14

Cross Drainage Works

14.1. Introduction

A cross drainage work is a structure which is constructed at the crossing of a canal and a natural drain, so as dispose of drainage water without interrupting the continuous canal supplies. In whatever way the canal is aligned, such cross drainage works generally become unavoidable. In order to reduce the cross drainage works, the artificial canals are generally aligned along the ridge line called water-shed. When once the canal reaches the watershed line, cross drainage works are generally not required, unless the canal alignment is deviated from the watershed line. However, before the watershed is reached, the canal which takes off from the river has to cross a number of drains, which move from the watershed towards the river, as shown in Fig. 14.1. At all such crossings c_1, c_2, c_3, c_4, etc. cross drainage works are required.

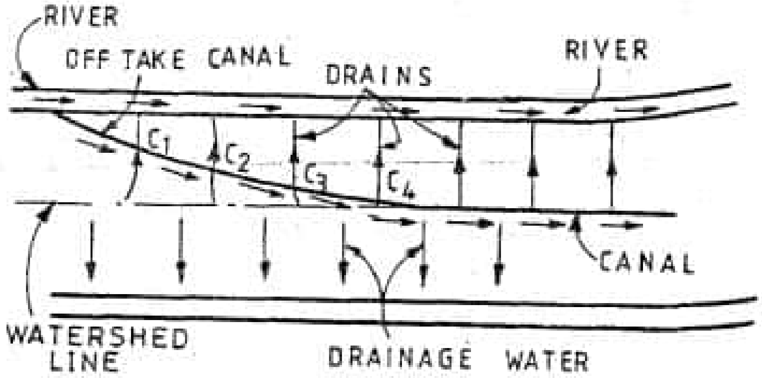

Fig. 14.1

A cross drainage work is generally a costly construction and must be avoided as far as possible. Since a watershed canal* crosses minimum number of drains, such an alignment is preferred to a contour canal which crosses maximum number of drains. The number of cross drainage works may also be reduced by diverting one drain into another and by changing the alignment of the canal, so that it crosses below the junction of two drains.

14.2. Types of Cross-drainage works

The drainage water intercepting the canal can be disposed of in either of the following ways :

(1) By passing the canal over the drainage. This may be accomplished either through (*i*) an *aqueduct;* or through a (*ii*) *syphon-aqueduct.*

(2) By passing the canal below the drainage. This may be accomplished either through (*i*) a *super-passage;* or through a (*ii*) *canal syphon* generally called a *syphon.*

(3) By passing the drain through the canal, so that the canal water and drainage water are allowed to intermingle with each other. This may be accomplished through (*i*) a *level crossing*; or through (*ii*) *inlets and outlets.*

* Also called a ridge canal.

All these different types of cross drainage works are described below in details.

14.2.1. Aqueduct and Syphon Aqueduct. In these works, the canal is taken over the natural drain, such that the drainage water runs below the canal (see Fig. 14.2) either freely or under syphoning pressure. *When the HFL of the drain is sufficiently below the bottom of the canal, so that the drainage water flows freely under gravity, the structure is known as an Aqueduct (Fig. 14.3). However, if the HFL of the drain is higher than the canal bed and the water passes through the aqueduct barrels under syphonic action, the structure is known as Syphon Aqueduct (See Fig. 14.4).*

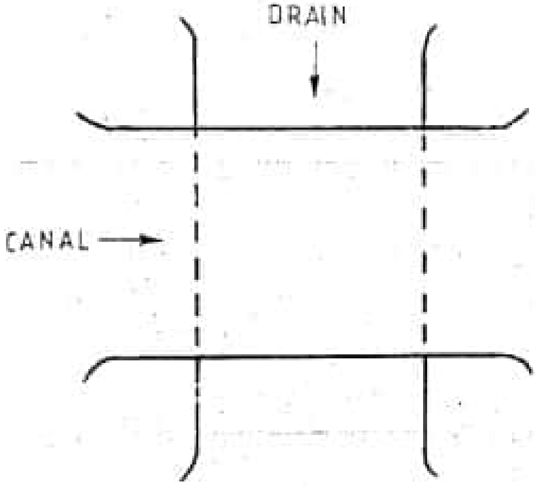

Fig. 14.2. Canal taken over the drain in an aqueduct or a syphon aqueduct (Line Plan of Crossing).

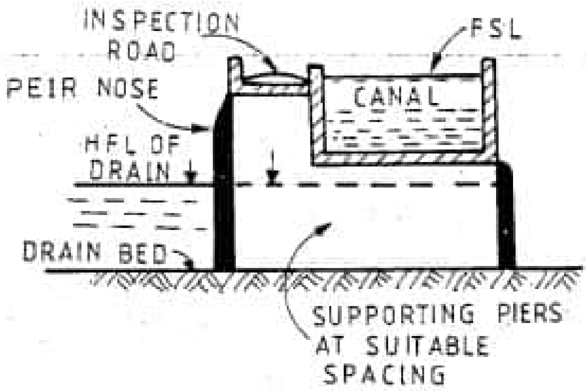

Fig. 14.3. Typical cross-section of an aqueduct.

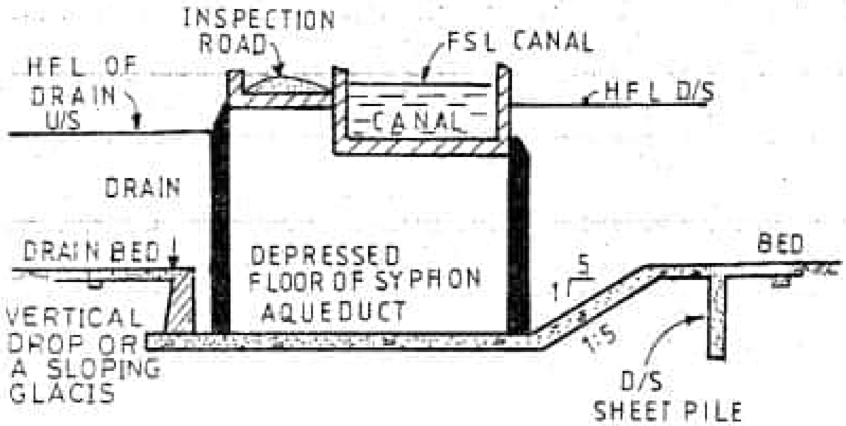

Fig. 14.4. Typical cross-section of a Syphon Aqueduct.

In this type of works, the canal water is taken across the drainage in a trough supported on piers. An inspection road is generally provided alongwith the trough, as shown. An aqueduct is just like a bridge except that instead of carrying a road or a railway, it carries a canal on its top. An aqueduct is provided when sufficient level difference is available between the canal and the natural drainage, and canal bed level is sufficiently higher than the torrent level. In Sirsa, a city near Roper in Punjab, an excellent aqueduct having 20 spans of about 13 m each has been constructed to carry a canal having bed width of 28 metres and a discharge of about 360 cumecs, with a torrent discharge of about 4300 cumecs. A difference of 3.3 metres was available between the bed level of canal and that of torrent in this case.

In the case of a syphon aqueduct, the drain bed is generally depressed and provided with pucca floor, as shown in Fig. 14.4. On the upstream side, the drainage bed may be joined to the pucca floor either by a vertical drop (when drop is of the order of 1 m) or by a glacis of 3 : 1 (when drop is more). The downstream rising slope should not be steeper than 5 : 1.

In this type of cross-drainage works (*i.e.* when the canal is taken over the drainage), the canal remains open to inspection throughout, and the damage caused by floods are rare. However, during heavy floods, the foundations of the work may be susceptible to scour; or waterway of the drain may get choked with debris, trees, etc.

14.2.2. Super-passage and syphon. In these works, the drain is taken over the canal such that the canal water runs below the drain (Fig. 14.5) either freely or under

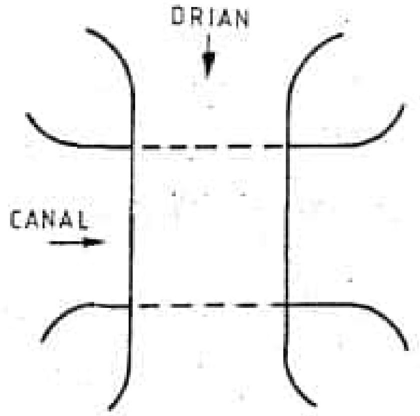

Fig. 14.5. Drain taken over the canal in a Superpassage or in a Syphon. (Line Plan of Crossing)

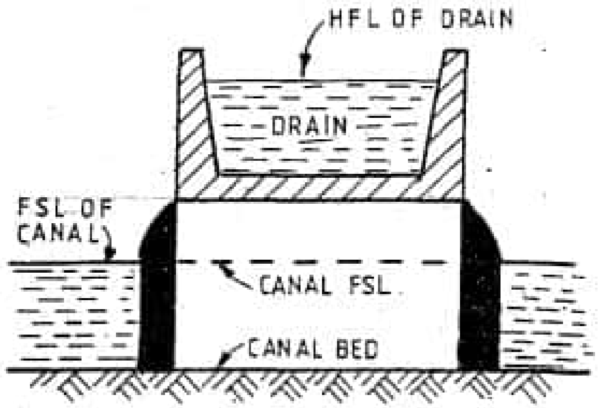

Fig. 14.6. Typical cross-section of a Superpassage.

syphoning pressure. *When the FSL of the canal is sufficiently below the bottom of the drain trough, so that the canal water flows freely under gravity, the structure is known as a Superpassage (Fig. 14.6). However, if the FSL of the canal is sufficiently above the bed level of the drainage trough, so that the canal flows under syphonic action under the trough, the structure is known as a canal syphon or a Syphon (Fig. 14.7).*

A superpassage is thus the reverse of an aqueduct, and similarly, a syphon is a reverse of an aqueduct syphon. However, in this type of cross-drainage works, the inspection road cannot be provided along the canal and a separate bridge is required for the road-way. For affecting economy, the canal may be flumed, but the drainage trough is never flumed.

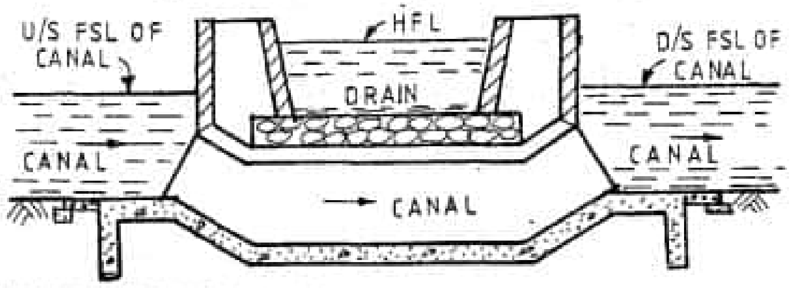

Fig. 14.7. Typical cross-section of a Canal Syphon (generally called a Syphon).

In the case of a syphon, the canal bed is depressed and a ramp is provided at the exit (see Fig. 14.7) so that the trouble of silting is minimised.

14.2.3. Level Crossing. In this type of cross-drainage work, the canal water and drain water are allowed to intermingle with each other. A level crossing is generally provided when a large canal and a huge drainage (such as a stream or a river) approach each other practically at the same level. A typical layout of a level crossing is shown Fig. 14.8.

A regulator is provided across the torrent (drainage) just on the downstream side of the crossing so as to control the discharge passing into the torrent. At the outgoing canal, a regulator is also provided so as control the discharge into the canal. A regulator at the end of the incoming canal is also sometimes required. The arrangement is practically the same as is provided on a canal headworks. This arrangement is generally provided when a huge sized canal crosses a large torrent carrying a very high but short lived* flood discharge. In this arrangement, the perennial drainage discharge is sometimes advantageously used, so as to augment the canal supplies.

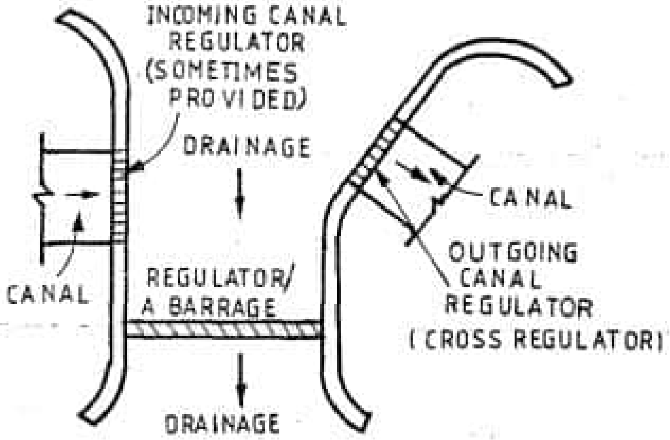

Fig. 14.8. Typical layout of a Level Crossing.

During dry season, when there are no floods, the torrent regulator is generally kept closed and the outgoing canal regulator is kept fully open, so that the canal flows without any interruption. During floods, however, the torrent regulator is opened so as to pass the flood discharge. A beautiful level crossing has been provided in Eastern U.P. under Sarda Sahayak Pariyojna ; where a canal carrying 370 cumecs crosses the Sarda river carrying a high flood discharge of the order of 10,000 cumecs.

14.2.4. Inlets and Outlets. An inlet is a structure constructed in order to allow the drainage water to enter the canal and get mixed with the canal water and thus to help in augmenting canal supplies. Such a structure is generally adopted when the drainage discharge is small and the drain crosses the canal with its bed level equal to or slightly higher than the canal F.S.L. Moreover, for the canal to remain in regime, the drain water must not admit heavy load of silt into the canal. Thus, in an inlet, the drainage water is simply added to the canal.

But, when the drainage discharge is high or if the canal is small, so that the canal section cannot take the entire drainage water, an outlet may sometimes be constructed to escape out the additional discharge at a suitable site, a little downstream along the canal. It is not necessary that the escaped discharge should be equal to the admitted discharge.

Similarly, it is also not necessary, that the number of inlets and outlets should be the same. There may be one outlet for two or three inlets. The outlet is generally combined with some other work where arrangement for escaping is in any case to be provided or may be added at a small extra cost.

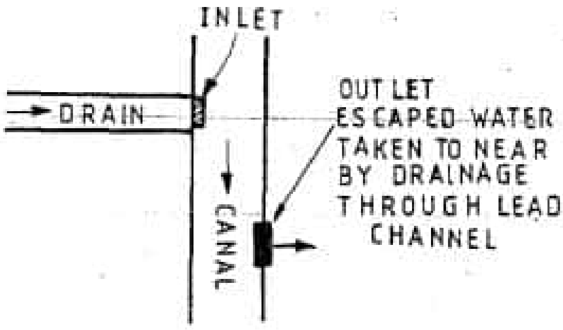

Fig. 14.9. Inlet and outlet (Plan).

An *inlet* essentially consists of an open cut in a canal bank, suitably protected by pitching, to admit the upland drainage

* When floods are intermittent and not continuous.

water into the canal. The bed and sides of the canal are also pitched for a certain distance upstream and downstream of the inlet. Similarly the *outlet* is another open cut in the canal bank with bed and sides of the cut properly pitched. The escaping water from the outlet is taken away by a lead channel to some nearby drain, on the downstream side of the surface outlet.

This type of cross-drainage work (*i.e.* those requiring intermingly of canal water with drainage water) are inferior to aqueduct or superpassage type of works, but they are cheaper. Hence, the aqueduct or superpassage type of works are generally used when high flood drainage discharge is large and continues for a sufficient time. A level crossing is used when the high flood drainage discharge is large but short lived. Inlets and outlets are used when the high flood drainage discharge is small.

14.3. Selection of a Suitable Type of Cross-Drainage Work

The relative bed levels, water levels, and discharge of the canal and the drainage are the primary factors which govern and dictate the type of cross drainage work that may prove to be most suitable at a particular place. For example, if the bed level of the canal is sufficiently above the HFL of the drain, an aqueduct is the first and obvious choice. But, if the bed level of the drain is sufficiently above the canal FSL, a superpassage may be constructed. Similarly, when a canal carries a small discharge compared to the drain, the canal may be taken below the drain by constructing a syphon, as against a syphon aqueduct which is adopted when the drain with smaller discharge can be taken below a large canal.

However, in actual field, such ideal conditions may not be available and the choice would then depend upon many other factors, such as :

(*i*) Suitable canal alignment.

(*ii*) Nature of available foundation.

(*iii*) Position of watertable and availability of dewatering equipment.

(*iv*) Suitability of soil for embankment.

(*v*) Permissible head loss in canal.

(*vi*) Availability of funds.

The relative bed levels of the canal and the drainage may be changed and manipulated by suitably changing the canal alignment, so that the point of crossing is shifted upstream or downstream of the drainage. For example, if the canal alignment is such that sufficient headway is not available between HFL of drain and bed of the canal, (although canal bed is higher) a syphon aqueduct has to be normally adopted. But, however, if other conditions (enumerated above) are not favourable for the construction of a syphon-aqueduct, the canal alignment may be changed so that the crossing is shifted to the downstream where drainage bed is low and thus sufficient headway becomes available for constructing an aqueduct in place of syphon aqueduct. The canal alignment is, therefore, finalised only after finalising the cross drainage works.

Compared to an aqueduct, a superpassage is inferior and should be avoided whenever possible. Similarly, a syphon-aqueduct (unless large drop in drainage bed is required) is superior to a syphon. A level crossing may become inevitable in certain cases. For example, when a large canal crosses a large torrent at almost equal bed levels, a level crossing may remain to be the only answer. An inlet may be adopted when a small drain crosses the canal with its bed level equal to canal FSL or slightly higher than it (*i.e.* bed conditions similar to those favouring the choice of a syphon or a superpassage). Inlets, though cheaper, are not preferred these days because their performance has not been very satisfactory.

14.4. Various Types of Aqueducts and Syphon-Aqueducts

They may be classified into three types depending on the sides of the aqueduct :

Type I. In this type, the sides of the aqueduct are earthen bank with complete earthen slopes. The length of the culvert through which the drainage water has to pass under the canal should not only be sufficient to accommodate the water section of the canal but also the earthen banks of the canal with adequate slopes (Fig. 14.10).

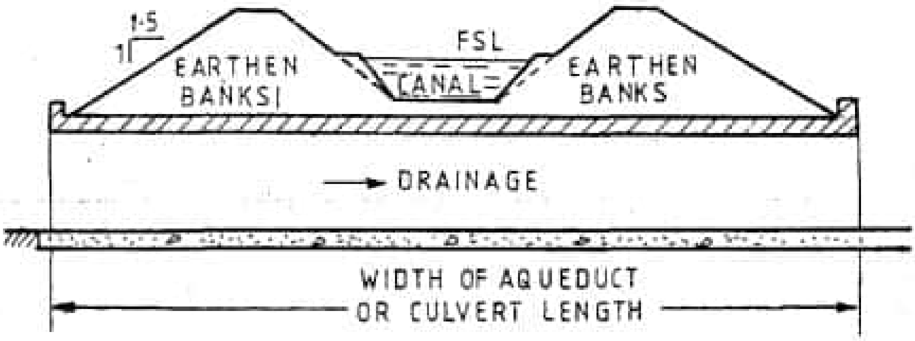

Fig. 14.10. Aqueduct (Type I)

Type II. In this type, the canal continues in its earthen section over the drainage, but the outer slopes of canal banks are replaced by retaining walls, thereby, reducing the length of the drainage culvert by that much extent (Fig. 14.11).

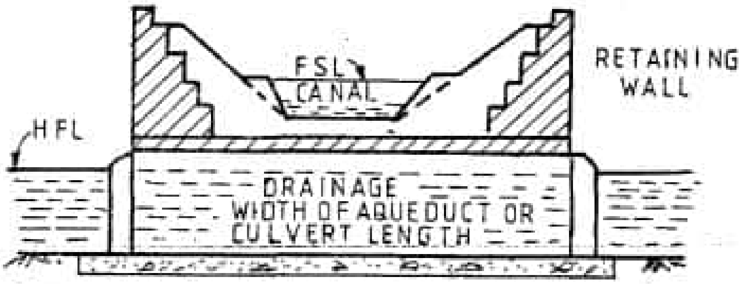

Fig. 14.11. Aqueduct (Type II)

Type III. In this type, earthen section of the canal is discontinued and the canal water is carried in a masonry or a concrete trough. The canal is generally flumed in this case, so as to effect economy in construction.

The culvert length or width of aqueduct is maximum in Type I and minimum in Type III. An intermediate value exists in Type II.

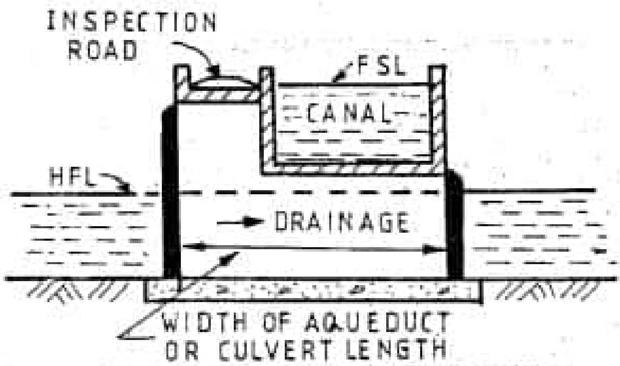

Fig. 14.12. Aqueduct (Type III)

Selection of the Suitable Type. *The selection of a particular type out of three types of aqueducts or syphon-aqueducts lies on the considerations of economy. The cheapest of the three types at a particular place shall be the obvious choice.*

In fact, in all cases, the cost of abutments and wing walls, is independent of the length of the culvert along the canal. In type I, no canal wings are required since the canal section is not at all changed. However, in this type, the width of the aqueduct is the largest. Type I will, therefore, prove economical only where the length of the aqueduct is small and where the cost of bank connections would be large in comparison to the savings obtained from the reduction in the width of the aqueduct.

In type III, the width of the aqueduct is minimum but the cost of bank connections is maximum. This type is, therefore, suitable where the length of the aqueduct is very large and where the cost of bank connections would be small in comparison to the savings obtained from the reduction in the width of the aqueduct.

On the basis of above discussion, it can be concluded that the choice of a particular type depends mainly upon the length of the aqueduct (i.e. the width of the drainage) in relation to the size of the canal. On a very small drain, type III is most economical; while on a very wide drainage, type I is most economical. Type II is intermediate between type I and type III. The exact choice of a particular type in a particular case can be made by working out the cost of all the types and then choosing the cheapest.

14.5. Design Considerations for Cross Drainage Works

The following steps may be involved in the design of an aqueduct or a syphon-aqueduct. The design of a superpassage and a syphon is done on the same lines as for aqueducts and syphon aqueducts, respectively, since hydraulically there is not much difference between them, except that the canal and the drainage are interchanged by each other.

14.5.1. Determination of Maximum Flood Discharge. The high flood discharge for smaller drains may be worked out by using empirical formulas ; and for large drains, other reliable methods such as Hydrograph analysis, Rational formula, etc. may be used.

14.5.2. Fixing the Waterway Requirements for Aqueducts and Syphon-Aqueducts. An approximate value of required waterway for the drain may be obtained by using the Lacey's equation, given by

$$P = 4.75\,.\,\sqrt{Q}$$

where P = is the watted perimeter in metres

Q = Total discharge in cumecs.

For wide drains, the wetted perimeter may be approximately taken equal to the width of the drain and hence, equal to the waterway required. However, no extra provision is generally made for the space occupied by piers. Hence, if the total waterway provided is equal to P, the effective or clear waterway will be less than P by as much extent as is occupied by pier widths. For smaller drains, a smaller figure for the waterway than that given by Lacey's regime perimeter, may be chosen. The maximum permissible reduction in waterway from Lacey's perimeter is 20%. Hence, for smaller drains, the width of the waterway provided should be so adjusted as to provide this required perimeter (minimum value $= 0.8\,P$). The decided clear water way width is provided in suitable number of bays (spans).

Size of the Barrels. After having fixed the waterway width & number of compartments (bays), the height of the drain barrels has to be fixed. In case of an aqueduct, the canal trough is carried clear above the drain HFL, and drain bed is not to be depressed. Hence, the height of bay openings is automatically fixed in aqueducts, as equal to the difference between HFL and DBL of drain.

However, in syphon-aqueducts, the required area of the drainage waterway can be obtained by dividing the drainage discharge by the permissible velocity through the barrels. This velocity through the barrels is generally limited to 2 to 3 m/sec. The waterway area is then divided by the decided waterway width of the drain openings, to compute the height of the openings, and the extent of depressed floor.