MODULE – 3

Design of Canal Drop (Notch Type)

INTRODUCTION

Canal Drops are required generally on Ridge canals. When the canal bed slope is flatter than the slope of the ridge on which the canal runs, these structures become an absolute necessity to keep the canal F.S.L. within the ground. In an irrigation project, while the main canal runs on the contour to get maximum command; the distributaries run on the ridge of the various blocks. These distributaries while running on the ridge, irrigate areas on both sides upto the dividing valleys of the command area. The general slope of the ridge, determines the bed slope of the distributary. If we choose a section of the channel, with a slope steeper than the general slope of the ridge, the canal cutting increases as the canal runs along, the cutting becomes deeper and deeper making the canal uneconomical. If we have to reduce the cuffing, we have to shift the alignment to lower down levels and run it on contour, i.e., the purpose of the ridge canal will be lost as we would have to run another channel on the other side of the ridge to irrigate that area. So to obviate these difficulties, the channel is designed with the general slope of the ridge and runs along the ridge. If, this slope gives excessive velocities, in the channel which the soils cannot take without getting eroded, then we have to design the channel, with slopes flatter than that of the ridge and introduce drops in the canal bed, where the cutting is equal to or just above full supply depth. The idea is not to run distributaries in embankment, but run in cutting such that the canal F.S.L. is below the ground. The process eliminates the possibility of breach irrigation.

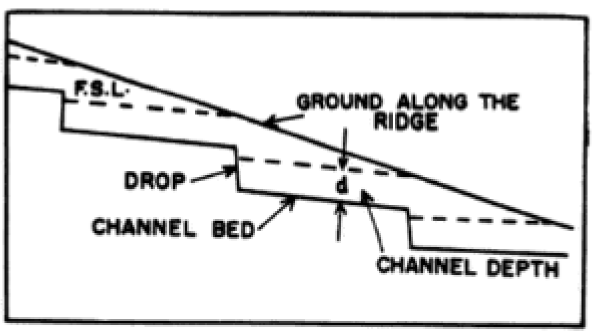

Fig 3.1

The sketch in Figure 3.1 shows this procedure to be fol-lowed. In a channel, where a series of drops are required. the height of drop, and the spacing of drops have to be worked out based on economics. In some channels, where there are a large number of drops, at close intervals, the canal is chuted (allow-ing high velocities) with effective energy dissipation methods at the end of the channel. Generally, in all channels, the drops are located where the canal cutting comes to 1 1/4 balanced depth of cutting or F.S.L. cutting. However, this principle should not be blindly followed. Where cutting in harder soils, or in rock is involved, shifting the location of drop, even if it be in a slight embankment is desirable and will economise in the cost of canal ex-cavation. These drops are of various types, namely vertical drop type. and glacis type. In the vertical drop type, the nappe impinges clear into the water cushion below. There is no clear standing waves and the dissipation of energy is effected by the turbulent diffusion, as the high velocity jet enters the deep pool of water downstream. In the glacis type, full advantage is taken of the fact that a standing wave is an effective natural means of energy dissipation. In selecting a type of fall, most suitable for a particular site, the main consideration is the height of drop, and the discharge passing over the fall or in other words, the amount of energy to be dissipated downstream of the fall. The C.W.P.C. recommends adoption of a vertical type of drop upto 1 meter and discharge 15 cumecs and glacis type for drop above I meter and discharge above 15 cumecs. The advantage in the notch type of drop is that it is self-adjusting for all discharges in the canal.

In small distributaries and field channels. generally vertical drops arc preferred. These are standardized and prefabricated so as to make construction at remote places easy. In canals, these drops are often combined with a regulator or a bridge to effect economy and avoid separate structures. In canals, where there is navigation, at the place of canal drop, we get an additional structure called 'Canal Lock' for the navigation of boats to negotiate the canal drop. In all such cases, the drop is combined with a Regulator and Bridge. and continues to function in maintaining the flow in the canal. While the lock will function whenever boats have to go up or down the canal. Figure 3.2 shows the arrangement of a canal lock and the drop-cum-regulator.

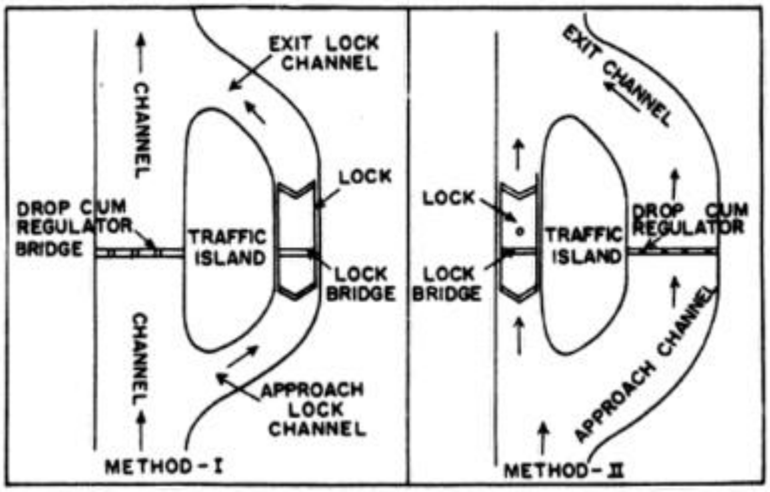

Fig 3.2

In method one. the drop-cum-regulator is located in the straight part. while a byepass channel with a traffic island is formed to locate the canal lock. In method two, the canal lock is located on the straight part, while the drop-cum-regulator is located on the byepass channel.

Q. Design a canal drop of 2 meters with the following data:

HYDRAULIC PARTICULARS OF THE CANAL		
Particulars	**Above the drop**	**Below the drop**
Full supply discharge	4 cumecs	4 cumecs
Bed width	6.00 meters	6.00 meters
Bed level	+10.00	**+8.00**
Full supply depth	1.5 m	**1.50m**
F.S.L	+11.50	**+9.50**
Top of the bank	2.00m wide @ +12.50	2.00m wide @ +10.50
Half supply depth	1.00m	
Ground level at the site of work +10.50		
Good soil is available for foundation @ +8.50		

DESIGN

3.1. TRAPEZOIDAL NOTCH

Canal discharge = 4 cumecs

F.S.L. U/S of drop = +11.50

F.S.L. D/S of drop = +9.50

Bed level U/S of the drop = +10.00

This shows that the rear FSL of canal is clear below the u/s bed level or sill of the notch. So the notch discharge is wholly free.

Assume 2 notches.

Discharge through each notch : 2 cumecs

Full supply depth = 1.5m

Half supply depth = 1.00 m

The discharge through a trapezoidal notch is given by

$$Q = 2.99\ C_d^{3/2}\ (L+0.4\ nd)$$

The discharge through a trapezoidal notch (combination of rectangular and V-notch) is given by the formula.

$$Q = \left[\frac{2}{3} * C * L * d^{\frac{3}{2}} * \sqrt{2g} + \frac{4}{15} * d^{\frac{5}{2}} * C * n * \sqrt{2g}\right]$$

Where Q is the discharge in cumecs

C is the coefficient of discharge = 0.70

L is the length of the notch (width of sill)

N = 2 tanα where α is the angle of inclination of the side of notch to the vertical, and

D = depth of water in meters

The same formula can be simplified as follows:

$$Q = \frac{2}{3} * C * d^{\frac{3}{2}} * \sqrt{2g}\left(L + \frac{2}{5}nd\right)$$

$$= \frac{2}{3} * C * d^{\frac{3}{2}} * \sqrt{2g}(L + 0.4 * nd)$$

$$= 2.99 * C * d^{\frac{3}{2}} * (L + 0.4 * nd)$$

For full supply condition Q = 2 cumecs, C = 0.7, d = 1.5m

$$\therefore \quad 2 = 2.99 * 0.76 * 1.5^{\frac{3}{2}} * (L + 0.4 * n * 1.5)$$

$$= 2.99 * 0.76 * 1.5^{\frac{3}{2}} * (L + 0.6 * n)$$

$$\therefore (L + 0.6 * n) = \frac{2}{2.99 * 0.76 * 1.5^{\frac{3}{2}}} = 0.52 \qquad \text{---------} \ (i)$$

For half supply condition

Q = 1cumecs, C = 0.70 and d = 1.00m (assumed)

$$\therefore 1 = 2.99 * 0.70 * 1.00^{\frac{3}{2}} * (L + 0.4 * n * 1.0)$$

$$= 2.99 * 0.70 * 1.00^{\frac{3}{2}} * (L + 0.4 * n)$$

$$(L + 0.4 * n) = \frac{1}{2.99 * 0.70} = 0.48 \qquad \text{-------------} \ (ii)$$

Solving equations (i) and (ii), we get

$$L + 0.6n = 0.52$$

$$L + 0.4n = 0.48$$

$$\therefore n = 0.20, \text{ and } L = 0.40$$

$$\therefore 2 \tan\alpha = 0.20$$

$$\therefore \tan \alpha = 0.10$$

$$\therefore \alpha = 5^{o} \text{- } 45'''$$

Dimensions of notch : the width of notch at sill + 10.00 is 40cms, and at FSL., i.e., @+11.50, it is (0.40 + 1.5*2 tanα) = 0.70 m or 70cms.

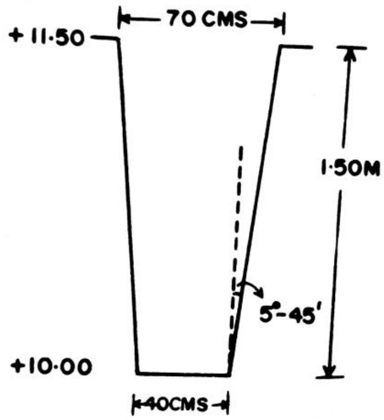

Fig 3.3 Notch details

3.2. LENGTH OF DROP WALL BETWEEN ABUTMENTS

The length of drop wall is generally about 7/8 of the bed width of channel u/s of drop and is never more than bed width d/s of drop.

Hence adopt length of drop wall as

$$\frac{6.00*7}{8} = 5.25 \text{ m.}$$

3.3. PROFILE OF THE DROP WALL

The thickness of drop wall at sill is generally 15 to 30cms wider than the length of the notch pier which is 1/2d, where d is the depth of water flowing over the sill of the notch.

The thickness of drop wall may be fixed as

$$\left(\frac{d}{2} + 0.15\right) \; i.e., \left(\frac{1.50}{2} + 0.15\right)$$

i.e., 0.75+0.15, or 90cms. Adopt one meter

the height of the drop wall depends upon the depth of water cushion that is to be allowed in rear. If a water cushion cistern of depth x meters below the bed of channel d/s of drop is provided, the effective depth of water cushion is (d_1+x), where d_1 is the full supply depth of channel d/s of drop.

The following formula is considered more suitable for the South Indian soils :

$$(x+d_1) = 0.9*d_c*\sqrt{h}$$

Where, dc is the depth of water flowing over the drop or depth of water in channel u/s of drop, h is the depth of drop, i.e., the difference in full supply level of the channel u/s and d/s of drop.

In this case, d1 = 1.5m, dc = 1.5m, h = 2.0m.

Substituting these values, $(x + 1.50) = 0.9*1.50*\sqrt{2.0}$

$\therefore x = 1.90 - 1.50 = 40$ cms.

Hence, the water cushion may be kept 40cms. below the d/s bed level of channel

Rear bed level of the channel = +8.00

Top level of the solid apron = +7.60

Top level or sill level of drop wall = +10.00

Bottom level of drop wall = +7.60

∴ Height of drop wall = 2.40m

Generally, the base width of drop wall may be about that of the elementary triangle, that is, about $\frac{H+D}{\sqrt{\rho}}$.

Where H is the vertical height of drop wall from sill to the apron, and d is the depth of water flowing over, ρ = of masonry = 2.25)

∴ Width of drop wall at foundation $= \frac{2.40+1.50}{\sqrt{2.25}} = \frac{3.90}{1.50} = 2.60m$

The profile of the drop wall may be shown in Fig3.4

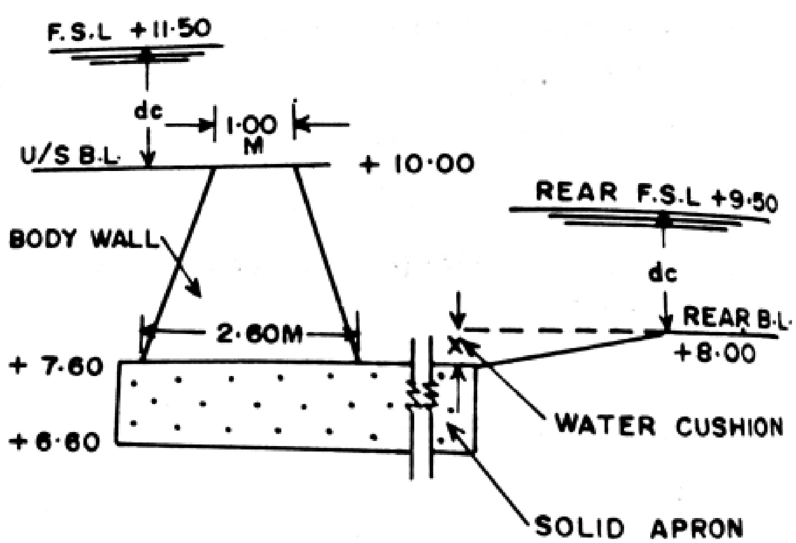

Fig 3.4: Drop Wall Profile

3.3.1 The length of horizontal floor of the cushion

Length of the soil apron from the toe of the drop wall is given by 2*dc+2$\sqrt{d_c * h}$ subject to a minimum of 1.50+2$\sqrt{d_c * h}$. Provide a minimum length of

$$1.50+2\sqrt{d_c * h} = 1.50+2\sqrt{1.50 * 2} = 1.50+3.46 \text{ or provide } 5.00\text{m}$$

The thickness of the solid apron depends on the nature of its foundation. It must be sufficient to resist the uplift.

The uplift is maximum at the toe of the body wall. When the canal is full, the difference in water levels between the u/s and d/s of the body wall is 2.00m.

Assuming a hydraulic gradient with a slope of 1 in 4., head lost in creep upto the body wall is (assuming one meter thick concrete),

$$= \left(\frac{2.40+1.00+0.30+2.60}{4}\right) = 1.575m$$

Residual head = 2.00 – 1.575 = 0.425m

So, the thickness to be provided

$$\frac{0.425}{(\rho-1)} = \frac{0.425}{(2.25-1)} = 0.36\text{m}$$

But a minimum thickness of $\frac{1}{2}\sqrt{d_c + h}$ is usually provided to withstand the impact of the falling water.

This gives a minimum thickness of $\frac{1}{2}\sqrt{1.5 + 2.0} = 0.94$ meters.

However, provide one meter thick concrete.

∵ a length of 5.00 meters of solid apron is provided, residual uplift head at the end of soild apron is

$$2.00 - \frac{2.40+1.00+0.30+2.60+5.00}{4} = 2.00 - \frac{11.30}{4}$$

Which is negative, i.e., all the uplift pressure is destroyed and there is no residual uplift at the end of the solid apron.

3.3.2 Notches and the Notch Pier

The sills of notches should be at the bed level of the channel u/s and the two notches now designed are arranged in the notch pier over the body wall.

The top of the notch pier is kept at F.S.L., i.e., @+11.50. The width of notch pier is usually equal to the full supply depth u/s. in this case a width of 85 cms. is provided (Fig 3.5)

The notch is arranged in the drop wall as shown in **Fig 3.5**

The above arrangement reduces the eddies around the body wall.

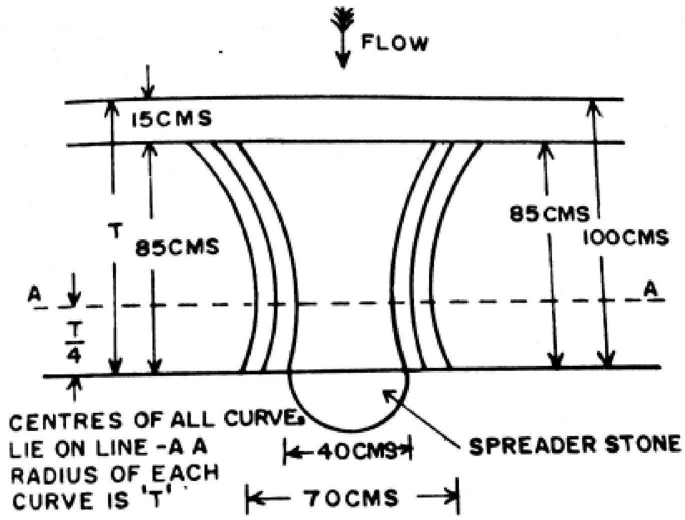

Fig 3.5 Drop wall plan

3.4 PROTECTIVE WORKS

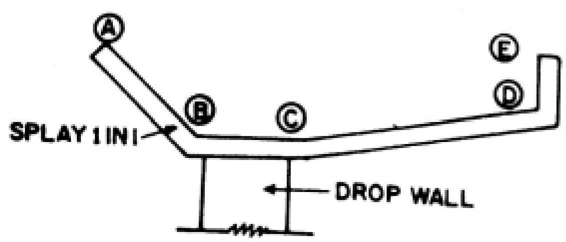

Fig 3.6 (a): Plan of the drop wall and Protective works

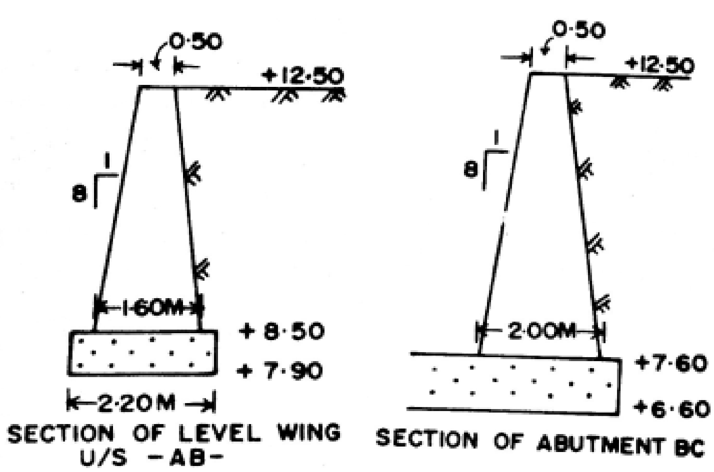

Fig 3.6 (b) & (c) Cross sections of abutment and wing wall

Abutments: BC is the abutment. Length of the abutment may be kept the same as the width of drop wall at foundations, i.e., 2.6 meters, top width of abutment is 0.50 meters. The top level of abutment is kept at the T.B.L. of the channel u/s, i.e., @+12.50. the wall will have a front batter of 1 in 8. The abutment will rest on foundation concrete 1.00meter thick. The foundation of the abutment will be continuation of the foundation of the drop wall.

Foundation top level at +7.60

Top of abutment at + 12.50

Total height 4.90m. provide a section as indicated giving a base width of 0.4*h.

Upstream wing wall: AB in Fig. 3.6 is the U/S wing wall. This wing wall is level at top with its level at +12.50. the top width is 0.50meters. This wall is splayed at 1 to 1 and has enough length such that it gets keyed into the bank well. The foundation of this wall need be as deep as that of the abutment. Since good foundation soil is available only below +8.50, thickness of foundation concrete may be adopted as 60cms.

The height of wall is 4.00 meters.

The front batter of 1 in 8 may be adopted.

Adopt a section as sketched in Fig. 3.6

Downstream sloping wing: CD in Fig. 3.6 is the D/S sloping wing. The top level of the wing at C is +12.50 and top width is 50cms. the wall also has a face batter of 1 in 8.

The section of the sloping wing at C will be same as the section of the abutment. The thickness of foundation, however, is restricted to 60cms, i.e., the top of foundation will be at +7.60 but the bottom of foundation will be at 7.00.

The top level of the sloping wing wall at D will be the same as the return DE top width is 50cms. Front batter is 1 in 8, top level will be the T.B.L. of the channel D/S, i.e., +10.50.

∴ Height of wall at D is (10.50 – 7.60) = 2.90 meters.

Adopt the section as in Fig. 3.7.

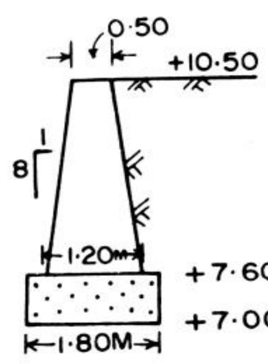

Fig. 3.7 : Cross section of return D/S DE

Section of level return : DE

Same section adopted at D may be adopted.

Splay of sloping wing: At level 8.00, i.e., bed level of channel below drop, the distance between the edges of returns is 6.00 meters, i.e., bed width of channel below drop.

This fixes the splay of the wing.

The level return is made sufficiently long so that it projects well into the top of bank D/S of drop.

3.5 LENGTH OF REVETMENTS AND BED PITCHING

(a) Measured from the face of the drop wall, the length of revetment U/S is generally kept 3 times the full supply depth (3d) or a minimum of 3 meters.

(b) Measured from the D/S edge of the solid apron, the length of the D/S revetment is kept 4 times (FSD + Ht. of drop) or a minimum of 6 meters. The length of bed pitching is kept at half the length of the corresponding revetment.

The difference in levels between the solid apron (@ +7.60) and the canal bed (@ + 8.00) is made up by a gentle reverse slope of 1 in 5 in the D/S bed pitching laid in continuation of soild apron.

Suitable bank connections are required. A berm of one meter width is provided in the canal both U/S and D/S. slope for canal cutting is taken as 1 to 1 and that for embankment is taken as 1½ :1.

3.6 SPECIFICATIONS

3.6.1 Foundation and Solid Apron

The foundation for the body wall of the drop, abutment, wing walls and returns U/S and D/S side of the drop are all laid in one monolithic mass of cement concrete, the proportion needs to be kept is 1:4:8.

For the portion of concrete forming the solid apron D/S of the body wall, imperviousness and weight (density) are the ,main criteria, so as to counteract the uplift pressure coming into play under the floor. So it will be quite economical to use fly-ash as admixture to the extent of 20 percent (replacement of cement) and this will economise the cost.

Of the total thickness of the solid apron D/S of the drop, the top 15 to 20 cms thickness is laid in C.C. with richer proportion, say in C.C. 1: 1 ½ : 3 or 1 : 2 : 4 using granite chips of 20 mm size. The use of fly-ash in this layer is not advisable. This wearing coat is necessary to withstand the impact of the water directly falling on the apron in the initial stages of flow. Once the full flow conditions are established on both sides of the drop, the depth of water D/S of the drop will act as a water cushion.

3.6.2 Body wall of drop, Abutments, wing walls and Returns U/S and D/S of drop

All these wall can be in stone masonry with C.C. mortar 1:6 well plastered on C.M. 1:4.

In case, coursed stone masonry is adopted, plastering is not necessary. Pointing the masonry in C.M. 1:3 will do.

3.6.3 Notches and Notch Piers

It is better, these items are done in rich concrete and plastered very smooth to get at the designed dimensions. It is better, the notch pier are well anchored into the body wall with dowel bars with nominal lateral reinforcement.

ASSIGNMENT