Hydraulics

Tutorial Sheet 9 – Basic hydraulics of flow in pipes

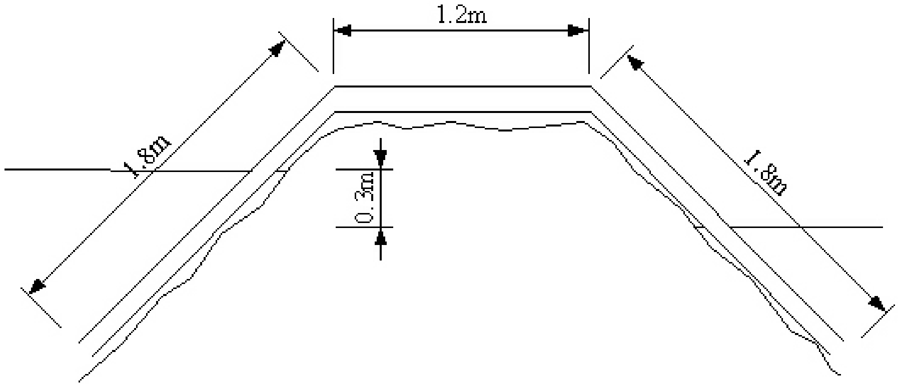
1. A horizontal $50\,\mathrm{mm}$ pipeline leaves a water tank with a square-edged entrance at $H = 6\,\mathrm{m}$ below the water surface and discharges into the atmosphere. Calculate the flow rate, assuming a friction factor $\lambda = 0.025$ and $\alpha = 1.2$ for four cases, with and without entrance loss $K = 0.5$, and for a pipe length L of $4.5\,\mathrm{m}$ and $45\,\mathrm{m}$. (Ans: $0.012\,\mathrm{m^3\,s^{-1}}$, $0.011\,\mathrm{m^3\,s^{-1}}$, $0.0044\,\mathrm{m^3\,s^{-1}}$, $0.0043\,\mathrm{m^3\,s^{-1}}$).

2. In Q1 you have examined the sensitivity to different losses. This does the same but mathematically. Now generalising, to estimate the relative importance of the velocity correction factor α, a local loss K, and friction λ: a horizontal pipeline of diameter D a depth H below the surface leaves a water tank with entrance loss coefficient K and discharges into the atmosphere. The pipe has length L and friction factor λ. Calculate the flow rate in terms of these quantities and using the total differential explore the sensitivity of the discharge Q to α, K, and λ by considering realistic values and uncertainties in those quantities for pipeline length/diameter ratios of 100 and 1000. Consider α in the range $1 - 1.3$, K might be, say, 0.5 ± 0.15, and the value of λ from the Moody diagram might be 0.02 ± 0.005, corresponding to uncertainties of 100% in the relative roughness.

3. Do Example 16 on page 74 of the lecture notes for yourself, paying attention to the plotting of the piezometric head line and the total head line. It might be easiest to do all calculations and plotting using a spreadsheet.

4. Repeat, but where instead of a nozzle, the pipe discharges into a tank where the water surface is $1\,\mathrm{m}$ above the pipe. Include the exit loss in your calculations, and again, carefully plot the lines mentioned in Question 1. (Ans: $Q = 0.0766\,\mathrm{m^3\,s^{-1}}$, ...)

5. An irrigation siphon placed over a canal bank is a pipe with a diameter of $100\,\mathrm{mm}$ and the dimensions shown. Estimate the flowrate for a head of $0.3\,\mathrm{m}$. Assume a re-entrant loss of $K = 0.8$; the full kinetic energy loss at the exit, but where $\alpha = 1$ because the flow distribution in the pipe has not had time to develop; a friction factor of $\lambda = 0.02$ and bend loss coefficients of $K = 0.2$.. (Ans: $0.0107\,\mathrm{m^3\,s^{-1}}$).



6. A town water supply has a reservoir whose surface is $100\,\mathrm{m}$ higher than that in the water tower in the town which acts as a distribution reservoir, which stores enough to average out flows between times of high and low demand. This means that when we design the pipeline joining the two we can consider mean demand, which is 250L per head per day. The town is estimated to have a population of $4,000$ people at the end of the 20 year design life. The reservoir and the tower are $5\,\mathrm{km}$ apart so that we can ignore local losses. The pipes to be used are concrete, with an equivalent roughness of $1\,\mathrm{mm}$. Design the pipe – that is, determine its minimum diameter so that the mean flow can be carried. Of course, in practice, the next larger commercial pipe size would be used. (Ans: a required diameter of at least $0.115\,\mathrm{m}$).

7. Now generalising, to estimate the relative importance of the velocity correction factor α, a local loss K, and friction λ: a horizontal pipeline of diameter D a depth H below the surface leaves a water tank with entrance loss coefficient K and discharges into the atmosphere. The pipe has length L

and friction factor λ. Calculate the flow rate in terms of these quantities (you could use the solution from the previous question) and using the total differential explore the sensitivity of the discharge Q to α, K, and λ by considering realistic values and uncertainties in those quantities for pipeline length/diameter ratios of 100 and 1000. Consider α in the range $1-1.3$, K might be, say, 0.5 ± 0.15, and the value of λ from the Moody diagram might be 0.02 ± 0.005, corresponding to uncertainties of 100% in the relative roughness.