LECTURE NOTES – VIII

« HYDROELECTRIC POWER PLANTS »

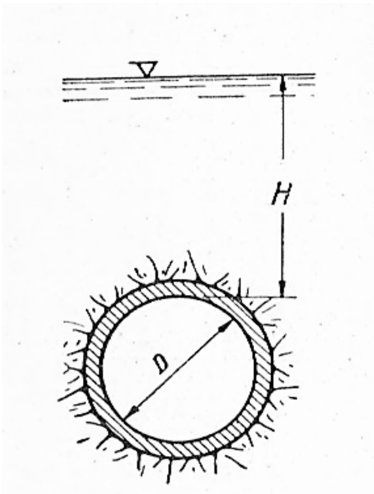
Prof. Dr. Atıl BULU

Istanbul Technical University
College of Civil Engineering
Civil Engineering Department
Hydraulics Division

CHAPTER 8

The Tunnel

Pressure tunnels may be classified according to the head above the arch of the tunnel.



Correspondingly, tunnel may be grouped into,

a) *Low-pressure tunnels*, with H lower than 5 m,
b) *Medium-pressure tunnels*, with H from 5 to 100 m,
c) *High-pressure tunnels*, with H higher than 100 m.

According to another classification,

a) *Unlined,*
b) *Lined*, either for structural purposes, or for the purpose water sealing.

Structural linings are called upon to carry the rock pressure and to offer protection against rock splitting from the tunnel roof.

Full circular linings, in addition to being capable of resisting external loads, are suitable for;

a) To take *internal water pressure*,
b) To prevent *water losses*,
c) To protect the rock against the *aggresivity* of conveyed water.

In case of low-pressure tunnels, the trimmed rock may be left unlined except for visible fissures which may be sealed with concrete or cement. In order to reduce hydraulic head losses, rock surfaces should be trimmed smooth or coated with a friction-reducing concrete layer.

A watertight lining is usually required for tunnels operating under medium heads. Seepage is more likely to occur as the head increases. Simple cement-mortar coatings are seldom satisfactory and *watertight concrete linings* have to be applied in most cases.

If the tunnel is unlined, or if the lining serves only for water sealing purposes, i.e., carries no load, *the permissible water pressure* is determined.

h = The depth of overburden over the arch,
γ_1 = Specific weight of the rock.
γ = Specific weight of the water

$$p_V = 0.1\gamma_1 h \quad (\text{kg/cm}^2)$$

And using a safety factor n, the permissible internal water pressure is,

$$p = \frac{p_V}{n}$$

Since,

$$p = 0.1\gamma H \quad (\text{kg/cm}^2)$$

The permissible head (static and dynamic), with γ = 1 ton/m^3,

$$p_V = np = 0.1n\gamma H$$
$$0.1\gamma_1 H = 0.1n\gamma H$$
$$H = \frac{\gamma_1}{n}h$$

Practical values for the safety factor n are from 4 to 6. The lower limit should be used for greater depth of overburden and for sound rock on the arch, whereas in case of a shallow cover and poor rock the upper limit is used. Consequently, with the specific weight of rock varying from 2.4 to 3.2 ton/m^3, the permissible head in meters related to the depth of overburden above the arch yields,

$$H = (0.4 \text{ to } 0.8)\ h$$

In *pressure tunnels operating under high heads*, linings of plain concrete and sometimes even of reinforced concrete are not satisfactory. Steel linings are used.

To reduce construction costs, relatively high flow velocities should be permitted in tunnels, higher than allowed in open channels. Suggested limit velocities,

Very rough rock surfaces → 1.0 – 2.0 m/sec
Trimmed rock surfaces → 1.5 – 3.0 m/sec
Concrete surface → 2.0 – 4.0 m/sec
Steel lining → 2.5 – 7.0 m/sec

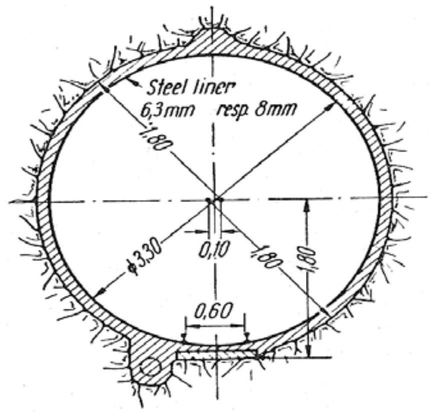


Figure. Steel-lined pressure tunnel

The minimum size of tunnels of circular cross-section is about 1.80 m in diameter. In case of lined tunnels, the computed cross-section should be increased by the thickness of the lining.

Friction losses may be calculated by the manning equation,

$$h_L = \frac{nV^2}{R^{4/3}} L$$

L = Length of the tunnel (m),
V = Mean flow velocity (m/sec),
R = Hydraulic radius (m)
n = Manning roughness coefficient.