UNIT 13 REGULATING STRUCTURES

Structure

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13.1 INTRODUCTION

The discharge released from a barrage into an irrigation canal has to be regulated according to the demand and the available supply. The regulation of supplies as available from the parent canal, to the different distributary canals has to be made as per the rotation that is set out for the equitable distribution of water to the cultivators. For effecting control, for this purpose, on the irrigation system some structures are required to be constructed at the barrage and also on the offtaking distributary canals.

Objectives

By the end of this unit you should be able to know about the basic composition, and fundamental design parameters of the following hydraulic structures :

- canal head regulators,
- distributary head regulators, and
- cross regulators.

13.2 CANAL HEAD REGULATORS

A canal head regulator which is located just upstream of a barrage (or placed appropriately near about a reservoir) is provided to help,

(a) regulate the discharge flowing into the offtaking channel, and

(b) control the entry of sediment into the channel.

A head regulator is generally aligned at an angle of 90° to 110° to the axis of the barrage (Figure 13.1) in order to minimise the entry of sediment entering into the channel, besides preventing backflow and stagnant pools in the undersluice pocket that lies in the vicinity of the regulator. Steel gates of spans usually in the range of 6 to 8 m, for manual operation, are provided in the regulator to control the discharge. Larger spans can be adopted for gates which are operated by electric winches.

To the designed full supply level of the canal, a working head of 1.0 to 1.2 m is added to obtain the pond level in the undersluice pocket, upstream of the canal head regulator. The head over the crest required to pass the full supply discharge in the canal at the specified pond level is subtracted from the pond level to obtain the crest level of the head regulator. To prevent the entry of sediment into the canal, the crest of the head regulator is always kept higher than the sill level of the undersluices. Wherever a sediment excluder is provided in the undersluice portion of the barrage, the crest level of the head regulator is decided considering the design requirements of the sediment excluder besides the requirements of waterway of the regulator, and the working head that is available.

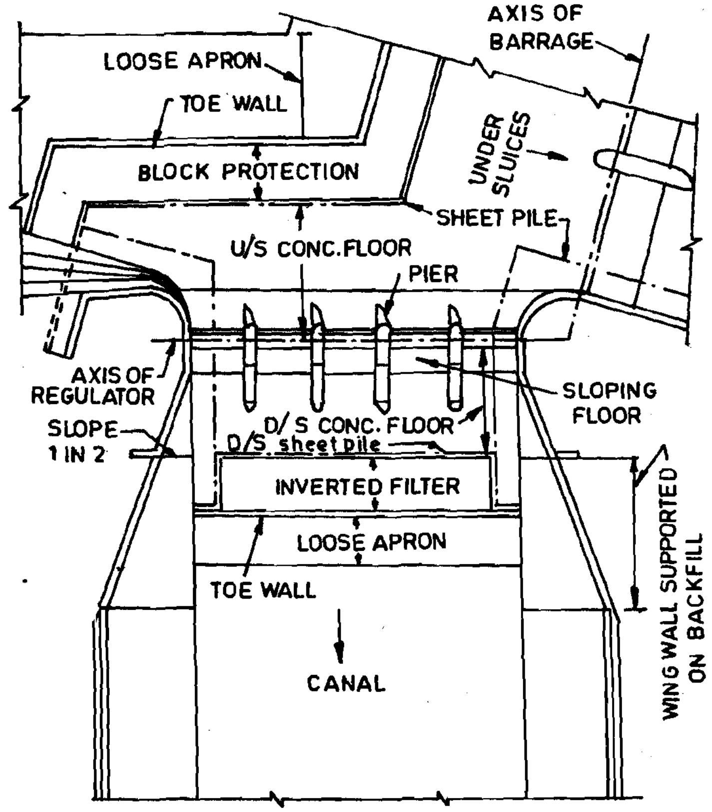

Figure 13.1 : Plan of a Canal Head Regulator

The width of the waterway in the head regulator is so determined that the full supply discharge can be fed into the canal with about 50% of the working head. Should the required waterway at the head regulator work out to be more than the bed width of the canal, a converging transition is provided downstream of the regulator to obtain the desired canal width. The following relation is used to determine the required head over the crest, H (m) :

$$Q = C\,(L - K\,n\,H)\,H^{3/2} \qquad \ldots (13.1)$$

where, Q = discharge (cumec),

C = a coefficient that depends on various factors like, head over the crest, shape and size of the crest, height of the crest over the upstream floor and the roughness of the crest surface. Model studies are suggested to determine the value of C. But in the absence of such studies, it may be taken as 1.71.

L = overall (i.e, gross) waterway (m),

K = a coefficient ranging from 0.01 to 0.10 depending on the shape of the abutment and the pier nose, and

n = number of end contractions.

The difference between the pond level and the crest level of the regulator is taken as the height of the gates. But during periods of high floods, the water level in the river would rise to a level much higher than the pond level in which case the flood water may spill over the gates. Providing gates up to the HFL would obviously be uneconomical besides the cost of the heavier gates and the machinery required to operate them under high water pressures would also be more expensive. Such spilling of the flood water into the canal is prevented by providing an RCC breast wall (Figure 13.2) between the pond level and the HFL. The breast wall spans between adjacent piers. With this arrangement, the gate opening between the crest level and the pond level is fully open when the gate is raised up fully, i.e., to the pond level. When the gate is lowered to the crest of the regulator, the opening is fully closed.

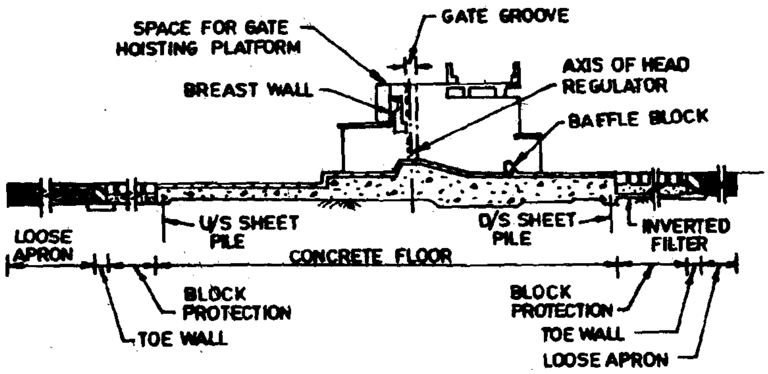

Figure 13.2 : Section of Canal Head Regulator

After fixing the crest level, waterway, number of spans and thickness of piers, the head regulator is designed on the same principles as a weir. The canal is generally kept closed when the highest flood passes down the river. This situation would lead to the worst static condition and the floor thickness must be such as to withstand the uplift pressure under this condition. The exit gradient for this situation should also be within safe limits. The floor is designed so as to counter the uplift pressure by its self weight, and also to develop the necessary bending strength. For economic reasons, it may be necessary to extend the piers upto the end of the floor to provide the required support to the upward bending slab; thus, reducing the thickness of the slab.

In the trough portion where the jump would form, it is seen that the worst uplift situation occurs when some water is passing into the canal. Hence, the safety of this part of the floor should be checked for varying discharges inclusive of the maximum. Extending the concrete floor upstream of the undersluices upto the end of the head regulator also reduces the uplift pressures on the downstream floor of the regulator.

Access across the canal head regulator is provided by a bridge and for operating the gates a working platform is incorporated in this arrangement.

SAQ 1

(a) Where is a canal head regulator located? Discuss the reasons for the same.

(b) What is the purpose of a canal head regulator? Elaborate in detail.

13.3 DISTRIBUTARY HEAD REGULATORS

The distributary head regulator is distinguished from a canal head regulator in that the former is located in a main canal for feeding the water into a distributary canal while the latter is located at the barrage at the head of the offtaking canal. The location of a distributary head regulator is at the entry point of the distributary where it takes off from the main canal (Figure 13.3).

The purpose of the distributary head regulator is to :

(a) divert and control the supplies offtaking from the main canal and entering the distributary,

(b) restrict the silt entering the distributary canal from the main canal, and

(c) measure the discharge being carried by the distributary.

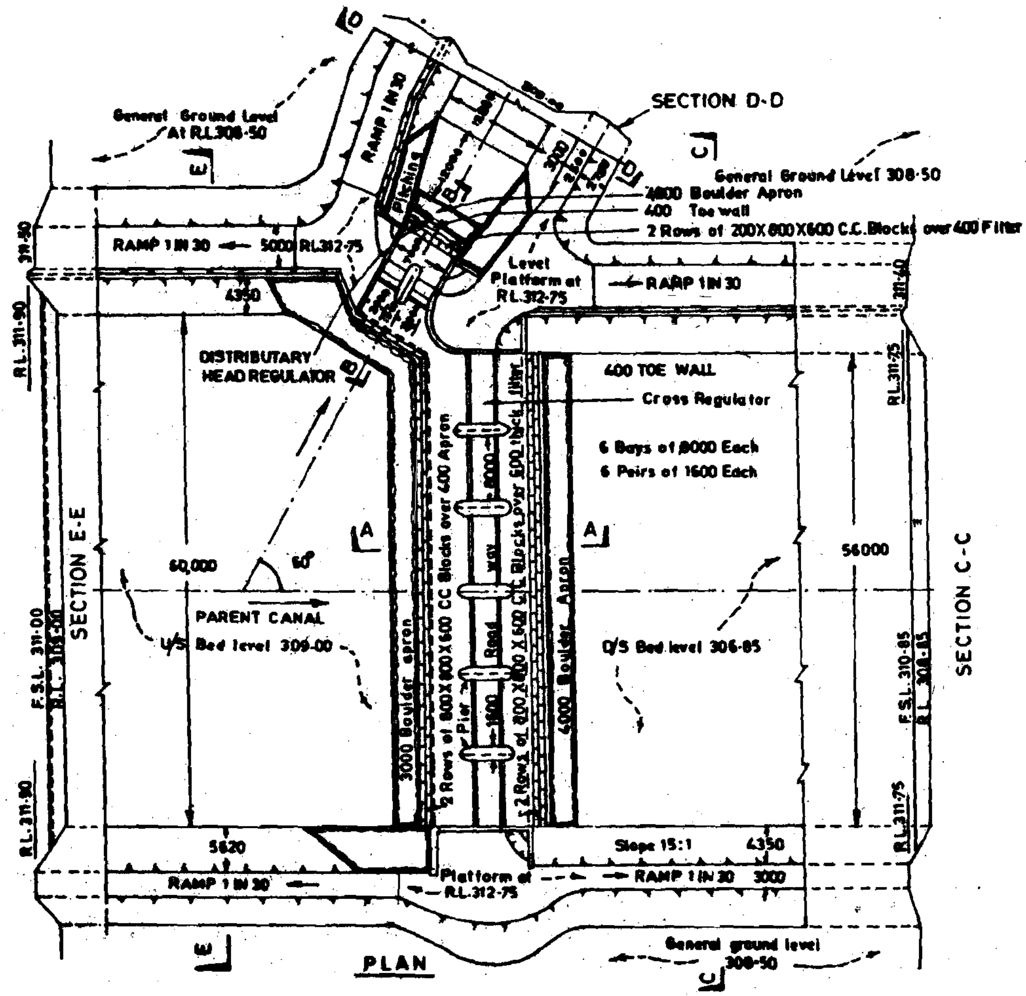

Figure 13.3 : Cross Regulator and Distributary Head Regulator

The supplies entering the distributary from the main canal are regulated by means of the regulator crest which has piers, placed along the length of the crest, at suitable intervals and abutments at either end. The piers and abutments are provided with grooves in which gates or wooden planks (needles) can be lowered and raised to vary the discharge (Figure 13.4). The gates are for large channels, while needles are for smaller spans. Gates of spans of upto 8 m can be operated by hand while larger gates, say, 20 m wide, have to be operated by mechanical means. Wooden planks are obviously used in smaller channels.

The quantity of silt drawn into the distributary channel may be unduly heavy on account of the following reasons :

(a) Lower layers of water (carrying major silt/sediment load) are more easily diverted into the offtaking channel as compared to the upper layers, because the lesser velocities are confined to the lower layers.

(b) Due to the difference in the central and near-bank velocities of flow, it has been seen that the bottom water has a tendency to move toward the banks at the regulator site, and so the concentration of sediment is generally higher near the banks (and the regulator is situated on the bank line itself).

Thus, if suitable measures are not taken to control the entry of sediments into the distributary, the offtaking channel will draw in and deposit more sediment than permitted, requiring repeated desilting operations.

It is obvious that by causing the sediment to concentrate in the lower layers of the flowing water (that is, near the bed of the main canal upstream of the offtaking point), and allowing only silt free upper layers of water to enter the distributary channel, sediment entry into the offtaking channel can be minimised. Providing a smooth bed in the main canal upstream of the offtaking channel will help in concentrating the sediment in the lower layers because the smooth bed will reduce the turbulence which is responsible in keeping the sediment in suspension. Further, steps to increase the velocity near the banks will also be helpful. The sediment withdrawal by the offtaking channel is also being affected by the alignment of the offtaking channel. The alignment of the offtaking canal should be kept such that its centre line is at an angle of 60° to 80° to the centre line of the main canal in the direction of flow to prevent excess sediment being drawn into the offtaking canal. On important works, the alignment is finalised after model studies.

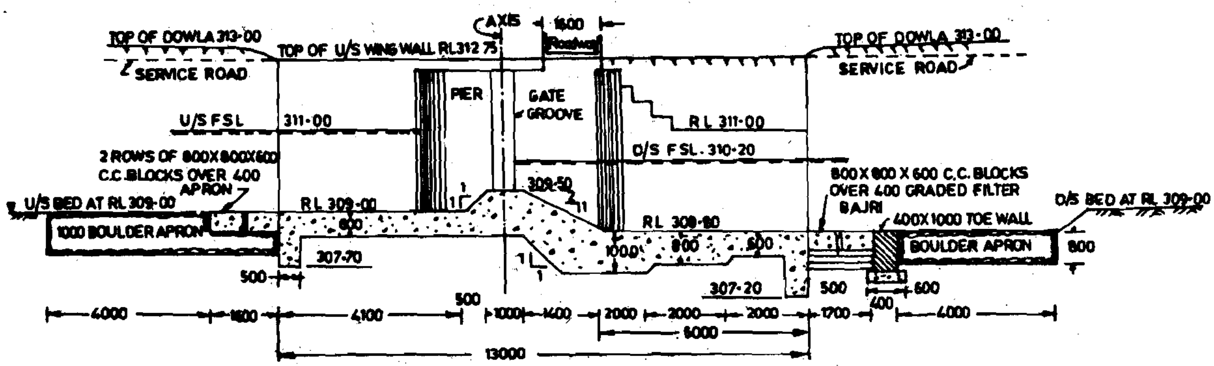

Figure 13.4 : Section at B-B through Distributary Head Regulator (*See Figure 13.3*)

The distributary head regulator can be used as a metering structure for which suitable head on crest versus discharge relationship can be determined for use by the field staff. This relationship will help in monitoring and regulating the discharge in the distributary.

13.4 CROSS REGULATOR

It is a control structure constructed across a canal (Figure 13.3) to regulate the level of the water upstream of the cross regulator (while the required discharge is allowed to pass downstream) for any of the following purposes :

(a) To allow the desired discharge in the offtaking canal that is situated upstream of the cross regulator,

(b) To release water from the canals by operating along with escapes,

(c) To maintain the water surface slopes in appropriate conjunction with the flow control over falls so the canals may attain their regime slopes and cross sections,

(d) To control the discharge released by one canal into another canal or lake.

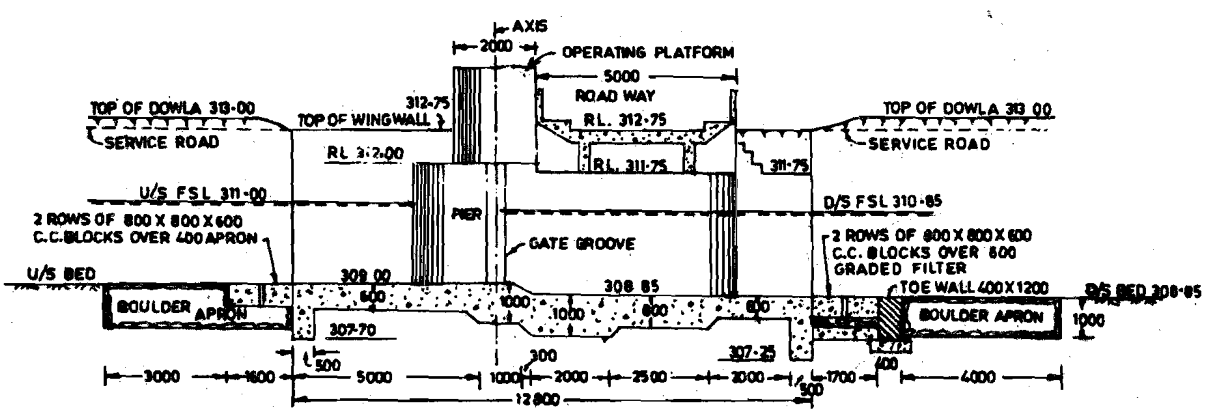

Figure 13.5 : Section at A-A through a Cross Regulator (*See Figure 13.3*)

It is general practice to provide a cross regulator in the main canal downstream of the offtaking canal. This permits the water level to be raised in the main canal, by means of gates provided in the structure for which suitable grooves are provided (Figure 13.5), when the supplies are low, to such a level that the offtaking canal can draw the desired discharge. A cross regulator is necessary on all irrigation systems, because the distributaries and field channels are required to be supplied with water according to a set roster even when the parent canal is carrying low supplies.

Economic and other special considerations dictate the provision of a bridge or fall along with the cross regulator.

SAQ 2

(a) How is a distributary head regulator different from a canal head regulator? Explain in detail.

(b) What causes heavy silt to be drawn into a distributary canal?

(c) How can you minimise the entry of silt into offtaking canals? Give details about these measures. Collect some actual field examples.

SAQ 3

What is a cross regulator and what are its functions? Give one field example along with a sketch.

13.5 DESIGN CRITERIA FOR CROSS REGULATOR AND DISTRIBUTARY HEAD REGULATOR

The design criteria for the canal head regulator have already been discussed in Block 2 (under Section 5.3 of Unit 5). And, as an extension, the design criteria for cross and distributary head regulators are discussed in the following sub-sections.

13.5.1 Design of Cross Regulator

The waterway of a cross regulator adopted should be such that the resulting afflux is less than 0.15 m.

The full supply level in the main canal is maintained by the cross regulator so as to feed the distributary canal even when the supply in the main canal is (2/3)rd of the actual capacity of the main canal.

The crest level of the cross regulator should be kept 0.15 m (minimum) above the bed of the canal but in no case higher than 40% of the normal depth of the canal on the upstream. The width of the crest should be more than (2/3)rd of the head, and adequate enough to accommodate the gate sill. The raised crest may be provided with upstream and downstream slopes of 2 (H) : 1 (V). The length of impervious floor and depths of cutoffs at the upstream and downstream ends of the floor are designed with regard to the considerations of hydraulic jump, uplift pressures, safe exit gradient and maximum scour depth. Block protection, inverted filters and launching aprons are provided on the upstream and downstream ends of the impervious floors.

13.5.2 Design of Distributary Head Regulator

The overall waterway should be kept at least 70% of the normal canal width (at mid depth) of the offtaking canal d/s of the head regulator, while the effective waterway should be kept at least 60% of the width of the offtaking canal; the objective of this criterion being that the mean velocity at full supply should be within 2.5 m/s.

The crest level of the distributary head regulator is fixed such that the full supply discharge of the offtaking canal can be drawn even when the parent canal is carrying low supplies which may be (2/3)rd of the full supply discharge of the parent canal. The water level at the offtaking canal should be worked out by backwater calculations. The crest level of the head regulator is calculated by deducting the head (H) required to cause the desired discharge from the computed water surface level at the offtake. However, the crest level should not be lower than the bed level of the offtaking canal. It is usual to keep the crest level of the head regulator 0.3 to 0.6 m higher than the crest level of the cross regulator.

The discharge through the head regulator is given by the following relation :

$$Q = C_d B_E H^{3/2} \qquad \ldots (13.2)$$

where, C_d = coefficient of discharge,

= 1.84 for sharp crested weirs (when the crest width $< 2H/3$)

= 1.705 for broad crested weir (when the crest width $> 2.5H$ for free flow conditions),

B_E = effective waterway,

$$= B_T - 2(n K_P + K_A) H \quad \text{. . . (13.3)}$$

B_T = overall waterway, which is the same as the clear crest length,

K_P = coefficient of contraction for piers, ranging from 0.005 to 0.02, depending on the pier geometry,

K_A = coefficient of contraction for abutments, ranging from 0.1 to 0.2, depending on the geometry of the abutment,

n = number of piers.

Note : For submerged condition suitable alterations in the relevant parameters are to be made.

SAQ 4

(a) What are the design criteria for distributary head regulators? Give justifications.

(b) Describe the design criteria for cross regulators giving the reasons for each criterion.

13.6 SIMPLE DISTRIBUTARY HEAD REGULATOR

A simple distributary head regulator (Figure 13.6) serves the purpose of regulating the supplies. The wings are laid out to link the parent canal with the offtaking canal. The length of waterway or crest is obtained by the drowned weir formula, such as :

$$Q = C_d\, L\, \sqrt{(2g)} \left[(2/3)\, H_L^{3/2} + h_d \sqrt{H_L} \right] \quad \text{. . . (13.4)}$$

where, C_d = average coefficient of discharge = 0.65,

L = length of crest,

H_L = upstream water surface level – downstream water surface level, and

h_d = downstream water surface level – crest level.

The wings have grooves for inserting and removing stoplogs. The road is taken across the parent canal and the offtake by means of a bridge. The floor is designed on the basis of Bligh's theory for the extreme condition which occurs when the offtaking canal is closed while the parent canal is running full.

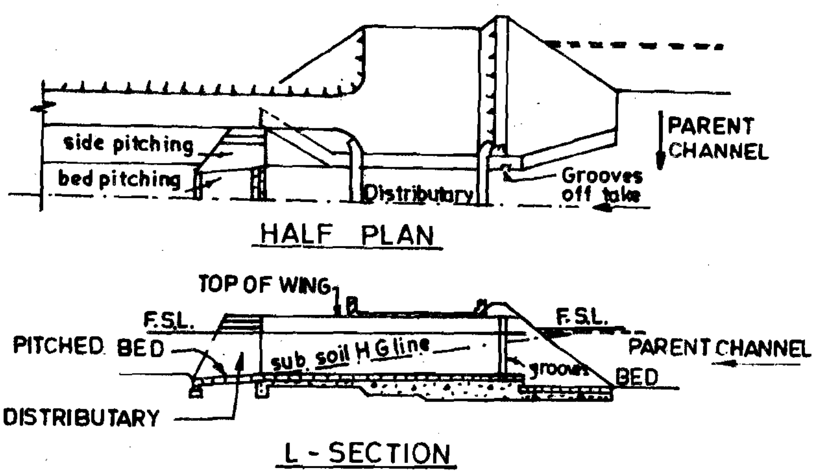

Figure 13.6 : Simple Distributary Head Regulator

13.7 VENTURI HEAD REGULATOR

The venturi head regulator consists of a flumed throat with suitable wings to attain the normal bed width of the offtake downstream (Figure 13.7). Theoretically, the maximum discharge passing through an open venturi flume occurs when critical flow is obtained; this flow is given by the expression :

$$Q = 1.71\, W d^{3/2} \qquad \ldots (13.5)$$

where, W = width of the throat, and

d = depth of water upstream of the throat (ignoring the approach velocity head).

Design Criteria

(i) Angle of offtake may be kept between from 60° to 90°, in the direction of flow.

(ii) Bed width may vary upto 6 m.

(iii) Width of throat should be more than one-third the bed width of the offtaking canal and not less than the value given by the expression :

$$W = Q / (1.2\, d^{3/2}) \qquad \ldots (13.6)$$

where, d = depth of the sill below the FSL, and

Q = discharge.

(iv) If there is a regulator in the parent canal downstream of the head of the offtaking canal or if there is a large drop, the width of the throat may be kept 1/4 of bed width or $Q / (1.4\, d^{3/2})$ whichever is greater, but with a minimum of 0.6 m.

(v) The drop in water surface through the head regulator should be assumed as $d/8$ (minimum). The width of the throat and the sill level are interdependent and may be kept within the limits as outlined above.

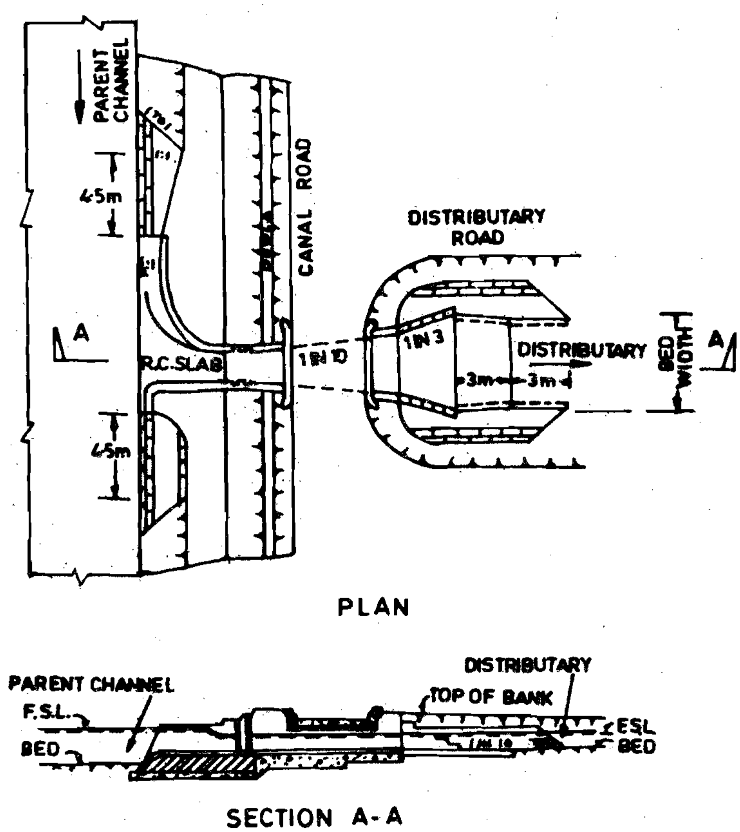

Figure 13.7 : Venturi Head

(vi) The throat is set-back ($1.4\,W + 0.6$) m from the FSL of the parent canal. The side slope of the parent canal should be kept as 0.5 (H) : 1 (V).

(vii) The length of the throat is kept 2.5 d, measured from the FSL of the parent canal. Since the grooves create some eddies, the grooves for installing planks to raise the head of the offtaking canal should be set as far down the throat as possible. In case of narrow flumes, the grooves are fixed below the flume wherever possible.

(viii) The throat sill is given a batter of 0.5 : 1 on the u/s face to fit with the side slope of the parent channel, and is given a rounded surface at the top. Downstream of the throat, the masonry floor should be extended to the start of 1 : 3 splay of the wing walls.

(ix) Where the bed of the offtaking canal at the head is lower than the sill of the throat, the difference in level is provided with a glacis having a slope of 1 : 10. A minimum floor length of 1.5 m should be provided below the glacis. If the drop is more than 0.15 m, a vertical drop should be provided immediately below the throat.

(x) The upstream wings walls are warped and curved. But, the d/s wings are kept vertical above the sill and turned sharply and stepped down to 1 : 1. The side walls of the flume are splayed out from the end of the throat at 1 : 10 over a length of 4.5 m or till the width of the flume becomes 2/3rd the bed width of the offtaking canal. Thereafter the splay should be increased to 1 : 3 till the full bed width is attained. The side walls are simultaneously stepped down to the bed level.

(xi) Both the parent canal and the offtaking canal are provided with a pitching.

It has been observed that if the above mentioned principles are followed, the head loss is $H/9$ or less and the discharge slightly over the theoretical value because of the streamlined approach and the velocity of approach.

Example 13.1

Design a venturi head (regulator) given that:

(i) Discharge in parent canal = 12 cumec,

Bed width = 15 m,

Water depth = 1.5 m, and

Bed level = 100.00 m

:i) Discharge in offtaking canal = 1 cumec,

Bed width = 3 m, and

Water depth = 0.6 m

Solution

FSL of parent canal = 100.00 + 1.5 = 101.5 m

Allowing for a drop in head equal to 0.2 m, and thus, keep the FSL of the offtaking distributary at an RL of 101.5 – 0.2 = 101.3 m.

Bed level of offtaking canal = 101.3 – 0.6 = 100.7 m.

The width of the throat should at least not be less than the le. st of the following values :

(a) (1/3)rd bed width of offtake, i.e., 1 m.

(b) As determined by

$$W = Q\,/(1.2\,d^{3/2})$$

$$= 1.0\,/(1.2\,d^{3/2}) = 0.833\,/\,d^{3/2}$$

$$\text{or } d = (0.833/W)^{2/3}$$

The following values of d corresponding to various values of W are obtained as shown below :

W (m)	1.0	1.2	1.4	1.6
d (m)	0.885	0.784	0.707	0.647
sill level = 101.5 – d	100.615	100.716	100.793	100.853

Any one of the above combination may be adopted. Say, the third one is adopted, that is a throat width of 1.4 m and a head over the sill as 0.707 m. The sill level will be 100.793 – 100.7 = 0.093 m above the bed of the offtake.

Set back of throat = $1.4\ W + 0.6 = 1.4 \times 1.4 + 0.6 = 2.56$ m from FSL line of the parent canal.

Length of the throat = $2.5\ d = 2.5 \times 0.707 = 1.768$ m.

The floor should be designed by Bligh's theory with FSL acting in the main canal, and with the offtake closed.

SAQ 5

What is a venturi head? Can you think of its main advantage over other regulators?

SAQ 6

Design a venturi head (regulator) for the following conditions :

Parent canal, Q = 10 cumec, bed width = 12 m and water depth = 1.2 m, bed level = 100 m.

Offtaking canal, Q = 0.8 cumec, bed width = 3 m, and water depth = 0.5 m.

13.8 SUMMARY

Canal head regulators situated at the barrage or weir site regulate the water entering the main canal. The cross regulator assists in raising the water level in the parent channel to feed the distributary canal when the supplies are low in the parent canal. The distributary head regulator controls the discharge entering the offtaking canal from the parent canal. Besides controlling the discharge, these regulators also control the sediment entering the main canal and the distributary canal.

13.9 KEY WORDS

Canal Head Regulator : A structure provided at a barrage or any reservoir to regulate the discharge flowing into the offtaking channel, and control the entry of sediment into the channel.

Cross Regulator : A structure constructed across a canal to regulate the level of the water upstream of the cross regulator while the discharge is allowed to pass downstream.

Distributary Head Regulator : Regulator located at the entry point of the distributary where it takes off from the main canal.

Simple Distributary Head Regulator : A distributary head regulator that serves only one purpose, that is, to regulate the supplies.

Venturi Head : A head regulator consisting of a flumed throat with suitable wings to attain the normal bed width of the offtake downstream.

13.10 ANSWERS TO SAQs

Read through the relevant sections and reference material.

FURTHER READING

1) Asawa, G. L.; "*Irrigation Engineering*", Wiley Eastern Ltd, New Delhi, 568p, 1983.

2) Varshney, R. S.; Gupta, S. C.; Gupta, R.; *Theory and Design of Irrigation Structures*, Nem Chand & Bros, Roorkee, 858p, 1972.

3) Singh, Bharat; "*Fundamentals of Irrigation Engineering*", Nem Chand & Bros, Roorkee, 8th ed, 608 p, 1988.

4) Novak, P.; Moffat, A. I. B.; Nalluri, C.; Narayanan, R.; '*Hydraulic Structures*', Unwin Hyman, London, 546p, 1990.