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Indian Standard

FLOW GAUGING STRUCTURES — GUIDELINES FOR SELECTION

भारतीय मानक

बहाव-मापी संरचनाओं के चुनाव की निर्देशिका

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BUREAU OF INDIAN STANDARDS

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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards on 25 August 1989, after the draft finalized by the Fluid Flow Measurement Sectional Committee had been approved by the River Valley Projects Division Council.

Indian Standard have been prepared on Various types of gauging structures used for the purpose of fluid flow measurement. Each type of structure has its own performance characteristics and can be used within a specified range of conditions. This standard is prepared to give guidelines to the users in selecting a structure most suited to, and appropriate for their requirements. This standard has been based on ISO 8368 : 1985 'Guidelines for the selection of flow gauging structures'.

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

FLOW GAUGING STRUCTURES — GUIDELINES FOR SELECTION

1 SCOPE

1.1 This standard gives broad guidelines for selection of a particular type of flow gauging structure for fluid flow measurement in open channels. It sets out the factors and summarizes the parameters, which may influence such a selection. For details of individual structure the appropriate standards has to be referred.

In general a flow gauging structure is used when high accuracy is required for continuous record of flow.

2 REFERENCES

2.1 The following Indian Standards are necessary adjuncts to this standard.

IS No.	*Title*
IS 1191 : 1971	Glossary of terms and symbols used in connection with the measurement of liquid flow with a free surface (*first revision*)
IS 6059 : 1971	Recommendation for liquid flow measurement in open channels by weirs and flumes — weirs of finite crest width for free discharge
IS 6062 : 1971	Method of measurement of flow of water in open channels using standing wave flumes fall
IS 6063 : 1971	Method of measurement of flow of water in open channels using standing wave flume
IS 6330 : 1971	Recommendations for liquid flow measurement in open channels by weirs and flumes-end-depth method for estimation of flow in rectangular channel with a free over fall (approximate method)
IS 9108 : 1979	Liquid flow measurement in open channels using thin plate weirs
IS 9117 : 1979	Recommendations for liquid flow measurement in open channels by weirs and flumes-end-depth method for estimation of flow in non-rectangular channels with a free overfall (approximate method).

3 DEFINITIONS AND SYMBOLS

3.1 For the purpose of this standard, the definitions and symbols given in IS 1191 : 1971 shall apply.

4 TYPES OF STRUCTURE

4.1 The types of structure that can be used for the purpose of fluid flow measurement are as follows:

a) Thin-plate weirs:
   i) Rectangular,
   ii) Triangular-notch (V-notch)
b) Finite crest width (broad-crested weirs),
   i) Rectangular
   ii) Round-nose*
c) Triangular profile weirs*;
d) Standing wave flume (free flow)
   i) Rectangular
e) Standing wave flume falls
f) Free overall in rectangular channel (end depth method)
g) Free overall in non-rectangular channel (end depth method)

5 FACTORS AFFECTING CHOICE

5.1 General

The factors which affect choice can be considered under the following headings:

a) Purpose;
b) Range of flow;
c) Afflux;
d) Size and nature of channel;
e) Channel slope and sediment load;
f) Operation and maintenance;
g) Passage of fish;
h) Cost

Structure should be selected according to the requirements of accuracy and range of performance.

5.2 Purpose and Accuracy

5.2.1 Table 1 tabulates the various structures and indicates some of the purposes for which they may be applicable, together with a guide to their limitations.

*Indian standards on these structures are under preparation.

Table 1 Applications and Limitations of Structures

(*Clauses* 5.2.1, 5.5.2 *and* 7.1)

Type	Indian International Standard	Typical Uncertainties in Computed Discharge, %	Modular Limit	Geometric Limitations	Typical Application
Thin-plate weirs	IS 9108 : 1979 ISO 1438/1	1 to 4	*	2†	Laboratory, pump tests, sediment-free water
Broad-crested weirs a) rectangular profile b) round-nose horizontal crest c) V-shaped	IS 6059 : 1979 ISO 3846 ISO 4374	3 to 5	66% 80% 80%	1,5† 1,5† 1,5—3,0†	Where economy and ease of construction are important factors. Irrigation channels with little fall available and wide range of flow
Triangular profile weirs	— ISO 4360/1	2 to 5	75%	3,5†	Hydrometric networks and principal irrigation channels
Flat-V weirs	— ISO 4377	2 to 5	70%	2,5†	Hydrometric works with wide range of flow
Long-throated flumes	IS 6063 : 1971 ISO 4359	2 to 5	74%	0,7‡	Sediment-laden channels, flow with debris, flow with migratory fish, conduits and partially filled pipes, flow in sewers
End-depth method	IS 9117 : 1979 ISO 3847	5 to 10	*	N/A§	Where accuracy may be relaxed for simplicity and economy

*Nappe to be fully aerated.

†Maximum H/P, where H is the total upstream head and P is the height of the weir.

‡Maximum A_t/A_u, where A_t and A_u are the cross-sectional areas of the throat and approach channel, respectively.

§N/A = Not applicable.

5.2.2 The purpose for which the structure is required will determine the range of accuracy which is necessary. The accuracy in a single determination of discharge depends upon the estimation of the component uncertainties involved.

5.2.3 In broad terms, thin-plate weirs will have a range of uncertainties from 1 to 4 percent and flumes and other types of weirs a range from 2 to 5 percent. Deviations from the construction, installation or use as laid down in the appropriate Indian Standard will result in measurement errors.

5.3 Range of Flow

5.3.1 It is necessary to consider the relation between maximum flow and minimum flow when deciding which type of structure to use, and an indication of the range of some typical structures is given in Table 2. For the best overall accuracy over a wide range of small discharges, a thin-plate V-notch weir should be used in preference to the thin-plate rectangular notch or rectangular full width weir. For a wide range of larger discharges, a trapezoidal flume should be used in preference to a broad-crested weir, free overall or rectangular throat flume.

5.4 Afflux

5.4.1 The rise in level immediately upstream of, and due to, a structure known as afflux may interfere with the flow system and cause drainage problems, or overflow, of limit the effectiveness of irrigation systems, or cause extra pumping costs. A number of structures have been developed with high coefficients of discharge and whose accuracy is relatively unimpaired by high submergence ratios. The triangular profile wires, and flumes are examples of this type of structure.

5.5 Size and Nature of Channel

5.5.1 The shape and size of the channel have a bearing on the practicality of selecting any particular type of structure. The material forming the bed and sides of the channel will influence the acceptable head loss through the structure without introducing appreciable leakage through the bed and banks. It will also determine the degree of protection necessary to alleviate scour downstream of the structure.

5.5.2 Broad-crested weirs are best used in rectangular channels, but they can be used with good accuracy in non-rectangular channels if a smooth, rectangular approach channel extends upstream of the weir for a distance not less than

Table 2 Comparative Discharges for Various Weirs and Flumes

(*Clauses* 5.3.1 and 7.1)

Sl No. (1)	Structure (2)	*D* (m) (3)	*P* (m) (4)	*b* (m) (5)	*m* (slope) (6)	*L* (m) (7)	Discharge m³/s *Min* (8)	*Max* (9)
	Weirs							
i)	Thin-plate, full width	—	0·2	1·0	—	—	0·005	0.67
		—	1·0	1·0	—	—	0·005	7·70
ii)	Thin-plate, contracted	—	0·2	1·0	—	—	0.009	0·45
		—	1·0	1·0	—	—	0·009	4·90
iii)	Thin-plate, V-notch	—	—	θ = 90°	—	—	0·001	1·80
iv)	Round-nose broad-crest	—	0·15	1·0	—	0·6	0·030	0·18
		—	1·0	1·0	—	5·0	0·100	3·13
v)	Rectangular broad-crested	—	0·2	1·0	—	0·8	0·030	0·26
		—	1·0	1·0	—	2·0	0·130	3·07
vi)	V-shaped broad-crested	—	0·30	θ = 90°		1·50	0.002	0·45
		—	0·15	θ = 150°		1·50	0·007	1·68
vii)	Triangular profile	—	0·2	1·0	—	—	0·010	1·17
		—	1·0	1·0	—	—	0·010	13·00
viii)	Flat-V	—	0·2	4	1 : 10	—	0·014	5·00
		—	1·0	80	1 : 40	—	0·055	630
	Flumes							
ix)	Rectangular	—	0·0	1·0	—	2·0	0·033	1·70
x)	Trapezoidal	—	0·0	1·0	5 : 1	4·0	0·270	41·00
xi)	U-throated	0·3	0·0	0·3	—	0·6	0·002	0·07
		1·0	0·0	1·0	—	2·0	0·019	1·40

D : diameter of U-shaped throat

P : height of weir

b : breadth of weir of flume throat

m : side slopes : 1 vertical: *m* horizontal

L : length of flume throat or weir crest.

NOTE — Dimensions are given as examples for comparison purposes only.

four times the maximum head. Flumes can be used in channels of any shape if flow conditions in the approach channel are reasonably uniform and steady. The modular limit of each device requires careful consideration. The submergence ratio should be checked for the whole range of flow to be measured and compared with values for the modular limit given in Table 1.

5.6 Channel Slope and Sediment Load

5.6.1 For flows with suspended load, the use of thin-plate weirs should be avoided because the crest edge may be damaged or worn out by the suspended materials. In addition, the rating of weirs can be affected by deposition of sediment in the approach section to the weir. In streams with bed load, the use of structures which significantly reduce the stream velocity is not recommended, as it may result in fluctuations of the bed level as the flow varies. Flumes will generally perform better than weirs in streams with sediment load.

For gradients less than 1 : 1 000 and Froude numbers less than 0·25 there is no restriction on the type of structure.

For gradients between 1 : 1 000 and 1 : 250 and Froude numbers between 0·25 and 0·5, flumes have an advantage over weirs with regard to the transport of the sediment. For gradients greater than 1 : 250 and Froude numbers greater than 0·5, standard weirs and flumes are not usually suitable, but may be usable under such circumstances when there is no transport of sediment.

5.7 Operation and Maintenance

5.7.1 The accuracy of any device is very dependent upon the degree of maintenance it receives. However, flumes are particularly susceptible to errors of calibration due to algal growths in the throat.

5.7.2 When structures operate at temperatures below freezing point, consideration shall also be given to the effect of the accumulation of ice on the calibration. In general, weirs, and thin-plate weirs in particular, are less affected by ice than flumes. In some cases, the problem of calibration errors can be overcome by heating the air space over a structure.

5.7.3 The calibration of thin-plate weirs can be affected by damage to the crest and corners and failure to clean the upstream face where algal growths will introduce errors into the calibration. The choice of structure, therefore, will be influenced by the regularity with which maintenance can be carred out. Broad crested weirs, triangular profile weirs, long-throated flumes and free overfall structures will normally pass floating debris more effectively than thin-plate weirs. The use of the thin-plate V-notch weir, in particular, should be avoided unless a debris trap is installed uptream.

5.8 Passage of Fish

5.8.1 The movement of fish upstream for spawning may be restricted if a structure fails to make proper provision for their passage.

5.8.2 The principal factors which affect their movement past such an obstruction are the afflux at the obstruction and its overall length, and the depth of water below the obstruction and over its crest.

5.8.3 If a thin-plate or broad-crested weir is to be installed, there should be a sufficient depth of water from which the fish can take off to clear the weir. Flumes constitute a minimal obstruction, depending upon the velocities through the throat and the overall length. Triangular profile weirs need careful consideration as they may from a serious obstruction, particularly where energy dissipators are incorporated in the stilling basin.

5.9 Cost

5.9.1 The financial values of the flow passing through the gauging device and the benefit in terms of improved accuracy against the cost of the stucture will have a direct bearing on the relative investment values of different types of structures. The total capital costs of construction and long-term maintenance costs should be considered.

6 RECOMMENDATIONS

6.1 Thin-Plate Weirs

6.1.1 Thin-plate weirs are dependent on the full development of the contraction below the nappe but are relatively inexpensive to construct, although the manufacture of the crest requires particular care. They are recommended where high accuracy is required and are particularly suitable for laboratory work and use in artificial channels and other circumstances where good maintenance can be assured and there is little risk of damage to, or deterioration of, the crest. Particular applications include the gauging of compensation flows, flow measurement in water supply pumping tests and flow measurement in many industrial situations. Thin-plate V-notch weirs are particularly suitable where the ratio of high to low flow is large and where accuracy at low flow is important, owing to their greater sensitivity. Thin-plate weirs of both rectangular and V-notch types are well suited for temporary installations.

6.2 Broad-Crested Weirs

6.2.1 Broad-crested weirs are relatively inexpensive to construct and robust and thus insensitive to minor damage. They are best used in rectangular channels where regular maintenance permits clearance of any deposition upstream and of algae from the crest. Round-nose broad-crested weirs have a good discharge range and submergence ratio and are appropriate for use in and smaller medium size installations.

6.3 Triangular Profile Weirs

6.3.1 Triangular profile weirs are particularly appropriate for the measurement of flow in natural watercourses where minimum head losses are sought and where relatively high accuracy is required. They have a good discharge range and modular limit, are robust, insensitive to minor damage and will operate even when the flow is silt-laden.

The triangular profile has a constant coefficient of discharge over a wide range of heads. The weir can also be used under submerged flow conditions; in this case, a second head measurement is necessary and is achieved by means of tapping points at the crest.

The accuracy obtained over a wide range of flows and heads makes them excellent structures for hydrometric work.

6.4 Flumes

6.4.1 *General*

Flumes are recommended where material is being transported along the channel, particularly where there is bed movement. Protective works downstream of the throat to contain the hydraulic jump are easily incorporated into the main structure.

6.4.2 *Rectangular Flumes*

The dimensions of rectangular flumes are easily adapted to the size of the channel and such flumes readily fit into rectangular channels and are almost universally used in measuring the inflow to sewage treatment works. They are suitable where relatively high accuracy is required over a wide range of flows and afflux needs to be kept to a minimum.

6.4.3 *Trapezoidal Flumes*

Trapezoidal flumes are used for purposes similar to those employing rectangular flumes but are particularly recommended if it is necessary to accommodate the gauging station in a trapezoidal channel and skilled labour is available for the construction work. They are suitable where relatively high accuracy is required over a wide range of flowed and afflux needs to be kept to a minimum.

6.5 End-Depth Method

6.5.1 The method utilizing existing falls is convenient for approximate measurement where accuracy is not of paramount importance.

7 SUMMARY

7.1 Tables 1 and 2 set out the broad parameters which may be considered in the choice of a structure. Limitations and values of coefficients are set out in the appropriate Standard to which reference should be made for detailed design purposes.

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