Hydraulics Structures

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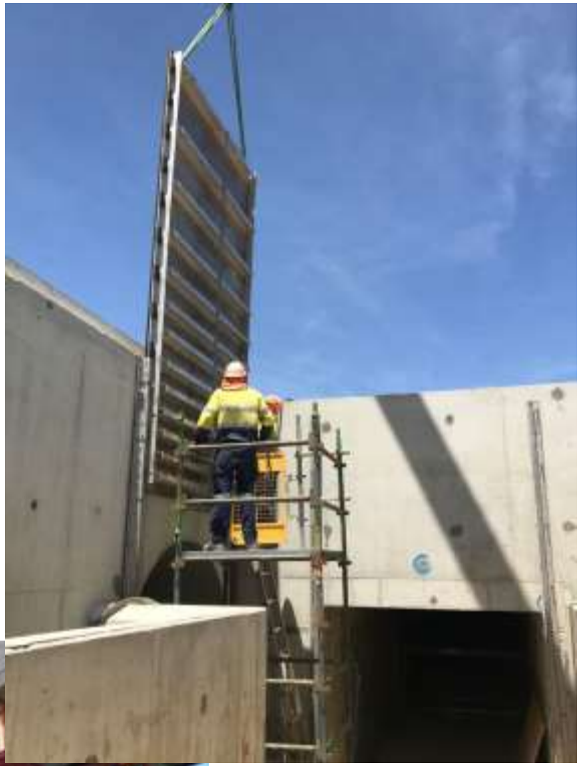
GATES

In **hydraulic** engineering, a **gate** is a rotating or sliding **structure**, supported by hinges or by a rotating horizontal or vertical axis, that can be located at an extreme of a large pipe or canal in order to control the flow of water or any fluid from one side to the other.

Types of gates:

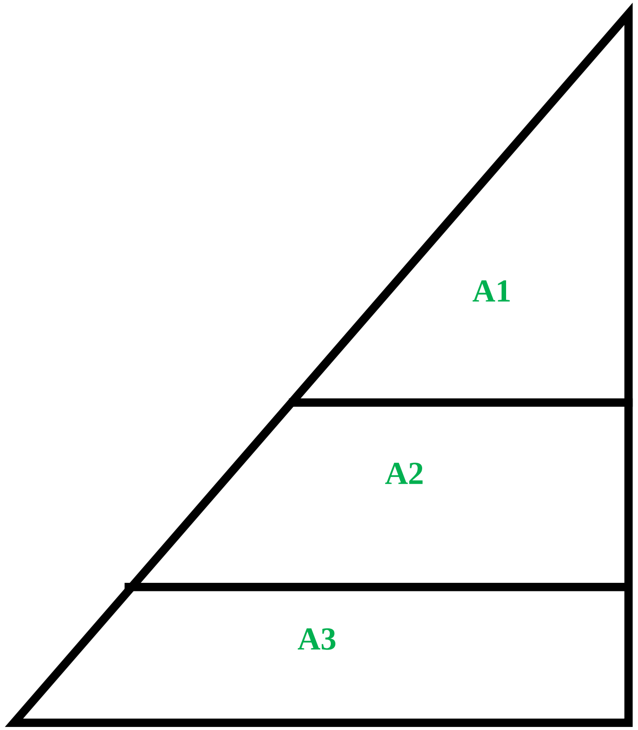
1. Stop logs.
2. Sliding gates.
3. Radial gates.
4. Rolling gates.

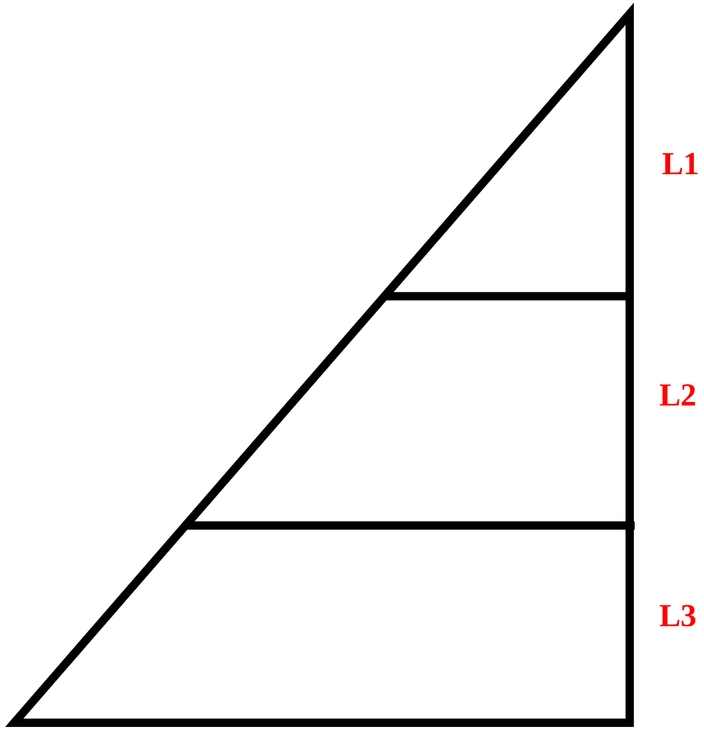


Design principles of sliding gates: -

There are two methods used for designing gates: -

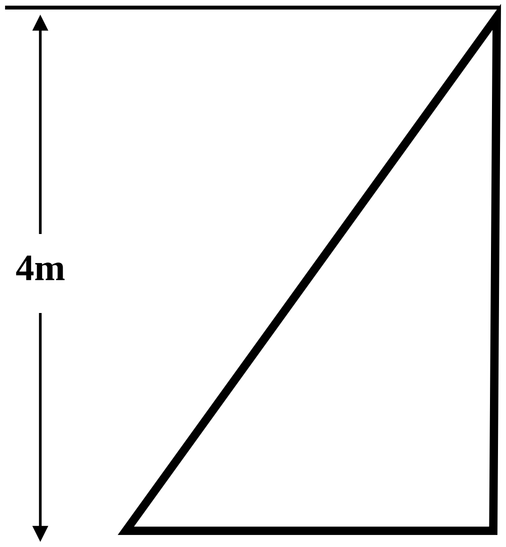
1. Divide the area of load to equal areas.
2. Divide the height of the gate to equal spaces.





Example: Using the first method. Design a 4 m height of the gate with 3 m clear span.

Solution:
Assume 3 division of the pressure area



$$A_1 = A_2 = A_3 = \frac{1}{3}A$$

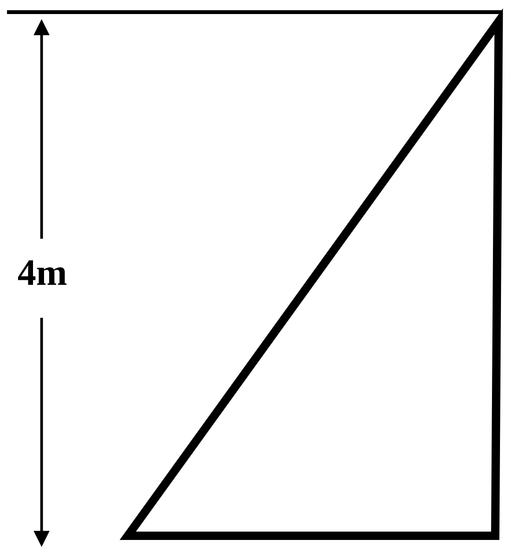
$$A = \frac{1}{2}\gamma H^2 = \frac{1}{2} * 1 * 4^2 = 8\ ton/m$$

$$A_1 = A_2 = A_3 = \frac{1}{3}A = \frac{1}{3}(8) = 2.67\ ton/m$$

$$A_1 = \frac{1}{2}\gamma {y_1}^2 = 2{,}67 \rightarrow\ y_1 = 2.31\ m$$

$$A_1 = \frac{1}{2}\gamma {y_1}^2 = 2{,}67 \rightarrow \; y_1 = 2.31\; m$$

$$A_1 + A_2 = \frac{1}{2}\gamma {y_2}^2 = 5.34 \rightarrow \; y_2 = 3.27m$$

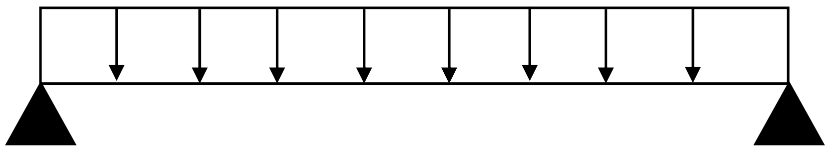


h_2= 3.27 – 2.31= 0.96 m

h_3= 4 – 3.27= 0.73 m

Each joist will carry a load equal to w=2.67 ton/m for simply support beam: -

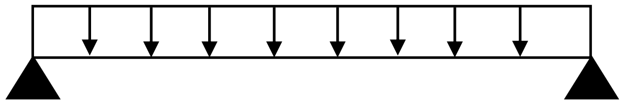
$$M = \frac{WL^2}{8} = \frac{2.67\,(3)^2}{8} = 3\; ton\;.m$$



This moment is the same on any of the three joists.

If the table of British system used (inch and Ib) Then: -

$$M = \frac{WL^2}{8} = \frac{2.67\,(3)^2}{8} = 3\ ton\,.m$$



$B.M_B = B.M_{SI} * 88000$

$= 3 * 88000$

$= 264000$ in. Ib

Use for steel f_s = 20000 Ib/in^2

Where f_s = working stress

$$Z = \frac{B.M}{f_s}$$

Z = Modulus section

$$Z = \frac{264000}{20000} = 13.2\ in^3$$

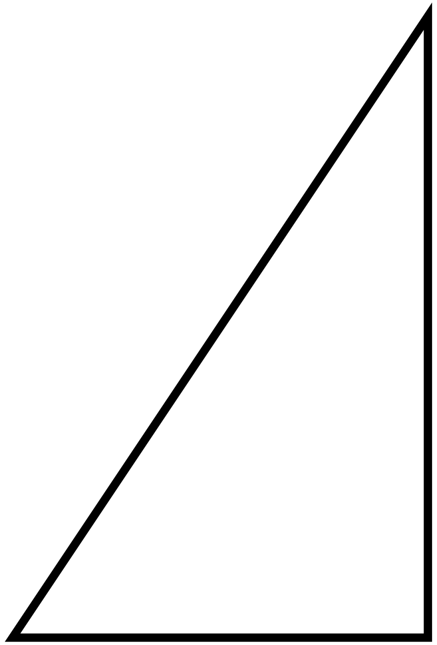
If (I - Beam) is used the dimensions: $(6'' X\ 4\frac{1}{2}'')$

Total weight can be considered as: - W=2.67 ton/m

Moment for continuous plate:

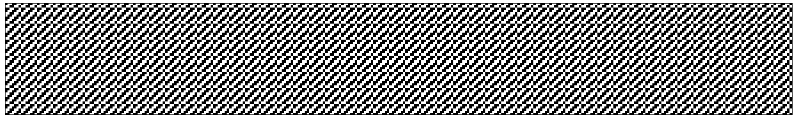
$$M = \frac{WL^2}{10} = \frac{2.67 * 1 * 1.25}{10} = 0.33\ ton\ .m$$

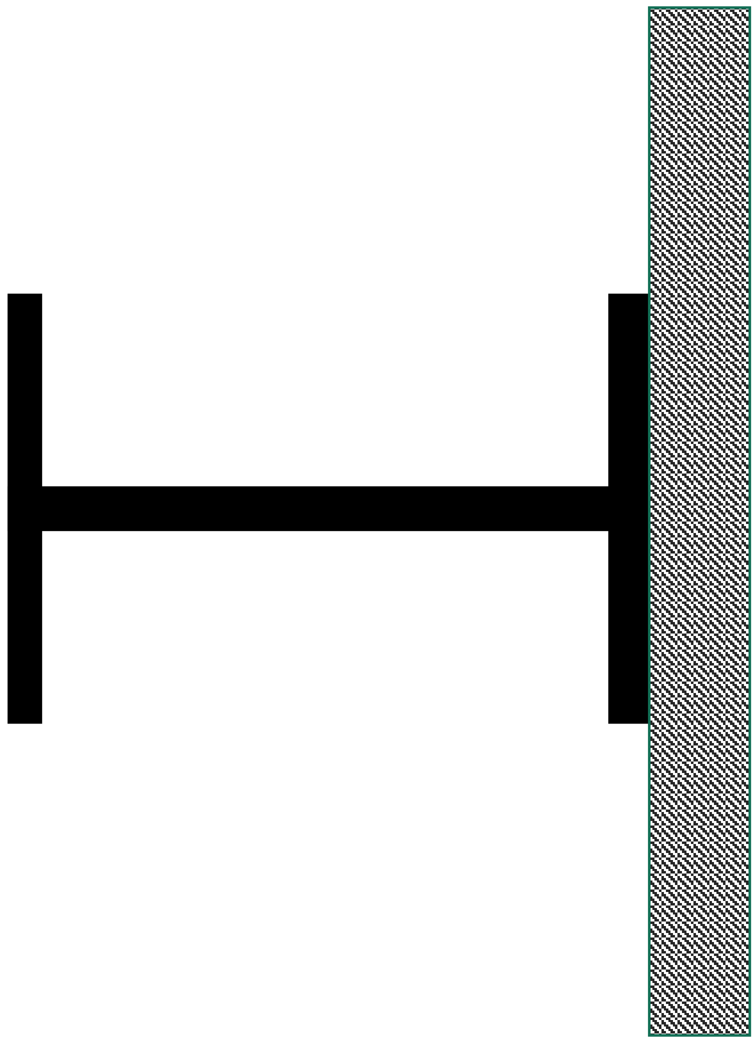
$$Z = \frac{B.M}{f_s} = \frac{0.33 * 88000}{20000} = 1.47\ in^3$$



$$Z = \frac{I}{C} = \frac{\frac{bd^3}{12}}{\frac{d}{2}} = \frac{bd^2}{6}$$

$$1.47 = \frac{39.3\ (d^2)}{6} \rightarrow d = 0.47\ \approx 0.5\ in$$





CULVERTS

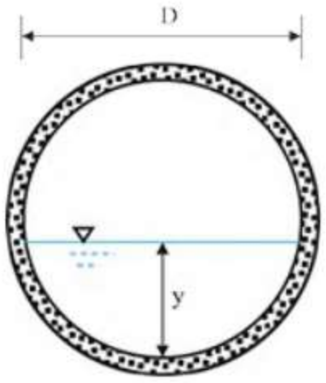
A culvert is a conduit under an embankment that transports stream water from one side of the embankment to the other side through hydraulic inlet, outlet, and barrel control.

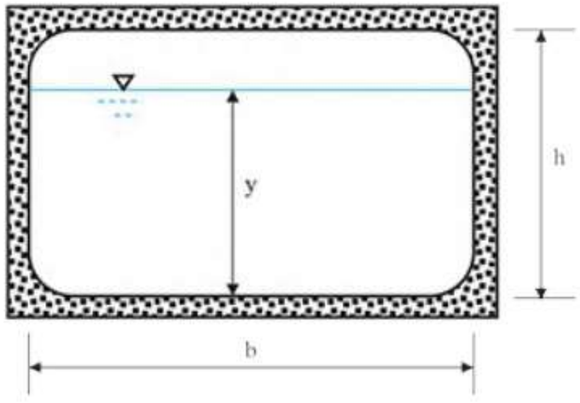
The factors which combine to determine the nature of flow in a pipe or box culverts are: -

- Slope
- Size
- Length
- Shape
- Roughness of the barrel
- Inlet and Outlet geometry

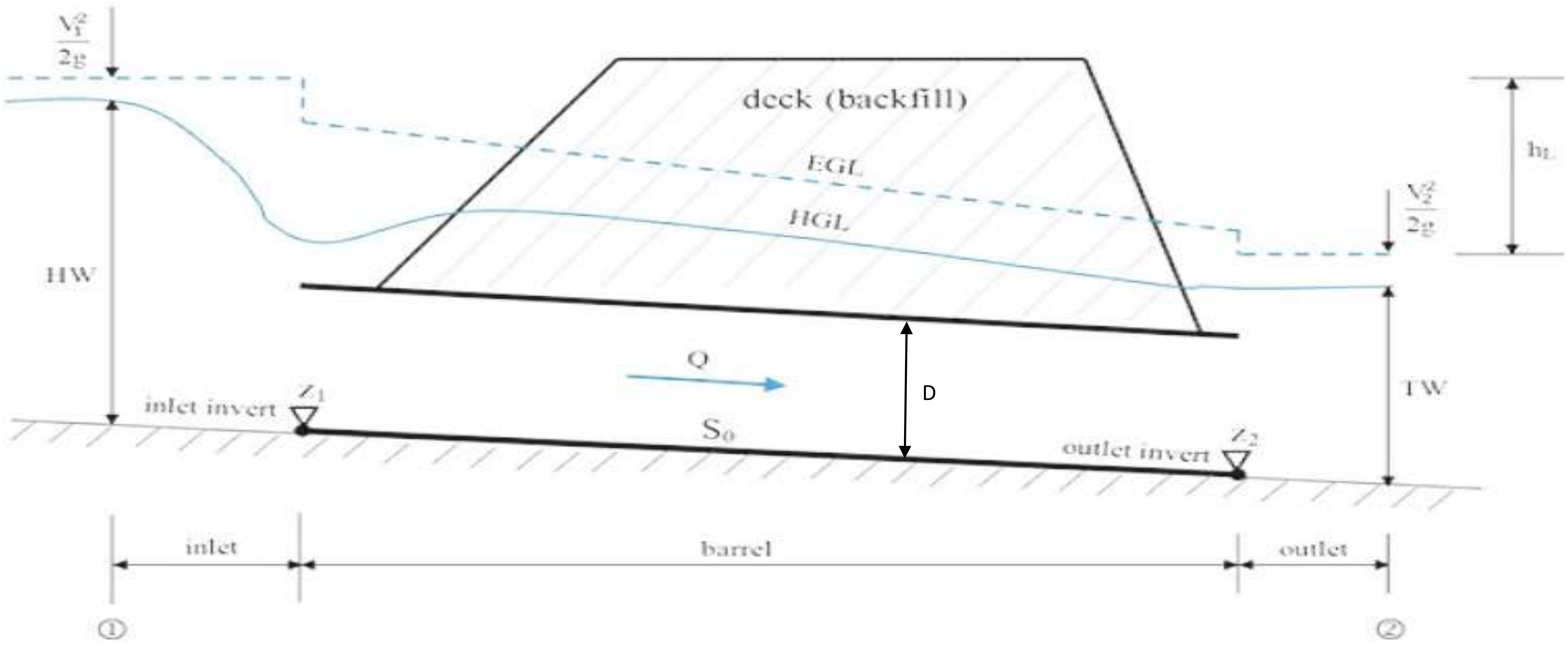
Types of culverts:

- A culvert consists of four parts, namely inlet, barrel, outlet, and deck. Water flows through the inlet into the barrel and exits at the outlet.
- Most commonly, the barrel has a circular or rectangular shape.





The figure below shows the notations for full flow condition



❖ Pipe Culverts

If the flow is full flow, Manning's Equation is used to calculate the friction loss along the pipe,

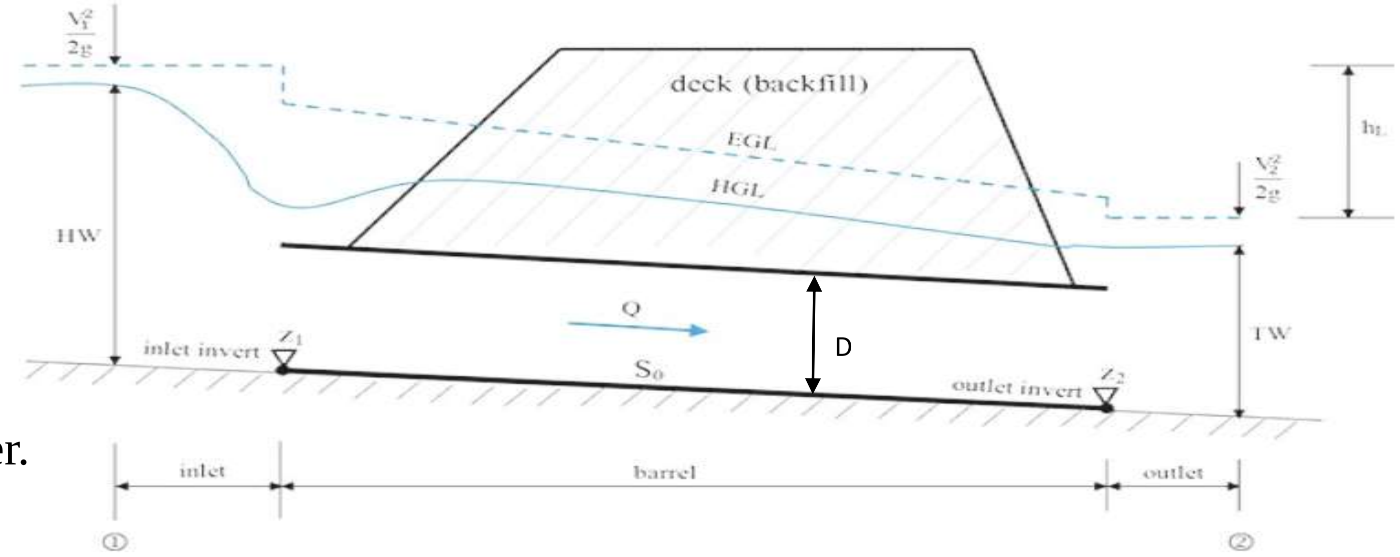
$$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

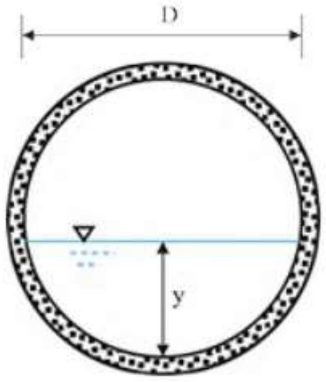
$$h_f = S * L = \frac{2gn^2L}{R^{\frac{4}{3}}} * \frac{V^2}{2g}$$

$$R = \frac{D}{4}$$

where, h_f is the head loss, , D is the pipe diameter.

- The Entrance loss $h_e = k_e \frac{V^2}{2g}$
- The Exit loss $h_o = k_o \frac{V^2}{2g}$





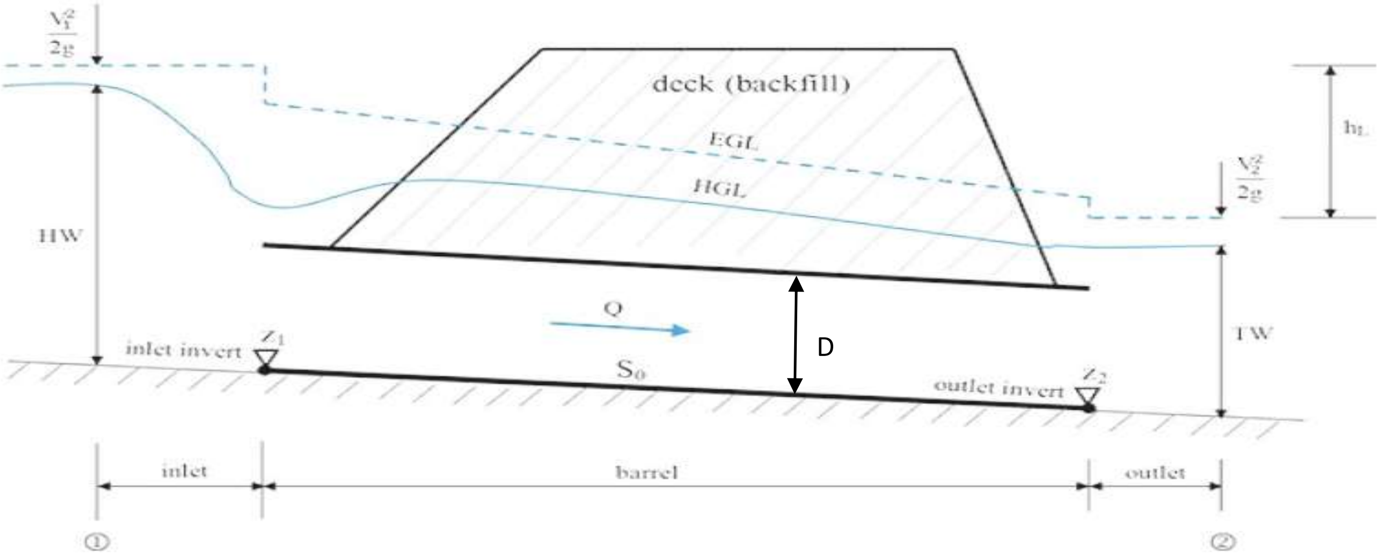
The effective head producing the discharge through the culvert is (h_L), which is the difference between the upstream and downstream energy levels.

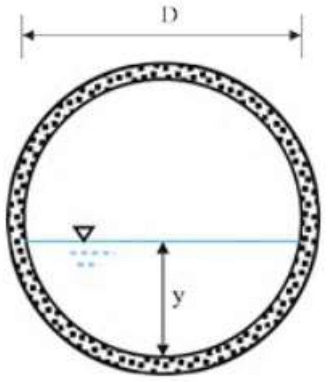
$$H_w + L\ sin\theta = T_w + h_L$$

$$H_w + L\ sin\theta = T_w + h_e + h_f + h_o$$

$$H_w - T_w + L\ sin\theta = k_e\frac{V^2}{2g} + \frac{2gn^2L}{R^{\frac{4}{3}}} * \frac{V^2}{2g} + k_o\frac{V^2}{2g}$$

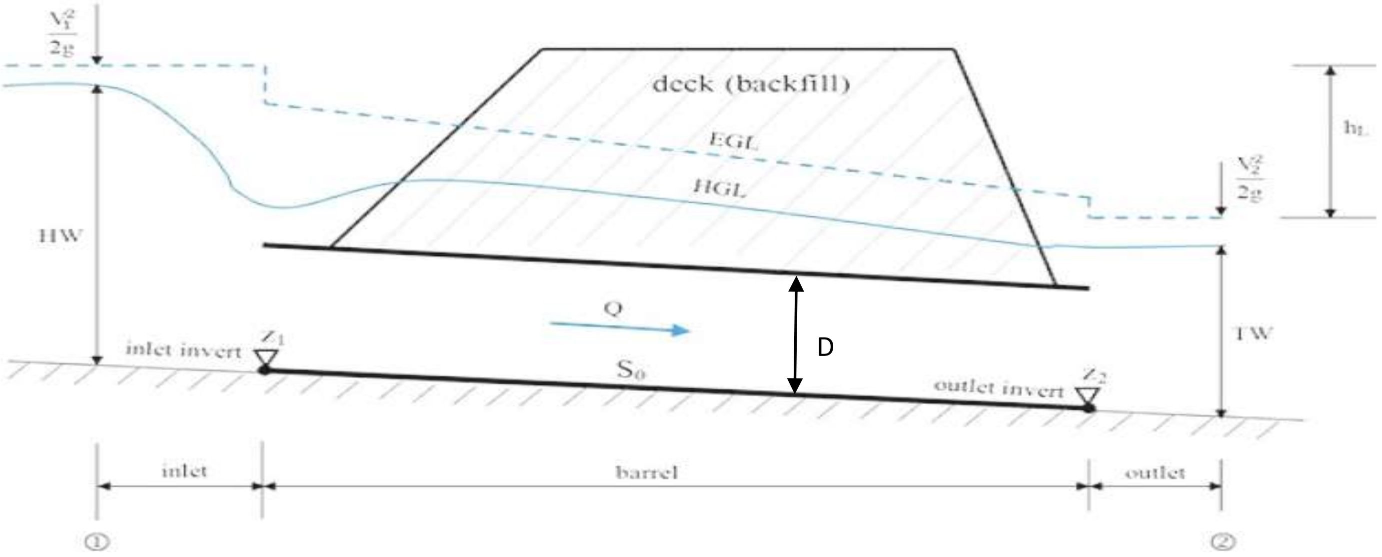
$$(H_w - T_w + L\ sin\theta) = (k_e + \frac{2gn^2L}{R^{\frac{4}{3}}} + k_o)\frac{V^2}{2g}$$



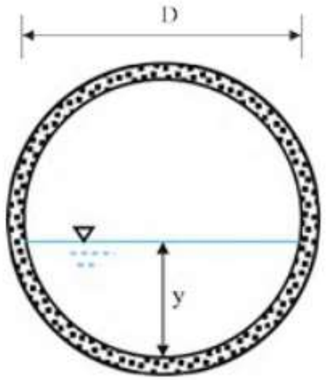


The common value of k_e for inlet is given by U.S.B.R (US Bureau of Reclamation)

- 0.5 for square edge inlets with vertical walls.
- 0.1 for rounded inlets.
- 0.15 for grooved ended pipes.



The value of k_o is taken equal to 1.0 for most outlets.



The value of ($\underline{L\ sin\theta}$) could be neglected when the ground close to flat (IRAQ).

❖ Box Culverts

The R.C. Box culverts are used to pass a flow under a highway, railway or any other ground infrastructure and should keep the head loss at minimum.

It is same as the pipe culvert as the flow is assumed to be full and discharge is a function of the difference in head between head water and tail water. However, the dimension of the box culvert can be estimated by the following equation:

$$\Delta H = \left(k_e + \frac{2gn^2L}{R^{\frac{4}{3}}} + k_o\right)\frac{Q^2}{2gA^2}$$

❖ Box Culverts

$$\Delta H = \left(k_e + \frac{2gn^2L}{R^{\frac{4}{3}}} + k_o\right)\frac{Q^2}{2gA^2}$$

where, ΔH is the difference in head between head water and tail water.

k_e is the inlet loss coefficient. (0.5 for square entrance and 0.16 for bell mouth and rounded entrance)

k_o is the outlet loss coefficient. (1.0 for most cases)

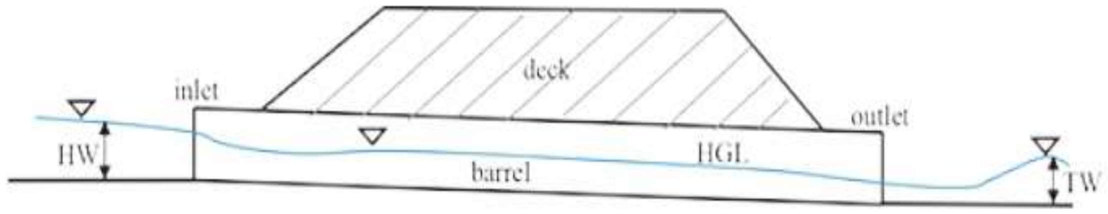
R is the hydraulics radius of the culvert.

L is the length of the culvert.

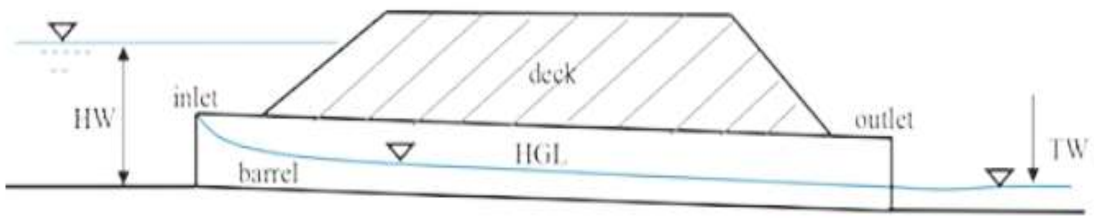
n is the Manning's coefficient.

- **Inlet-Control Conditions**

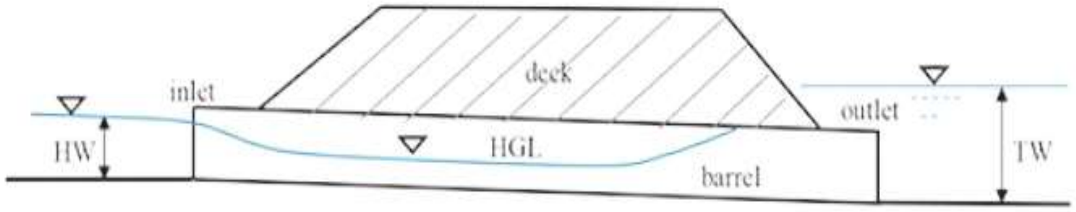
For a culvert, if an open channel flow occurs just downstream of its entrance and maintains itself in most portion of the barrel, the culvert has an inlet-control condition. The discharge through the barrel is equal to the maximum flow rate that the inlet allows; it is also smaller than the maximum flow rate that the outlet allows. Such a condition may exist for situations in which the inlet and outlet are either unsubmerged or submerged.



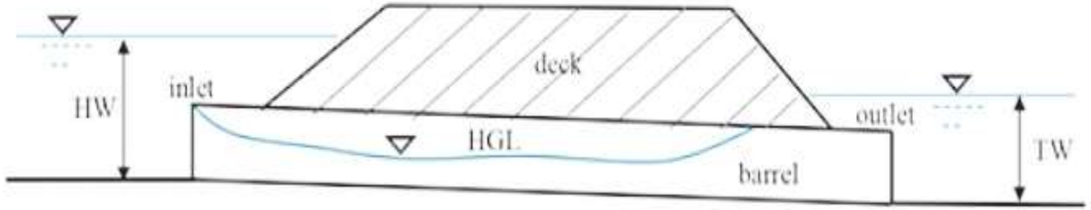
(a)



(c)



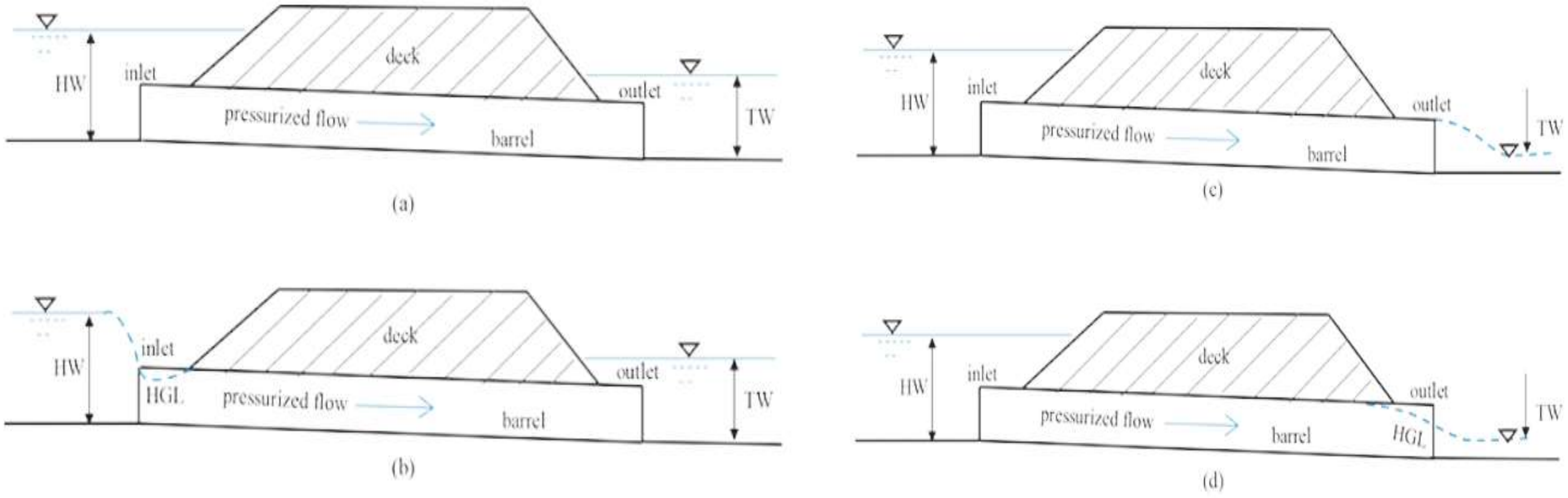
(b)



(d)

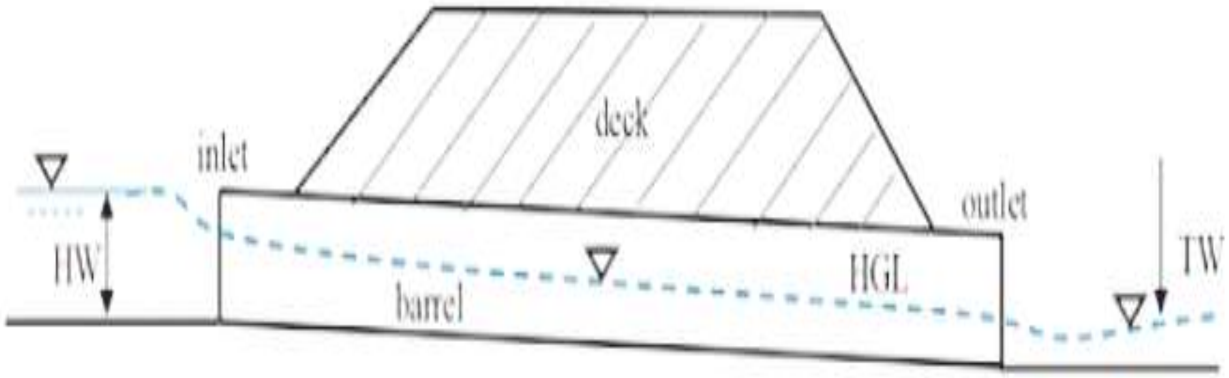
➢ **Outlet-Control Conditions**

For a culvert, an outlet-control condition exists if the maximum flow rate allowed by the inlet is larger than the maximum flow rate allowed by the outlet. That is, the discharge through the barrel is controlled by the outlet. Such a condition may exist for situations that the inlet and outlet are either submerged or unsubmerged.



➢ Outlet-Control Conditions

For a culvert, an outlet-control condition exists if the maximum flow rate allowed by the inlet is larger than the maximum flow rate allowed by the outlet. That is, the discharge through the barrel is controlled by the outlet. Such a condition may exist for situations that the inlet and outlet are either submerged or unsubmerged.



(c)

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