Free Surface Flow

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Lecture 61

Welcome back, students, to Module 12: Hydraulics of Mobile Bed Channels, and to the last lecture of this particular module as well as the course. We will see one to two, maybe a maximum of three problems that will give you a better understanding of the concepts we have studied in Module 12. So, I will write down the problems. There is a wide alluvial channel. A wide alluvial channel has a bed material of median size 0.8 millimeter.

The channel has a longitudinal slope of 5×10^{-4}. The depth and velocity in the channel were measured as 1.6 meters and 0.90 meters per second, respectively. To estimate, we have to estimate the bed load—that is the first part. The second part is the total load, and the third part is the suspended load per meter width of the channel.

So, this is the problem. Starting with the first part, that is the bed load q_B. We know it is written that the channel is wide. Since the channel is wide, we can write the hydraulic radius is equal to the normal depth, which is 1.6 meters. And then, the next step is we will apply Manning's formula.

By Manning's formula, V is $1/n\ {y_0}^{2/3}\ {S_0}^{0.5}$. We are going to substitute the values in this particular equation. We know V is 0.90. It is equal to $1/n$, which is what we have to find. The normal depth is given as 2/3, and we are also given So, which is $(5 \times 10^{-4})^{0.5}$. This equation will give us Manning's n as 0.034, all right. We will continue our solution, and you know we have seen an equation where we calculate.

So, you remember we have this to calculate ns as $d^{1/6}$. If you remember from our lectures and even the problems before that. This is the formula, right? So, we are going to calculate ns, which is 0 for d given as 8.8 mm. So, we will write in terms of meter $(0.0008)^{1/6}/21.1$, and ns will come out to be 0.0144.

Now, we will again use the shear stress formula. What was the shear stress formula due to grain? For grain, the formula is tau naught dash is equal to $(n_s/n)^{3/2}$. If you remember from the lecture slides, $\gamma y_0 S_0$, we are going to find □o' is equal to 0.0144 divided by 0.0340 raised to $\gamma y_0 S_0$ or $0.2756\ \gamma y_0 S_0$t or we can also write τo' is equal to $\tau o/(\gamma_s - \gamma)d$ right and this becomes $0.2756\ \gamma y_0 S_0$that is $(\gamma_s - \gamma)d$. And therefore, this comes to be

0.2756 into we know the values γ is 1.6. into So is $(5 \times 10^{-4})/\ 1.65 \times 0.0008$ and τ_o' comes to be 0.167 ok. Let me write it down in the next page also. So, τo' came out to be 0.167 and we also remember the dimensionless bed load transport formula that is Φb is equal to $qb/\gamma_s\ .\ (gd^3)^{0.5}(\gamma s - \gamma)^{0.5}$ and this equal to $qb/2.65 * 9790 * (9.81 * (0.0008^3))^{0.5} * 1/(1.65^{0.5})$ or Φb comes out to be $0.4234qb$ So, now we will apply the Meyer-Petter formula and that is Φb is equal to 8 $(\tau *' - 0.047)^{3/2}$. that is $0.4234\ qb$ is equal to 8 into this value came out to be $(0.167 - 0.047)^{3/2}$. So, qb comes to be 0.785 newton per second per meter. So, this gives us part A solution all right. we will for the part B which says to calculate total load q_T. So, we use England and Hansen Now, what is the formula?

If you recall, total load Φ_T is $qt/\gamma_s((gd^3)^{0.5})((\gamma_s - \gamma)/\gamma)^{0.5}$, ok. So, Φ_T will come out to be $qT/2.65 \times 9790 \times (9.81 * 0.0008^3)^{0.5} \times (1/1.65)^{0.5}$, or Φ_T comes out to be $0.4234\ qT$. So, we have obtained this relation, right. So, we are going to use for the actual shear stress the Darcy-Weisbach equation.

Weisbach equation friction factor f formula. So, I think we will take the next slide. So, what was the formula? f is $8gRS_0/V^2$. So, that becomes $8 \times 9.81 \times 1.65 \times 5 \times 10^{-4}$, V is already given 0.9^2, and the friction factor we are getting is 0.077.

Now, we have the friction formula. So, we will use T^* is $\gamma y_0 S_0/(\gamma_s - \gamma)d$. Now, we will substitute the values because everything is known here: $1.6 \times 5 \times (10^{-4})/1.65 \times 0.0008$. This becomes 0.6061, and again using the England and Hansen formula, which is phi t into f is equal to 0.4 T^* raised to the power 5 by 2. So, phi t we know that is Φ_T came out to be from here $0.4234\ qT$. So, we get $0.4234\ qT$ and f we already obtained 0.077 is equal to 0.4 and $0.6061^5/2$. So, we get q_T or the total load is equal to from this equation if we solve we are going to get 3.486 newton per second per meter width.

This is the solution to part *B*, the total load. So, now we will see the third part, that is the suspended load *qs*. So, you know in general total load is the sum of suspended load plus bed load. That is, *qs* is equal to. What is *qs*?

It is the suspended load and *qb* is the bed load. Therefore, and q_T is total load. So, we can write q_T is equal to $qs + qb$, and therefore *qs* will be $qT - qb$, and that is the suspended load *qs* is q_T the value that we have got was 3.486 - and what was q_b? 0.785.

So, *qs* is 2.701 Newton per second per meter width. So, this is the solution to part *C*. Just giving you a final recap. We were given a simple wide alluvial channel, and we had to calculate the parameters that were given. So, just summarizing what we have done in this problem, we were asked to first find the bed load transport, then the total load transport, and then the suspended load transport. It is easier because for the bed load transport, we used the Manning's equation to first obtain the Manning's number.

And then we applied the Manning's grain roughness formula and used the bed shear stresses formula to obtain the bed load transport, which came out to be around 0.785 Newton per second per meter width. So, normally the procedure is to find the bed load and the suspended load and then the total load by summing those. The total load is easy to calculate because we used the England and Hansen formula, and then we used the Darcy's restriction formula again, applying the England and Hansen formula to obtain the total load. For the suspended load, it was simply the subtraction of the total load minus the bed load, and therefore, we got the part *C* solution. So, I think this whole problem gives a very clear-cut understanding of how to calculate these things.

Now, a problem can be made more complicated if you are not given a wide rectangular channel; the channel could be non-rectangular. The channel could be circular, triangular, or any other cross-section. So, the problem can be made more complex, but the idea here is to let you solve the problem concept-wise. So, if your concept is correct, then you can solve any type of problem. And I think with this, we will end this particular module.

And also, I will be appearing online for your problem-solving sessions from time to time, as I have done previously, and therefore, I will see you in the sessions. Thank you so much.