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LIQUID FLOW MEASUREMENT IN OPEN CHANNELS
BY SLOPE AREA METHOD

1st EDITION

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BRIEF HISTORY

The ISO Recommendation R 1070, *Liquid flow measurement in open channels by slope area method*, was drawn up by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels*, the Secretariat of which is held by the Indian Standards Institution (ISI).

Work on this question led, in 1965, to the adoption of a Draft ISO Recommendation.

In January 1967, this Draft ISO Recommendation (No. 1140) was circulated to all the ISO Member Bodies for enquiry. It was approved, subject to a few modifications of an editorial nature, by the following Member Bodies :

Argentina	India	Romania
Australia	Ireland	Spain
Belgium	Israel	Switzerland
Canada	Italy	Thailand
France	Japan	U.A.R.
Germany	Korea, Rep. of	United Kingdom
Greece	Netherlands	

Two Member Bodies opposed the approval of the Draft :

Czechoslovakia
U.S.A.

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in May 1969, to accept it as an ISO RECOMMENDATION.

ISO Recommendation R 1070 May 1969

LIQUID FLOW MEASUREMENT IN OPEN CHANNELS BY SLOPE AREA METHOD

1. SCOPE

This ISO Recommendation deals with the methods of determining the slope and area of cross-section of the stream, and of computing the discharge therefrom. The method provides an approximate estimate of the discharge in somewhat special conditions in the stream and is used when estimation of discharge by more accurate methods, like the velocity area methods, is not possible. The slope area method can be used with some degree of accuracy in channels with stable boundaries such as rock (or very cohesive clay) bed and sides, and in channels with relatively coarse bed material; this method may also be used in other cases such as alluvial channels including channels with defined spills or non-uniform channel sections, subject to the acceptance of larger errors involved in the selection of the value of the Manning's coefficient n or Chezy's coefficient C. It is, however, not desirable to use this method in the case of very large channels or channels with very flat slopes of high sediment concentration or channels with significant curvature.

This ISO Recommendation deals only with ad hoc measurements of discharge and should not be employed for establishing rating curves. Although the accuracy of results from applying the slope area method is less than that from applying the velocity area methods, it is sometimes necessary to use the slope area method to define the extreme high stage end of rating curves because the magnitude of extremely rare floods is such that other methods of measuring discharge cannot be used.

2. DEFINITIONS

For the purpose of this ISO Recommendation, the definitions given in ISO Recommendation R 772, *Vocabulary of terms and symbols used in connection with the measurement of liquid flow with a free surface*, apply.

3. UNITS OF MEASUREMENT

The units of measurement used in this ISO Recommendation are seconds and metres (or feet).

4. PRINCIPLE OF THE METHOD OF MEASUREMENT

A measuring reach is chosen for which the mean area of cross-section of the stream is determined and the surface slope of the flowing water in that reach is measured. The mean velocity is then established by using known empirical formulae which relate the velocity to the hydraulic mean depth, the surface slope corrected for kinetic energy of the flowing water and the characteristics of the bed and bed material. The discharge is computed as the product of the mean velocity and the mean area of cross-section of the stream.

5. SELECTION AND DEMARCATION OF SITE

5.1 Initial survey of site

It is desirable that approximate measurements of widths, depths and surface slopes should be made in a preliminary survey to decide on the suitability of a site conforming, as far as possible, with the conditions given in clauses 5.2 and 5.3. It is intended that these measurements should only serve as a guide.

5.2 Selection of site

5.2.1 The accuracy of the determination of discharge by the slope area method is increased if the river banks and bed are reasonably stable and the river reach fairly straight and uniform in section and free from obstructions and disturbances.

5.2.2 The length of the reach depends upon river slopes at very low stages and flood stages. The slope should be such that the surface fall in the length of the reach used at each site is at least ten times the expected error in "measurement of fall".

5.2.3 The flow in the reach should be free from significant disturbances due to the effect of tributaries joining upstream or downstream or of any structure. The reach should be one in which no substantial expansion occurs.

5.2.4 The orientation of the reach should be such that the direction of the flow is as closely as possible normal to that of the prevailing wind.

5.2.5 The flow in the channel should, as far as possible, be contained within its banks at all stages at which this method is used, as otherwise the overflow would have to be separately measured.

5.2.6 The site should not be unduly exposed to wind.

5.2.7 The site should be easily accessible at all times.

5.3 Demarcation of site

The site, after selection, should be provided with means for the demarcation of the cross-section and for the determination of the stage.

The position of each cross-section normal to the general direction of flow should be defined on the two banks by clearly visible and readily identifiable markers.

5.4 Changes occurring after the selection of the site

If, after the site has been selected, changes occur which do not comply with the above requirements, steps should be taken to rectify the changes to make it conform to these requirements. If this is not possible, another site should be selected.

6. DEVICES FOR MEASUREMENT OF SLOPE

6.1 Reference gauge

The reference gauge should be a vertical gauge, or an inclined gauge. The markings should be clear and sufficiently accurate for the purpose for which the measurements are required; the lowest marking and the highest marking on the reference gauge should be respectively below and above the lowest and highest anticipated water levels.

The reference gauge should be securely fixed to an immovable and rigid support in the stream and should be correlated to a fixed bench mark by precise levelling to the national datum.

6.1.1 *Vertical gauge*. This staff gauge should be truly vertical. It should be of such a shape as not to cause any noticeable heading up of flow.

6.1.2 *Inclined gauge*. The inclined gauge should fit closely and be solidly anchored to the slope of the natural bank of the water-course. It may be calibrated on the site by precise levelling.

6.2 Liquid level recorder*

This is particularly useful where large fluctuations of discharge occur during short intervals as in the case of hill torrents and flashy rivers. It may consist of a recorder operated by a float, or of a pneumatic recorder. The float-operated recorder should be installed above a vertical stilling well communicating with the channel. The pneumatic recorder may be installed at a distance in a place in which both access and use are easy. It is essential, however, to combine the recorder always with a reference gauge, placed near the point of measurement of the recorder.

6.3 Crest stage gauge

This is suitable for use where only the peak level attained during each flood has to be determined. Peak discharges can be calculated from two such gauges installed in a reach of the river, provided the time lag in the reach can be taken as nil.

7. PROCEDURE FOR INSTALLING GAUGES AND MAKING OBSERVATIONS

7.1 Installation

Gauges should be installed, on both banks of the river, at not fewer than three cross-sections, making a total of at least six gauges. The gauge data should be related to a standard system of levels.

7.2 Procedure for observation of gauges

The gauge should be read from such a position as to avoid all parallax errors. The gauge should be observed continuously for a minimum period of 2 minutes or the period of a complete oscillation, whichever is longer, and the maximum and minimum readings taken and averaged.

7.3 Recording

Information regarding the date, time, weather conditions, direction of wind, current, etc., should be recorded before the commencement of operations.

All gauges should be observed at suitable intervals and readings recorded throughout the period of measurement including initial and terminal readings.

8. COMPUTATION OF SURFACE SLOPE

8.1 Computation of slope from gauges

Slope is computed from the gauge observations at either end of the reach, the intermediate gauge(s) being used to confirm that the slope is uniform throughout the reach. The gauges should be read to the smallest marking on the gauge which is generally 2 mm on the metric gauge (0.01 ft on gauges marked with FPS units) and should be steady when observed.

NOTE. – When accurate gauges do not exist or have been destroyed, and when no other method can be employed, a rough estimate of the slope during the peak stage can be made by means of flood marks on the banks. Several dependable highwater flood marks for each bank should be used in determining the water level.

* For detailed provisions regarding stilling well, recorder, etc., reference should be made to clauses 6.2.2 and X.3 of ISO Recommendation R 1100, *Liquid flow measurement in open channels – Establishment and operation of a gauging station and the determination of the stage-discharge relation.*

9. AREA OF THE CROSS-SECTION OF STREAM AND ITS WETTED PERIMETER

9.1 Number of cross-sections

In the reach selected, a minimum of three cross-sections is generally desirable. These should be clearly marked on the banks by means of masonry pillars or easily identifiable markers. If for any reason, it is not possible to measure more than one cross-section, the central one only may be observed.

9.2 Measurement of cross-sections

These cross-sections should be measured for each discharge observation at, or as near as possible to, the time at which the gauge observations are made. It is often impossible to measure the cross-section during flood and, therefore, to this extent, an error may be introduced owing to an unobserved and temporary change in cross-sections. If, however, the side is inerodable, it will be sufficient to observe the cross-sections before and after the floods.

The method of measurement of the cross-sectional area should be in accordance with section 6 of ISO Recommendation R 748, *Liquid flow measurement in open channels by velocity area methods.*

9.3 Determination of mean area of cross-section of stream

If the reach is substantially uniform and there are insignificant differences in the cross-sectional areas, $A_1, A_2 \ldots A_m$, determined in accordance with clause 9.2 at the chosen cross-sections, the mean area of cross-section of stream $\overline{A}$ may be taken as

$$\overline{A} = \frac{A_1 + 2A_2 + \ldots 2A_{m-1} + A_m}{2\ (m-1)}$$

9.4 Determination of wetted perimeter

For each chosen cross-section, the area of which is measured in accordance with clause 9.2, the corresponding wetted perimeter should be determined and if the wetted perimeters are $P_1, P_2 \ldots P_m$ respectively, then the mean wetted perimeter $\overline{P}$ may be taken as

$$\overline{P} = \frac{P_1 + 2P_2 + \ldots 2P_{m-1} + P_m}{2\ (m-1)}$$

10. VELOCITY OF STREAM

10.1 Evaluation of velocity

The mean velocity between two cross-sections ($A_0 \neq A_1$, see Figure below) when the flow is not significantly different from steady flow, using Manning's formula, will be

$$\bar{v} = \frac{R_h^{2/3} S^{1/2}}{n} \text{ (in SI units)}$$

$$\bar{v} = \frac{1.5 R_h^{2/3} S^{1/2}}{n} \text{ (in FPS units)}$$

where

- $\bar{v}$ is the mean velocity;
- R_h is the hydraulic mean depth;
- n is the Manning's coefficient of rugosity having a value given in clause 10.2;
- S is the slope corrected for the kinetic energy difference at the two ends, namely,

$$\frac{z_1 - z_0 + \left(\frac{v_1^2}{2g} - \frac{v_0^2}{2g}\right)}{L}$$

The reach should as far as possible be uniform. If no uniform reach is available, the reach should preferably be converging rather than diverging to facilitate an appropriate correction for change in kinetic energy. However, if the reach is expanding, then the slope correction would include some allowance for eddy loss as well as the correction for the change in kinetic energy between the ends.

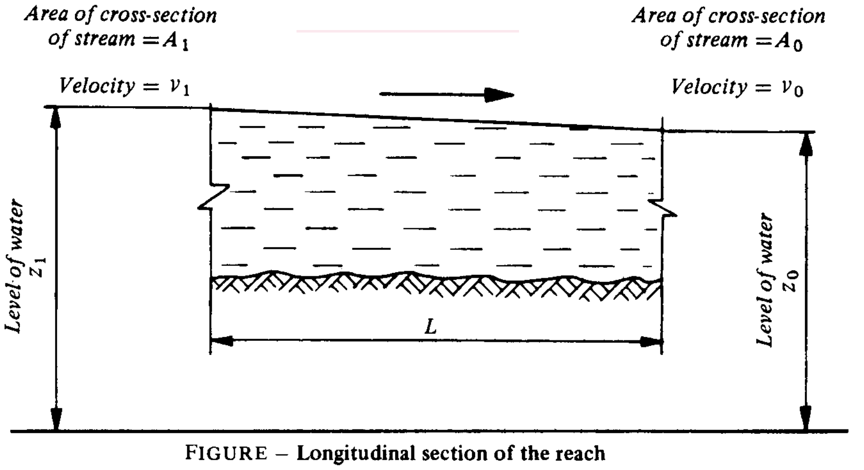

FIGURE – **Longitudinal section of the reach**

The mean velocity for the same conditions as above, using Chezy's formula, will be

$$\bar{v} = C\sqrt{R_h S}$$

where C is Chezy's coefficient and $\bar{v}$, R_h and S are as defined above in the case of Manning's formula.

10.2 Values of Manning's coefficient *n* and Chezy's coefficient *C*

Where a reasonable value of rugosity coefficient can be extrapolated from discharge measurements taken by a more accurate method, for example current meter method or float method and slope observations, at lower stages, the highest of which is as close as possible to the stage measured, the values so obtained may be used provided there are no changes in the channel characteristics. The accuracy of this extrapolated coefficient decreases as the difference between the measured stage and the highest of the lower stages increases.

In the absence of measured data, the values given in Table 1 of the Appendix may be assumed for open channels with relatively coarse bed material and not characterized by bed formations.

In the case of alluvial open channels with other than coarse bed material and in the case of open channels having vegetations, clay and rocky banks, etc., the values given in Table 2 of the Appendix may be used as a guide.

11. COMPUTATION OF DISCHARGE

The discharge should be calculated by multiplying the mean velocity obtained from clause 10.1 by the mean area of the cross-section of the stream obtained from clause 9.3.

In case the cross-sectional area of the stream is not uniform in the reach, the use of average values for the area A, wetted perimeter P, and hydraulic mean depth R_h will not yield correct results; in such cases the conveyance factor for each part of the section is evaluated and added to get the conveyance factor for the whole section and then the geometric mean of the conveyance factors at the two end sections gives the conveyance factor for the reach.

In the case of a composite section, the values of the rugosity coefficient over different portions of the section are likely to be different. The section should be split into relatively homogeneous segments and the velocities and discharges for these segments calculated separately and added.

12. ERRORS

The accuracy of the measurement depends on the correct determination of slope and of the coefficient of rugosity. The coefficient is likely to change with varying stages of floods. If no experimental determination has been made, considerable experience is necessary in choosing the correct value of the rugosity coefficient to be assumed.

An error will also be introduced if the chosen areas of the cross-sections of the stream are not approximately equal.