

### Learning outcomes

At the end of this chapter and exercise, the students should be able to:

- a. classify and know the main types and elements of hydraulic waterways
- b. differentiate between free-surface and pressurized waterways
- c. identify its main elements
- d. recognize where surge control measures need to be applied
- e. assess water losses
- f. recognize where tunnel lining is required and design it
- g. recognize where tunnel lining needs to be watertight and design it
- h. know, understand, and apply the basic equations behind the design of pervious and impervious tunnel linings
- i. define and identify critical situations in pressurized waterways
- j. propose and design countermeasures

### Contents

#### 1. Definitions

- a. Pressure tunnel - mild-sloped hydraulic waterway
- b. Pressure shaft – steep-sloped hydraulic waterway
- c. Hydraulic gradient – difference in pressure load  $\Delta H$  between two locations at given distance  $L$
- d. Rock cover (or overburden)
- e. Hydraulic jacking

#### 2. Pressurized waterways - Introduction

- a. Main characteristics
- b. Chronological evolution & typical longitudinal profiles
- c. Main purposes of a surge tank
- d. Waterway route – main design criteria
- e. Water losses
- f. Selection of waterway section (tunnel, shaft, w-w/o lining, w-w/o surge tank)
- g. Objectives of lining waterways
- h. Unlined tunnels – when can it be done?
- i. Excavation with tunnel boring machine
- j. Excavation with raise-boring machine
- k. Lining with shotcrete. Purpose, advantages, and limitations.
- l. Lining with in-situ cast concrete. Purpose, advantages, and limitations.
- m. Lining with in-situ reinforced cast concrete. Purpose, advantages, and limitations.
- n. Lining with watertight steel/membrane. Purpose, advantages, and limitations.

#### 3. Design of pervious linings

- a. Theory of thick-wall cylinder under internal and external water pressure
- b. Load sharing with surrounding rock as means to limit concrete cracking
- c. First filling of pressurized tunnels and shafts. Example.

#### 4. Exercise 3

- Pressurized waterways