भारतीय मानक

बलुआ मिट्टी में अस्तर रहित नहरों की अनुप्रस्थ काट के डिजाइन का मापदण्ड

(पहला पुनरीक्षण)

Indian Standard

CRITERIA FOR DESIGN OF CROSS-SECTION FOR UNLINED CANALS IN ALLUVIAL SOIL

(First Revision)

ICS 93.160

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Canals and Cross Drainage Works Sectional Committee, WRD 13

FOREWORD

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

Among the different types of terrain through which a canal may pass the most common one is the alluvial tract. The cross-section of the canal in alluvial soil, therefore, needs to be designed on considerations of stable and regime flow.

This standard was first published in 1973 deriving assistance from the following publications:

India Central Board of Irrigation and Power. Statistical design formulae for alluvial canal system, 1967.

Lacey (G). Sediment as factor in the design of unlined irrigation canals. General report on Q. 20 Sixth Congress on Irrigation and Drainage, New Delhi, 1966. International Commission on Irrigation and Drainage.

This revision of the standard has been taken up to incorporate the latest technological changes in this field as well as to account for the experiences gained during the last three decades.

There is no ISO standard on the subject. This standard has been prepared based on indigenous data and taking into consideration the practices prevalent in the field in India.

The composition of the Committee responsible for the formulation of this standard is given in Annex E.

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, should 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

CRITERIA FOR DESIGN OF CROSS-SECTION FOR UNLINED CANALS IN ALLUVIAL SOIL

(First Revision)

1 SCOPE

This standard covers criteria for design of cross-section of unlined canals in alluvial soil.

2 REFERENCE

The following Indian Standard contains provisions which through reference in this text, constitute provisions of this standard. At the time of publication, the edition indicated was 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 edition of the standard indicated below:

IS No.	*Title*
IS 5968 : 1987	Guide for planning and layout of canals system for irrigation (*first revision*)

3 DATA REQUIRED

3.1 The following data shall be collected for design of canal sections:

a) Topographic map of area to a scale of 1 : 10 000 showing alignment of canal communication lines (roads, railway, etc) and other features. A contour interval of 2 m in hilly areas and 0.3 m in plains is to be adopted in the preparation of this map;

b) Longitudinal section of the ground along the proposed alignment to a horizontal scale of 1 : 10 000 and vertical scale of 1 : 100, showing the upstream water level at point of offtake, bed slope, Lacey's silt factor '*f*' or Manning's Rugosity coefficient '*n*', side slope assumed, velocity and depth, the discharge for which the canal is to be designed in various reaches, sub-soil characteristics at every 5 km and also wherever marked change is noticed, pre-monsoon and post-monsoon ground water levels, position of crossings (roads, railways, drainage, etc) and position of curves;

c) Cross-section of the ground at every km; and

d) Transmission losses.

4 DESIGN

4.1 Having determined the canal capacity in various reaches in accordance with IS 5968 the section required to carry the design discharge shall be worked out. A trapezoidal section is recommended for the canal. From the longitudinal section of the ground along the proposed alignment the average slope of the ground shall be determined. This would be the maximum average slope which can be provided on the canal (for design slope *see* **4.8**)

4.2 Side Slopes

These shall depend on the local soil characteristics and shall be designed to withstand the following conditions during the operation of the canal:

a) The sudden draw-down condition for inner slopes, and

b) The canal running full with banks saturated due to rainfall.

4.2.1 Canal in filling will generally have side slopes of 1.5 : 1, for canals in cutting the side slope should be between 1 : 1 and 1.5 : 1 depending upon the type of the soil.

4.3 Freeboard

Freeboard in a canal is governed by consideration of the canal size and location, rain water inflow, water surface fluctuation caused by regulators, wind action, soil characteristics, hydraulic gradients, service road requirements, and availability of excavated material. A minimum freeboard of 0.5 m for discharge (Q) less than 10 cumecs and 0.75 m for discharge (Q) greater than 10 cumecs is recommended. The freeboard shall be measured from the full supply level to the level of the top of bank.

NOTE — The height of the dowel portion shall not be used for freeboard purposes.

4.4 Bank Top Width

The minimum values recommended for top width of the bank are as given in Table 1.

4.5 Radii of Curvature

The values of radius of curvature of the canal shall be determined according to IS 5968.

Table 1 Minimum Values for Top Width of the Bank

(*Clause* 4.4)

Sl No.	Discharge (m^3/s)	Minimum Bank Top Width	
		Inspection Bank m	Non-inspection Bank m
(1)	(2)	(3)	(4)
i)	0.15 to 7.5	5.0	1.5
ii)	7.5 to 10.0	5.0	2.5
iii)	10.0 to 15.0	6.0	2.5
iv)	15.0 to 30.0	7.0	3.5

NOTES

1 Width between and outside of these limits may be used when justified by specific conditions.

2 For distributory canals carrying less than 1.5 cumecs and minor canals, it is generally not economical to construct a service road on top of bank as this usually requires more materials than the excavation provides. In such cases, service road may be provided on natural ground surface adjacent to the bank, however, the importance of providing adequate service roads where they are needed should always be kept in view.

3 The banks should invariably cover the hydraulic gradient. The width of the non-inspection bank should be checked to see that cover for hydraulic gradient as given in **4.10.1** is provided.

4.6 Berms

Berms along earthen canal are usually provided to reduce bank loads which may cause sloughing of earth into the canal section and to lower the elevation of the service road for easier maintenance. Berms are to be provided in all cuttings when the depth of cutting is more than 3 m. Where a canal is constructed in a deep through cut requiring waste banks, berms should be provided between the canal section cut and the waste bank. Various other factors may be involved in determining whether berms should be used and care should be taken that their use is justified by the results obtained. However, the following practice is recommended:

a) When the full supply level is above ground level but the bed is below ground level, that is, the canal is partly in cutting and partly in filling berm may be kept at natural surface level equal to 2 *D* in width (*see* Fig. 1A) where *D* is the full supply depth.

b) When the full supply level and the bed level are both above the ground level, that is, the canal is in filling; the berm may be kept at the full supply level equal to 3 *D* in width (*see* Fig. 1B).

c) When the full supply level is below ground level, that is, the canal is completely in cutting the berm may be kept at the full supply level equal to 2 *D* in width (*see* Fig. 1C).

4.6.1 In embankments, adequate berms may be provided so as to retain the minimum cover over the hydraulic grade line (*see* **4.4**).

4.7 Dowel

Dowel having top width of 0.5 m, height above road level of 0.5 m and side slopes 1.5 : 1 shall be provided on the service road side between the road and the canal (*see* Fig. 1).

4.8 Bed Width, Depth and Slope

These shall be designed for the various reaches to carry the required discharges according to the best prevalent practice (*see* Notes).

NOTES

1 A number of methods for design of unlined canals in alluvium are in vogue in the country but all of them have some limitations. The use of such a method which has been applied and proved to give good results under similar conditions is the best solution.

2 For design of alluvial channels, Lacey's regime equations have been in use for nearly four decades. The method of design according to Lacey's equation is given in Annex A.

3 Though the Lacey's equations have been in common use in the country, it has been long realized that these equations are not perfect and suffer from certain shortcomings. The major difficulty experienced in the application of Lacey's equations is the choice of the appropriate value of silt factor. Moreover, the divergence from dimensions given by Lacey's equation in existing stable canals has been found significant in many cases. In view of the necessity for evolving formulae more accurate than Lacey's but without sacrificing the simplicity of regime equations, type-fitted equations were evolved which are given in Annex B. Within the range of data tested, these equations are anticipated to give channel dimensions which would be nearer to regime conditions. The regime type-fitted equations recommended for application are not considered the last word on the subject. It should be fully realized that further modifications in the equations are possible and necessary as and when more field observations of stable sites on the canal systems become available. Till the use of these equations is recommended since they are expected to yield more accurate results than Lacey's and other regime formulae.

Lacey modified his equations so as to include sediment concentration (X in parts per million) and size and density of the sediment as defined by its fall velocity (V_s in m/s) as additional parameters affecting the regime dimensions of a stable channel. These are given in Annex C.

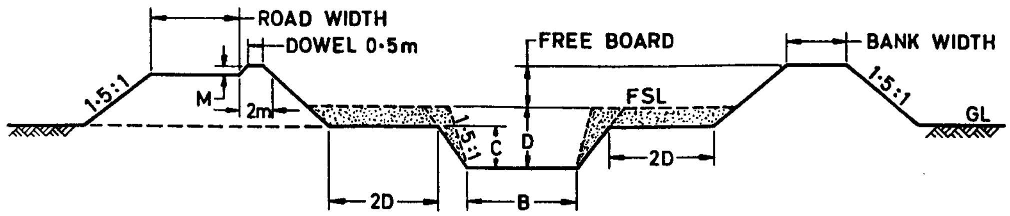
4 Another method of design is by tractive force approach which is given in Annex D.

4.9 Falls

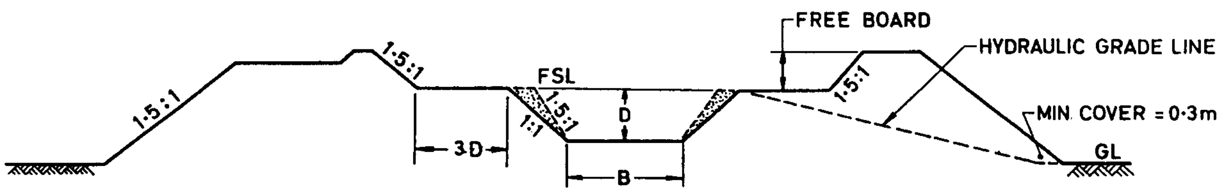
Having decided on the desirable canal slope and canal dimensions, the water surface and bed lines shall be marked in the longitudinal section providing falls where necessary. Falls may be provided to see that the canal runs partly in cutting and partly in filling, which will minimize construction and operation costs and also to enable flow irrigation to be provided over as large an area as possible.

4.10 Hydraulic Grade Line

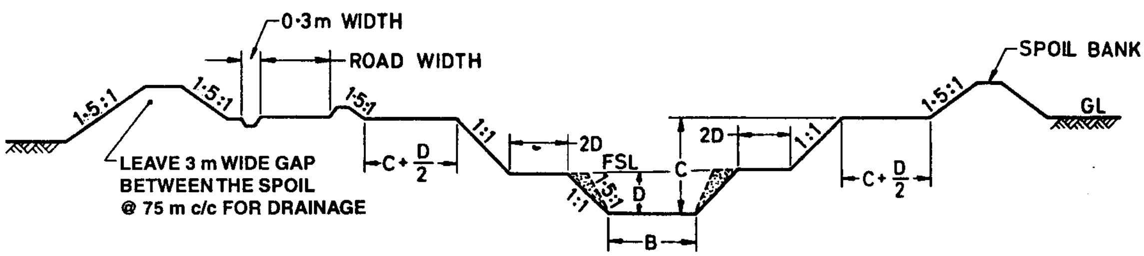
When water runs against fill banks the lines of saturation slant downwards from the water surface



1A TYPICAL SECTION OF CANAL PARTLY IN CUTTING & PARTLY IN FILLING



1B TYPICAL SECTION OF CANAL WHOLLY IN FILLING



1C TYPICAL SECTION OF A CANAL WHOLLY IN CUTTING

FIG. 1 TYPICAL CROSS-SECTIONS OF UNLINED CANALS IN ALLUVIAL SOILS

through the embankment material. The gradient depends mainly on the characteristics and relative placement of the different types of material in the embankment. For embankments more than 5 m high, the true position of the saturation line shall be worked out by laboratory tests and the stability of the slope checked. However, the following empirical values for the hydraulic gradients (horizontal to vertical) may be used for banks less than 5 m high:

For silty soils	4 : 1
For silty sand	5 : 1
For sandy soils	6 : 1

4.10.1 The hydraulic grade line shall have a cover of 0.3 m. When counter berms are required for this purpose, top level of the same shall be 0.3 m below full supply level and the top width of the same shall be 2 m for branch canals and 1 m for distributories. In case of canals in very high filling a second counter berm may be provided so as to cover the hydraulic grade line.

4.11 Catch Water Drainage

Effective system of catch water drainage shall be provided to prevent damage due to rain.

ANNEX A

(*Clause* 4.8, *Note* 2)

LACEY'S METHOD FOR DESIGN OF UNLINED CANALS IN ALLUVIUM

A-1 DETAILS OF THE METHOD

A-1.1 According to Lacey, a canal is said to have attained regime condition when a balance between silting and scouring and dynamic equilibrium in the forces generating and maintaining the canal cross-section and gradient are obtained. If a canal runs indefinitely with constant discharge and sediment charge rates, it will attain a definite stable section having a definite slope. If a canal is designed with a section too small for a given discharge and it's slope is kept steeper than required, scour will occur till final regime is obtained. On the other hand, if the section is too large for the discharge and the slope is flatter than required, silting will occur till true regime is obtained. In practice true regime conditions do not develop because of variations in discharge and sediment rates.

A-1.2 On analysis of data from a large number of natural drainages and canals running for long, Lacey developed relations for determining regime slope and channel dimensions. He postulated, firstly, that the required slope and channel dimensions are dependent on the characteristics of the boundary material which he quantified in terms of the silt factor (f) defined as:

$$f = \frac{2.39\,\bar{v}^2}{R} \qquad \ldots (1)$$

or

$$f = 1.76\sqrt{D_{50}} \qquad \ldots (2)$$

where

$\bar{v}$ = the mean velocity of flow in m/s;

R = the hydraulic mean depth of an existing stable canal, and

D_{50} = the average particle size of the boundary material in mm.

Thus, in case, the conditions on a canal to be designed are similar to those on an existing stable canal, the value of f may be determined by use of formula (1) using the observed value of $\bar{v}$ and R on the existing stable canal. Alternatively, the value of f may be determined by use of formula (2) after determining the D_{50} size of boundary material.

Having determined the value of 'f' the following three relationships may be used for determining required slope and canal dimensions:

$$S = \frac{0.000\,3 f^{5/3}}{Q^{1/6}} \qquad \ldots (3)$$

$$P = 4.75\sqrt{Q} \qquad \ldots (4)$$

$$R = 0.47\left(\frac{Q}{f}\right)^{1/3} \qquad \ldots (5)$$

where

S = slope of the canal,

Q = discharge in m^3/s,

P = wetted perimeter of the section in m, and

R = hydraulic mean depth in m.

A-1.3 Knowing the desirable values of P, R, the curves given in Fig. 2 may be used for determining the corresponding canal bed width (B) and depth (D) for a canal having internal side slope of 1/2 : 1 (it is assumed that the canal attains a slope of 1/2 : 1 after running in regime).

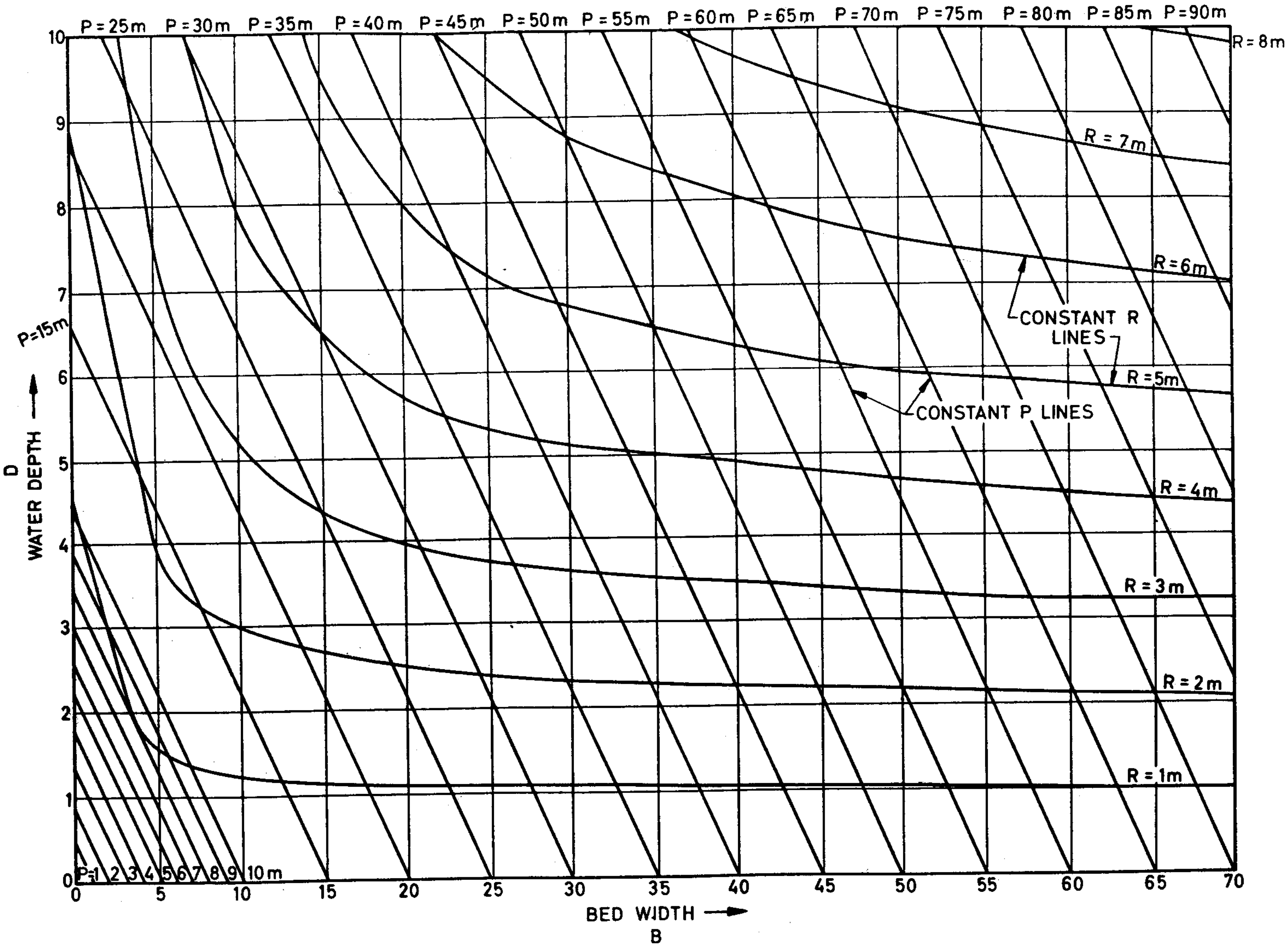


FIG. 2 HYDRAULIC CHART OF RELATIONSHIP BETWEEN B, D, R AND P FOR A CHANNEL HAVING INSIDE SLOPE ½ : 1

ANNEX B

(*Clause* 4.8, *Note* 3)

REGIME TYPE FITTED EQUATIONS FOR DESIGN OF UNLINED CANALS IN ALLUVIAL SOIL

B-1 The regime type fitted equations evolved on the basis of data collected from various States in India are given in Table 2.

Table 2 Regime Type Fitted Equations

(*Clause* B-1)

Sl No.	Hydraulic Parameter	All India Canals	Punjab Canals	U.P. Canals	Bengal Canals
i)	S (Slope)	$\frac{0.000\,315}{(Q)^{0.165\,1}}$	$\frac{0.000\,251}{(Q)^{0.096\,1}}$	$\frac{0.000\,36}{(Q)^{0.145\,0}}$	$\frac{0.000\,134\,6}{(Q)^{0.037\,5}}$
ii)	P (Wetted perimeter)	$4.30\,(Q)^{0.523\,1}$	$7.00\,(Q)^{0.601\,9}$	$3.98\,(Q)^{0.502\,0}$	$5.52\,(Q)^{0.419\,0}$
iii)	R (Hydraulic mean depth)	$0.515\,(Q)^{0.340\,6}$	$0.466\,(Q)^{0.338\,9}$	$0.448\,(Q)^{0.364\,9}$	$0.438\,(Q)^{0.445\,4}$

NOTE — In the above equations average boundary condition is taken care of by fitting different equations to data obtained from different States and assuming similar average boundary conditions in a State.

ANNEX C

(*Clause* 4.8, *Note* 3)

LACEY'S MODIFIED EQUATIONS FOR DESIGN OF UNLINED CANALS IN ALLUVIUM

C-1 DETAILS

C-1.1 While Retaining the Equation

$$q = 0.207\sqrt{Q} \quad (cf\,P = 4.75\,\sqrt{Q}) \qquad \ldots (6)$$

Lacey gave the following additional equations so as to include the effect of sediment concentration and size and density of the sediment as defined by it's fall velocity on the regime dimensions of a stable canal.

$$\bar{v} = K_1 q^{1/3}\,(X.V_S)^{1/6} \qquad \ldots (7)$$

$$\bar{D} = K_2 \frac{q^{2/3}}{(X.V_S)^{1/6}} \qquad \ldots (8)$$

$$S/E = K_3 \frac{(X.V_S)^{1/3}\,m^{1/2}}{q^{1/3}} \qquad \ldots (9)$$

where

q = discharge intensity in canal in $m^3/s/m$ width,

$\bar{v}$ = mean velocity of flow in canal in m/s,

X = sediment concentration in ppm,

V_S = fall velocity of sediment in m/s,

$\bar{D}$ = mean depth of flow in m,

S = slope of the canal,

E = Lacey number

$$= \frac{\text{Mean depth}}{\text{Hydraulic depth}} = \frac{\bar{D}}{R}, \text{ and}$$

K_1, K_2, K_3 = constants

C-1.2 Lacey did not give any values for the constants. The values of the constants are to be determined on basis of observed data in various regions before the above equations can be used for design purposes.

NOTE — On the basis of observations taken on different canal systems in Uttar Pradesh the following values for the constants were obtained:

$$K_1 = 0.60,\ K_2 = 1.532,\ K_3 = 35.56$$

With these values of the constants, the canal section can be designed by use of equations 6 to 9. It is, however, felt that these values of the constants need further verification on different canal systems of the country before they can be generally adopted.

ANNEX D

(*Clause* 4.8, *Note* 4)

TRACTIVE FORCE APPROACH FOR DESIGN OF UNLINED CANALS

D-1 DETAILS

D-1.1 The unit tractive force exerted on bed of a running canal can be calculated from the formula:

$$\tau = \gamma . R . S. \quad \ldots (10)$$

where

τ = unit tractive force in kg/m^2,

γ = the unit weight of water in kg/m^3 (usually 1 000 kg/m^3),

R = the hydraulic mean radius in m, and

S = the canal slope.

The permissible tractive force may be defined as the maximum tractive force that will not cause serious erosion of the material forming the canal bed on a level surface. The permissible tractive force is a function of average particle size (D_{50}) of canal bed in case of canals in sandy soils and void ratio in case of canals in clayey soils and sediment concentration. The values of permissible tractive force for straight canal have been given by some authors on the basis of laboratory experiments but the same can better be determined by analysis of observed data on existing canals. Once this is done this would provide a rational approach to the design of section of regime channels. The values of permissible tractive force for sinuous canals may be reduced by 10 percent for slightly sinuous ones, by 25 percent for moderately sinuous ones and by 40 percent for very sinuous ones.

D-1.2 In this approach, first the sediment concentration X of the canal flow and the D_{50} size of bed material in case of non-cohesive soils and void ratio of the bed material in case of cohesive soils is determined and from these corresponding permissible tractive force shall be obtained by use of observed data of existing canals. A suitable bed slope is then selected either with reference to average ground slope along the canal alignment or on the basis of experience and the value of R shall be obtained from equation (10). Knowing the value of R and assuming a suitable value of n for the canal, referring to Table 3 as a guide, the average desirable velocity of flow in the canal may be determined by using the Manning's formula given below:

$$\bar{v} = \frac{1}{n} R^{2/3} S^{1/2} \quad \ldots (11)$$

Thus the area of cross-section required may be determined and knowing R and A the desirable canal bed width (B) or depth (D) may be calculated.

Table 3 Values of Rugosity Coefficient (n) for Unlined Canals

(*Clause* D-1.2)

Sl No.	Type of Canal	Minimum	Normal	Maximum
(1)	(2)	(3)	(4)	(5)
i)	*Earth, straight and uniform*:			
	a) Clean, recently completed	0.016	0.018	0.020
	b) Clean, after weathering	0.018	0.022	0.025
	c) Gravel, uniform section, clean	0.022	0.025	0.030
	d) With short grass, few weeds	0.022	0.027	0.033
ii)	*Earth, winding and sluggish*:			
	a) No vegetation	0.023	0.025	0.030
	b) Grass, some weeds	0.025	0.030	0.033
	c) Dense weeds or aquatic plants in deep channels	0.030	0.035	0.035
	d) Earth bottom and rubble sides	0.030	0.035	0.040
	e) Stony bottom and weedy banks	0.025	0.035	0.040
	f) Cobble bottom and clean sides	0.030	0.040	0.050
iii)	*Dragline excavated or dredged*:			
	a) No vegetation	0.025	0.028	0.033
	b) Light brush on banks	0.035	0.050	0.060
iv)	*Channels not maintained (weeds and brush uncut)*:			
	a) Dense weeds, high as flow depth	0.050	0.080	0.120
	b) Clean bottom, brush on sides	0.040	0.050	0.080
	c) Same, highest stage of flow	0.045	0.070	0.110
	d) Dense brush, high stage	0.080	0.100	0.140

NOTES

1 For normal alluvial soils, it is usual in India to assume a value of n = 0.020 for bigger canals (Q > 15 cumecs) and n = 0.022 5 for smaller canals (Q < 15 cumecs).

2 A suitable value of n should be adopted keeping in view the local conditions and the above values as a guide.

ANNEX E

(*Foreword*)

COMMITTEE COMPOSITION

Canals and Cross Drainage Works Sectional Committee, WRD 13

Organization	*Representative(s)*
Sardar Sarovar Narmada Nigam Ltd, Gandhi Nagar, Gujarat	SHRI G. L. JAVA (***Chairman***)
Bhakra Beas Management Board, Nangal Township, Punjab	DIRECTOR (WR) EXECUTIVE ENGINEER (*Alternate*)
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Central Water Commission, New Delhi	DIRECTOR [BCD N & W & NWS] DIRECTOR (SSD & C) (*Alternate*)
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Continental Construction Ltd, New Delhi	SHRI P. A. KAPUR SHRI. T. B. S. RAO (*Alternate*)
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Irrigation Department, Government of Maharashtra, Nasik	SUPERINTENDING ENGINEER (GATES) EXECUTIVE ENGINEER (CSI) (*Alternate*)
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Water and Land Management Institute, Lucknow	PROF P. K. SINHA
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Review of Indian Standards

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 Catalogue' and 'Standards: Monthly Additions'.

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Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

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Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110 002
Telephones : 323 01 31, 323 33 75, 323 94 02

Telegrams : Manaksanstha
(Common to all offices)

Regional Offices :		Telephone
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