value he suggested is point four; however, this now a days you can say that the K we cannot actually considered as point four, it will be influenced by several other parameter; anyway right at this moment we are considering that K to be constant and let me take as K as 0.4, and then how we will consider the shear stress at very near to the bed this is our bed . So, shear stress at bed, if we assume that assuming that shear stress near the boundary near the boundary as equal to tau 0, means, tau 0 is basically bed shear stress and our interest is to have some expression for tau 0; and if that shear stress we consider that very near to bed is we are considering as tau 0, that is the shear stress.

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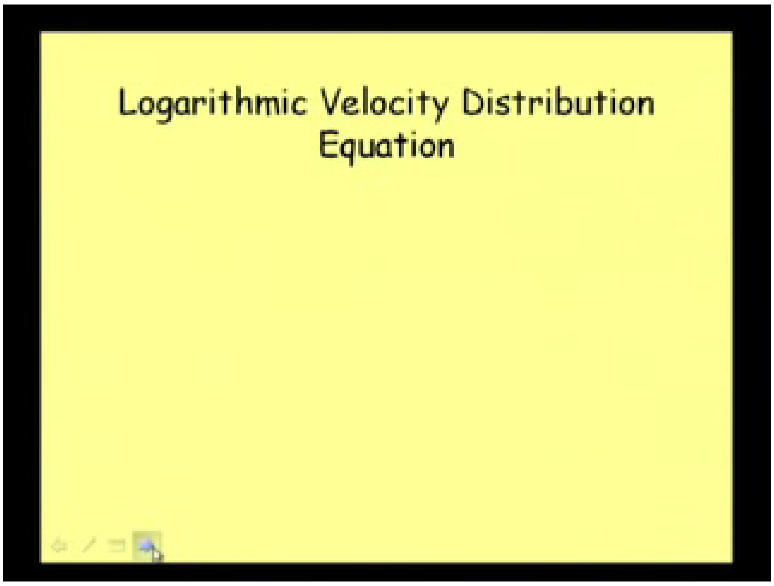

With that if we start with that if we start, then we can ultimately derive an expression for velocity distribution, and that velocity distribution expression we will be finding that u can be expressed in term of logarithmic equation, and that is why that we term as logarithmic velocity distribution equation; well, you can concentrate into the slide that as….

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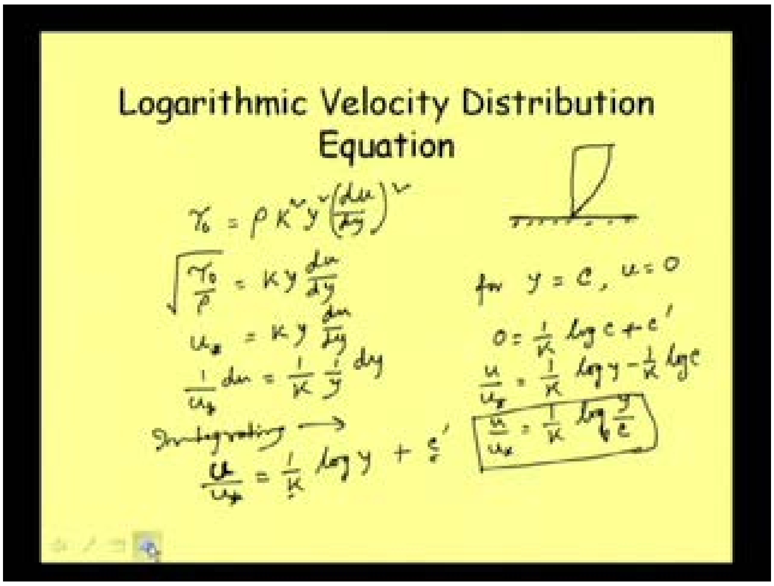

Now, we are talking about bed shear and we are we are writing say tau 0; well, we can write a small diagram here also, that this is the bed, and we are writing this as a tau 0, tau

0 is equal to rho K square y square into d u d y whole square d u d y whole square; then we know that tau 0 by rho already we have expressed this root over this root over this is equal to we can write K y, then d u d y K y d u d y; well, now, tau 0 by rho that we can write as shear velocity u star, and this is equal to K y d u d y; now, we can we are in a position that we can separate the variable and we can interrogate it. So, we can from here we can write that 1 by u star into d u is equal to 1 by K one by y into d y.

Then integrating this integrating this what we can get, integrating we can get, this will be u by u star u by u star, so u is the velocity at any point we are getting interrogation of d u and u star is remaining here, this is equal to 1 by K, then this will become log of y 1 by K and then we are getting log of y and plus say c log of y plus c, this is say c dash, I am writing this c dash as a constant of integration. Well, now, from this we need to find out what this value of c, and how we can write this. In fact, from this integration we are almost getting any relation that if we try to know what the velocity u, what the velocity u at any depth we can find with respect to y. But and then here we have the von Karman constant, that value also we can take as 0.4, but what this constant of interrogation that will be; so, that we can find from the boundary condition that if for, say, y equal to let a very small distance c at y equal to c say u is equal to 0.

So, u will become somewhere 0, if I draw the velocity diagram if I draw the velocity diagram y will become somewhere 0, but very near to the bed say at y equal to c u is equal to 0. So, with that if I write, then we will be getting that from the boundary condition 0 is equal to say 1 by K log of c is equal to plus c dash, so, we can write that c dash is equal to minus 1 by K log of c; so, finally, we can write u by u star is equal to 1 by K then log of y and c, in place of c dash we can write minus 1 by K log of c; well, then this we can write that u by u star is equal to 1 by K log of y by c well. So, this is one relation we are getting this is one relation we are getting; well, now, we know that this 1 by K we can express K we can write as0.4, and this logarithmic actually it is e base.

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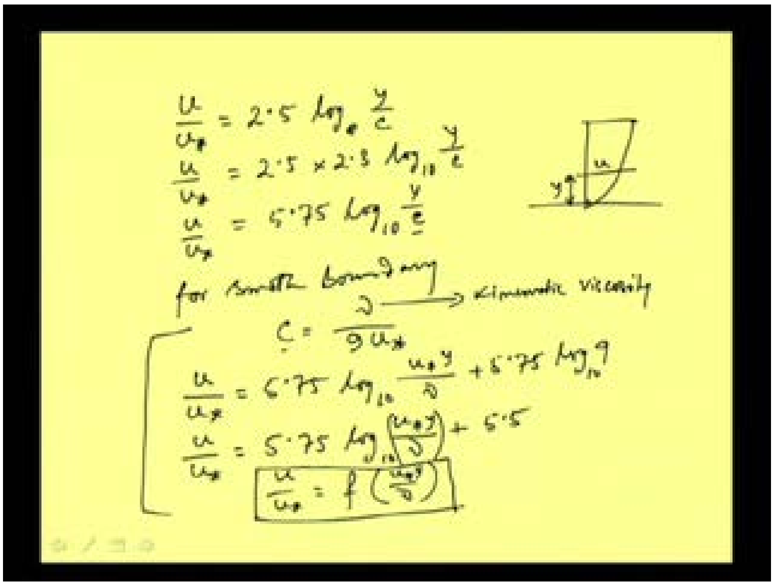

So, we can write from this expression. Let me write in a take a fresh page can write u by u star that we can write as 1 by K, K can write as 2.5, 1 by K can be written as 2.5 and then it is log e y by c, then if we convert it to log 10, then we can write u by u star is equal to 2.5 into 2.3 converting it to 10 base, so 10 y by c, so that will give us ultimately u by u star is equal to this if we combine them we are getting 5.75, 5.75 log of 10 y by c; well, this equation is in the logarithmic form, and of course, we are having problem with this c value again that we need to find experimentally, otherwise this equation we can call as logarithmic equation.

Then for smooth boundary, that is why we were discussing what is smooth and what is rough to get a complete expression for this equation; now, for smooth boundary, smooth boundary means we are talking about hydraulically smooth boundary, we are talking about hydraulically smooth boundary, again for smooth boundary Von Karman's, he conducted experiment and on the basis of his data he could get that C can be expressed as this C, this C can be expressed as nu by 9 u star 9 u star; now, if we put this value of C, then we can write it in the form that u by u star is equal to 5.75, then log of ten, and this 1 by C, so it will be 9 we will be writing separately, so it will be say u star y by nu; then of course, we can write plus 5.75 into log of 9, we are writing separately in this; now this u star y means, y is what, y is the depth at any point, y is depth at any point, we are talking about a depth at any point y.

So, at any depth y when we are having that, we want to find the velocity u at any depth y, then we can find out this u do not confuse this is not the u star. So, we want to find this u, so, u we can find in terms of y of course, for that we need to know this shear velocity u star, and to know this shear velocity we need to know rho density of water, of course, we will be knowing, but we need to know the shear stress tau 0. So, once we know the tau 0 we can find it, and we can have this we can have this equation, and u by u star of course we have a different name for this expressions 75 log of 10 base, this u star let me write this u star y right now and then nu and then plus this value if we simplify it is coming as 5.5.

Well, that means, these are constant, all u star y by nu; we know that what is the expression for Reynolds number; expression for Reynolds number is u v, that means, velocity at a particular point, and if we try to calculate the Reynolds number we know that u v by nu, nu is the kinematic viscosity, well, here nu is kinematic viscosity, nu is kinematic viscosity. So, as we know that u star or say u y by nu is the expression for Reynolds number, but here our this velocity is not the velocity that we are having at a particular point or something like that it is called shear velocity.

So, this Reynolds number this Reynolds number is also called shear Reynolds number, and that is why we can write it in the form that u by u star is a function of; that means, all these we can just club as function of u star y by nu u star y by nu. So, this is one important expression that we will be using in our subsequent analysis; then this is what we are doing 1 point we are knowing that, see till now we are expressing tau 0 as some value root over sorry u star as root over tau 0 by rho, and tau 0 we got one expression that W R S, if you remember just now we did that tau 0 is equal to w means unit weight sometimes we can write it as gamma also, so gamma R S. Now, all these things are applicable when it is a case of uniform flow as we did cancel all these things; in fact, if we apply it to some other cases we will have to make it very small, we will have to discredited it and we need to consider that this part is smooth and that way only we can express that things.

Well. So, understanding of these things are required; now, this if it is not a smooth boundary if it is not a smooth boundary then also we have an expression for this C, that also let us keep that also.

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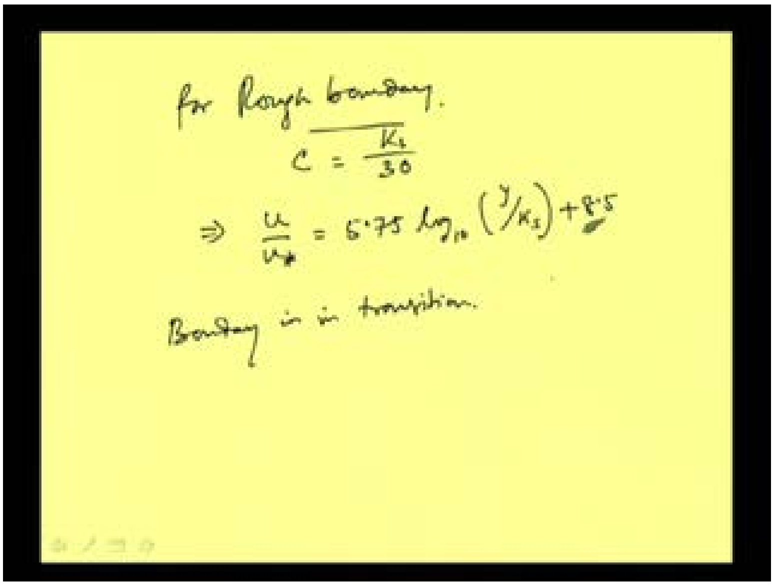

Let us keep that is if it is not a smooth boundary for rough boundary for a rough boundary, of course, that may not be coming right now into our application in deriving under subsequent relation, but still as information we can do that; in terms of Nicolas experiment again that sand grain roughness K s, in terms of sand grain roughness K s, c can be given as K s by 30 K s by 30, and using that if we go for this expression then we will be getting u by u star, that is replacing C value by K s by thirty we will be getting 5.75 log of ten, then it is y by K s it is y by K s plus 8.5. So, that means, this here for rough boundary our velocity distribution is not dependent from the Reynolds number rather it is depending on the depth and the roughness this ratio this value.

So, that way these things are this information's will be useful and for, of course, this we are talking about that is rough boundary and smooth boundary, if the boundary is in transition, if the boundary is in transition then also in a different books in the books of Ranga Raju, K G Ranga Raju also he has given that his experiments compiling the experimentation done by different people at different time, he gave that value that this particular value can be changed as c 1, and I mean some constant and for transition transition, means, again this transition depends on the ratio how much is the ratio K s by delta. So, depending on different value of K s by delta depending on different value of K s by delta you he gave some value of this parameter say c 1 some coefficients, and then for that can be used for transition boundary also; well, now, with this with these information's now we can proceed further we can proceed further.

Well, so, till now what we know is that when a fluid is moving when a fluid is moving then it is exciting some stress at the bay, other that we will called as boundary. At the boundary it is exacting some stress. And that stress, we know that this can be express as, if you write it as tau zero then we get zero velocity u star and then that stress if it is exist a particular limit then there will be erosion, there will be erosion. And then considering that erosion means ah that again we use a concept that is called as incipient motion condition, that means ah the force required, force required take the particle or the velocity required to move the particle. This is one issue and then the particle has its own weight, so it will be having its own resistance, it will try to stand in its position. Now when the force or the velocity are just sufficient to move the particle then particle is just in the (( )) of motion, just in the (( )) motion. So that situation we called as incipient motion condition, that situation we called as incipient motion condition.

Well, now for deriving a relationship, for its incipient motion condition there are different approaches or different approaches are possible. Well, one approach is call that competent velocity, competent velocity. And based on these approach also we derive some relationship, competent velocity means, we talk about velocity and one point you should always remember, because the sediment movement, these are very complex, these are very complex. It is not that straight simple like in boundary channel. And because the reason is there that sediment what we are talking about say in a (( )), although we give in a particular size of sediment in nature we cannot have that uniform size of sediment. It will be mixture of various size of sediment. And sometimes we talked at only frictional resistance between the sediments are existing that is to move the sediment from its position, say frictional resistance between two sediment are working and then that is why or sometimes it is situate on the responsible, this is moving.

Suppose, if some forces moved on that way, it can be moved. But sometimes, in sediment there can be finer material as (( )) and that way there can be some cohesive force between the sediment also. So as whole in the sediment, we can have say cohesive force. Well, by sediment we are including here, say bolder also small bolder or (( )) or say very fine sand to very core sand to fine sand all these we are including. And most of the study generally consider that sediment to be cohesion less, that sediment to be cohesion less and that with some expression at derived. And so these expression there lot of assumptions always. Well, and then so when they are lot of assumptions exist analytical solutions are (( )) analytical expression of a particular ah value is not possible in it. If we go by some analytical approach, there will be lot assumptions and what will be derive ultimately that may not be giving as exact result. So, generally recourse are made to experimentation, recourse are made to experimentation. Lot of laboratory experiment has been conducted already by different scientist all about world at different places and then similarly again there is another point, that is the experimentation that is conducted in the laboratory is than in a small scale. I mean, you cannot represent a river exactly as it is. You will have to reduce the scale.

And the scale even you reduce, then the sediment size if you reduce to that particular in the same scale, suppose a hundred meter wide channel we are expressing representing by a one meter width channel then there is scale is one is to hundred. Now they are some sediments are flowing in the river, if we need to reduce it that sediment size, this will be very small. If you reduce it to one is to hundred scale that will be powder and (( )) will be completely same, so we cannot do that, because it will be completely cohesive in that if you reduce it to that size. So that will lot of complexity are there in experimentation also. But still which our knowledge of hydraulic model that hydraulic model study that will be talking as different topic in our later part of this course hydraulic engineering.

And there will be discussing all those things in details, but what I want to emphasize at this point that this sort of analysis on sediment, I really very complex. We normally, we always need to go for experimentation and a part from the experimentation as they are difficulties in experimentation also from the understanding what we derived in experimentation we need to observe in the real field also. So observation in the real field also I necessary.

And considering all these things some theory has been developed. And using those theory whatever engineering purpose we have seen that being little conservative, being remaining in safer side we can always design our structure, design our structure. Of course just (( )) and all these things have still active research area. We are yet to come out with a very concrete decision about these sort of (( )) in many cases well. And then say what we we were discussing is that there can be different approaches for having some analytical understanding of incipient motion condition. And one is competent velocity approach there we can make an assumption or we take it like that. There will be a competent velocity there will be a competent velocity which will be just sufficient which will be just sufficient to remove or to move the sediment particle in the (( )).

So, that velocity you can express somehow and you get a relation. But another approach is the critical force approach, we can call it is critical force approach or competent force. So, there will be a force, which will be sufficient it which will be a just sufficient to move the particle from it is position, and then we will try to equate the force required to (( )) particle, and then what is the actually force exerted by the flow on the particle. There are two things; one is the force when the fluid is moving it will be exacting some force, and then we need to see the (( )) force, when it is just (( )) equal to the force required to move the particle or just any more then that the force term, the particle start moving will be getting a insufficient motion condition.

Again when we talk about force, when we talk about force there can be two concepts. One is the lift concept, and other is the drag concept. Well, lift concept we know that when a fluid is (( )) some of Z is moving into (( )) it is moving around object then will be lift force acting on the particle on drag force acting on the (( )) well.

Now, in to know the (( )) move the force can be significant. And that way sometimes you consider it from the… That means it can be consider that lift force you can consider or sometimes you can consists see the drag force. That in this sort of analysis, when we talk about (( )) hydraulics, then the particle will be in the beat. It is restring under beat, another (( )) that when the flow is moving over the particle, drag force will be significant, drag force will be significant, and that way generally this drag force approach is (( )). Generally this drag force approach is adopted and lead as to a term that is called critical tractive force; that is called critical tractive force.

So, we will be discussing the how this critical tractive force, we can explicit an using this critical tractive force, how we can find that (( )) will be move in a beat this flow will be different form the flow in a rigid boundary channel or in that critical tractive force is below particular value, then we can consider this as a as similar as that of a rigid boundary channel well. Then shield this is a very popular name in the sediment shield, that is shields. Shields gave a semi theoretical analysis for computing critical tractive force, shields gave a semi empirical semi theoretical (( )). Why because in lease analysis, he initially came with the understanding of various forces, and he equated this different forces, and (( )) theoretical basics is there.

But when that theoretical forces were equated, then in fact to (( )) this force, directly it was not possible, because the sediment sizes are different. Suppose we want to know how much force will be require for lifting or for dragging the particle. It will depends on the (( )) particle. Now, when we talk the weight of the individual particle, then we need to know what is the volume of that particle?

Now, in the beam in the particle would not be objectively (( )), it will be of different type, different shape. So, to find out (( )) volume of the particle, we need to make some (( )) based on the shape of the particle volume we can consider that, it will be proportional to the diameter cube. If the diameters of the particle is g then we can call it is proportional to the diameter cube. However, exactly how much is not possible, so that way he by his analytical understanding he derived the relation that is can be equal to, this things this this value can be related. Then these he collected lot of data, conducted lot of experiment, and collected lot of data and those data were used to relate this sort of parameter.

Parameter means, the parameters for which he has know the analytical (( )) these are related or this can be related. This is one is function of other, so that way some non-dimensional parameter whose were related, and then some (( )) and then from there critical (( )), but it can be that was analyze. Of course, later on some other scientist has also then on the direction and has modified, he is analysis or other he is data and as given some other value, of course more or less close to the value what was given by shield, well. So, that we will be discussing in our next class, that how's (( )) can be used, and then based on the (( )) will be having on understanding, what sort of shear stress will be sufficient, to make up particle moving, and if to particle start moving, then we will need to know that how the break form will change, how the break form will change?

And then the question coming, if the break form change then how the resistance value, that is we were using (( )) for resistance parameter, whether that will be valued or we need to take some more spatial understanding or some more collection to this value, well. That will be discussing in the next class.

Thank you very much.