1- Canal drops:

1-1 Definition and Location of Canal drops:

Definition: Whenever the available natural ground slope is steeper than the designed bed slope of the channel, the difference is adjusted by constructing vertical 'falls' or 'drops' in the canal bed at suitable intervals, as shown in Fig..1. Such a drop in a natural canal bed will not be stable and, therefore, in order to retain this drop, a masonry structure is constructed. Such a pucca structure is called a canal fall or a canal drop.

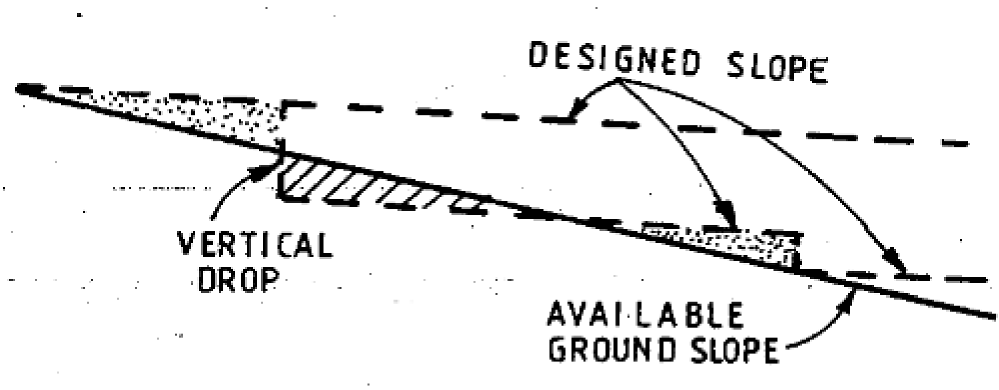

Fig.1

Proper location: The location of a fall in a canal depends upon the topography of the country through which the canal is passing. In case of the main canal, which does not directly irrigate any area, the site of a fall is determined by considerations of economy in 'cost of excavation and filling' versus 'cost of fall'. The excavation and filling on two sides of a fall should be tried to be balanced, because the unbalanced earthwork is quite costly. An economy between these two factors has to be worked out before deciding the locations and extent of falls.

2- Types of drops:

Various types of falls have been designed and tried since the inception of the idea of 'falls construction' came into being. The important types of such falls, which were used in olden days and those which are being used in modern days, are described below

1- **Ogee Falls**: The 'Ogee type fall' was constructed in olden days on projects like Ganga canal. The water was gradually led down. by providing convex and cincave curves , as shown in fig.2

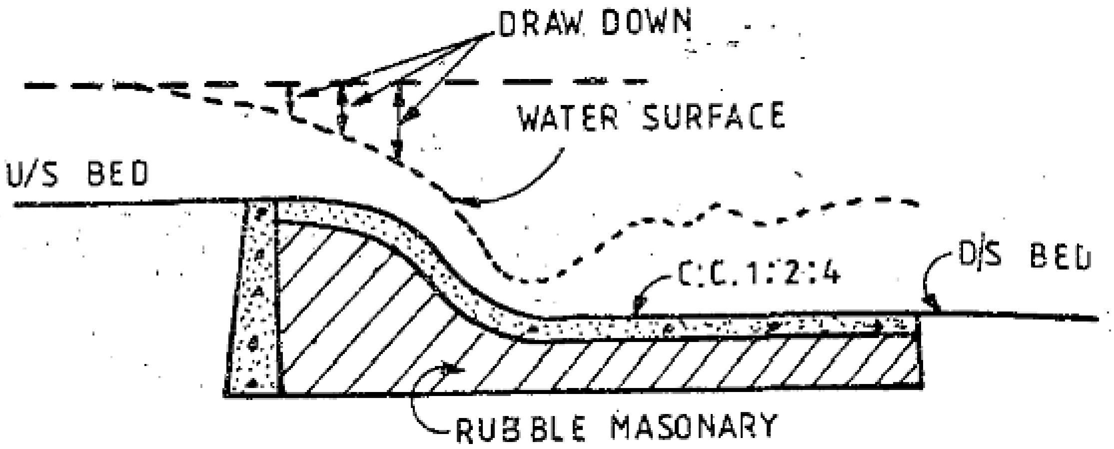

fig.2 Ogee Falls

2- **Rapids**: In Western Yamuna canal, long rapids at slopes of 1 : 15 to 1 : 20 (i.e., gently sloping .glacis) with boulder facings, were provided. They worked quite satisfac-torily, but were very expensive, and hence became obsolete.

3- **Trapezoidal Notch Falls**. The trapezoidal notch fall was designed by Ried in 1894. It consists of a number of trapezoidal notches constructed in a high crested wall across the channel with a smooth entrance and a flat.circular lip projecting downstream from each notch to spread out the falling jet. Fig.3

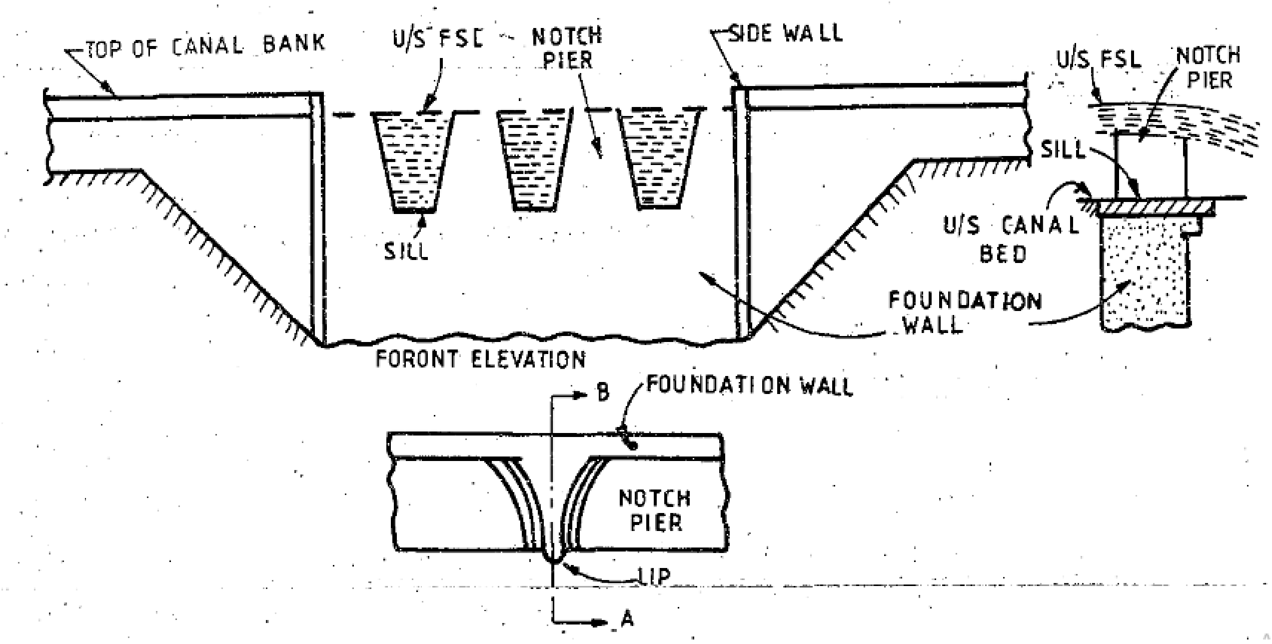

Fig.3 **Trapezoidal Notch Falls**

4- **Well Type Falls or Cylinder Falls, or Syphon Well Drops**. This type of a fall consists of an inlet well with a pipe at its bottom, carrying water from the inlet well to downstream well or a cistern. The downstream well is necessary in the case of falls greater than 1.8 m and for discharges greater than 0.29 cumecs. The waterfalls into the inlet well, through a trapezoidal notch constructed in the steining of the well, from where it emerges near the bottom, dissipating its energy in turbulence inside the well fig .4

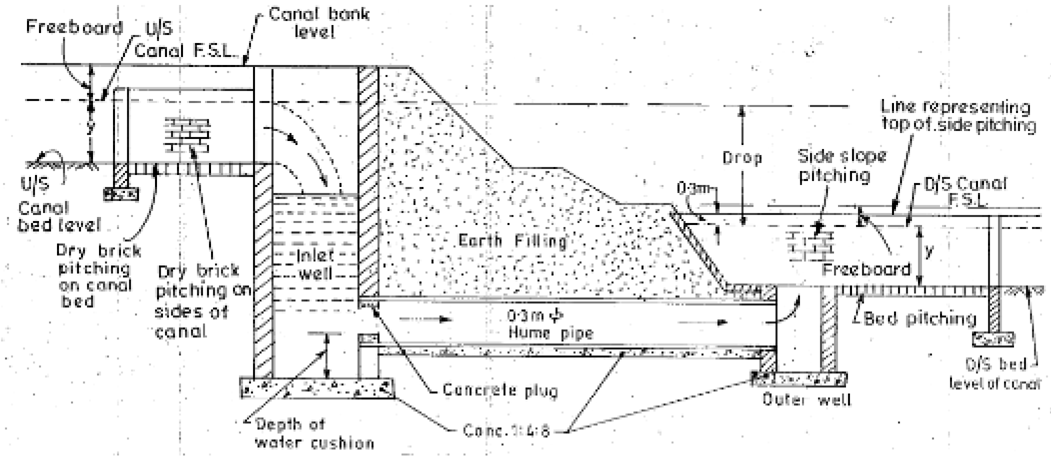

Fig.4 Syphon Well

5- **Simple Vertical Drop Type and Sarda Type Falls**. A raised crest fall with a vertical impact (Fig. 5) was first of all introduced on Sarda. Canal System in U.P, owing to its economy and simplicity. The necessity for economic falls.· arose because of the need for construction of a large number of smaller falls on the Sarda.

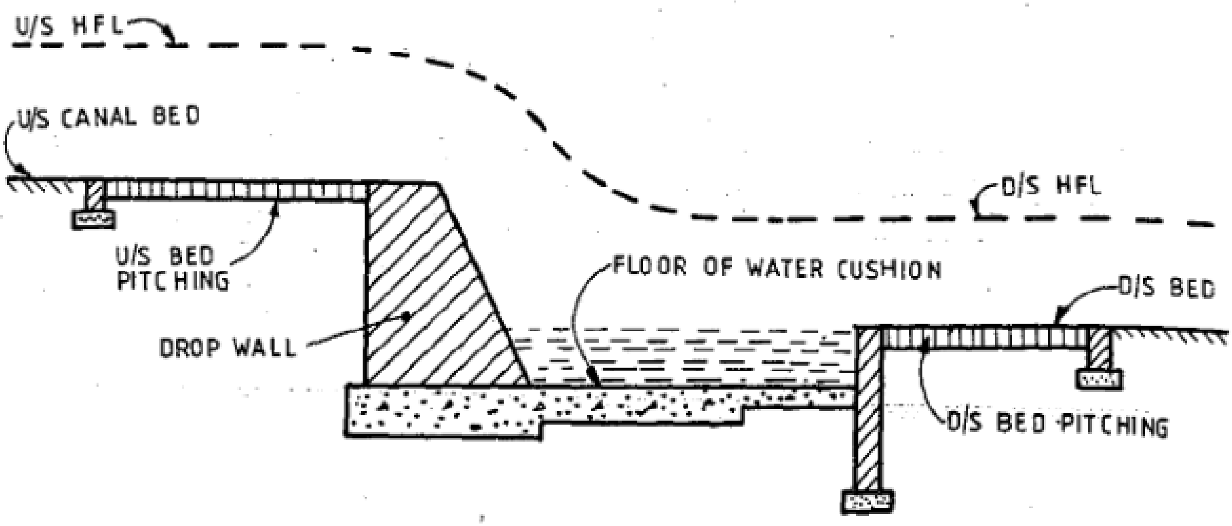

Fig.5 Simple Vertical Drop

6- **Straight Glacis Falls in this type of a modern fall**: a 'straight glacis' (generally sloping 2 : 1) .is provided after a 'raised crest' (see Fig .6). The hydraulic jump is made to occur on the glacis, causing sufficient energy dissipation. This type of falls gives very good performance if not fumed, although they may be flumed for economy. They are suitable for up to 60 cumecs discharge and 1.5 m drop.

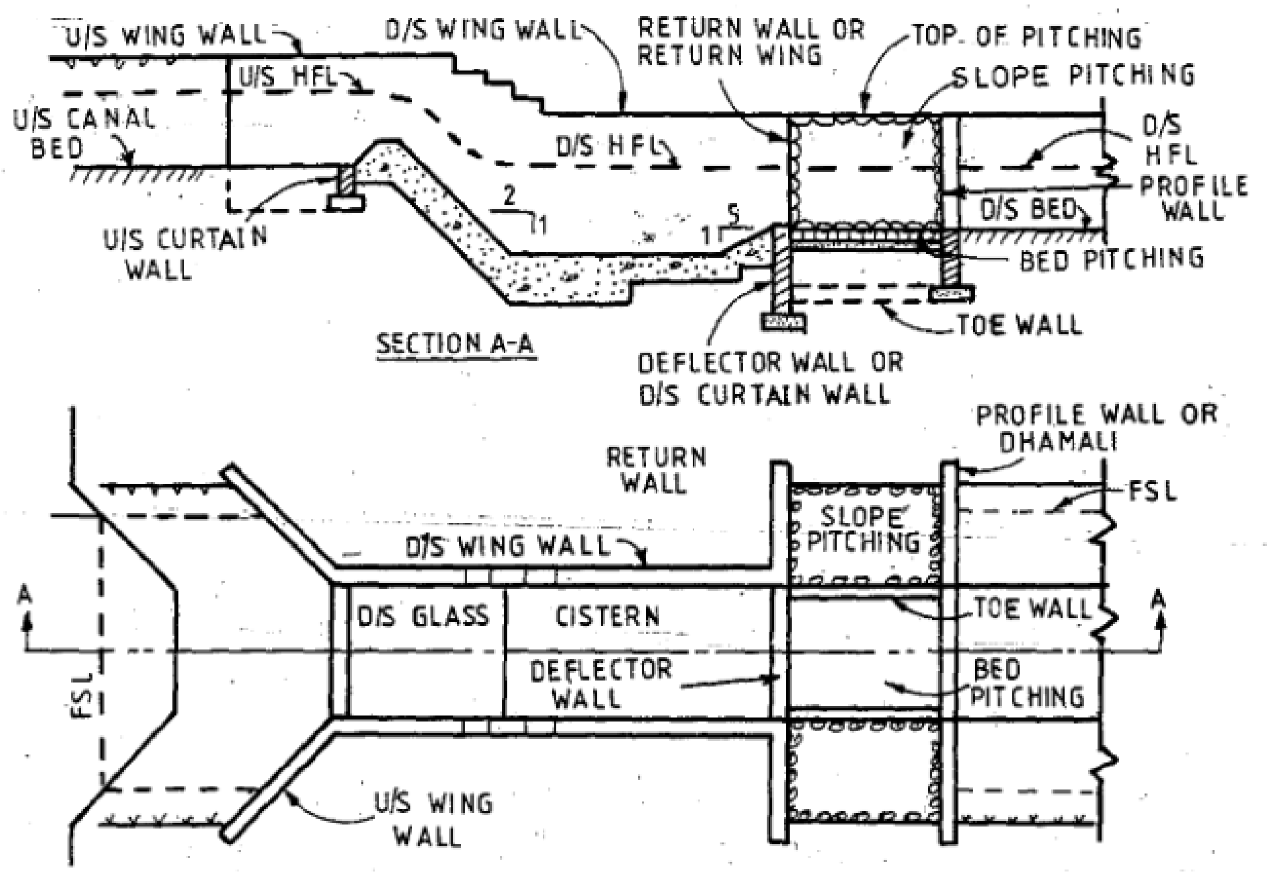

Fig .6 'Straight Glacis fall (without fuming), without Regulator and Bridge Details.

7- **Montague Type Falls**. The energy dissipation on a straight glacis remains incomplete due to vertical component of velocity remaining unaffected. An improvement in energy dissipation may be brought about in this type of fall [see Fig. .7 (a)], by replacing the straight glacis with a parabolic glacis', commonly known as 'Montague Profile'

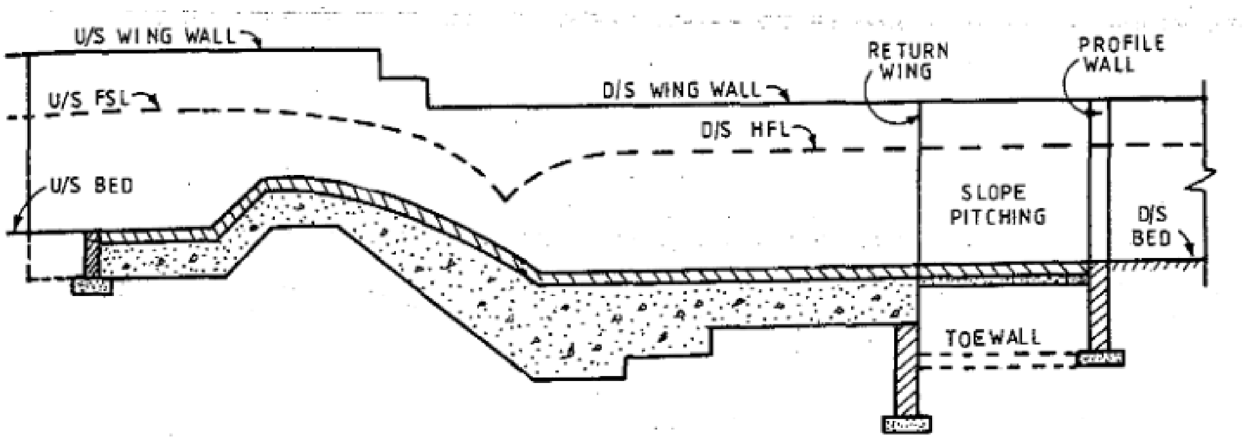

Fig.7 a. Montague Type fall.

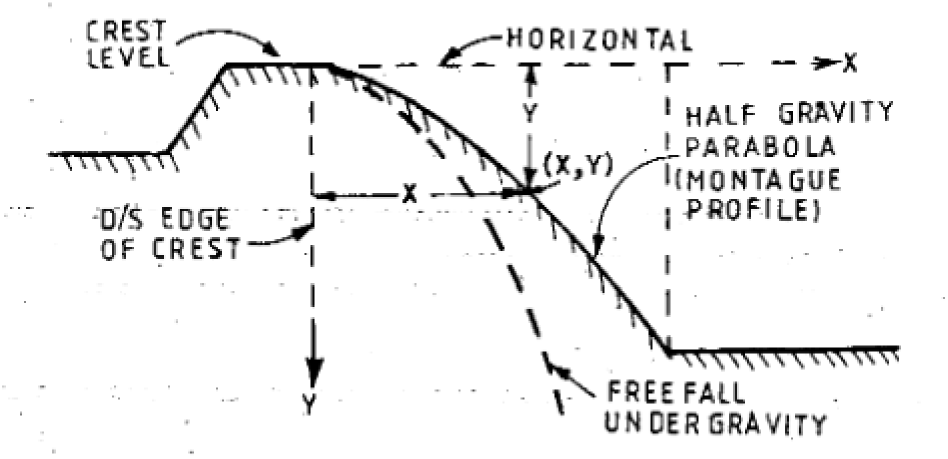

Fig.7 b. Montague Profile.

The Montague profile is given by the equation.

$$X = U\sqrt{\frac{4Y}{g}} + Y$$

Where

X = The horizontal ordinate of any point of the proflie measuredfrom the dis edge of crest.

Y = Vertical ordinate measured from the crest level.

U = Initial velocity of water leaving the cres.

8- **Inglis Falls or Baffle Falls:** A straight glacis type fall when added with a baffle platform and a baffle wall as shown in Fig. 12.8, was developed by Englis, and is called 'Englis Fall' or 'Baffle Fall'. They are quite suitable for all discharges and for drops of more than 1.5 m. They can be flumed easily as to affect economy. The baffle wall is provided at a calculated height and a calculated distance from the toe of the glacis, so as to ensure the formation of the . jump on the baffle platform, as shown in Fig.8

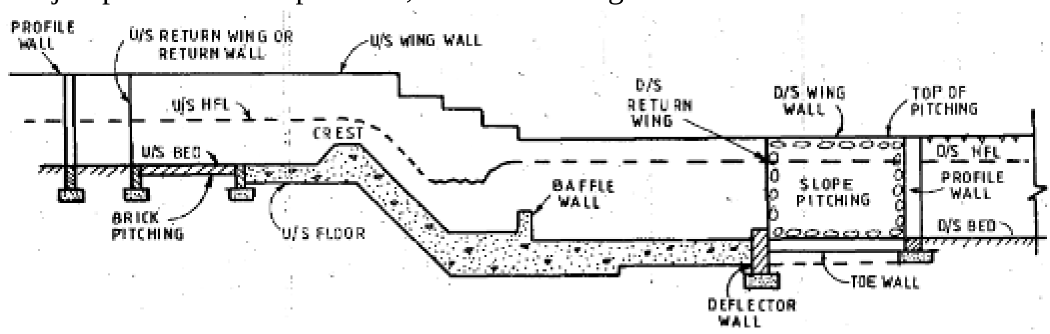

Fig.8 Inglis Falls or Baffle Falls

3- Design principles of various types of falls

1- Design of a Trapezoidal Notch Fall.

As pointed out earlier, a notch fall provides a proportionate fall, in the sense that there is no heading up or drawdown of water level in the canal near the fall. The whole width of the channel is divided into several notches. The crest (i.e. the sill level or the level of the bottom of the notch) may be kept higher than the bed level of the canal, which will tend to increase the length of the weir, but in no case, the total length of the weir openings should exceed the bed "width of the canal upstream, and may well be reduced to about 7/8th of the bed width

Discharge Formula. The discharge passing through one notch of a notch fall can be obtained by adding the discharge of a rectangular notch and a V-notch

The discharge passing .through a trapezoidal notch such as shown in Fig..9 is given by

$$Q = \frac{2}{3} C_d \cdot \sqrt{2g}\ l \,.\, H^{3/2} + \frac{8}{15} \cdot C_d \cdot \sqrt{2g} \tan \frac{\alpha}{2} H^{5/2}$$

$$= \frac{2}{3} C_d \cdot \sqrt{2g} \left[l H^{3/2} + \frac{4}{5} \tan \frac{\alpha}{2} H^{5/2} \right]$$

$$= \frac{2}{3} C_d \cdot \sqrt{2g} \left[l H^{3/2} + \frac{2}{5} \left(2 \tan \frac{\alpha}{2} \right) H^{5/2} \right]$$

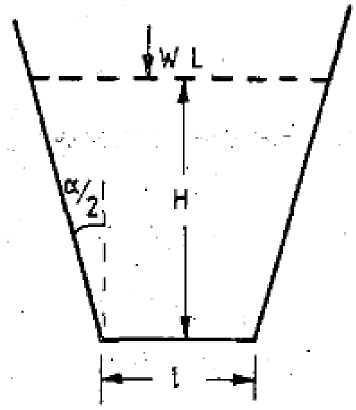

fig 9

If $2 \tan \frac{\alpha}{2}$ is represented by n, then

$$Q = \frac{2}{3} C_d \cdot \sqrt{2g} \left[l H^{3/2} + 0.4 \,.\, n H^{5/2} \right]$$

where, C_d = Coefficient of discharge ≈ 0.75

$$Q = \frac{2}{3} \times 0.75 \sqrt{2 \times 9.81} \left[l H^{3/2} + 0.4\, n H^{5/2} \right]$$

$$Q = 2.22 H^{3/2} \left[l + 0.4 n H \right]$$

The above discharge equation contains two unknowns l and n. For solving this equation,two values of Q and corresponding values of H must be assumed. It is a common practice to design notches for full supply discharge (Q100) and half supply discharge (Q50) with values of H equal to the normal water depths in the channel in the 'respective cases. Let the normal water depths in the channel at full discharge and half discharge be represented by Y100 andy50 respectively. Then H100 =Y100, and H50 = Y50·

The depth of water in the channel at 50% discharge (i.e. y50 can be approximately evaluated in terms of full supply depth (y100) as follows :

Let $V = C \cdot y^{0.64}$ ...(Kennedy's Eq. for Vel. in channels)

Now $Q = A.V.$

$\therefore$ $Q = B \,.\, y \,.\, C \,.\, y^{0.64}$ Using $A \approx B.y$ (neglecting sy^2)

or $Q = C \,.\, B \,.\, y^{1.64}$

$\therefore$ $Q_{100} = C \,.\, B \,.\, y_{100}^{1.64}$

and $Q_{50} = C \,.\, B \,.\, y_{50}^{1.64}$

or $$\frac{Q_{50}}{Q_{100}} = \left(\frac{y_{50}}{y_{100}}\right)^{1.64}$$

or $$\frac{y_{50}}{y_{100}} = \left(\frac{Q_{50}}{Q_{100}}\right)^{\frac{1}{1.64}} = (0.5)^{\frac{1}{1.64}} = 0.66$$

$\therefore$ $y_{50} = 0.66 \cdot y_{100}$

Number of Notches. The number. of notches should be so adjusted by the hit and trial method that the top width of the notch lies between to full water depth above the ill of the notch. This hit and trial procedure would become clear when we solve a numerical example.

Notch Piers. The thickness of notch piers should not be less than half the water depth and maybe kept more if they have to carry a heavy super structure. The top length of piers should not be less than their thickness. In plan, the notch profile is set back by 0.5 m from the downstream face of the notch . fall for larger canals, and by 0.25 m for distributaries. All curves are circular arcs, and all centers lie in the plane of the profile. The splay upstream from the notch section is 45°, and the downstream splay is kept at 22.5°. The lip is circular and is corbelled 'out by 0.8 m on larger canals, and by 0.6 m on distributaries.

Example 1. Design the size and number of notches required for a canal drop with the following particulars.

Full supply discharge =4cumecs

Bed width =6.0m

F.S. depth. =I.5m

Half supply depth =I.0m

Assume any other data if required.

Solution. The bed width of the canal is 6 m. Each potch at top should be roughly equal to F.S. depth i.e. 1.5 m. So let us, in the first trial, provide 3 notches.

Full supply discharge through e.ach notch=4/3= 1.33 cμmecs

$$Q = 2.22 H^{3/2} [l + 0.4\, nH]$$

Using $Q_{100} = 2.22\, (y_{100})^{3/2}\, [l + 0.4n\, y_{100}]$

where $Q_{100} = 1.33$ cumecs

$y_{100} = 1.5$ m

$\therefore$ We have $1.33 = 2.22 \,.\, (1.5)^{3/2}\, [l + 0.4n \times 1.5]$

or $1.33 = 2.22 \times 1.84\, [l + 0.6n]$

or $l + 0.6n = 0.326$ ...(*i*)

Now, using

$$Q_{50} = 2.22 \,.\, (y_{50})^{3/2}\, [l + 0.4n \,.\, y_{50}]$$

where $Q_{50} = \frac{1.33}{2} = 0.67$ cumecs

$y_{50} = 1.0$ m

$\therefore$ $0.67 = 2.22 \,.\, (1.0)^{3/2}\, [l + 0.4n \times 1]$

or $l + 0.4n = 0.3$ ...(*ii*)

Subtracting (*ii*) from (*i*) we get

$0.2n = 0.026$

or $n = 0.13.$

Putting the value of n in (*ii*) we get

$l + 0.4 \times 0.13 = 0.3$

or $l = 0.248$; say **0.25 m.**

By this trial, we find the top width

$= 0.25 + 2 \tan \alpha \cdot H = 0.25 + n \,.\, H$

$= 0.25 + 0.13 \times 1.5 = 0.25 + 0.195$

$= 0.445$; say 0.45 m, which is much less than the full depth of 1.5 m.

To increase the top width, and to make it near 1 to 3/4th FSD, it is necessary to increase l and n which can be done by reducing the number of notches. The values of l and n obtained for 3 notches will increase in direct proportion, when number of notches are reduced. In other words, the values l of and n will become 3 times, when number of notches are reduced 3 times. Thus, when we provide only one notch instead of 3 notches, the values of n and l will triple. Similarly, when we use 2 notches against 3, i.e., 1/5 times the values n and l will become 1.5 times of those obtained for 3 notches.

Hence when we use 2 notches, values will be:

$$n = 1.5 \times 0.13 = 0.20$$
$$l = 1.5 \times 0.25 = 0.3 \text{ m}$$
and $$\text{Top width} = 1.5 \times 0.45 = \mathbf{0.68\ m.}$$

Since the width is still quite low, we may use only one notch .

When we use only one notch, the values will be:

$$n = 3 \times 0.13 = 0.39$$
$$l = 3 \times 0.25 = 0.75 \text{ m}$$
$$\text{Top width} = 3 \times 0.45 = 1.35 \approx \text{FSD (O.K.)}$$
$$\frac{\alpha}{2} = \tan^{-1}\frac{n}{2} = \tan^{-1}\frac{0.39}{2} = 11°$$

Since this condition gives us top width = 1.35 m, which is O.K., we may pro-vide one notch, centrally placed in the given channel of 6 m width. The section of the. notch to be adopted is also shown in Fig.10

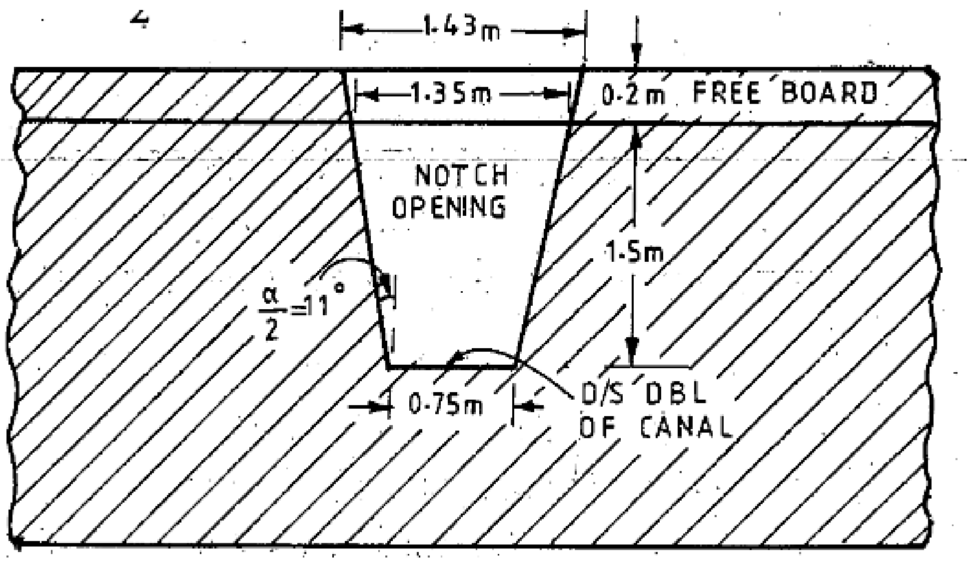

Fig 10

Check for raised crest if possible. It has also been noticed that when lesser number of notches are Provided, with their. bottoms kept at U/S DBL of canal the concentration of flow gets increased considerably.to avoid such an eventuality,its preferable to increase the number of notches, and this may sometimes be. achieved by providing the notches in the raised crest. In other words, the bottom of notch opening will be kept higher than U/S DBL of canal. This raising may be between 10% to 30% of full depth. The design calculations are hence to be repeated to compute n and l with a raised crest, whenever a detailed designing is being done, and number of notches determined are low.

These calculations for the above question will be as follows :

Let us assume a raised crest equal to 20% of FSD

$$= 20\% \times 1.5 \text{ m} = 0.3 \text{ m.}$$

$Q = 2.22\, H^{3/2}\, [l + 0.4nH]$, we have

$$Q_{100} = 2.22\,(1.5 - 0.3)^{3/2}\,[l + 0.4n\,(1.5 - 0.3)]$$

or $$Q_{100} = 2.92\,(l + 0.48n) \qquad ...(iii)$$

Also $$Q_{50} = 2.22\,(1.0 - 0.3)^{3/2}\,[l + 0.4n\,(1.0 - 0.3)]$$

[$\because$ FSD at $\frac{1}{2}$ discharge = 1.0 m (given)]

or $$Q_{50} = 1.3\,(l + 0.28\,n) \qquad ...(iv)$$

But $$Q_{100} = 2Q_{50}$$

$\therefore$ $$2.92\,(l + 0.48\,n) = 2 \times 1.3\,(l + 0.28\,n)$$

This gives a negative value of n, which is not feasible, and hence such a raised crest may not be feasible in this particular case. Hence, the design made earlier, and shown in Fig. 10, holds good.