Free Surface Flow

Dr. Mohammad Saud Afzal
Department of Civil Engineering
Indian Institute of Technology Kharagpur

Lecture 32

Welcome back, students, to the second lecture of this module, which is about problems in gradually varied flow. Today, we are going to solve one question, which is quite lengthy in nature. So, I will start by writing down the question. I think it will be very good practice, and this is one of the most lengthy problems that we are going to see. So, the question is: there is a trapezoidal channel which has three reaches.

A, B, and C, connected in series with the following properties. So, drawing the table to mark the properties, this is reach, this is $\boldsymbol{B}$, that is bed width. Side slope $\boldsymbol{M}$ or $\boldsymbol{m}$, bed slope So, and Manning's number. Reaches are A, B, and C, and bed width is 4 meters, 4 meters, 4 meters. Side slope is 1, 1, and 1.

Now, bed slopes are different: 0.0004, 0.009, 0.004. And 0.015, 0.012, and 0.015. We have to sketch the resulting water surface profiles or we Okay. For a discharge of $\boldsymbol{Q}$ is equal to 22.5 meter cube per second. The assumption is the length of the can be assumed to be sufficiently GVF to develop fully. So, the solution is.

We have been given $\boldsymbol{Q}$ is equal to 22.5 meter cube per second. Now, look at individual, we look at one reach, reach A first. Here $\boldsymbol{B}$ is equal to 4 meter, m is 1. So 0.0004 and $\boldsymbol{n}$ is equal to 0.015. So, there is a term called phi ($\boldsymbol{\varphi}$) if you remember from our lectures that we needed to calculate while calculating the normal depth and the critical depth and $\boldsymbol{\varphi}$ is $\frac{Qn}{\sqrt{S_0}B^{8/3}}$ right and that is $\frac{22.5\times 0.015}{\sqrt{0.0004}\times 4^{8/3}}$ and this comes to 0.4186 And we are going to see corresponding to $\boldsymbol{\varphi}$ is equal to 0.4186 and m is equal to 1 from table 1 in this PPT. So, let us go and have a little small look table 1. So, 0.4186, m is equal to 1 and 0.48 value of $\boldsymbol{\varphi}$, $\boldsymbol{m}$ is equal to 1 point. So, this is 0.

0.4186. So, somewhere here, $\boldsymbol{m}$ is equal to 1, and this value comes to be ηo, which is between 0.55 and 0.560. For this particular question. So, I have already interpolated the result. So, I know this value PPT $\boldsymbol{\eta_o}$ is equal to $\boldsymbol{y_o/\beta}$ or $\boldsymbol{B}$, not $\boldsymbol{\beta}$.

Comes to be 0.566, and therefore, y_o is 0.556 × 4, or yo is 2.224 meters. Now, this was the normal depth. Now, we are going to calculate the critical depth. For critical depth, we need to calculate a quantity called ψ, which is $\frac{Qm^{1.5}}{\sqrt{g}B^{2.5}}$ or $\frac{22.5\times1^{1.5}}{\sqrt{9.81}\times4^{2.5}}$, that is equal to 0.2245.

And for ψ is equal to 0.2245 from Table 2 in this PPT. So, let us go and have a look at this Table 2. So, ψ 0.2245. 0.2245, so somewhere in between this and this.

So, we are going, so 0.2245 will be somewhere between this. So, I have already calculated this value for the sake of convenience: ε is equal to $\frac{my_c}{B}$, which is equal to 0.329. So, ε is 0.329. This implies $\frac{1\times y_c}{4}$ is equal to 0.329, or y_c is equal to 1.316 meters.

This is the normal depth. Continued: y_c, which is 2.224 meters, is greater than y_c, which is 1.316 meters. This implies a mild slope. So, this is one particular reach. So, similarly for reach B and reach C. If we calculate following the similar method as of reach A, we will obtain as follows. y_o meter, $\frac{Qm^{1.5}}{\sqrt{g}B^{2.5}}$, and y_c in meter, location of the reach. So, A, B, and C: this we already calculated as 0.4186, and this 0.556, 2.224, and this came out to be 0.2245, this came out to be 0.329, and therefore, 1.316. So, y_o was greater than y_c, so this was a mild slope.

Now, for reach B and reach C, we need to do the long calculations, but since I have already calculated these values for you beforehand, this value is 0.0706. 0.203, 0.812, 0.2245, 0.329, 1.316, and therefore, this came out to be steep slope. Reach C was 0.1324, 0.296, 1.172, 0.2245, 0.329, 1.316. and this was also a steep slope.

So, the calculations normally we do this one using the tables. So, what we write down here is reach A is a mild slope channel as yo is greater than yc, and reaches B and C are steep slope. steep slope channels. Reach B is steeper than reach C. The various

reaches are schematically drawn; we will draw this figure. So first, let us draw the schematics. So this is mild slope. This is mild slope A, B, C, D. This is steeper, and this is steep slope, alright. This is this is CDL, NDL, y_c is equal to 1.316. this is ***S3***, this is ***S2***, this is ***M2***, y_{os} 2.264 meter and this is 1.316 meter and this is 0.812 meter. This is the rough sketch that can be drawn. So, what we can infer from this is the CDL is drawn at a height of 1.316 meter above the bed level and the NDL are drawn at appropriate y_0 values. So, we also need to show the controls. So, this is one control and this is the another control. Control are the point where there is a change. the controls are. So, these are the control 1, 2, these controls are marked in the figure. Reach A will have ***M2*** drawdown curve, reach B. has ***S2*** drawdown curve.

We have already marked it in the figure, and reach C shall have ***S3*** rising curve, as indicated in the figure above. It may be noted that the resulting profile, as above, is a serial combination of break-in grade, as already in the theory.

Alright, so you see this is quite a lengthy question, which has three reaches. So, I will just summarize what has been done. So, there were three reaches: reach A, B, and C. They have different properties, different Manning's numbers, and different bed profiles as well, including different bed slopes. So, you see, we have some ready-made tables for the calculation of normal depth and critical depth, which were given as tables in this particular slide at the beginning itself. So, table 1 is used for the calculation of normal depth, and table 2 is used for the calculation of critical depth.

So, for these, we calculated y_0 (normal depth) and y_c (critical depth). So, we estimated whether it is a mild or a steep profile. For the first case, we determined a mild slope. We did the same calculation for reach B and C and found out that it was a steep slope. Now, that being found out, we started drawing the different values that we found out here: y_c, y_0, and what the normal depth line is.

So, we also started judging what type of grade change was there, changing from mild to steeper to steep, and we marked the control point. So, all these are one set of comprehensive equations, and this is sort of an example that makes complete sense of gradually varied profile problems. So, I think it is a nice point to stop the lecture here, and in the next lecture, we will continue with some more problems. Thank you so much.