FACULTY OF **ENGINEERING**

DEGREE COURSE: **CIVIL AND ENVIRONMENTAL ENGINEERING BS**

SUBJECT: HYDRAULICS AND HYDRAULIC CONSTRUCTIONS

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OBJECTIVES

The course will teach the following:

- understanding of the main hydraulic processes, their principles and basic mechanics;
- whole description of mathematical equations under appropriate basic assumptions and boundary conditions;
- methods to perform the main hydrological applications;
- methods to design the main hydraulic constructions using appropriate empirical and mathematical approaches.

CONTENTS

The course (6 CFU) has 48 lessons and is split into three main modules:

1. Elements of Hydraulics (3 CFU), where attention is paid to fluid statics and dynamics;
2. Elements of Hydrology (1 CFU), where the methodologies to assess hydrological variables useful to design hydraulic constructions are described;
3. Hydraulic Constructions (2 CFU), where the attention is addressed to the design and verification of constructions in urban context, such as aqueducts and sewers, and in a natural context, such as fluvial structures.

For each module the specific topics are illustrated in the following:

MODULE OF HYDRAULICS

1. **The physical basis of hydraulics:** systems and units of measurement, fluids as continuum systems, stresses, the meaning of pressure.
2. **Physical properties of fluids**: density and specific weight, compressibility, viscosity, state equation.
3. **Equations of fluid statics:** static equation in fluid mechanics, fundamental equation for hydrostatics of heavy fluids, incompressible flows: fundamental equation of fluid statics, hydrostatic loads plane.
4. **Pressure diagrams**: immiscible fluids, gas superimposed on a liquid, fluid at a pressure greater or lower that the atmospheric one.

5. **Pressure measurements:** conversion of units of pressure measurements, Bourdon pressure gauge, piezometer, simple manometer, differential manometer, air manometer.
6. **Thrust on a plane surface**: global equation for static equilibrium, thrust on a plane surface, prism of the pressures.
7. **Thrust on a curved surface:** thrust on a curved surface, calculation of the thrust on a curved surface through the global equation, calculation of the thrust on a curved surface through the method of the components.
8. **Fluid kinematics**: Eulerian and Lagrangian reference systems, trajectories and streamlines, non-uniform and unsteady flow, flow rate and average velocity, continuity equation in local form, continuity equation for currents.
9. **Bernoulli's theorem**: Bernoulli's theorem, indefinite equation of hydrodynamic equilibrium, meaning of the triad of Bernoulli, extension to linear currents.
10. **Velocity and flow rate measurements:** Pitot tube, Venturi tube.
11. **Outflow from orifice:** orifices, coefficient of contraction, nozzles, bottom orifices, lateral orifices, partial contraction, additional external pipe, additional internal pipe.
12. **Short pipes. Ideal flow motion:** pipes with a constant and variable diameter, depressed pipe, outflow from atmosphere, outflow from nozzle, siphons.
13. **Global equation of fluid dynamics and local head losses:** global equation of fluid dynamics for a steady flow, flow from nozzle, introduction to local head losses, losses at the inflow, losses at sudden enlargement, losses at the outflow.
14. **Short pipes. Real flow motion:** flow regimes, flow resistance, practical formulas, laminar flow, turbulent flow, Moody diagram.
15. **Local head losses as turbulent processes:** head losses for a divergent, inflow head losses, inflow head losses in the case of a submerged pipe in a reservoir.
16. **Long pipes:** problems of design, problems of verification, turbines, pumps.
17. **Introduction to free-surface flows:** preliminaries, specific energy, critical energy for a rectangular section, critical energy for a generic section, in-depth analyses.
18. **Flow regimes for free-surface flows:** uniform flow for free-surface currents, non-uniform flow for free-surface currents, non-uniform flow profiles in a steep slope channel, non-uniform flow profiles in a mild slope channel, transformation from a subcritical flow in a supercritical flow.
19. **Hydraulic jump:** hydraulic jump, transformation from a supercritical flow in a subcritical flow.
20. **Self evaluation test on Hydraulics:** 4 multiple choice questions.

MODULE OF HYDROLOGY

21. **Introduction to Hydrology:** hydrological budget, drainage basin, hydrological budget at a basin scale, rainfall and flow rate measurements.
22. **Morphological characteristics of a drainage basin:** planimetric characteristics**,** hypsographic curve and average elevation, average slope of a river, time of concentration.
23. **Elements of statistics:** random variables and probability distributions, analysis of sampled data, verification of a model, hydrological annals.
24. **Statistics of extreme events:** Gumbel distribution, pluviometric curves, design storm hyetograph, design examples.
25. **Rainfall-runoff relationships:** classification of rainfall-runoff relationships, empirical semi-empirical and analytical models, Curve Number method, unit hydrograph and instantaneous unit hydrograph.
26. **Self evaluation test on Hydrology**: 4 multiple choice questions

MODULE OF HYDRAULIC CONSTRUCTIONS

Sub-module of Aqueducts

27. **Aqueducts**: introduction to aqueducts, evaluation of water flow rate, surface water intakes, groundwater intakes, spring water collection systems, water intakes from aquifers.
28. **Hydraulic systems**: water pipes, calculations of water pipes, problems of design. Problems of verification: calculation of flow rate and energy gradient.
Problems of verification: calculation of roughness, applications of a water pipe, water pipe with uniform supply along the path.
29. **Hydraulic systems:** system of reservoirs, verification and design of a system of three reservoirs.
30. **Problems of minimum cost design:** aqueduct with distributions - problems of minimum cost, pumping station - problems of minimum cost.
31. **Reservoirs for aqueducts:** uses of a reservoir, classification of the reservoirs.
32. **Water networks:** urban water networks, design criteria, criteria for correct operation, backfilling.
33. **Calculation for water networks:** branched networks, applications of branched networks, Hardy-Cross method, application of Hardy-Cross method, brief notes on node method.
34. **Special structures for aqueducts:** manholes, crossings, anchorages, equipment along the path of pipes.
35. **Self evaluation test on Aqueducts:** 4 multiple choice questions.

Sub-module of Sewers

36. **Sewer collectors:** introduction to sewers, disposition of the networks, alignment and excavation, pipes, special structures.
37. **Black sewers:** black sewer collectors, calculation of the flow rate, calculation of the collector.
38. **White sewers:** white sewer collectors, rational method, exercise on the rational method, reservoir method.
39. **Combined sewers:** design of a combined sewer pipe, reference rules.
40. **Pumping stations for sewers:** pumping stations for sewers, sketch of a pumping station, types of plants.
41. **Sewer systems:** sketch of a separated sewer, detail of a road section with a white sewer, detail of a storm drain.
42. **Self evaluation test on Sewers:** 4 multiple choice questions

Sub-module of Fluvial Constructions

43. **Fluvial constructions:** classification of the fluvial constructions, criteria for choosing fluvial constructions.
44. **Fluvial constructions in mountain territories:** river with check dams and bed sills, equilibrium slope, structure of the check dams, sketches and types of check dams, stability of a check dam.
45. **Fluvial constructions in valley territories. Part 1:** embankments, detention basins, spillways and sluices, weirs.
46. **Fluvial constructions in valley territories. Part 2:** groins, gabions, bank defenses, environmental engineering techniques.
47. **Dams:** types of dams, characteristics of the dams, loads acting on the dams, accessory structures.
48. **Hydraulic reclamations:** drainage reclamations, land reclamations.

LEARNING OUTCOMES

At the end of the course, the student will be able to

- explain the topics of Hydraulics, Hydrology and Hydraulic Constructions using appropriate technical language,
- describe the engineering approaches to design hydraulic constructions.

ASSESSMENT

Written exam: multiple choice and open questions

RECOMMENDED TEXTBOOKS

- Streeter, V.L., FLUID MECHANICS, McGraw-Hill Book Company, 1-568 pp.
- Massey, B., Ward-Smith, J., MECHANICS OF FLUIDS, Taylor and Francis Group, 1-709 pp.
- Chow, V.T., OPEN-CHANNEL HYDRAULICS, McGraw-Hill Book Company, 1-728 pp.
- Graf, W.H., Altinakar, M.S., FLUVIAL HYDRAULICS: FLOW AND TRANSPORT PROCESSES IN CHANNELS OF SIMPLE GEOMETRY, John Wiley and Sons, 1-682 pp.
- Bras, R.L., HYDROLOGY: AN INTRODUCTION TO HYDROLOGICAL SCIENCES, Addison-Wesley Publishing Company, 1-324 pp.
- Qasim, S.R., Motley, E.M., Zhu, G., WATER WORKS ENGINEERING: PLANNING, DESIGN AND OPERATION, Prentice Hall PTR, 1-844 pp.
- Mara, D., Sleigh, A., Tayler, K., PC-BASED SIMPLIFIED SEWER DESIGN, University of Leeds, 1-122 pp.
- Novak, P., Moffat, A.I.B., Nalluri, C., Narayanan, HYDRAULIC STRUCTURES, Taylor and Francis Group, 1-725 pp.