IS 7784-2-3 (1996): Code of practice for design of cross drainage works, Part 2: Specific requirements, Section 3: Canal syphons [WRD 13: Canals and Cross Drainage Works]

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(Reaffirmed 2001)

भारतीय मानक

आर-पार जल निकास कार्य के डिजाइन की रीति संहिता

भाग 2 विशिष्ट अपेक्षाएँ

अनुभाग 3 नहर साईफन

(पहला पुनरीक्षण)

Indian Standard

CODE OF PRACTICE FOR DESIGN OF CROSS DRAINAGE WORKS

PART 2 SPECIFIC REQUIREMENTS

Section 3 Canal Syphons

(First Revision)

ICS 93.140

BUREAU OF INDIAN STANDARDS
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August 1996

Price Group 4

Cross Drainage Works Sectional Committee, RVD 17

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Cross Drainage Works Sectional Committee had been approved by the River Valley Division Council.

IS 7784 has been published in two parts. Part 1 of the standard covers general requirements of the design of cross drainage works. Part 2 covers specific requirements and has been published in the following five sections:

Section 1	Aqueducts
Section 2	Superpassages
Section 3	Canal syphons
Section 4	Level crossings
Section 5	Syphon aqueducts

This standard (Section 3) covers specific design requirements for canal syphons.

Canal syphon is a structure with a closed conduit designed to run full and usually under pressure, to transport canal water under the drainage channel or a road or a railway line.

This standard was first published in the year 1980. This revision was taken up in view of the revision of Part 1 of the standard, which lays down general requirements for design of Cross Drainage Works. As modifications have been effected in Part 1 of the standard, this revision is intended to modify the provisions of the existing standard so as to align the same with Part 1.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

CODE OF PRACTICE FOR DESIGN OF CROSS DRAINAGE WORKS

PART 2 SPECIFIC REQUIREMENTS

Section 3 Canal Syphons

(First Revision)

1 SCOPE

This standard (Part 2/Sec 3) deals with the specific requirements of design of canal syphons.

2 REFERENCES

2.1 The following standards contain provisions which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
456 : 1978	Code of practice for plain and reinforced concrete (*third revision*)
4410 (Part 15/Sec 5) : 1992	Glossary of terms relating to river valley projects : Part 15 Canal structure, Section 5 Cross drainage works
7784 (Part 1) : 1993	Code of practice for design of cross drainage works : Part 1 General features (*first revision*)
10751 : 1983	Criteria for design of guide banks for alluvial river
11388 : 1985	Recommendations for design of trash rack for intakes

3 TERMINOLOGY

3.1 For the purpose of this standard, the definitions given in IS 4410 (Part 15/Sec 5) : 1992 shall apply.

3.2 Wherever the term 'canal' is used it should be taken to mean 'canal/carrier channel'

4 DATA FOR DESIGN

4.1 For the design of canal syphon, data given in IS 7784 (Part 1) : 1993 shall be made available.

5 GENERAL DESIGN CONSIDERATION

5.1 Shape

5.1.1 For syphoning of canal water circular, rectangular, horse shoe shaped, single or multi cell barrels can be adopted.

5.1.2 Precast RCC pipes may be economical for syphoning small discharges. For large discharges, keeping in view hydraulic considerations and convenience of construction, circular or horse shoe shaped conduits are more suitable.

5.2 Materials

5.2.1 For the construction of the syphon barrels, steel, prestressed concrete, RCC or masonry or a combination of these may be used depending upon the availability of materials, labour and relative economy.

5.3 Layout

5.3.1 Syphon barrel shall preferably be kept perpendicular to the drainage channel at the site of crossing. The barrel shall be founded below the anticipated/design scour level corresponding to design flood. Depth of barrel below the anticipated scour level shall be at least one third of the over all height of the barrels. It shall also be seen that in order to provide an over burden cushion against abrasive damage to the syphon, top of the syphon is at least 300 mm to 750 mm below the drainage channel bed level (Fig. 1).

NOTE — In case a bridge is provided monolithic with the syphon or very near to the syphon, anticipated/ design scour depth as applicable to piers/abutments as given in IS 7784 (Part 1) : 1993 shall be adopted.

5.3.2 In case the site conditions so warrant and keeping the overall economy in view, the barrels may be founded at levels higher than that required as per **5.3.1** above. This can be achieved either by providing upstream and downstream cut-off across

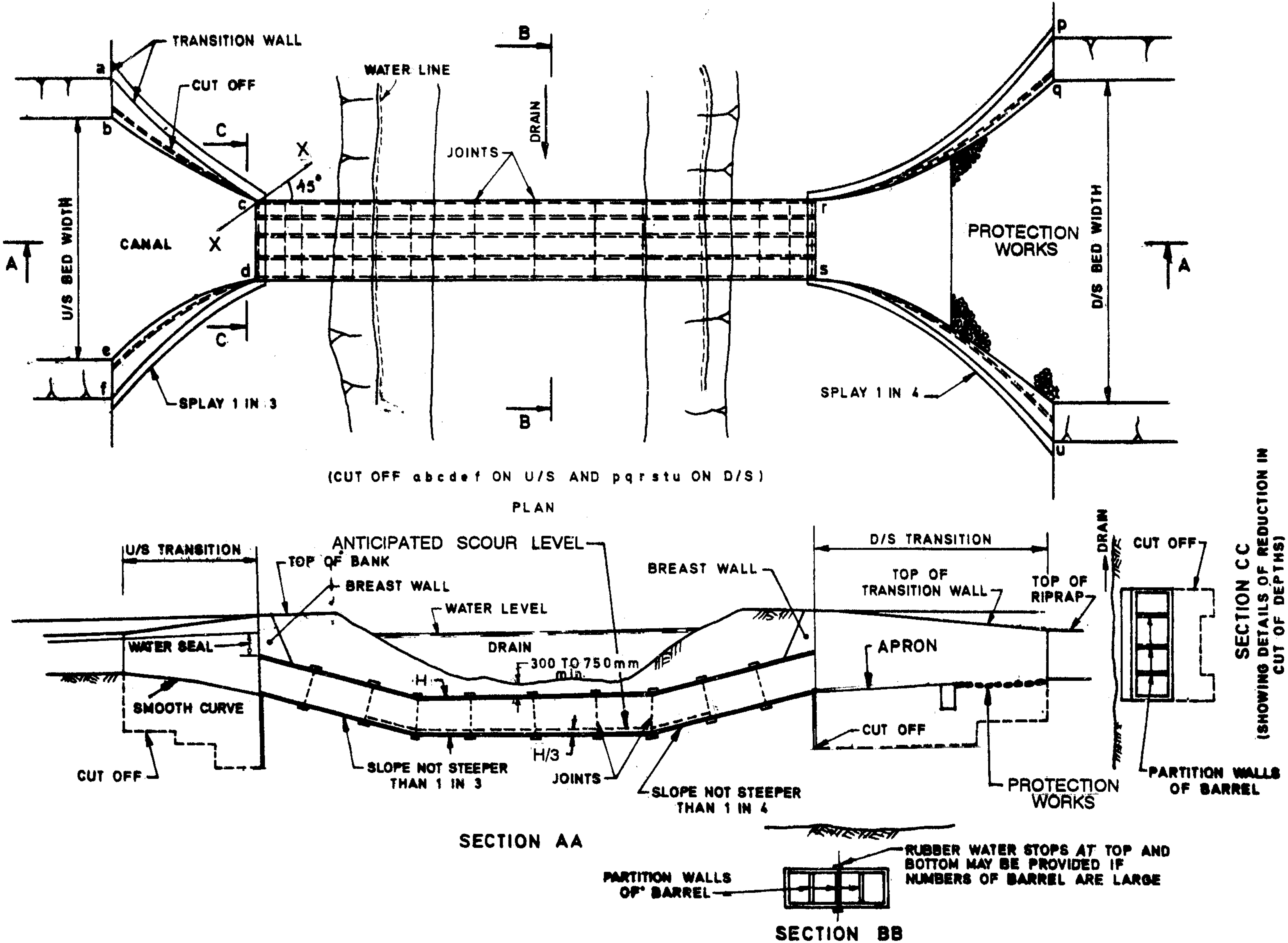

FIG. 1 PROFILE OF TYPICAL CANAL SYPHON

the drainage flow and penetrating the safe scour level, or by suitable combination of cut-offs, horizontal floor and apron/pitching designed to take care of scour (Fig. 2).

5.3.3 Syphon barrels under deep bed portion of the drainage channel are generally kept horizontal. Barrels in slope at entry and exit on the upstream and downstream sides are provided to join the horizontal barrels. The barrels on sloping portion should not be steeper than 1 in 3 on the entry side and 1 in 4 on the exit side. A water seal of 1.5 times the change in velocity head, with a minimum of 150 mm should be provided over the crown of the barrels at start, to prevent air from entering the barrel (Fig. 1). Instead of sloping portions, at entry and exit, wells may be provided.

5.3.4 The invert level of the canal syphon at the entrance is normally kept at the bed level of the carrier channel. The invert level at entrance shall be worked out by subtracting the proposed height of the barrel opening plus water seal plus the velocity head, from the total energy line in the channel at the entrance to barrel.

5.3.5 The invert level at the exit shall be kept lower than the level at the entrance to the barrels by the amount of loss of head through the barrels.

5.3.6 Cut off under the entrance and exit ends of the barrel shall continue under the wing walls. Cut off shall be designed to take care of exit gradient. In case of multi-barrel syphon, cut off depth at the entry and exit sides of the barrel may be reduced in the middle portion. In cases where transition walls/ wing walls are long, cut off depth may be reduced along the wall.

5.4 Fluming

Fluming ratio shall be adopted as given in IS 7784 (Part 1) : 1993.

5.5 Entrance and Exit Transitions

5.5.1 Transition walls shall be long enough to cover the bank slope effectively. Splay of 3 : 1 on upstream and 4 : 1 on the downstream at full supply level (FSL), with properly designed entry and exit transition curves to keep down the loss of head through the canal syphon, is preferable. Splay on upstream and downstream may be reduced if the same is justified by the site conditions.

5.5.2 In order to align and design transition walls properly a complete layout plan of the work showing the carrier channel banks, slopes, etc, should be drawn out on a contour plan of the site.

5.5.3 Transition walls should normally rest on natural ground. In exceptional cases, they may rest on made up soils, properly compacted.

5.5.4 The transition walls shall at their ends turn at right angles to the flow in the channel and shall extend for a minimum length of 1.0 m into the bank. Suitable pitching should be provided, as necessary, beyond these transition walls depending upon site conditions.

5.5.5 The vertical transition in the bed profile at the entry and exit ends of the barrel shall be smooth to ensure gradual increase in the velocity while approaching the barrels and gradually decrease again to the design velocity downstream, in the carrier channel. The bottom grade at the entry shall be tangential to the invert of the conduit. The bottom grade at the exit need not be tangential, except where the velocity of flow in the syphon is high.

6 HYDRAULIC DESIGN

6.1 Waterway

The waterway required is calculated by dividing the full supply discharge by the velocity in the barrels which shall not exceed the permissible velocity given in IS 7784 (Part 1) : 1993.

6.2 Entry Water Surface Profile

The vertical profile of the syphon involves a change from steep to mild slope. At these points the formation of hydraulic jump at part discharges shall be examined and pressure accounted for while considering uplift.

6.3 Loss of Head

The loss of head at the entry, at the exit and in the barrel due to friction and due to elbows and joints shall be calculated in accordance with IS 7784 (Part 1) : 1993. Estimated losses shall be increased by 10 percent for use in design.

6.4 Cut Off

The normal scour depth shall be computed for the carrier channel flow in accordance with IS 7784 (Part 1) : 1993. Depth of cut off below the entrance and exit ends of the barrel can be taken as 1.5 times the normal scour depth below full supply level. Cut-off shall then be checked for permissible exit gradient. The cut-off shall cater to the three dimensional flow patterns that exist at the following conditions:

a) Drainage channel full and carrier channel dry, and

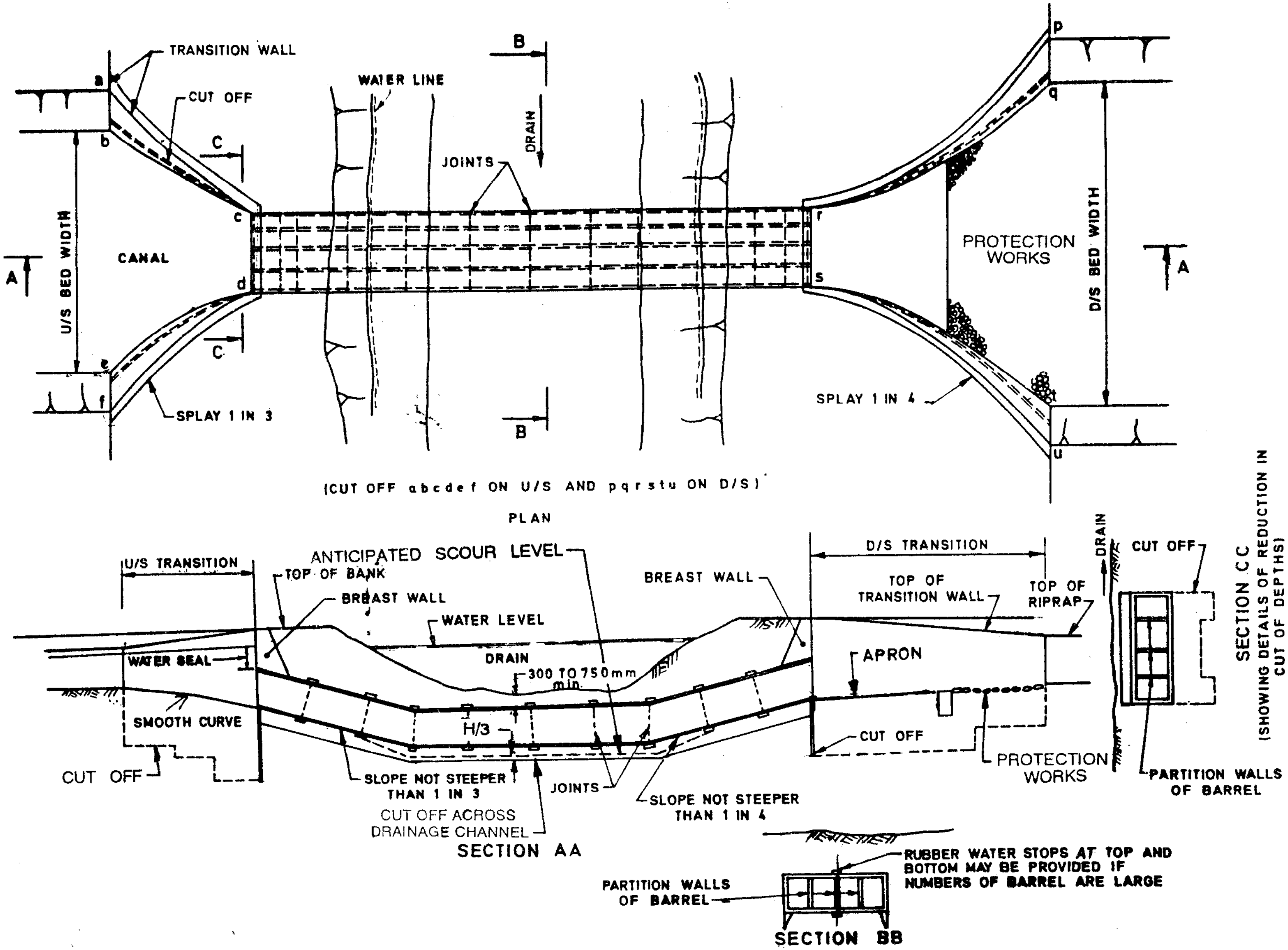

FIG. 2 PROFILE OF TYPICAL CANAL SYPHON WITH BOTTOM ABOVE DESIGN SCOUR LEVEL

b) Carrier channel full and drainage channel dry.

The worst case occurs along section *x-x* (*see* Fig. 1). The depth of the cut off provided, shall be the greater of that obtained from the condition of scour and exit gradient.

6.5 Uplift

6.5.1 The syphon barrels shall be checked for self-flotation condition, that is, the condition obtained immediately after completion or part completion of the structure, should a flood occur. The barrels may be located deeper if required and/or if found necessary extra dead load in the form of lean cement concrete, masonry, etc, shall be added on the top of the barrel. This extra load is taken into account while calculating the moments.

6.5.2 The calculations for uplift acting on the barrel shall be done for the following conditions:

a) Drainage channel full and carrier channel dry, and

b) Carrier channel full and drainage channel dry.

6.5.2.1 A factor of safety of 1.2 should be ensured against the worst of the above two conditions of uplift for which the barrel is designed. The barrels shall be checked for construction condition, that is, water table at the drainage bed with channel and drainage both dry and top cover not in position with a factor of safety of not less than 1.2.

6.5.3 In case a bridge is provided monolithic with syphon, the traffic load should be ignored while checking for uplift.

7 STRUCTURAL DESIGN

7.1 The various loadings assumed in the design of barrels consist of the following :

a) Self weight of the structure;

b) Super-imposed loads;

c) Surcharge;

d) Full internal water pressure;

e) Soil reaction and uplift pressure; and

f) Earth pressure of sides.

The combination of loads which will result in the maximum stresses shall be carefully considered.

7.2 Transverse Analysis

7.2.1 The length of barrels of the structure can be divided into two portions, one under the drainage channel bed and the other under drainage channel banks. The transverse analysis of barrels shall be carried out by any standard method for the following conditions to determine the worst moments, shear and thrust at any section.

a) Portion under drainage channel bed

i) Carrier channel dry and drainage channel with maximum discharge

ii) Carrier channel running full and drainage channel dry.

b) Portion under the drainage channel bank

i) Carrier channel dry and drainage channel with HFL. The saturation level for the earthfill may be properly accounted for with appropriate hydraulic gradient line from HFL of the drainage channel with regard to the type of soil composing the banks.

ii) Carrier channel running full and drainage channel dry.

7.2.2 Partition walls are the inside walls of a multicell barrel (*see* Fig. 1) The partition walls are not subject to any significant lateral pressure when all the barrel openings are running. The minimum thickness of the wall shall be 225 mm for RCC and 450 mm for masonry. Partition walls shall be designed to allow for differential head created due to an empty adjacent barrel. Reinforcement in partition walls shall be anchored into the slab. In case of RCC walls, suitable haunches in square or rectangular barrels with haunch reinforcement shall also be provided. Masonry partition walls shall be adequately anchored to the top and bottom slabs to ensure that there is no separation.

7.2.3 Barrels with RCC slab or arch roofing supported on masonry or plain concrete abutments and piers are designed for the same conditions as RCC barrels. The roofing is however, properly anchored down by means of anchor bolts in the case of slab roof, and straps in case of an arch roof, to make it safe against uplift pressure.

7.2.4 When pipes are used, they shall rest on 250 mm thick cement concrete of M 15 grade (*see* IS 456 : 1978), which shall be increased to 550 mm at joints. The end offsets and clear spacing between adjacent pipes shall be a minimum of 250 mm. Standard joints shall be used and these shall be properly grouted to make them water tight. At bends, walls shall be provided to receive the pipe ends.

7.3 Longitudinal Analysis

7.3.1 Longitudinal analysis shall be made in cases where loose soil, or various types of soils, are met with at the completed final level of the foundation.

7.3.2 In case a socket and spigot arrangement of collars is provided, the vertical displacement of one unit will cause extra loads and stresses in the other unit due to the restraining effect of the collar. For analysis of these loads the barrels in the longitudinal direction shall be considered as beams on elastic foundations. The analysis should be carried out according to the principles given by M. Hetenyi[1] or any other standard method of analysis.

Certain simplifying assumptions as given below may be made while analysing for longitudinal moments:

a) The subgrade reaction throughout the length of the barrels is constant.

b) Ends of the barrels are free.

c) Entire cross-section of the barrel is effective in resisting the forces and moments

d) Foundation reactions are vertical.

e) Self weight of barrels and weight of water in barrels may be omitted, since this will not contribute to unequal settlement.

7.3.3 The restraining force of a collar can be determined by equating the deflection of the two units at the joint. The collar shall be designed for the cantilever moment due to this force.

7.3.4 The bending moment in the barrel in the longitudinal direction due to superimposed loads as well as collar reaction shall be calculated as per standard expressions for different loading conditions given by M. Hetenyi and the required reinforcement shall be provided. However, nominal reinforcement in accordance with IS 456 : 1978 shall be ensured.

7.4 Face Wall (Breast Wall)

7.4.1 This is sometimes called head wall or breast wall. Such walls are provided at the outer ends of conduits to support the outer slope of drainage channel banks. Their top may be kept level with top of the transition walls. Where the top of the face wall is higher than that of the transition walls, the top of transition wall at entry is connected to the top of the face wall with uniform increase in height of walls.

7.4.2 The face walls shall be designed as masonry gravity walls for arch or flat slab roofing. In the case of RCC barrels these walls shall be constructed monolithic with the top slab. Adequate anchorage of reinforcement as well as reinforcement for proper transfer of loads and moments to the top slab, shall be provided.

A minimum top width of 150 mm and 350 mm shall be provided in case of RCC walls and masonry walls respectively.

7.4.3 A smooth curve between the face wall and the top slab of the RCC barrel, and for cut water and ease water of partition walls, may be provided.

8 MISCELLANEOUS DETAILS

8.1 Joints

In case of RCC barrels, expansion/contraction joints with water stops around the periphery shall be provided not more than 20 m apart, while in case of plain concrete slab and masonry walls, the joints shall be provided not more than 10 m apart. The position and details of waterstops shall be in accordance with the provisions of IS 7784 (Part 1) : 1993. In case of multi-barrel syphons, units of 3 or 4 barrels can be adopted side by side with longitudinal joints having water stops all around.

8.2 In case of barrels resting on compressible soils, collars encircling the plain joint shall be provided. This will protect the water-stop from vertical shear due to excessive settlement. The cross section of the collars shall be of size not less than 300 mm × 300 mm. In case of syphons of multiple barrels of more than one unit, the collars shall be designed to be flexible.

8.3 Drainage Protection

Drainage channel slopes shall be protected by pitching for suitable length upstream and downstream of the site of crossing. In case barrels are founded above the anticipated scour, slope and bed protection as per 5.3.2 shall be given.

8.4 Wherever drainage channel is flumed at a carrier channel crossing (Fig. 3) suitable guide banks should be constructed for confining it in a reasonable width and guiding it smoothly near the syphon. The design of guide banks shall conform to IS 10751 : 1983.

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[1] HETENYI M "Beams on Elastic Foundations" Messrs Cushing Malloy, USA.

8.5 Bed Protection for Canals

Beyond the ends of concrete masonry floor of the syphon/transitions, cement concrete or brick blocks or stone/stones in wirecrates over graded inverted filter shall be provided for a suitable length, to allow for the release of balance differential head of water without permitting the escape of fine soil particles from the bed. Similar protection should be provided along the length of transition walls.

8.5.1 The outer slopes of the carrier channel banks shall be adequately protected up to HFL of the drain plus free board.

8.6 Stop Log Grooves

In big syphons, stop log grooves may be provided on the upstream entrance end and at the downstream, to isolate one or more barrels for periodic inspections, repairs and maintenance.

8.7 Trash Racks

Trash racks may be provided at the entrance to the syphon structure where a large quantity of floating material is expected in the carrier channel water. Usually the racks are constructed of flat steel bars set on edge and are either joined by through bolts with pipe nipples for spacers, or welded to the edge of cross bars. The racks are generally made in panels for ease in handling to facilitate cleaning; these are usually inclined at a slope of 1 horizontal to 4 vertical. (*see* IS 11388 : 1985).

8.8 Free Board in the Carrier Channel

The free board for the carrier channel bank upstream of the transition wall shall be increased by 50 percent subject to a minimum of 0.3 m to prevent overtopping. The increased free board shall be extended to a minimum distance of 10 times the bed width of the carrier channel.

8.9 Dewatering

In long syphons, it is desirable to provide a sump pit at a suitable location for ease of dewatering.

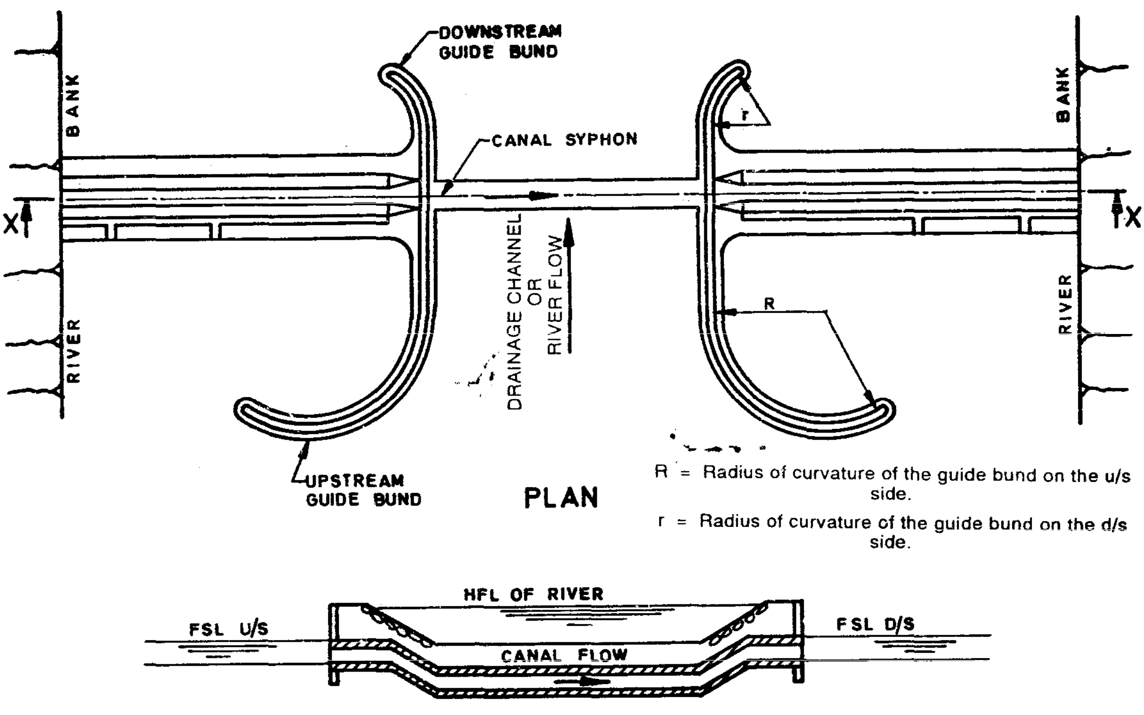

FIG. 3 TYPICAL PLAN OF DRAINAGE FLUMING

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Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Handbook' and 'Standards : Monthly Additions'.

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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