22

Outlet Works Through Dams and River Intakes

22.1. Sluicesways or Dam Outlets

The most of the water which is stored in a reservoir for irrigation, water supply or power generation purposes, is stored below the spillway crest level. The spillway is provided at normal pool level, such that the floods are discharged safely above the spillway. But, in order to draw water from the reservoir as and when needed, for irrigation, water supply, navigation or power purposes, it is absolutely necessary that outlet works are provided either through the body of the dam or adjacent to it through some hill side at one end of the dam. This water may be discharged into the downstream channel below the dam or may be transported at distances where required (to some power house, etc.) through pipes or canals. The opening, *i.e.* a pipe or a tunnel provided for this withdrawal of water is known as a *dam outlet or a sluiceway.*

The outlets of most of the dams consist of one or more sluiceways with their inlets at about minimum pool level. In most of the cases, a number of outlets are generally provided at different levels ; as a single large capacity outlet may be structurally unsatisfactory or difficult to construct. Moreover, by having more number of smaller capacity outlets, greater control on discharge can be obtained, which can be varied as and when desired. Hence, when wider fluctuations in the demand are anticipated, it is always, advisable to go in for more number of small capacity sluiceways, although it may prove to be somewhat costlier as compared to a few large capacity sluiceways.

A sluiceway is a pipe or a tunnel, circular or rectangular in section, that passes through the body of the dam or through some hillside at one end of the dam and discharges into the stream below. For masonry or concrete gravity dams, these sluiceways can easily pass through the body of the dam or the spillway (Fig. 22.1) ; but for earthen dams, it is preferred to place them outside the limits of the embankments. But, if no such adjacent hill site is available and there is no alternative left but to pass the sluiceway through the dam, *projecting collars* must be provided so as to reduce seepage along the outside of the conduit as shown in Fig. 22.2. The seepage is thus, reduced by increasing the length of the seepage path by at least 25 per cent.

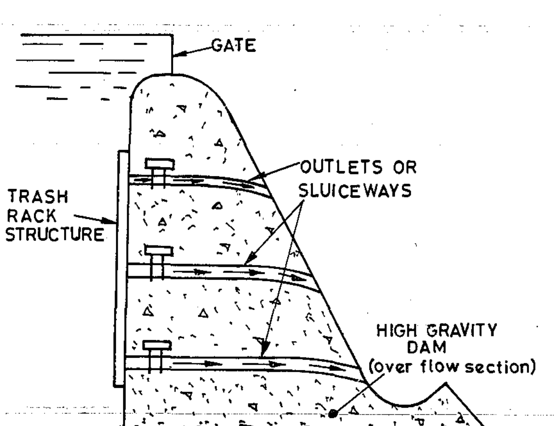


Fig. 22.1. Typical outlet arrangements through a concrete gravity dam.

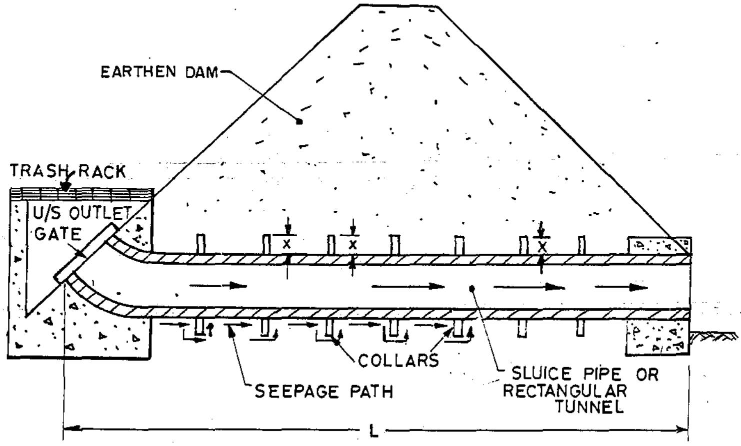


Fig. 22.2. Typical outlet arrangement through an earthen dam.

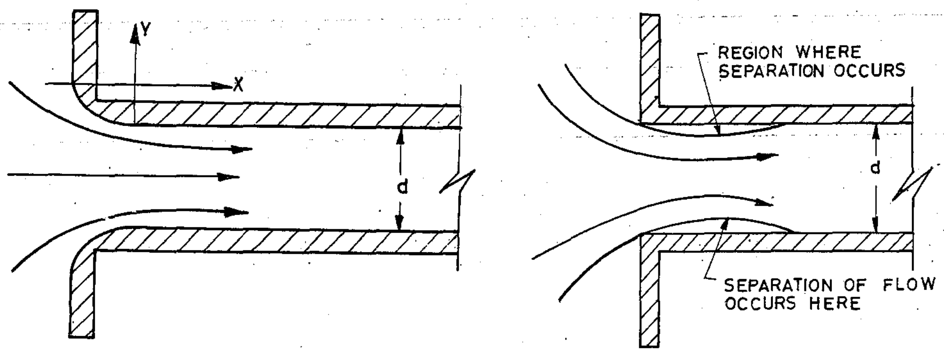
In Fig. 22.2, if L is the total length of sluiceway from upstream to downstream, the length of the seepage path will be given as :

$$= L + (2x)N$$

where x is the projection of each collar ; and
N is the number of collars.

The increase in seepage path, *i.e.* $2 \cdot N \cdot x$ must generally be greater than $L/4$.

The interior of sluiceway tunnel or pipe, must be smooth, without any projections or cavities. The projections or cavities, etc. if at all present, may cause separation of flow from the boundary of the conduit, causing development of negative pressures and the consequent danger of cavitation*. The entrance of the sluiceway is also very impor-



(*a*) Square edged entrance (*b*) Bell-mouthed entrance.

Fig. 22.3

tant, since a square edged entrance [Fig. 22.3 (*a*)] is likely to cause more separation of flow and more danger of consequent cavitation as compared to a bell mouthed or some other type of entrance. There have been several such cases where large scale damages have occurred due to cavitation in the vicinity of square-edged entrances. A bell-mouthed entrance [Fig. 22.3 (*b*)] is much better and superior to any other type, and the

* Explained earlier in Chapter 21.

extra cost involved in shaping this entrance is usually justified except for small projects under low heads.

The shape of the bell mouth is generally elliptical, and Douma has suggested the following equations for it :

(*i*) *For circular conduits.*

$$4X^2 + 44.4\,Y^2 = d^2 \qquad \text{...(22.1)}$$

where X, Y are the co-ordinates of any point on the curve as defined in Fig. 22.2 (*b*) ; and
d is diameter of the circular conduit.

(*ii*) *For rectangular tunnels or conduits*

$$X^2 + 10.4\,Y^2 = d^2 \qquad \text{...(22.2)}$$

where X and Y have same meaning as above ; and
d is the width or height of the conduit, depending on whether the sides or top and bottom curves are being designed.

22.2. Hydraulics of Outlet Works

The discharge passing through the dam outlet can be calculated easily, be using the equation :

$$Q = C_d \cdot A\sqrt{2gH} \qquad \text{...[22.3(a)]}$$

where Q = Discharge
A = Area of outlet sluice
H = Differential head causing flow, *i.e.* the difference of u/s and d/s water levels.
C_d = Coefficient of discharge, whose value depends upon various factors such as the type of gate and trash rack provided, conduit friction, transitions etc.

For precise designs, the total head losses encountered in the outlet conduits may be calculated. These losses include those caused by trash racks, conduit entrance, conduit friction, gates and valves, transitions and bends. The entrance loss may be taken as $0.5\,\frac{V^2}{2g}$ for square edged entrance, and equal to $0.04\,\frac{V^2}{2g}$ for bell mouthed entrance, where V is the flow velocity through the conduit. Head losses caused by conduit friction may be calculated by standard pipe formulas, such as :

$$h_L = \frac{f' \cdot LV^2}{2gd}$$

or

$$h_L = \frac{n^2 \cdot V^2 \cdot L}{R^{4/3}}$$

The head loss through the gate depends upon the type of gate and valve provided. A loss of about $0.2\,\frac{V^2}{2g}$ may be taken for fully open gate and butterfly valves. This head loss is taken as nil for ring follower gates. The head loss through the trash rack depends upon the velocity, and may be taken as shown in Table 22.1.

Table 22.1. Head Loss through Trash Racks

Velocity through trash rack in m/sec	*Head loss in metres*
0.15	0.006
0.30	0.03
0.45	0.09
0.62	0.15

The net effective head which is responsible for flow, should then be taken as $= H_{eff} =$ Differential head (H) – Head losses. The discharge can then be calculated easily, using

$$Q = A\sqrt{2g \cdot H_{eff}} \qquad \text{...[22.3 (b)]}$$

22.3. River Intakes

When water is withdrawn through a conduit from a river or a reservoir independently, and as such the entrance of the conduit is not an integral part of the dam or any other related structure, then an intake structure must be constructed at the entrance of the conduit. An intake structure may vary from a simple concrete block supporting the end of the conduit pipe to huge concrete towers, depending upon various factors such as, reservoir characteristics, capacity and discharge requirements, climatic conditions, etc. The basic function of an intake structure is to help in safely withdrawing water from the reservoir over a predetermined range of pool levels, and thus to protect the conduit from being damaged or clogged by ice, trash, debris, waves, etc.

Various types of intake structures are discussed below :

(1) **Simple Submerged Intakes.** A simple submerged intake consists of a simple concrete block, or a rock filled timber crib supporting the starting end of the withdrawal pipe, as shown in Figs. 22.4 (*a*) and (*b*).

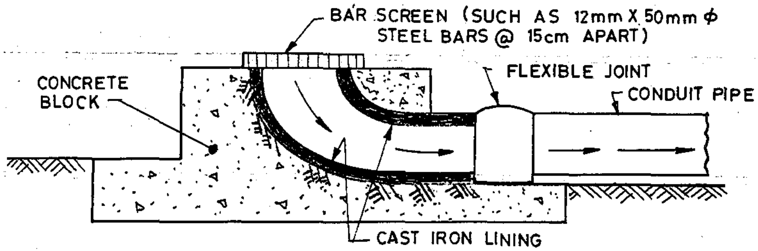


Fig. 22.4. (*a*) Simple concrete block submerged intake.

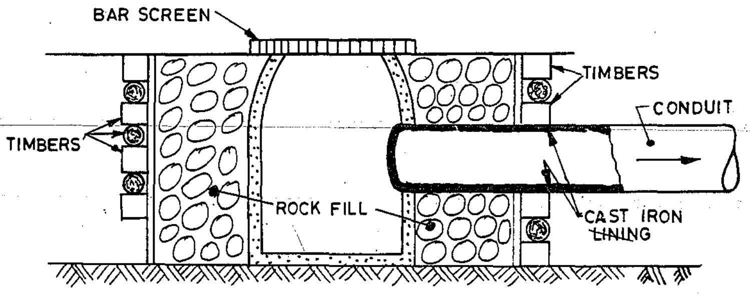


Fig. 22.4. (*b*) Rock-filled timber-crib submerged intake.

Such intake structures should be placed in the river or the reservoir at a place where they may not get buried under the sediment. These submerged intakes are very economical and donot obstruct navigation, and are, therefore, widely used on small works, and are particularly suitable as water-supply intakes from small rivers*. They are sometimes used as intakes to sluiceways of earthen dams with hydraulically operated gates for flow regulation. These intakes are not used on bigger projects as their main disadvantage is the fact that they are not easily accessible for repairing of their gates, etc.

(2) **Intake Towers.** Intake towers are generally used on large projects and where there are large fluctuations of water level. Openings at various levels, called *ports* are generally provided in these concrete towers, which may help in regulating the flow through the towers and permit some selection of the quality of water to be withdrawn. If the ports are submerged at all levels, then there is no problem of any clogging or damage by ice or debris, etc. However, the level of the lowest port should be high enough above the reservoir bed, so that the sediment is not drawn into them. There are two major types of intake towers, *viz.*

(*i*) Wet intake towers ; and

(*ii*) Dry intake towers.

(*i*) *Wet intake towers.* A typical section of a wet intake tower is shown in Fig. 22.5 (*a*). It consists of a concrete circular shell filled with water upto the reservoir level, and has

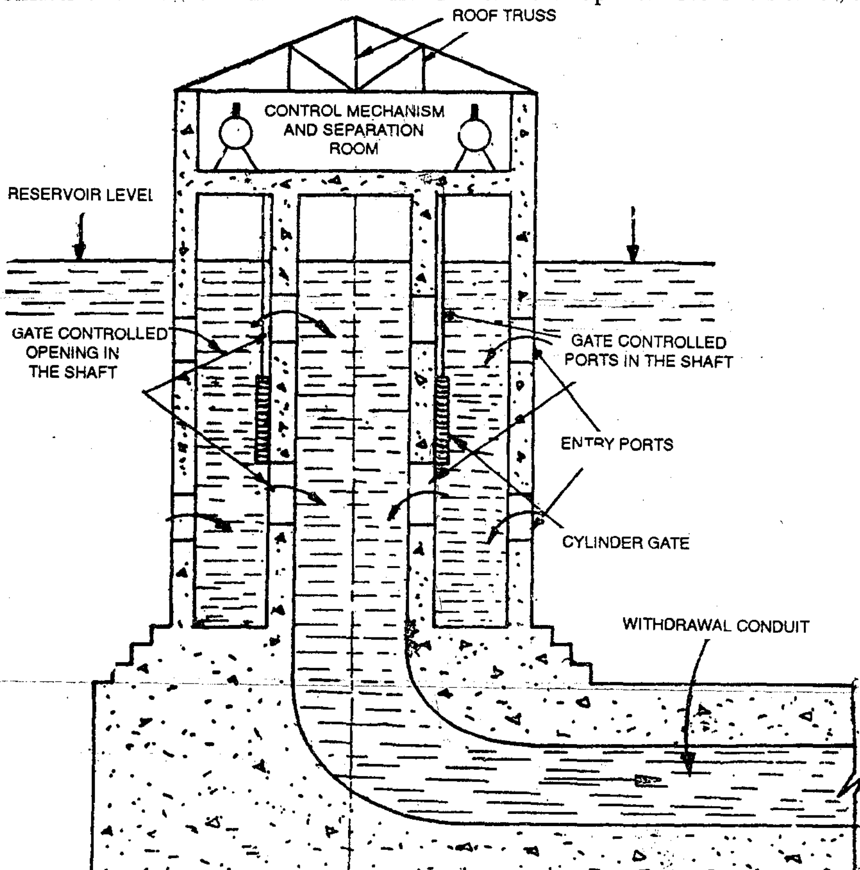


Fig. 22.5. (*a*) Wet Intake tower.

* More detailed description of river and canal intakes is given in "Water Supply Engineering" by the same author.

a vertical inside shaft which is connected to the withdrawal pipe. Openings are made into the inside shaft also. Gates are usually placed on the shaft, so as to control the flow of water into the shaft and the withdrawal conduit.

(*ii*) *Dry Intake Towers.* The essential difference between a wet intake tower and a dry intake tower is that, whereas in a wet intake tower, the water enters from the entry ports into the tower and then it enters into the conduit pipe through separate gate controlled openings ; in a dry intake tower, the water is directly drawn into the withdrawal conduit through the gated entry ports as shown in Fig. 22.5 (*b*). *A dry intake tower will, therefore, have no water inside* the tower if its gates are closed, whereas the

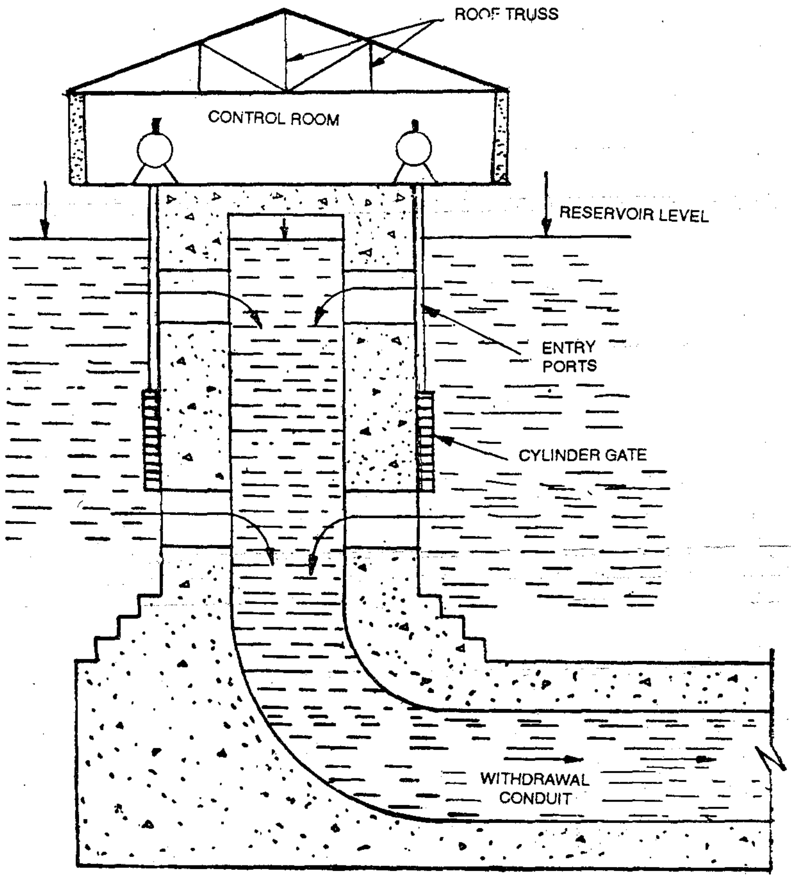


Fig. 22.5 (*b*). Dry Intake Tower.

wet intake tower will be *full of water even if its gates are closed.* When the entry ports are closed, a dry intake tower will be subjected to additional buoyant forces and hence, must be of heavier construction than the wet intake towers. However, the dry intake towers are useful and beneficial in the sense that water can be withdrawn from any selected level of the reservoir by opening the port at that level.

Intake towers are huge structures standing in the river, and hence should be located so as not to interfere with navigation, and must be properly designed so as to withstand the worst possible combination of various forces, such as hydrostatic pressures, wind and earthquake forces, and forces caused by waves, ice and debris, etc.

22.4. Trash Racks

The entrances to intakes and dam outlets are generally covered with trash racks so as to prevent the entry of debris, ice, etc. into the conduit. These racks are generally nothing but bar screens, made from steel bars spaced at 5 to 15 cm centre to centre (in both directions) depending upon the maximum size of the debris required to be excluded from entering the conduit. The velocity of flow through the trash rack is kept low (generally less than 0.62 m/sec), so as to minimise losses. This is sometimes accomplished by constructing the trash rack in the form of a half cylinder, as shown in Fig. 22.6.

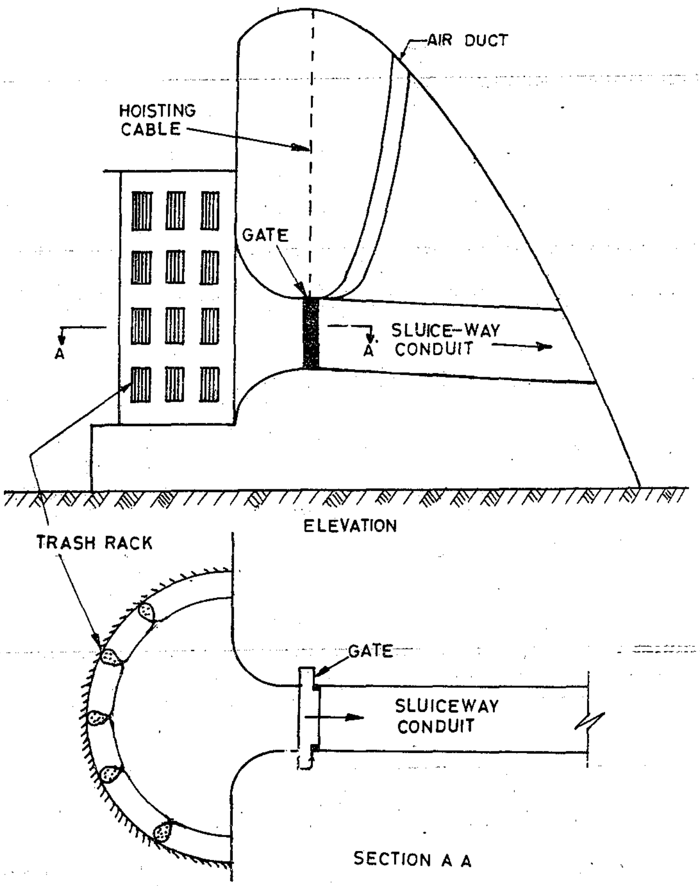


Fig. 22.6. Half Cylinder-Trash rack and Tractor gate installation.

The floating debris, ice, etc. which are stopped by the racks and thus get collected on them, are removed by manual labour when required ; but on large projects, where much debris are expected, automatic power-driven racks are used. Steam or electrically heated racks are preferred in cold countries, so as to prevent ice formation on trash racks.

PROBLEMS

1. (*a*) What is meant by a 'Dam sluice' ? Why are such sluices necessary in dam construction ?

(*b*) Show with neat sketches, the provision of sluiceways in

(*i*) an earth dam.

(*ii*) a concrete gravity dam.

2. Write short notes on :

(*i*) Sluiceways in dams.

(*ii*) River intakes.

(*iii*) Trash Racks.