LECTURE NOTES ON

WATER RESOURCES ENGINEERING-II
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P.PAVITHRA
Assistant Professor

G.PULLAIAH COLLEGE OF ENGINEERING AND TECHNOLOGY

CIVIL ENGINEERING

UNIT – 1

CONCEPT:-

The two major categories of structures that are built on canals are the regulation works and cross-drainage works. A brief description of some of the important ones is given below.

Regulation Works

Canal Falls

While canals are designed with a slope which is close to the regime slope, the ground slope may differ from it considerably. Many a times, the ground slope is more than the canal slope and this may result in a canal in heavy filling. To overcome this situation, the canal has to be provided with falls which require a masonry or concrete work. The drop in canal bed results in the potential energy of water being converted to kinetic energy and this excess energy has to be dissipated before allowing the flow over the unprotected canal bed. Also, the water surface upstream of the fall also needs to be maintained at its normal level. The fall thus has to be provided with a crest and some means of energy dissipation. The fall can be flumed or unflumed. In a flumed fall, the trapezoidal canal section is contracted to a rectangular section having a width less than the bed width of the canal and expanded back after the works. In unflumed falls, while there is no reduction of the bed width, the section is however converted into a rectangular one. Only two types of falls are discussed here.

Vertical drop fall

This type of fall depends on a vertical impact for energy dissipation. The crest height is determined using the formula

$$Q = C\, L\, H^{3/2}$$

Where C can be taken as 1.71, L is the length of the crest and H the head over the crest.

The energy dissipation in this case is by vertical impact of the water on the downstream bed and a pool of water. A cistern of certain depth and length- known as the cistern element is provided. There are many empirical formulae available to compute the length and depth of the cistern such as the one given by UP Irrigation Research Institute (UPIRI) as below is SI units.

$$L_c = 5\sqrt{E\, H_L}$$

$$x_c = 0.25\left(E H_L\right)^{2/3}$$

in which L_c and x_c are the length and the depth of the cistern respectively neglecting velocity head, E can be taken equal to head H over the crest and H_L equal to drop in canal bed levels.

Glacis Fall

This type of fall is preferred for larger drops and utilizes the hydraulic jump for energy dissipation .The crest is joined to the upstream floor at a slope of 1:1, while the downstream glacis is generally at at slope of 2H:1V. The downstream floor may be carried to a level lower than the canal bed for certain length to provide a cistern, with the length and depth of the cistern being 1.25 E_2 and 0.25 E_2 respectively, where E_2 is the downstream specific energy.

Distributary Head Regulator

This is the work provided at the head of a branch canal or a distributary and serves the purpose of controlling and regulating the flow into the offtake as well as metering of the flow. The arrangement is more or less similar to that of a canal head regulator, with a raised crest, upstream and downstream floors and cutoffs. The width of the regulator and height of crest are fixed such that the offtake may be able to draw its full supply discharge even if the water level in the parent channel is lower than the full supply level. On smaller works, the control is in the form of wooden planks which can be placed in grooves provided in piers for this purpose, while on larger works manually operated gates are provided. Curved vanes or cantilever platform as discussed separately are usually provided to control entry of excess sediment into the offtake

Cross Regulator

Cross regulators are structures constructed across a canal and spanning its entire width. The width is divided into suitable number of spans and provided with gates so as to regulate the flow in the canal downstream of the regulator. Cross regulators serve many purposes such as

(i) If the canal downstream of the cross regulator has to be closed in an emergency, the cross regulator gates can be closed and the discharge diverted to any drain. This requires an escape to be constructed just upstream of the cross regulator.

(ii) The canal water level upstream of the cross regulator can be regulated depending upon the gate openings. This may be required if the canal is carrying less than the full supply discharge and some offtake upstream has to be supplied with its full supply discharge.

Cross Drainage Works

These are works provided at the crossing of a canal and a stream. Depending on whether the canal crosses the stream at top, bottom or at the same level, these are divided into three categories.

Aqueducts and Siphon Aqueducts

Aqueducts are works where the canal crosses over the stream and the high flood level of the stream is lower than the canal bed level so that the flow in the stream remains an open channel flow. The canal section may cross over the stream without any modification i.e. with the banks as they are or with slight modification wherein the outer edges of the banks are replaced by retaining walls. Such works are however suitable only when the stream to be crossed is small. For any major work, the canal is flumed to a rectangular trough – masonary or concrete – and after the crossing restored to its normal section Siphon aqueducts are provided when the high flood level of the stream is higher than the canal bed level. In such a case the flow in the stream becomes a pressure flow through the siphon barrels The design of aqueducts and siphon aqueducts requires consideration of the following factors:

Waterway of stream- The waterway provided in an aqueduct is generally close to the Lacey's regime perimeter. This helps in developing a stable channel upstream of the works without much silting or scouring. The width is divided into suitable spans with the help of piers. In a siphon aqueduct, the velocity in the barrels becomes one of the considerations in deciding the waterway.

Headway i.e. the clearance between the downstream bed of the stream and the bottom of the canal trough should be sufficient so as to prevent the blockage of the barrels. While this may not present much of a problem in aqueducts, lowering of the stream bed upstream of the siphon barrels may have to be resorted to at times

Afflux will be caused by the flow of stream under the canal trough. This results because of the head loss due to constriction, piers or siphon. Afflux can be computed using appropriate formulae for the head loss and is used in determining the hydraulic grade line specially in case of siphon aqueducts.

Fluming of the canal requires contraction as well as expansion transitions. While the splay in contraction can be kept about 1:2, the expansion is generally provided with a splay of 1:3 or more. Suitable design of transitions for contraction and expansion is required and procedures for this design are available.The considerations of uplift and exit gradient have also to be taken care of. The worst condition for the stream bed being when the stream is dry and the canal is carrying its full supply discharge. In case of siphon aqueducts, the canal trough is also subjected to uplift when the canal is dry and the stream is in high flood.

Superpassages and Siphons

These are works where the stream crosses over the canal. In a superpassage the canal full supply level is lower than the river bed level and the flow in canal is an open channel flow. In a siphon the canal full supply level is higher than the stream bed level and therefore the canal water flows under pressure through barrels under the stream trough.

The design considerations for these works are similar to those for aqueducts and siphon aqueducts. The stream however is not flumed and mostly carried with the original section.

Level Crossing

In this work the canal and stream cross at nearly the same level. There is intermixing of the canal and river water and the flow is controlled by regulator gates on the canal as well as the stream. A sill with its top at the canal full supply level is provided on the upstream side of the stream to prevent stagnant water pool in the stream during dry season.

Level crossings have a problem with sediment getting deposited in the pool formed at the crossing. This could lead to degradation in the river downstream. Also there is need for constant watch and warning mechanism so that the stream gates could be opened well in time in case a flood has to be passed. The canal may also have to be closed during floods to prevent the river sediment from entering the canal.

Selection of Type

The selection of the type of cross drainage work depends on the relative bed levels of the canal and the stream at the crossing and their discharge. Thus in case the stream is carrying a large discharge, it may not be feasible to siphon it under the canal even though the levels may dictate a siphon aqueduct. The type of crossing can be altered by a suitable realignment of the canal if required, resulting in change in bed levels of both the canal and the stream.

A cross drainage work is a structure carrying the discharge from a natural stream across a canal intercepting the stream.

Canal comes across obstructions like rivers, natural drains and other canals.

The various types of structures that are built to carry the canal water across the above mentioned obstructions or vice versa are called cross drainage works.

It is generally a very costly item and should be avoided by

- Diverting one stream into another.
- Changing the alignment of the canal so that it crosses below the junction of two streams.

Types of cross drainage works

Depending upon levels and discharge, it may be of the following types:

Cross drainage works carrying canal across the drainage:

Aqueduct:

When the HFL of the drain is sufficiently below the bottom of the canal such that the drainage waterflows freely under gravity, the structure is known as Aqueduct.In this, canal water is carried across the drainage in a trough supported on piers.

Bridge carrying water

Provided when sufficient level difference is available between the canal and natural and canal bed is sufficiently higher than HFL.

Crossing works: (aqueducts)

Siphon Aqueduct:
In case of the siphon Aqueduct, the HFL of the drain is much higher above the canal bed, and water runs under siphonic action through the Aqueduct barrels.
The drain bed is generally depressed and provided with pucci floors, on the upstream side, the drainage bed may be joined to the pucca floor either by a vertical drop or by glacis of 3:1. The downstrean rising slope should not be steeper than 5:1. When the canal is passed over the drain, the canal remains open for inspection throughout and the damage caused by flood is rare. However during heavy floods, the foundations are succeptible to scour or the waterway of drain may get choked due to debris, tress etc.

Cross drainage works carrying drainage over canal:
The structures that fall under this type are:

Super passage

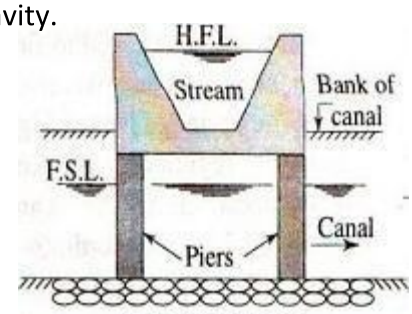
Canal siphon or called syphon only

Super passage:

The hydraulic structure in which the drainage is passing over the irrigation canal is known as super passage. This structure is suitable when the bed level of drainage is above the flood surface level of the canal. The water of the canal passes clearly below the drainage

A super passage is similar to an aqueduct, except in this case the drain is over the canal.

The FSL of the canal is lower than the underside of the trough carrying drainage water. Thus, the canal water runs under the gravity.
Reverse of an aqueduct



Super passage

Canal Syphon:

If two canals cross each other and one of the canals is siphoned under the other, then the hydraulic structure at crossing is called “canal siphon”. For example, lower Jhelum canal is siphoned under the Rasul-Qadirabad (Punjab, Pakistan) link canal and the crossing structure is called “L.J.C siphon”

In case of siphon the FSL of the canal is much above the bed level of the drainage trough, so that the canal runs under the siphonic action.

The canal bed is lowered and a ramp is provided at the exit so that the trouble of silting is minimized.Reverse of an aqueduct siphon

In the above two types, the inspection road cannot be provided along the canal and a separate bridge is required for roadway.
For economy, the canal may be flumed but the drainage trough is never flumed.

Selection of suitable site for cross drainage works

1. The factors which affect the selection of suitable type of cross drainage works are:

2. Relative bed levels and water levels of canal and drainage

3. Size of the canal and drainage.

4. The following considerations are important

5. When the bed level of the canal is much above the HFL of the drainage, an aqueduct is the obvious choice.

6. When the bed level of the drain is well above FSL of canal, super passage is provided.

7. The necessary headway between the canal bed level and the drainage HFL can be increased by shifting the crossing to the downstream of drainage. If, however, it is not possible to change the canal alignment, a siphon aqueduct may be provided.

8. When canal bed level is much lower, but the FSL of canal is higher than the bed level of drainage, a canal siphon is preferred.

9. When the drainage and canal cross each other practically at same level, a level crossing may be preferred. This type of work is avoided as far as possible.

Factors which influence the choice / Selection of Cross Drainage Works

The considerations which govern the choice between aqueduct and siphon aqueduct are:

1. Suitable canal alignment
2. Suitable soil available for bank connections
3. Nature of available foundations
4. Permissible head loss in canal
5. Availibility of funds

Compared to an aqueduct a super passage is inferior and should be avoided whenever possible. Siphon aqueduct is preferred over siphon unless large drop in drainage bed is required.

Classification of aqueduct and siphon aqueduct

Depending upon the nature of the sides of the aqueduct or siphon aqueduct it may be classified under three headings:

Type I:

Sides of the aqueduct in earthen banks with complete earthen slopes. The length of culvert should be sufficient to accomodate both, water section of canal, as well as earthen banks of canal with aqueduct slope.

Sides of the aqueduct in earthen banks, with other slopes supported by masonry wall. In this case, canal continues in its earthen section over the drainage but the outer slopes of the canal banks are replaced by retaining wall, reducing the length of drainage culvert.

Type II:

Sides of the aqueduct made of concrete or masonry. Its earthen section of the canal is discontinued and canal water is carried in masonry or concrete trough, canal is generally flumed in this section.

IMPORTANT QUETSIONS:-

1. (a)Give the explanation about roughening devices?

   (b) Discuss their use in construction of falls
2. Discuss what do you understand by level crossing?
3. Design the floor on Bligh's theory taking coefficient of creep = 8 safe exit gradients may be taken as 1/5
4. State how will you determine the following in a siphon aqueduct:

   i) Contraction of canal water way. (ii) Water way for the drain
5. a) Explain Montague type fall what is the advantage over straight glacis type fall?

   b) Give few notes about OFF-Taken alignment?
6. a)How do you select a suitable type of cross-drainage work?

   b) Explain super passage