Free Surface Flow
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Lecture 54

Welcome back. So, today we are going to do some problems on RVUF using the concepts that we have studied in the previous three lectures. So, with that being said, let us get started. A rectangular channel carries a flow with the velocity of 0.65 m/s and a depth of 1.4 meters. If the discharge is abruptly increased threefold, the discharge has been made thrice suddenly.

And how? Sudden lifting of a gate on the upstream. So, in the rectangular channel, the discharge is made thrice. How? This has been done by suddenly lifting a gate on the upstream side. The question is: estimate the velocity and height of the resulting surge.

So, a surge will be generated. We have to estimate the velocity, that is V_w, and the height of the surge. So, the absolute velocity of the surge is, let us say, V_w along the downstream. downstream direction. So, how do we solve it?

How do we make it a steady state by superimposing a velocity $(-V_w)$ on the system steady, low is simulated as in figure below? this is y_2, this is y_1, it is given as 1.4 meter. $(V_w - V_1)$, this is $(V_w - V_2)$, this this is brought to rest ok so this is the sketch y_1 is 1.4 meter and velocity V_1 is also given as 0.65 meters per second. So, we know that So, V_2 y_2 is 3 into the discharge first discharge 1.4×0.65 this is Q_1 ok. So, our the second this the discharge the new discharge. because it has been size made tripled that we already know.

So, this is not division this is Q_1. $3 \times Q_1$. So, V_2 y_2 is $3 \times 1.40 \times 0.65$ that is 2.73 m³/s So, by continuity equation, what is the continuity equation? $y_1 \times$ actually $By_1(V_w - V_1)$ is $By_2 (V_w - V_2)$. So, B gets cancelled. So, 1.4 is given $\times$ $(V_w - 0.65) = V_w\, y_2 - V_2\, y_2$ and this value we know from here or $1.4 * (V_w - 0.65) = V_w\, y_2 - 2.73$ or $V_w\, (y_2 - 1.40) = 1.82$. or we can write $V_w = 1.82\,/(y_2 - 1.40)$. Now, we have written V_w in terms of y_2. So, we know for a positive surge moving in the downstream direction. We have used the equations from the slide and we have used also before $(V_w - V_1)^2$ by $gy_1 = (1/2) \times (y_2/y_1)\,((y_2/y_1) + 1)$. This is the equation from lectures slide. Now, we substitute instead of V_w , we put this equation $(1.82/(y_2 + 40) - 0.65)^2\,/\,(9.81 \times 1.40) = (1/2) \times (y_2/1.40) \times ((y_2/1.40) + 1)$ or we can write $273\,((273 - 0.65\, y_2)^2)/(y_2 - 1.4)^2 = 3.504\, y_2 * (1.40 + y_2)$.

So, how are we going to solve this trial and error method? Trial and error. So, we have only one equation and one variable; we get $y_2 = 1.76$. What is going to be the height of the surge? $\Delta y = (y_2 - y_1)$ or (1.76 - 1.40), that is 0.36 m.

So, $\Delta y = 0.36$ m. Height of the surge. And now, since y_2 is known, we can calculate V_w as 1.82 / (1.76 - 1.40). It is 5.06 m/s. So, $V_w = 5.06$ m/s in the downstream. So, we were asked to solve V_w and the height of the resulting surge. So, the height of the resulting surge we found out, and we also found out the V_w. Now, we are going to see the next problem. The question is: a 4 meter wide rectangular channel carries a discharge of 12 m³/s at a depth of 2 meters.

So, there is a 4-meter-wide rectangular channel carrying a discharge of 12 m³/s at a depth of 2 meters. The question calculate the height and velocity of a surge produced when the flow is suddenly stopped completely by the full closure of a sluice gate at the downstream end.

It is important to understand what type of surge is going to be generated. Many initial conditions are given: the width of the channel, the discharge, and the depth are all provided. Now, we said that the flow is suddenly stopped by the full closure of the sluice gate at the downstream end. So, first, we need to identify the type of surge that is going to be produced. So, with this action, we know as we have studied in theory a positive surge with V_w or minus V_w, basically, that is traveling upstream. So, this is Type 2 that will be generated. as a result of the sudden stopping of the flow. We will draw the figure first. So, we will draw on the left-hand side.

Let us draw the gate, this is gate, this is y_2 and this is $V_2 = 0$. and this is $y_1 = 2$ meter and this is the velocity is equal to that we do not know yet. We will calculate this. positive surge moving upstream. So, by super imposing V_w that is plus on the system, a steady flow is simulated as V_w. shown in figure on the next page. So, we will draw the steady state figure now. So this was 0, but now this is V_w, this is $(V_1 + V_w)$ and this is now at rest V_w, V_w. So, we know that here y_1 is 2.0 meter.

This means $BV_1 y_1 = Q$ and therefore, y_1 is going to be Q/By_1 sorry V_1 is going to be Q/By_1 and Q is 12.0 / 2 × y_1 is, width is 4, that gives us 1.5 m/s. So, V_1 is nothing but 1.5 m/s. and V_2 we already know it is 0 and $y_2 > 2$ meter that also we know. applying continuity equation that is $By_1(V_1 + V_w) = By_2(V_2 + V_w)$.

So, B-B will get canceled, V_2 is 0. We can write $2 \times (1.5 + V_w) = V_w \times y_2$ or $V_w = 3/(y_2 - 2)$. So, this is a case of a positive surge moving upstream. We can use the equation $(V_1 + V_w)^2$. By $g\, y1 = (1/2) \times (y_2/y_2) \times ((y_2/y_2) + 1)$.

That is. $(1.5 + 3/(y_2 - 2))^2$. Equal to $9.81 \times 2.0 \times (1/2) \times (y_2 / 2.0) \times (y_2 / 2.0 + 1)$. $(1.5 y_2/(y_2 - 2))^2 = 2.4525.\, y_2 \times (y_2 + 2.0)$. So, this is the equation.

This is solved using the trial-and-error method. Solving by the trial-and-error method yields y_2 as 2.728 meters. How do you check? Substitute this value in equation star and

Confirmed. So now, what we have is y_2, which is 2.728 meters. So now, The height of the surge will be very simple. It is $(y_2 - y_1)$, and this is y_2 is 2.728 - 2.0, which is 0.728 meters.

The height of the surge $\Delta y = y_2 - y_1 = 0.728$. Now, the velocity of the surge 3 divided by 2 points. So, if you look at this $3 / (y2 - 2)$ or $3 / (2.728 - 2.0)$ or 3.0 / 0.728 or 4.12 m/s.

So, V_w is equal to 4.121 meters per second in the flow. Hence, the surge is of height 0.728 meters and moves upstream with a velocity of 4.121 meters per second. So, we have solved both type 1 and type 2 problems today.

I think that is enough for today, and we will solve more problems on these types of surges in the next class. Thank you so much.