Module 3

Irrigation Engineering Principles

Lesson 8

Conveyance Structures for Canal Flows

Instructional objectives

On completion of this lesson, the student shall learn the following:

1. The need for structures of a canal irrigation system for conveying water from one point to another.
2. Structures for conveying water across, over or under natural streams
3. Transitions in canals at change of cross section

3.8.0 Introduction

A canal conveying water from the head works has to run for large distances and has to maintain the water levels appropriately, as designed along its length. It has to run through terrains which generally would have a different slope small than the canal . The surrounding areas would invariably have its own drainage system ranging from small streams to large rivers . The canal has to carry the water across these water bodies as well as across artificial obstacles like railway line or roads .

The main structures of a canal system for conveyance of canal flow and control of water levels are as follows .

1. Pipe conduits, culverts and inverted syphons to carry flow under railways and highways .

2. Aqueducts, syphon aqueducts, super-passage, canal siphon or level crossings across natural drainage courses or other depressions.

3. Transitions at changes in cross sections.

This lesson deals with the concepts of planning, layout and design of canal structures for flow conveyance across artificial and natural obstacles .

3.8.1 Structures for crossing canals across roads and railway lines

These are structural elements to convey canal water under roads or railway lines. For small roads, carrying relatively less traffic, the pipe conduit is sufficient. A general view of the pipe conduit is shown in Figure 1 and its typical plan and cross section in Figure 2. For canals crossing under major highways and railway tracks, reinforced concrete culverts are more commonly adopted. These roads or railway crossings are usually having a straight profile along its length. The water level in the canal for this type of crossing is lower than the level of the obstruction it crosses, as may be noticed from Figure 2 and the flow through the pipe may be free or under mild pressure.

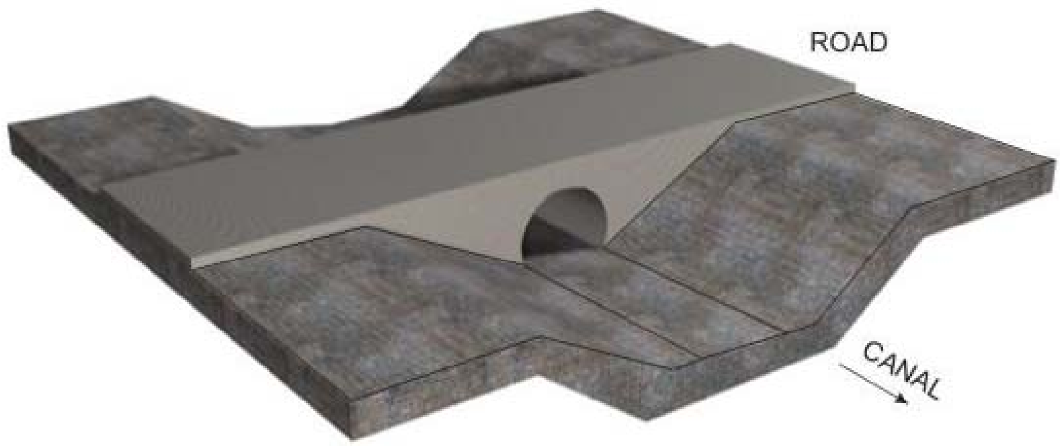

FIGURE 1. Pipe conduits for canals crossing small roads

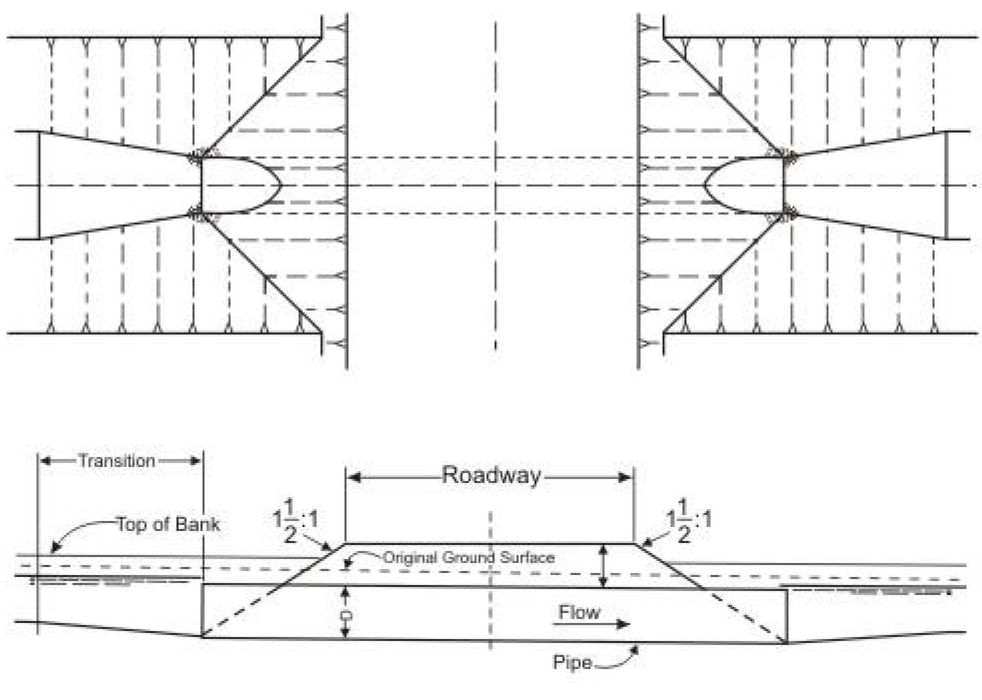

FIGURE 2. Plan and section of road crossing with pipe conduit

Pipe road crossings are relatively economical, easily designed and built, and have proven a reliable means of conveying water under a roadway. Pipe installations are normally installed by cut and cover method below minor roads but for important roads, where traffic cannot be interrupted, it may be accomplished by jacking the pipe through the roadway foundation.

The inverted syphons are structures for canal water conveyance below roads, railway lines and other structures (Figure 3). The longitudinal profile is not exactly in a straight line and the central portion is seen to sag beneath the object to be crossed. The inverted syphon, therefore, is provided where the water level in the canal is about the same as the level of the obstruction (Figure 4).

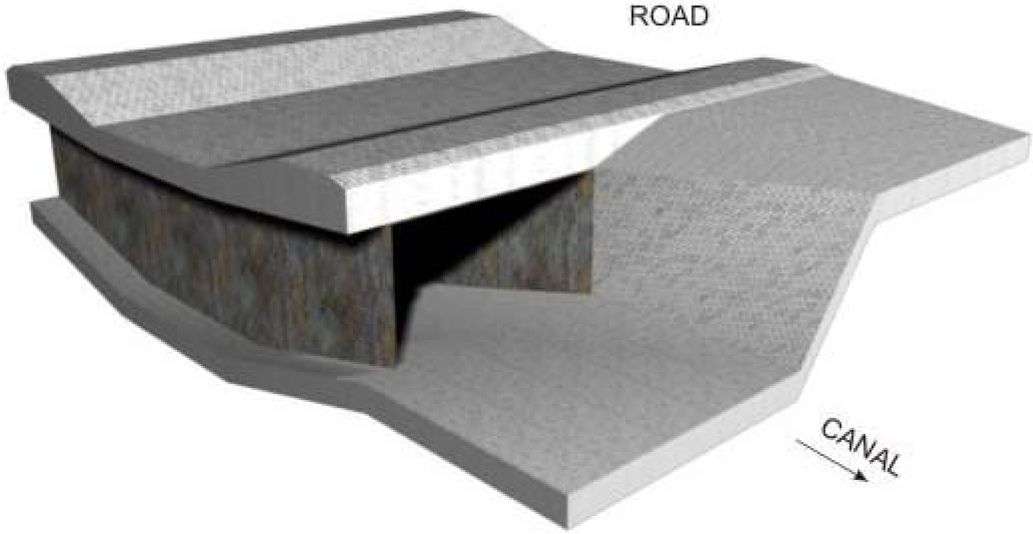

FIGURE 3. Inverted Syphon below roads showing rectangular section. Circular section also possible

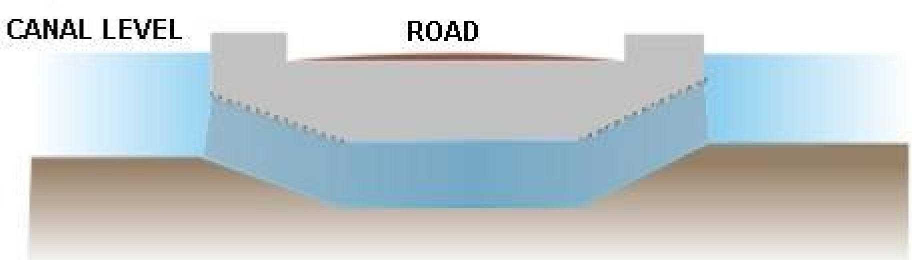

FIGURE 4a. Canal Full Supply Level(FSL) and road level are nearly same

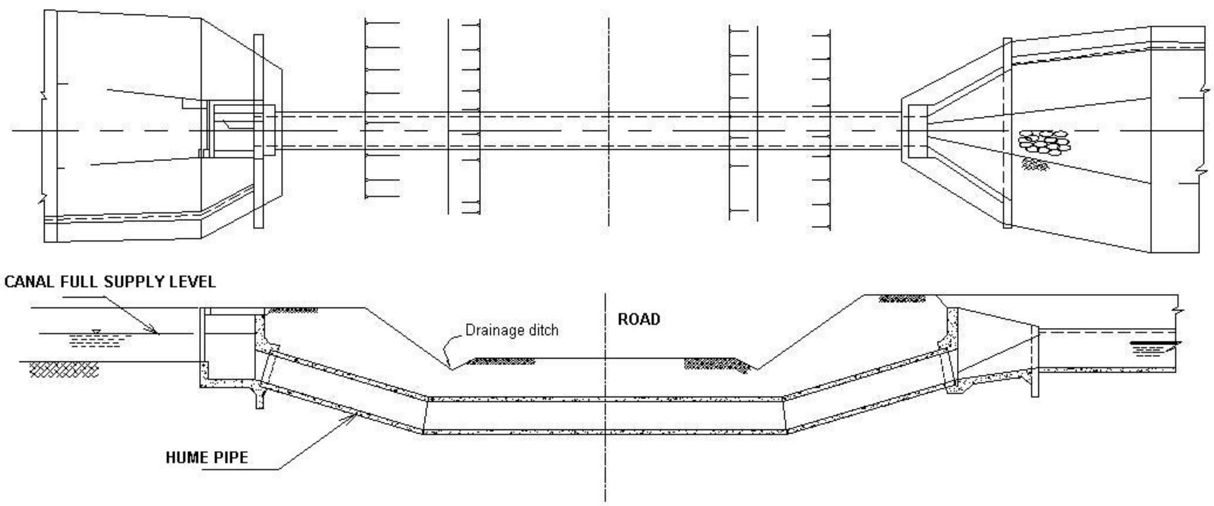

FIGURE 4b. An example of an inverted syphon of a small canal crossing a road

The inverted syphon is a closed conduit designed to run full and under pressure. If made of pressure pipes, they should be able to withstand the load of cover and wheel from outside and the hydrostatic head from inside. Transitions for changes in cross sections are nearly always used at inlet and outlet of a siphon to reduce head losses and prevent erosion in unlined canals caused by the velocity changes between the canal and the pipe.

3.8.2 Structures for crossing canals across natural streams (cross drainage works)

These structural elements are required for conveying the canals across natural drainage. When a canal layout is planned, it is usually seen to cross a number of channels draining the area, varying from small and shallow depressions to large rivers. It is not generally possible to construct cross-drainage structures for each of the small streams. Some of the small drainage courses are, therefore, diverted into one big channel and allowed to cross the canal. However, for larger streams and river, where the cost of diversion becomes costlier than providing a separate cross-drainage work, individual structures to cross the canal across the stream is provided.

There could be a variety of combinations of the relative position of the canal with respect the natural channel that is to be crossed. These conditions are shown in Figures 5 to 9. The notations used in the figures are as follows:

(a) CBL: Canal Bed Level;

(b) SBL: Stream Bed Level;
(c) FSL: Canal Full Supply Level; and
(d) HFL: Stream High Flood Level

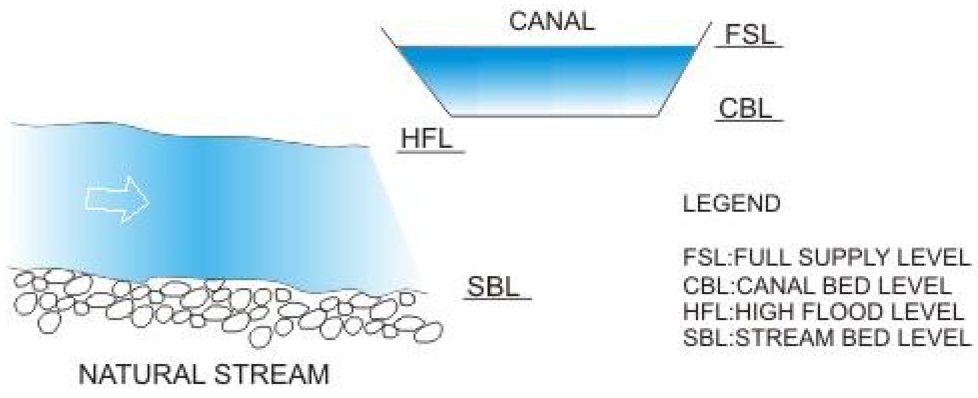

FIGURE 5. Relative position of canal (shown in cross section) with respect to a natural stream (shown in longitudinal section), when canal bed level is higher than stream high flood level

Figure 5 shows the relative position of canal (shown in cross-section) with respect to a natural stream (shown in longitudinal section), when canal bed level is higher than stream high flood level.

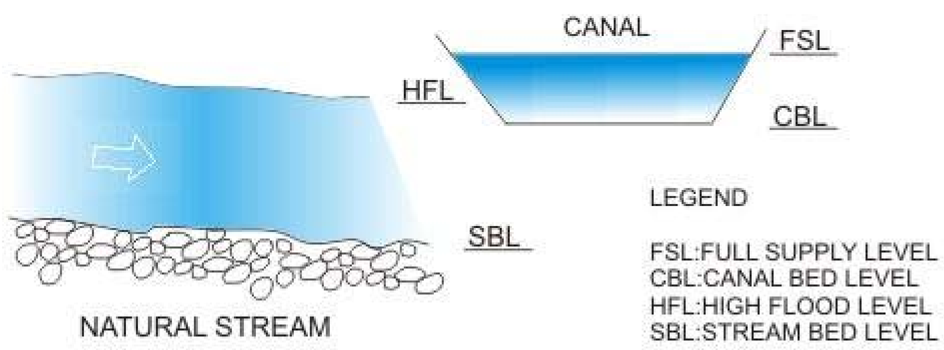

FIGURE 6 . Relative position of a canal whose canal bed level is below the high flood of the stream.

Figure 6 shows the relative position of a canal whose bed level is below but full supply level is above the stream high flood level.

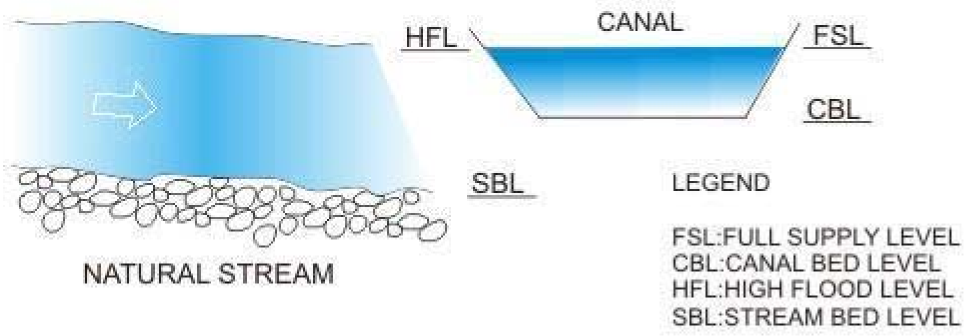

FIGURE 7 . Canal with full supply level almost matching the high flood level of the natural stream

Figure 7 shows a canal with full supply level almost matching the high flood level of the natural stream.

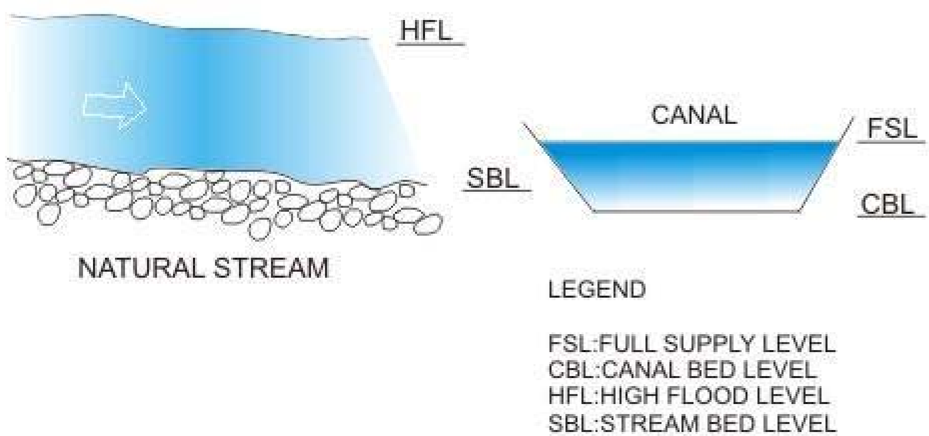

FIGURE 8 . Canal full supply level and bed levels below the levels of high flood level and bed level of the stream, respectively.

Figure 8 shows a canal full supply level and bed levels below the levels of high flood level and bed level of stream, respectively.

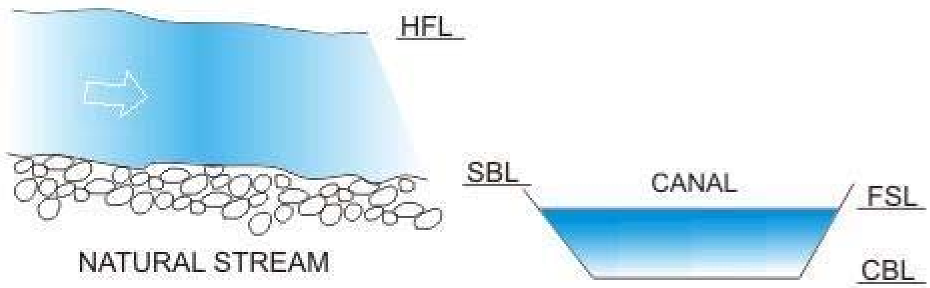

FIGURE 9 . Relation position of canal with respect to the natural stream where the canal full supply level is below the stream bed level

Figure 9 shows the relative position of canal with respect to the natural stream where the canal full supply level is below the stream bed level.

In general , the solution for all the illustrated conditions possible for conveying an irrigation canal across a natural channel is by providing a water conveying structure which may:

(a) Carry the canal over the natural stream;
(b) Carry the canal beneath the natural stream; or
(c) Carry the canal at the same level of the natural stream.

These three broad types of structures are discussed further in this lesson .

3.8.3 Structures to carry canal water over a natural stream

Conveying a canal over a natural watercourse may be accomplished in two ways:

(a) Normal canal section is reduced to a rectangular section and carried across the natural stream in the form of a bridge resting on piers and foundations (Figure 10) . This type of structure is called a ***trough type aqueduct*** .
(b) Normal canal section is continued across the natural stream but the stream section is flumed to pass through 'barrels' or rectangular passages (Figure 11). This type is called a ***barrel type aqueduct***.

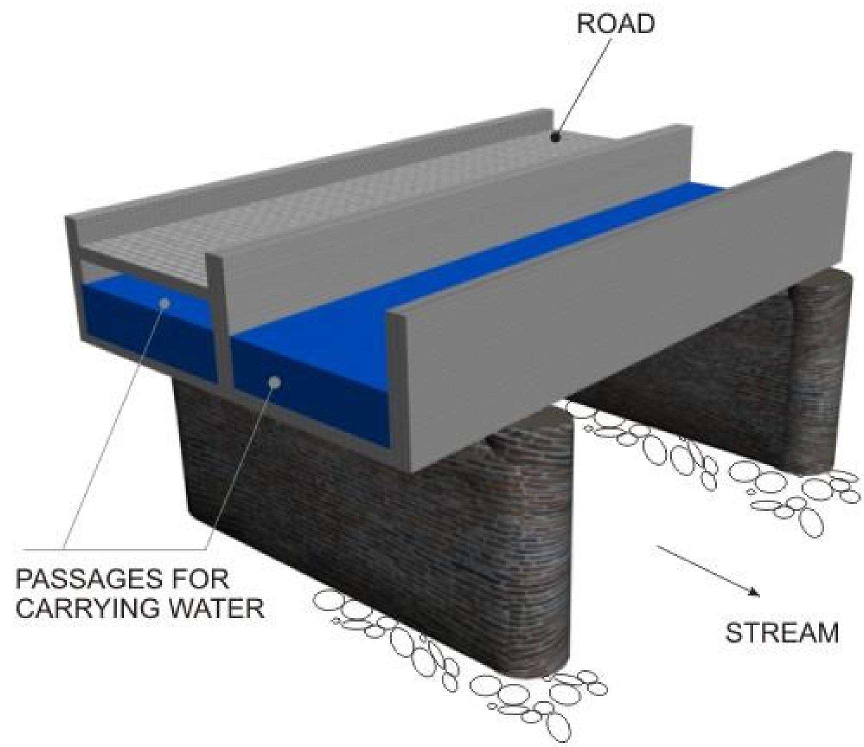

FIGURE 10. Trough type aqueduct

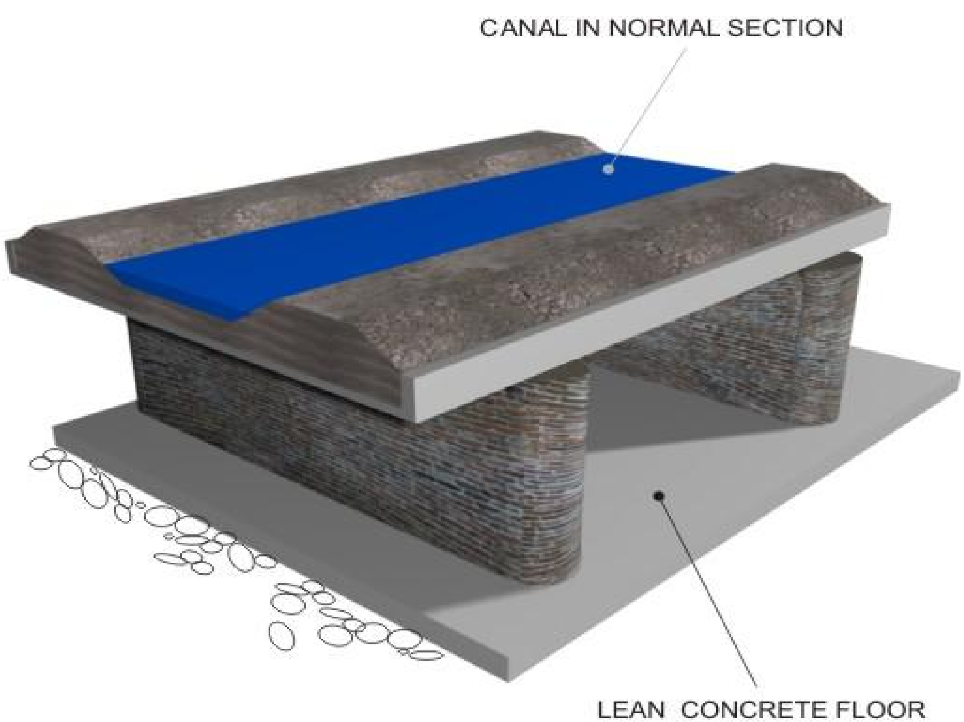

FIGURE 11. Barrel type aqueduct

Typical sections and plans of a trough type and a barrel type aqueducts are shown in Figures 12 and 13 respectively.

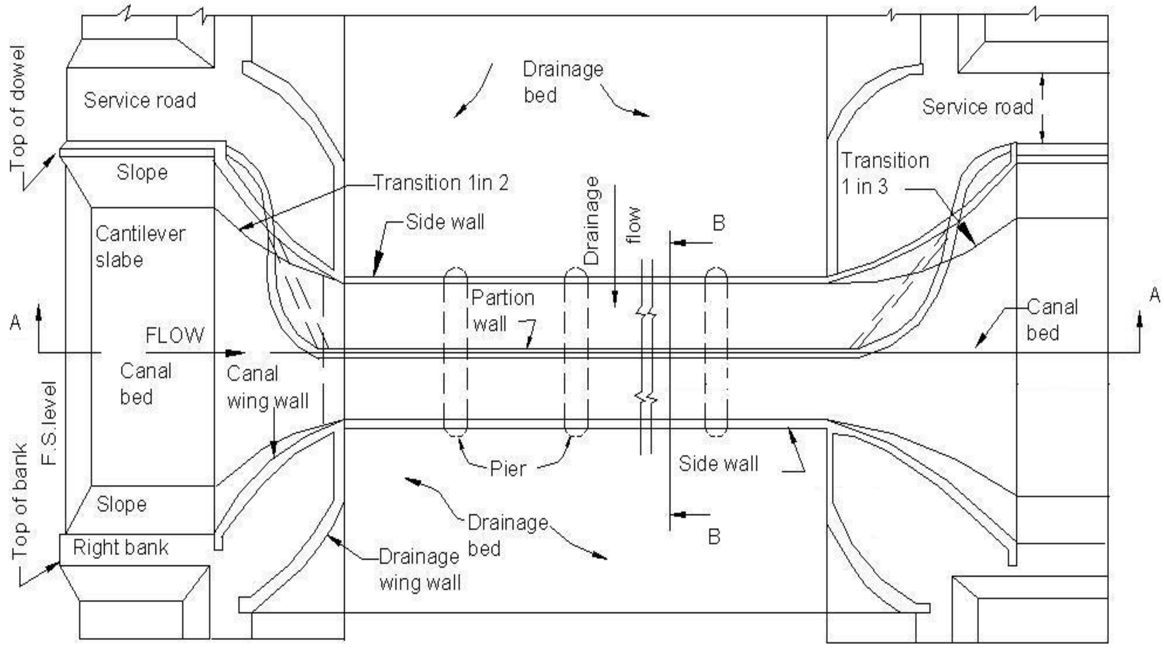

FIGURE 13a. A typical plan of a barrel type aqueduct

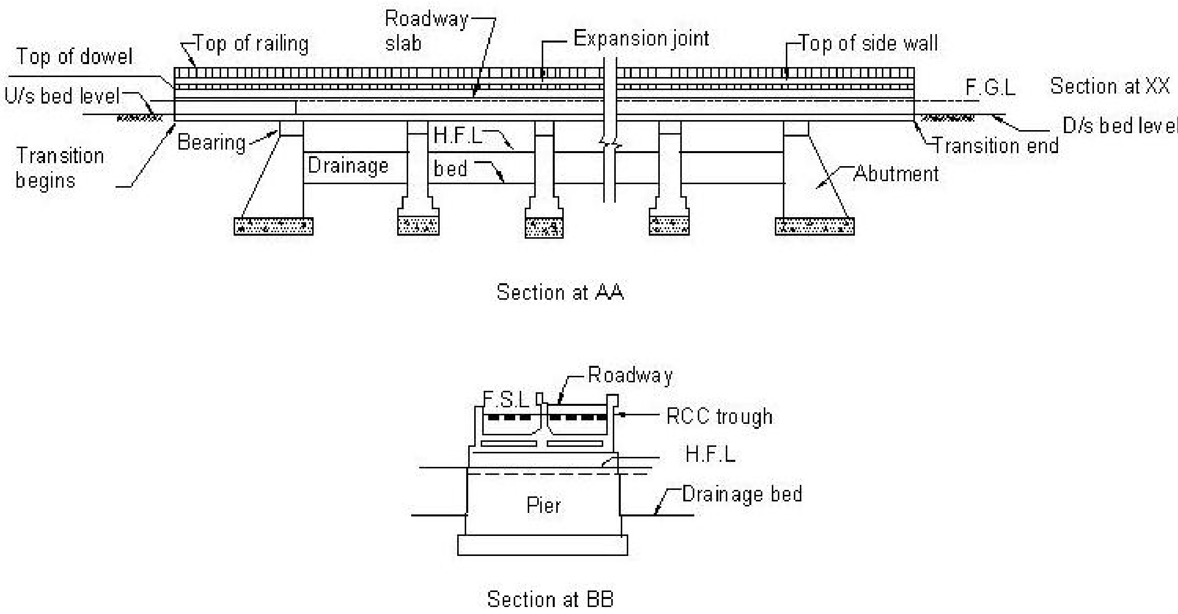

FIGURE 13b. Cross sections of the barrel type aqueduct shown in Fig. 13a.

For the aqueducts, it may be observed from Figures 12 and 13 that the HFL of the natural stream is lower than the bottom of the trough (or the roof of the barrel). In this case, the flow is not under pressure, that is, it has a free surface exposed to atmospheric pressure.

In case the HFL of the natural stream goes above the ***trough bottom level*** (TBL) or the ***barrel roof level*** (BRL), then the flow in the natural watercourse would be pressured and the sections are modified to form which is known as ***syphon aqueducts*** (Figures 14 and 15).

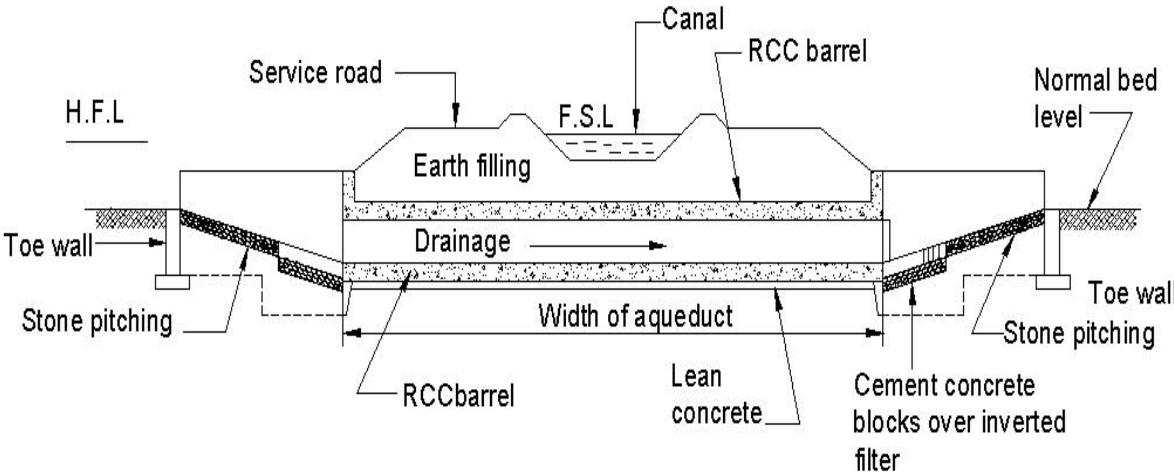

FIGURE 14. Section through a syphon aqueduct showing condition of pressured flow in natural drain

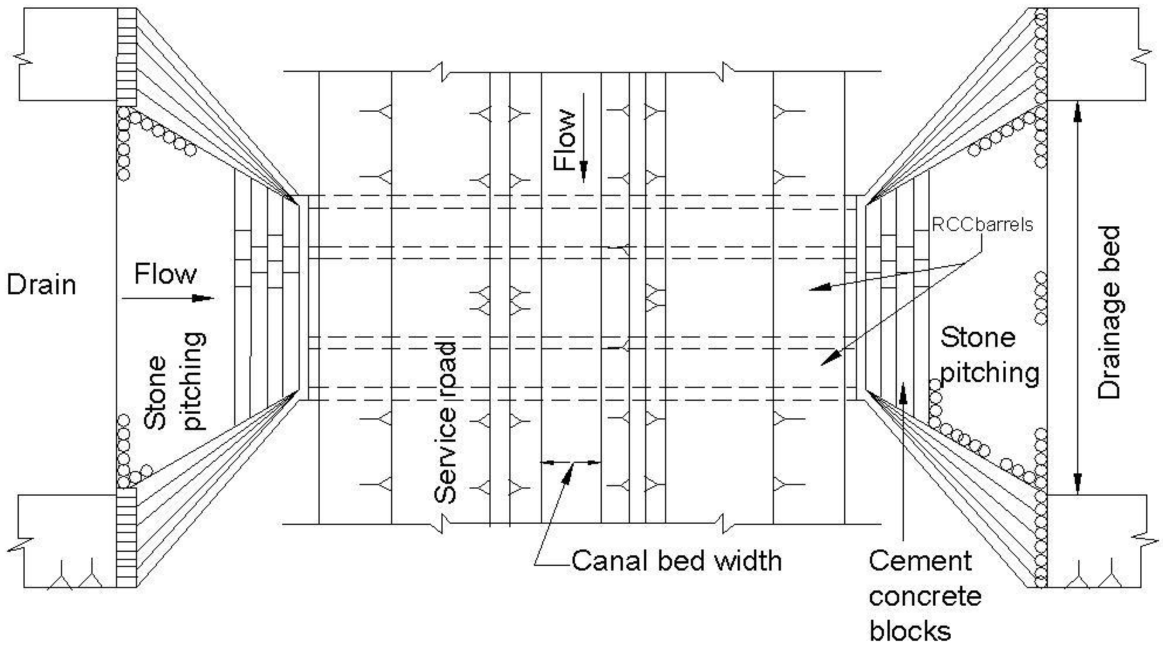

FIGURE 15. Plan of a syphon aqueduct if flow in natural drain is pressured

It may be observed that the trough type aqueduct or syphon aqueduct would be suitable for the canal crossing a larger stream or river, whereas the barrel type is suitable if the natural stream is rather small. The relative economics of the two types has to be established on case to case basis.

Further, the following points maybe noted for the two types of aqueducts or siphon aqueducts:

Trough type: The canal is flumed to not less than 75 percent of the bed width keeping in view the permissible head loss in the canal .Transitions 3:1 on the upstream and 5:1 on the downstream side are provided to join the flumed section to the normal canal section . For the trough-type syphon aqueduct the designer must consider the upward thrust also that might act during high floods in the natural stream when the stream water flows under pressure below the trough base and for worst condition , the canal may be assumed to be dry at that time. The dead weight of the trough may be made more than that of the upward thrust or it may be suitably anchored to the piers in order to may be counteract the uplift condition mentioned .

Barrel type: The barrel may be made up of RCC, which could be single or multi-cell, circular or rectangular in cross section. Many of the earlier structures were made of masonry walls and arch roofing. Precast RCC pipes may be economical for small discharges. For barrel-type syphon aqueducts, the barrel is horizontal in the central portion but slopes upwards on the upstream and downstream side at about an inclination of 3H : 1V and 4H : 1V respectively. A self-cleaning velocity of 6m/s and 3m/s is considered while designing RCC and masonry barrels respectively.

3.8.4 Structures to carry canal water below a natural stream

A canal can be conveyed below a natural stream with the help of structures like a ***super-passage*** or a siphon. These are exactly opposite in function to that of the aqueducts and siphon aqueducts, which are used to carry the canal water above the natural stream. The natural stream is flumed and made to pass in a trough above the canal. If the canal water flows with a free surface, that is, without touching the bottom of the trough, it is called a ***super-passage*** (Figure 16). Else, when the canal passes below the trough as a pressure flow, then it is termed as a ***syphon*** or a ***canal syphon***.

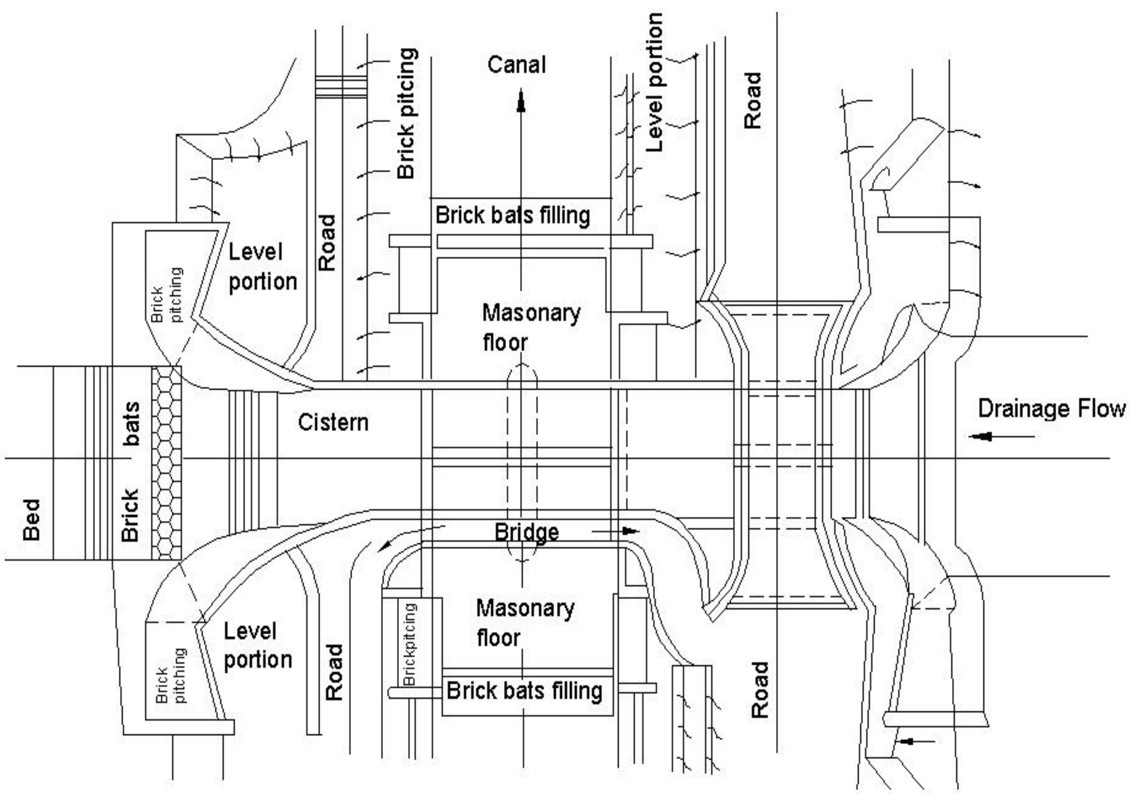

FIGURE 16a. Typical layout of a Super-passage

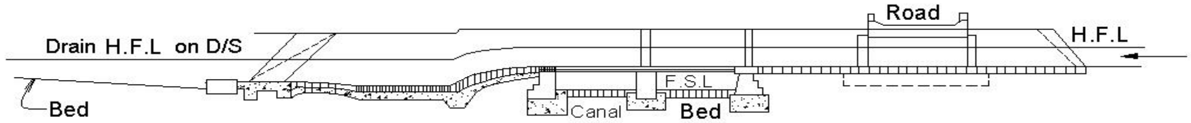

FIGURE 16b. Section through the Super-passage shown in Figure 16a.

Instead of a trough, the canal flow may be conveyed below the natural stream using small pre-cast RCC pipes (for small discharges) and rectangular or circular barrels, either in single or multiple cells, may be used (for large discharges), as shown in Figure

17.

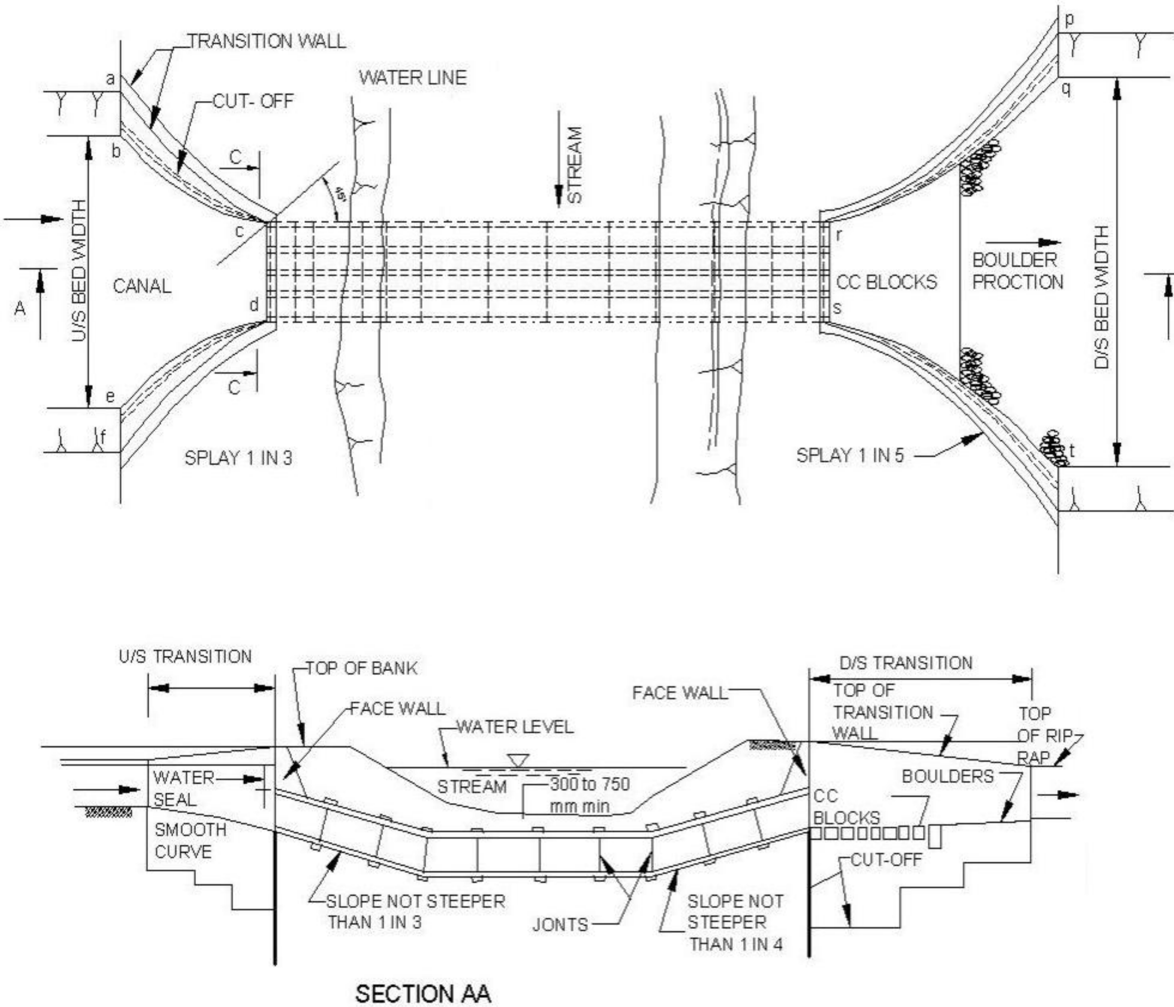

FIGURE 17. Plan and section of canal siphon

3.8.5 Structures to carry canal water at the same level as a natural stream

A structure in which the water of the stream is allowed to flow into the canal from one side and allowed to leave from the other, known as a ***level crossing***, falls into this category (Figure 18).

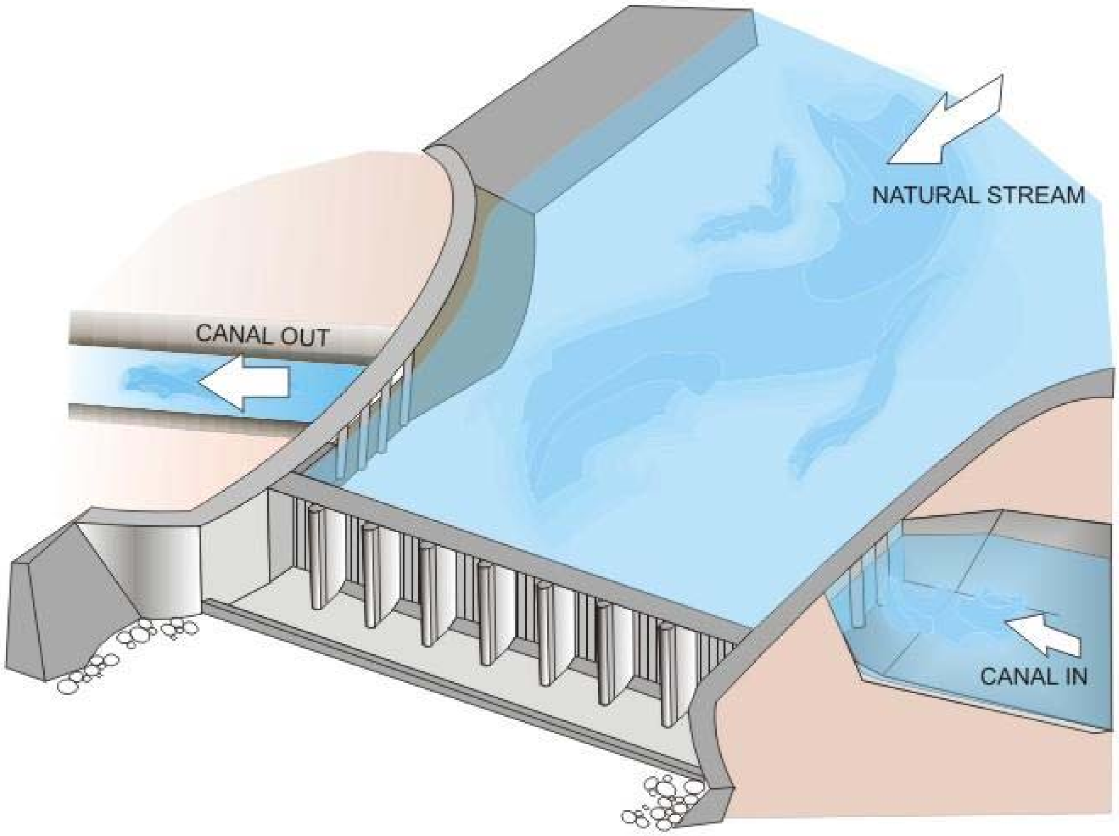

FIGURE 18. General view level crossing (gate hoisting arrangements not shown)

This type of structure is provided when a canal approaches a large sized drainage with high flood discharges at almost the same level. The flow control is usually provided on either side of the canal and on the outlet side of the drain. As such, this type of arrangement is very similar to canal head-works with a barrage. Advantage may be taken of the flow of the natural drainage to augment the flow of the outgoing canal. The barrage type regulator is kept closed during low flows to head up the water and allows the lean season drainage flow to enter the outgoing canal. During flood seasons, the barrage gates may be opened to allow much of the silt-laden drainage discharge to flow down.

Another structure, called an ***inlet***, is sometimes provided which allows the entry of the stream water into the canal through an opening in the canal bank, suitably protected by pitching the bed and sides for a certain distance upstream and downstream of the inlet. If the natural stream water is not utilized in the canal then an ***outlet,*** which is an opening on the opposite bank of the canal is provided. The canal bed and sides suitably pitched for protection.

3.8.6 Transitions at changes in canal cross-sections

A canal cross section may change gradually, in which case suitable flaring of the walls may be made to match the two sections (Figure 19).

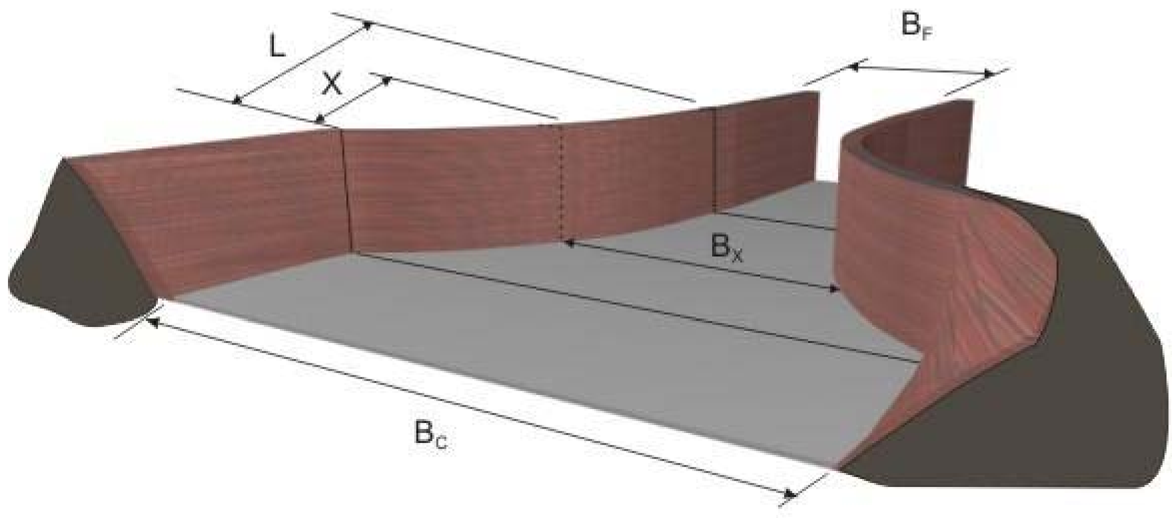

FIGURE 19. Transition canal banks warped to vertical and then flumed

For more abrupt changes, like a normal canal section being changed to a vertical walled aqueduct, suitable transitions have been designed which would avoid formation of any hydraulic with consequent loss of energy. A typical view of transition of a normal canal bank to a vertical walled flume section is shown in (Figure 20).

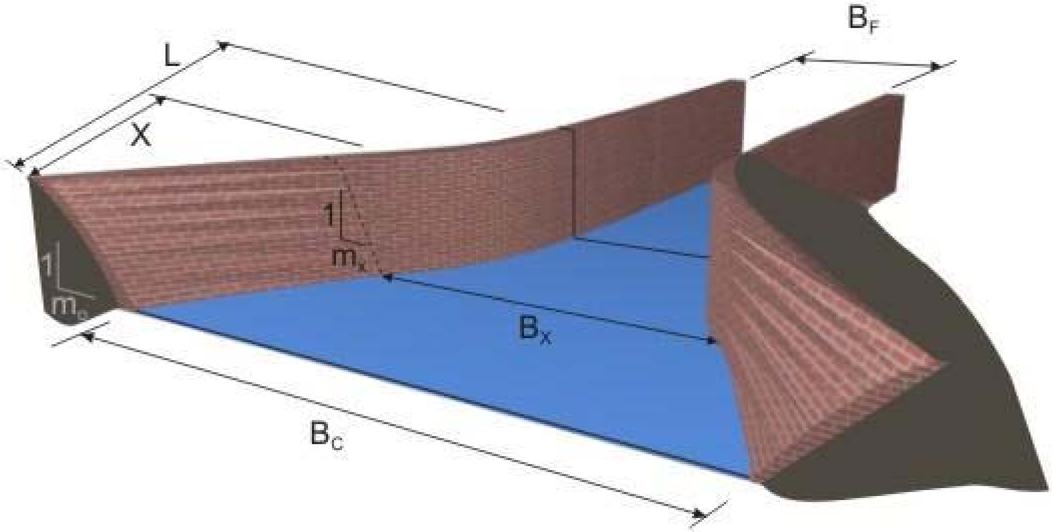

FIGURE 20. Transition with canal banks warped to vertical along with fluming

As may be observed, the banks of the normal canal section are first changed to vertical walls keeping the same canal bed width (***B_c***). Beyond this, the vertical section is reduced gradually to form a reduced sized flume of width (***B_f***). Various formulae have been proposed for deciding the intermediate curve, that is, an equation deciding the width (***B_x***) at any distance ***x*** from the start of the fluming, assuming a length L for the transition. One formula that is commonly used for this kind of transition is the UPIRI method, commonly known as Mitra's transition and is given as follows:

$$B_x = (B_c * B_f * L) / (L * B_c - X (B_c - B_f)) \qquad (1)$$

The length ***L*** of the transition is assumed to be equal to 2 *(B_c – B_f). In another type of transition, the vertical curved walls of a normal canal section is both transformed in to vertical walls of a flume as well as its section is reduced gradually, as shown in Figure 20. This results in reduction of the canal bed width from ***B_c*** to ***B_f*** and the side slopes from M_0 to O. The values for the bed width B_x at any length X from the start of the transition and the corresponding side slope ***m_x*** are given by the following expressions

$$B = B_c + X/L \, [1- (1- X/L)^n] \quad (B_c - B_f) \qquad (2)$$

$$m_x = m_0 \, [1 - (1- X/L)^{1/2}] \qquad (3)$$

Where $n = 0.8 - 0.26(m_0)^{½}$ and the length of transition L, is expressed as

$$L = 2.35 (B_c - B_f) + 1.65\, m_0\, h_c \qquad (4)$$

3.8.7 Planning and design of canal conveyance structures

Though a number of books are available for detailed design of conveyance structures of a canal, as mentioned in the reference list, one may consult the following Bureau of Indian Standard codes for planning, initial designs and construction of these structures.

- IS: 7784 "Code of practice for design of cross drainage works"

  (1) Part 1 -1975 General features (Reaffirmed 1987)

  (2) Part 2-1983 Specific requirements (Reaffirmed 1992) Section1. Aqueducts

  (3) Part 2 - 1980 Specific requirements (Reaffirmed 1992) Section2. Super-passage

  (4) Part 2 -1981 Specific requirements (Reaffirmed 1992) Section3. Canal syphons

  (5) Part 2 - 1980 Specific requirements (Reaffirmed 1992) Section4. Level crossings

  (6) Part 2 -1980 Specific requirements (Reaffirmed 1992) Section5. Syphon aqueducts

- IS: 11385-1985 "Code of practice for subsurface exploration for canals and cross drainage works" (Reaffirmed 1990)

- IS: 9913-1981 "Code of practice for construction of cross drainage works" (Reaffirmed 1992)

References

Asawa, G L (1996) "Irrigation engineering", Second edition, New Age Publications

- Garg, S K (1996) "Irrigation engineering and hydraulic structures", Twelfth Edition, Khanna Publishers

- IS: 11385-1985 “Code of practice for subsurface exploration for canals and cross drainage works” (Reaffirmed 1990)
- IS: 7784 “Code of practice for design of cross drainage works”, Parts 1 to 6
- IS: 9913-1981 “Code of practice for construction of cross drainage works” (Reaffirmed 1992)
- Varshney, R S, Gupta, S C and Gupta, R L (1993) “Theory and design of irrigation structures”, Volume II, Sixth Edition, Nem Chand Publication