École polytechnique fédérale de Lausanne
School of Architecture, Civil and Environmental Engineering
Civil Engineering & Environmental Science and Engineering Sections
CIVIL-312: Hydraulic Engineering and Infrastructures

Homework 3

Instructor: Prof. Mirko Musa
Due date: January 9, 2026

General Instructions

- This is an individual and mandatory assignment. Copying will result in a null grade (NA: *non acquis*) and a formal reprimand according to EPFL regulations.
- The assignment **must be typed on a computer** and submitted as a **PDF file** through the corresponding Moodle submission form. This helps ensure clarity and readability.
- Figures and graphs may be included either in-line with your solution or attached as appendix. These must be neat and, if applicable, created using tools such as Excel, Matlab, or Python.
- Your work must be supported by a clear, logically structured solution process. You are expected to organize your responses effectively. A classic problem-solving approach is recommended:
  - **Conceptualize:** Identify all relevant data and draw a clear sketch showing applied forces, boundary conditions, and interactions.
  - **Categorize:** Define the unknowns, make justified assumptions to simplify the problem, and determine the path to a solution.
  - **Analyze:** Apply the appropriate physical laws, set up equations, and carry out calculations to find the unknowns.
  - **Finalize:** Evaluate your results. Check units, physical consistency, and whether the solution is reasonable by comparing it to similar cases or known benchmarks.
- For any questions related to this assignment, please use the dedicated **Moodle forum** so that everyone can benefit from the discussion and clarifications.
- Late submissions will incur a 0.5 deduction from the final grade for every day of delay.

Problem 1

Design an ogee spillway whose crest is located 100 m above the riverbed. The spillway must safely convey a design discharge of 12 000 m^3/s. The structure consists of six overflow spans, each providing a clear waterway width of 15 m, separated by five piers of uniform thickness 3 m. Assume the width of the approach channel is equal to the total width of the spillway structure.

The downstream face of the overflow section has a slope of 0.8H : 1V, and the upstream face may be taken as vertical.

For the hydraulic design, adopt a design ogee discharge coefficient of $C_0 = 2.30$. The influence of end contractions is to be included using a pier contraction coefficient $K_p = 0.02$ and an abutment contraction coefficient $K_a = 0.20$.

The downstream crest profile shall follow the standard USBR non-dimensional form

$$\left(\frac{y}{H_d}\right) = \frac{1}{K}\left(\frac{x}{H_d}\right)^n,$$

where H_d is the design head, and x and y are measured from the crest apex (origin), with x positive downstream and y positive downward.

The upstream profile shall follow the profile for vertical upstream faces:

$$\frac{x^2}{A^2} = \frac{(B-y)^2}{B^2} = 1.$$

Part A (6 pts)

1. Determine the design head H_d that satisfies the discharge requirement after accounting for end contractions and velocity of approach. (Assume $H_d = H_e$.)
2. Compute the effective crest length L_e. Verify that the resulting L_e satisfies the discharge requirement.
3. Calculate the approach velocity head h_a assuming that the water level on top of the crest $H \approx H_d$. Compare h_a with the estimated design head and discuss any implications.
4. Develop the coordinates of the downstream profile up to the tangent point where it joins the straight downstream face of slope 0.8H : 1V.
5. Develop the coordinates of the upstream profile from the crest apex to its upstream limit.
6. Provide a clearly labeled computer-made plot of the full spillway crest and the maximum expected water level. Please, use a program like Excel, MATLAB, Python, etc. — not by hand.

Part B (4 pts)

Using the design head H_d obtained in Part A and the ogee discharge coefficient ratio $\phi(H_e/H_d)$ taken from the standard USBR curves (values provided in the example in class or standard tables), compute the spillway discharge for several heads different from the design head.

Consider the following values of the total head above crest:

$$\frac{H_e}{H_d} = 0.4,\ 0.6,\ 0.8,\ 1.0,\ 1.2,\ 1.4,\ 1.6.$$

1. Prepare a table including, for each H_e: H_e/H_d, ϕ, $C(H_e)$, $L_e(H_e)$, $H_e^{3/2}$, and $Q(H_e)$.
2. Plot the discharge Q as a function of the head H_e for the range $0.4H_d$ to $1.6H_d$. Label the axes as *Head above crest H_e (m)* and *Discharge Q (m^3/s)* and discuss the nonlinearity of the curve.

Based on the pressure head charts for standard ogee spillways shown in class (and reproduced in Figure 1), the minimum pressure on the crest occurs at $x = -0.2\,H_d$ for all head ratios considered. The vertical axis of the chart gives the non-dimensional pressure head h_p/H_d.

Using the design head H_d obtained previously and the values of H_e/H_d considered for the discharge–head relationship:

3. What is the minimum pressure head h_p for the head ratio $H_e/H_d = 1.33$ if the chart indicates $h_p/H_d \approx -0.43$ at that head ratio?
4. Based on the trend of the curves in Figure 1, estimate for which head ratio H_e/H_d this cavitation threshold is reached. A reasonable range based on the plot will suffice. (Use the cavitation threshold discussed in class.)

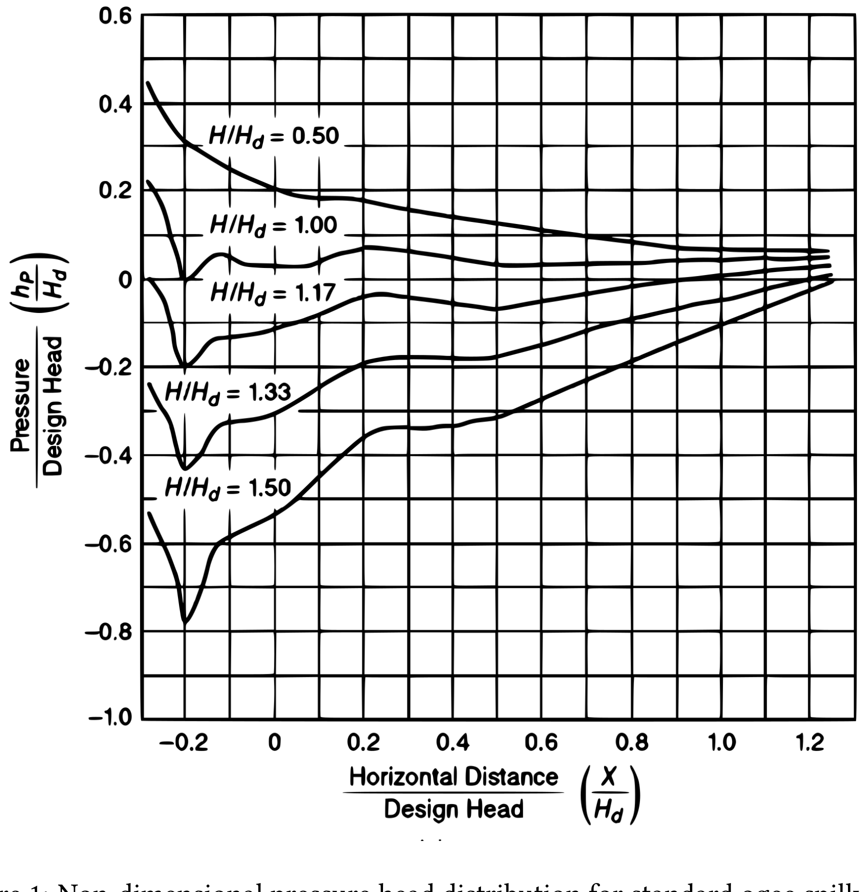

Figure 1: Non-dimensional pressure head distribution for standard ogee spillways.