IS : 7563 - 1986

(Reaffirmed 1995)

Indian Standard

CODE OF PRACTICE FOR STRUCTURAL DESIGN OF CUT AND COVER CONCRETE CONDUITS

(First Revision)

UDC 628·143·1/·2 [666·972] 624·04

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

Gr 5

October 1986

Indian Standard

CODE OF PRACTICE FOR STRUCTURAL DESIGN OF CUT AND COVER CONCRETE CONDUITS

(First Revision)

Water Conductor Systems Sectional Committee, BDC 58

Chairman
Shri P. M. Mane
39 Shivaji Co-operative Housing Society, Pune

Members	*Representing*
Chief Engineer	Mukerian Hydel Project Design, Chandigarh
Director (*Alternate*)	
Chief Engineer (HP)	Tamil Nadu Electricity Board, Coimbatore
Superintending Engineer (*Alternate*)	
Chief Engineer (General)	Public Works Department, Madras
Chief Engineer (Irrigation) (*Alternate*)	
Chief Engineer (Civil Designs)	Karnataka Power Corporation Ltd, Bangalore
Shri P. R. Malikarjuna (*Alternate*)	
Chief Engineer	Bhakra Beas Management Board, Chandigarh
Shri Sudershan Kumar (*Alternate*)	
Chief Engineer (Irrigation South)	Public Works and Electricity Department, Mysore
Superintending Engineer (*Alternate*)	
Shri C. Etty Darwin	In personal capacity, (*P. O., Muttada, Trivandrum*)
Director	Central Soils & Materials Research Station, New Delhi
Deputy Director (*Alternate*)	
Director (HCD-I)	Central Water Commission, New Delhi
Deputy Director (HCD-I) (*Alternate*)	
Dr A. K. Dube	Central Mining Research Station Unit, Roorkee
Dr J. L. Jethwa (*Alternate*)	
Dr B. Pant	Water Resources Development Training Centre, Roorkee
Shri J. P. Gupta	Power House Designs, Irrigation Department, Government of Uttar Pradesh, Roorkee
Shri A. P. Gupta (*Alternate*)	

(*Continued on page* 2)

(*Continued from page* 1)

Members	*Representing*
SHRI M. V. S. IYENGAR	The Hindustan Construction Co Ltd, New Delhi
SHRI M. G. KHAN (*Alternate*)	
JOINT DIRECTOR RESEARCH (GE-II)	Research Designs & Standards Organization, Lucknow
SHRI P. N. KHAR	National Hydroelectric Power Corporation Ltd, New Delhi
SHRI A. K. MEHTA	National Projects Construction Corporation Ltd, New Delhi
SHRI S. C. BALI (*Alternate*)	
MEMBER (CIVIL)	Kerala State Electricity Board, Trivandrum
SHRI S. L. MOKHASHI	Central Water & Power Research Station, Pune
SHRI A. V. Gopalkrishna (*Alternate*)	
SHRI G. PANT	Geological Survey of India, New Delhi
SHRI N. K. MANDWAL (*Alternate*)	
SHRI A. R. RAICHUR	In personal capacity (*147 Garodinagar, Bombay*)
SHRI Y. RAMA KRISHNA RAO	Andhra Pradesh State Electricity Board, Hyderabad
SUPERINTENDING ENGINEER (DESIGN AND PLANNING) (*Alternate*)	
SHRI G. V. SATHAYE	Central Designs Organization, Nasik
DR H. R. SHARMA*	Central Electricity Authority, New Delhi
SHRI S. C. SEN	Assam State Electricity Board, Gauhati
SHRI N. K. DAS (*Alternate*)	
SHRI A. K. SRIKANTIAH	Himachal Pradesh State Electricity Board, Sundernagar
SHRI RANJODH SINGH (*Alternate*)	
SHRI G. RAMAN, Director (Civ Engg)	Director General, ISI (*Ex-officio Member*)

Secretary

SHRI HEMANT KUMAR
Assistant Director (Civ Engg), ISI

Panel for Head Race Canals, BDC 58 : P5

Convener	
DR H. R. SHARMA	Central Electricity Authority, New Delhi
Members	
CHIEF ENGINEER (CIVIL)	Andhra Pradesh State Electricity Board, Hyderabad
SUPERINTENDING ENGINEER (D & P) (*Alternate*)	
CHIEF ENGINEER (PROJECT & CONSTRUCTION)	Tamil Nadu Electricity Board, Madras
SUPERINTENDING ENGINEER PROJECT/CIVIL (HYDEL) (*Alternate*)	

---

*Dr H. R. Sharma was the Chairman for the meeting in which this standard was finalized.

(*Continued on page* 19)

Indian Standard

CODE OF PRACTICE FOR STRUCTURAL DESIGN OF CUT AND COVER CONCRETE CONDUITS

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 31 December 1985, after the draft finalized by the Water Conductor Systems Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Water conductor system sometimes takes the form of cut and cover concrete conduits through high ground or hill slopes where the surface canals or tunnels are not feasible. This code covers recommendations regarding the structural design of such conduits. These recommendations should, however, be used with caution for important structures where it is advisable to make extensive field and laboratory investigations, if economic conditions justify such studies.

0.2.1 The rules indicated for the design in this code are applicable for circular conduits but may also be used for other shapes like rectangular, D-shaped, horse shoe, etc, till further reliable criteria are available.

0.3 Guidance is provided in IS : 4880 (Part 2)-1976* for geometric design of various sections usually adopted for water conductor system and IS : 4880 (Part 3)-1976† for hydraulic design.

0.4 In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

0.5 This standard was first published in 1975. This revision is based on the experience gained in the use of this standard. The modifications incorporated in this version mainly relate to loads due to backfill.

---

*Code of practice for design of tunnels conveying water: Part 2 Geometric design (*first revision*).

†Code of practice for design of tunnels conveying water: Part 3 Hydraulic design (*first revision*).

0.6 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*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This code covers the structural design of cut and cover concrete conduits meant for transporting water under pressure or otherwise. The provisions of the code are applicable only to conduits installed in a trench dug in undisturbed soil and backfilled to final grade.

2. GENERAL

2.1 The structural design of cut and cover concrete conduits is affected by many factors, namely, type of installation, rigidity of conduit, shape of conduit, nature of foundation, physical characteristics and degree of compaction of fill materials.

2.2 The conduit may be designed as a two-dimensional frame with the loads calculated on the basis of **3.1** to **3.3** for the foundation conditions shown in Fig. 1.

2.3 Most Common Installation of Underground Conduits

2.3.1 *Trench Conduit* — This condition applies to a conduit installed in a trench dug in undisturbed soil and backfilled up to top of trench (*see* Fig. 1A).

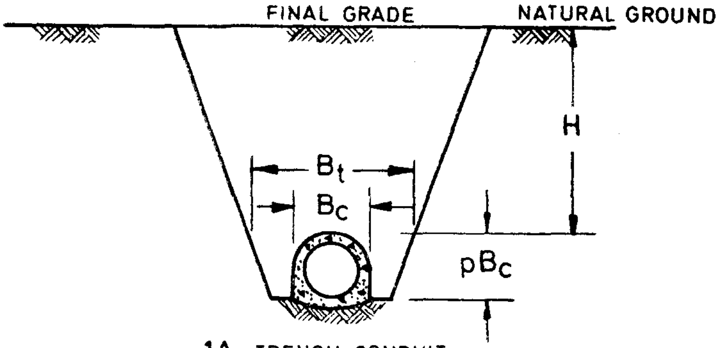
2.3.2 *Positive Projection Conduit* — This condition applies to a conduit installed in shallow bedding with its top projecting above the surface of natural ground and then covered with an embankment (*see* Fig. 1B).

2.3.3 *Negative Projection Conduit* — This condition applies to a conduit installed in a relatively narrow and shallow trench with its top at an elevation below the natural ground surface and having a superimposed fill above the top of trench (*see* Fig. 1C).

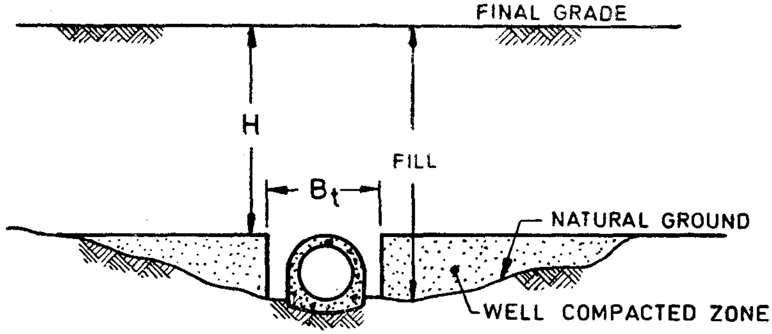
2.3.4 *Sub-Ditch* — An illustration of a sub-ditch is given in Fig. 1D.

---

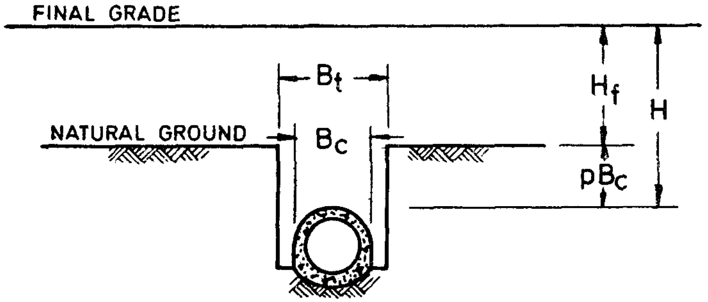
*Rules for rounding off numerical values (*revised*).



1A TRENCH CONDUIT

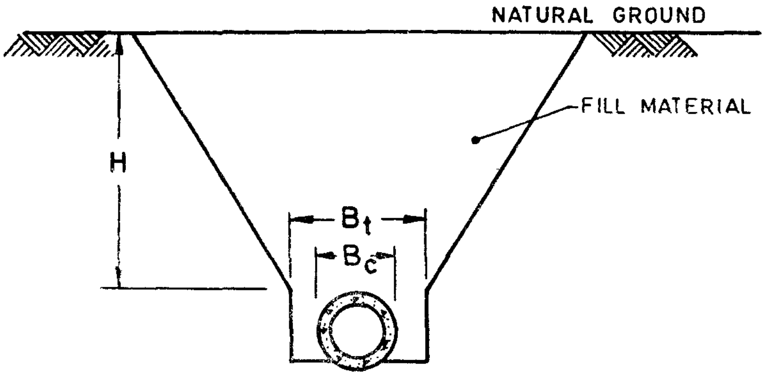


1B POSITIVE PROJECTION CONDUIT



1C NEGATIVE PROJECTION CONDUIT

FIG. 1 INSTALLATION CONDITIONS OF UNDERGROUND CONDUITS — *Contd*



1D ILLUSTRATION OF A SUBDITCH

FIG. 1 INSTALLATION CONDITIONS OF UNDERGROUND CONDUITS

3. DESIGN LOADS

3.0 Depending upon site conditions, a cut and cover concrete conduit, in addition to its self weight, is subjected to the forces listed below. The structural design of the conduit shall be based on the most unfavourable combination of all loads and effects listed below acting simultaneously:

a) Loads due to backfill,

b) Internal water pressure,

c) External water pressure,

d) Loads due to concentrations and surcharge including effects of live load, and

e) Seismic effects.

3.1 Loads Due to Backfill

3.1.1 *Vertical Load* — The vertical load due to backfill on rigid trench conduits resting on natural strata shall be given by equation (1):

$$W = 10\, C_t\, \gamma\, B^{2}{}_{t} \qquad \ldots\ldots(1)$$

where

W = vertical load at the top of conduit in N/m;

C_t = a coefficient for trench conduits to be taken from Fig. 2 for typical fill material, given by equation (2);

Υ = unit mass of fill material in kg/m^3; and

B_t = width of trench at the crown level of the conduit in m.

$$C_t = \frac{1 - e^{-2k_a} [H/B_t] \tan \phi'}{2K_a \tan \phi} \qquad \text{......(2)}$$

where

$K_a = \tan^2 (45° - \phi/2)$,

ϕ = angle of friction between the backfill and the natural soil on the side of the trench,

H = difference of final grade and top of conduit, and

ϕ' = angle of internal friction of fill material.

NOTE — If the local conditions and available equipment make it desirable to excavate trench with sloping sides or one which is very wide in comparison with the size of the conduit. It is a good practice to lay the pipe in relatively narrow subditch at the bottom of the wider trench as illustrated in Fig. 1 D.

3.1.2 *Lateral Pressure* — The lateral pressure diagram due to backfill will be trapezoidal with pressures at any horizontal plane given by equation (3):

$$p = 10\, r\, H_p\, K_a - 2\, C \sqrt{K_a} \qquad \text{......(3)}$$

where

p = lateral pressure at any horizontal plane in N/m^2,

r = unit mass of fill material in kg/m^3,

H_p = height of fill above any horizontal plane in m,

K_a = Rankine's ratio of active lateral pressure = $\tan^2 (45° - \phi/2)$,

ϕ = angle of internal friction of fill material in degrees, and

c = coefficient of fill material in N/m^2.

3.1.3 The physical characteristics of proposed fill material, that is, r, ϕ and c in most cases should be determined by laboratory tests. However, the values given in Table 1 may be adopted for preliminary design.

3.1.4 *Conduits in Sloping Sided Trenches* — In case of conduits installed in sloping sided trenches and then covered with backfill, the width of the trench for the purpose of calculating vertical load due to backfill shall be taken as the width at the level of the top of conduit, the treatment otherwise being the same as for vertical sided trenches.

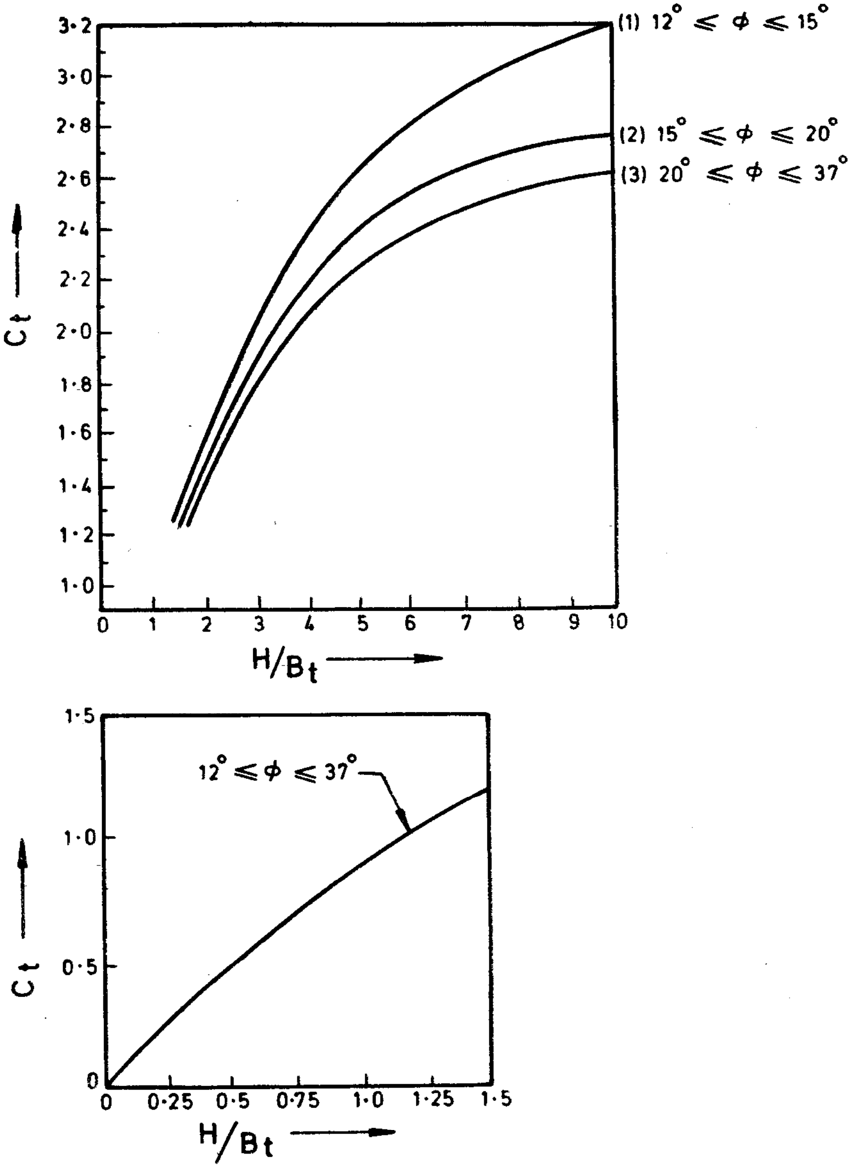


FIG. 2 COEFFICIENT C_T FOR TRENCH CONDITIONS

TABLE 1 PHYSICAL CHARACTERISTICS OF FILL MATERIALS

(*Clause* 3.1.3)

SL No.	FILL MATERIAL	UNIT MASS IN kg/m^3			ANGLE OF INTERNAL FRICTION (ϕ) IN DEGREES
		Dry	Natural Drained	Submerged	
(1)	(2)	(3)	(4)	(5)	(6)
i)	Clay, soft	950-1 500	1 600-1 900	550-900	About 10
ii)	Clay, compact	1 500-1 850	1 900-2 150	200-1 100	20-25
iii)	Cinders	650-720	1 100-1 200	1 600	30-45
iv)	Gravels, well graded	1 700-1 900	1 850-2 150	1 050-1 200	40-50
v)	Silt compact	1 350-1 700	1 850-2 100	800-1 050	25-40
vi)	Sand	1 450-1 700	1 700-1 900	900-1 050	25-40
vii)	Sand-clay compact	1 850-2 100	2 100-2 250	1 100-1 300	40-50

NOTE — Because of the uncertainity of and difficulty in determining the cohesion the disturbed and manipulated soil which usually contributes the backfill, the reduction in value of ϕ due to the second term in equation (3) may be neglected.

3.1.5 *Analysis* — The pressure and stresses on conduits may also be determined, if necessary, by detailed analysis using finite element techniques which takes into account the soil characteristics and conduit flexibilities.

3.2 Internal Water Pressure — The conduit shall be designed for internal water pressure to which it is subjected to.

3.3 External Water Pressure

3.3.1 *Vertical Load* — The total vertical load due to backfill, in cases where water surcharge is a possibility, shall be taken equal to the vertical load as computed in **3.1** using submerged unit weight of the fill material plus the weight of the projected volume of water above the top of conduit (*see* Fig. 3).

3.3.2 *Lateral Pressure* — The total horizontal unit pressure, in addition to the lateral pressure, as calculated in **3.1** using submerged unit mass of the fill material shall include the full hydrostatic pressure due to the water surcharge (*see* Fig. 3).

3.3.3 *Uplift* — The conduit shall be checked for safety against uplift. Minimum factor of safety against uplift shall be 1·1 under the empty conduit conditions.

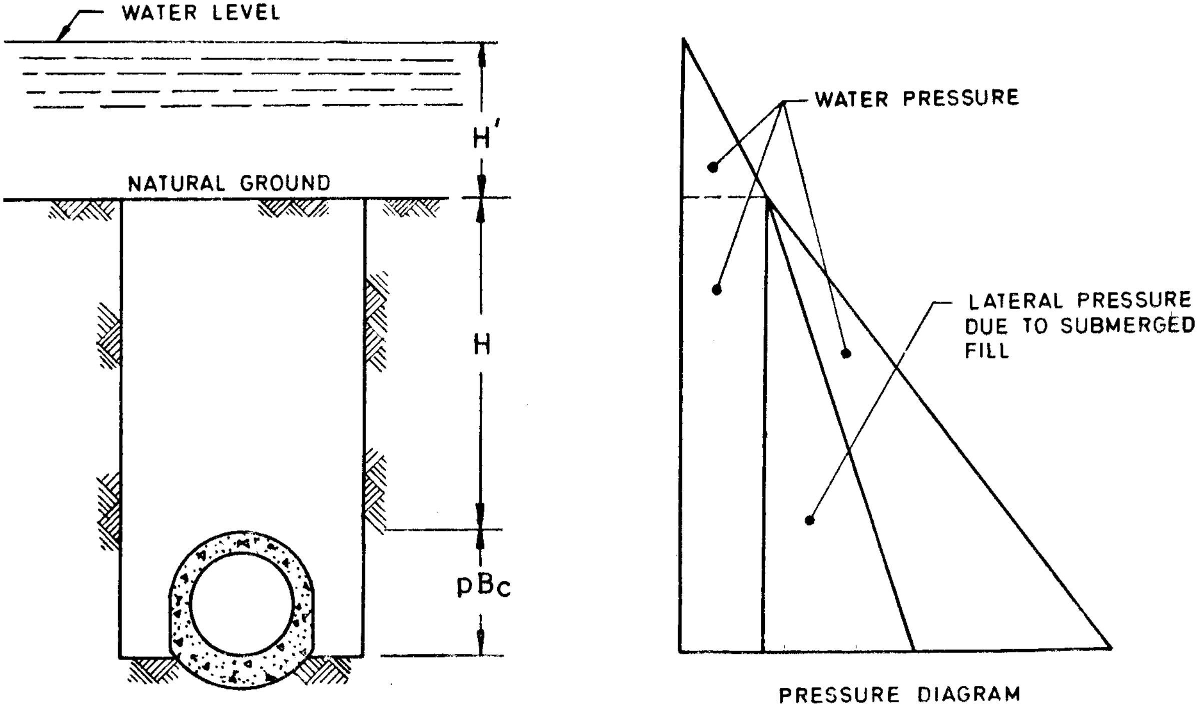


Fig. 3 Effect of Hydrostatic Water Pressure

3.4 Loads Due to Concentrations and Surcharge

3.4.1 *Dispersion of Concentrated Point Loads*

3.4.1.1 *Single concentration* — The vertical pressure transmitted to an underground conduit due to a single concentrated load at the surface of the fill shall be computed by equations (4) and (5):

$$W_{c} = \frac{3}{2\pi} \times \frac{P_{H}^{3}}{H_{S}^{5}} \qquad \ldots\ldots(4)$$

$$H_{S} = \frac{3}{\sqrt{H^{2} + X^{2} + Y^{2}}} \qquad \ldots\ldots(5)$$

where

W_{c} = unit vertical pressure at the top of conduit due to a concentrated load in N/m^{2},

P = concentrated load applied at the surface of fill in N,

H = height of fill above the top of conduit in m,

H_{s} = slant height of the top of conduit in m from the point of application of concentrated load and to be given by equation (5),

X = the projection of the slant height in m in X-direction (*see* Fig. 4), and

Y = the projection of the slant height in m in Y-direction (*see* Fig. 4).

3.4.1.2 *Multiple concentrations* — In case of multiple concentrations, such as combination of wheel loads, the effects shall be computed separately for each load and superimposed to get the combined effect.

3.4.1.3 In case the single concentrated load is directly above the conduit, the total load per metre run of the conduit shall be computed by equation (6):

$$P_{vc} = 4\ C_{s}\ P \qquad \ldots\ldots(6)$$

where

P_{vc} = total vertical load on the top of the conduit in N/m due to superimposed concentrated load;

C_s = the influence coefficient to be read from Table 2 corresponding to $A = \frac{B_c}{2}$, $B = \frac{1}{2}$ and the height of fill H in m above the top of conduit;

P = the concentrated load in N; and

B_c = outside width of conduit in m.

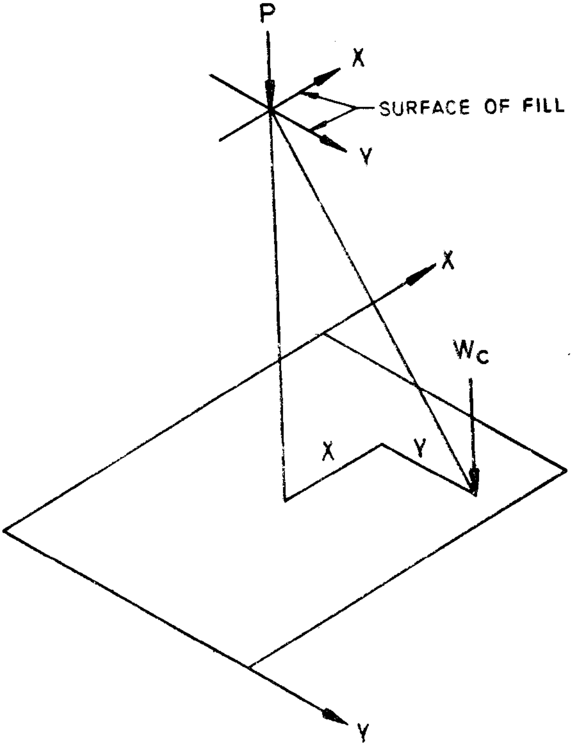


FIG. 4 DIAGRAM OF SURFACE LOAD TO UNDERGROUND CONDUIT

3.4.2 *Dispersion of Distributed Surcharge*

3.4.2.1 The distributed surcharges of considerable extent shall be assumed to continue downwards indefinitely with undiminishing force and may be treated as additional fill of equivalent weight.

TABLE 2 INFLUENCE COEFFICIENTS FOR RECTANGULAR AREA

(*Clauses* 3.4.1.3 *and* 3.4.2.3)

$m = \frac{A}{H}$ or $n = \frac{B_t}{H}$	$n = \frac{B_t}{H}$ or $m = \frac{A}{H}$																	
	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0	1·2	1·5	2·0	2·5	3·0	5·0	10·0	α
0·1	0·005	0·009	0·013	0·017	0·020	0·022	0·024	0·026	0·027	0·028	0·029	0·030	0·031	0·031	0·032	0·032	0·032	0·032
0·2	0·009	0·018	0·026	0·033	0·039	0·043	0·047	0·050	0·053	0·055	0·057	0·059	0·061	0·062	0·062	0·062	0·062	0·062
0·3	0·013	0·026	0·037	0·047	0·056	0·063	0·069	0·073	0·077	0·079	0·083	0·086	0·089	0·090	0·090	0·090	0·090	0·090
0·4	0·017	0·033	0·047	0·060	0·071	0·080	0·087	0·093	0·098	0·101	0·106	0·110	0·113	0·115	0·115	0·115	0·115	0·115
0·5	0·020	0·039	0·056	0·071	0·084	0·095	0·103	0·110	0·116	0·120	0·126	0·131	0·135	0·137	0·137	0·137	0·137	0·137
0·6	0·022	0·043	0·063	0·080	0·095	0·107	0·117	0·125	0·131	0·136	0·143	0·149	0·153	0·155	0·156	0·156	0·156	0·156
0·7	0·024	0·047	0·069	0·087	0·103	0·117	0·128	0·137	0·144	0·149	0·157	0·164	0·169	0·170	0·171	0·172	0·172	0·172
0·8	0·026	0·050	0·073	0·093	0·110	0·125	0·137	0·146	0·154	0·160	0·168	0·176	0·181	0·183	0·184	0·185	0·185	0·185
0·9	0·027	0·053	0·077	0·098	0·116	0·131	0·144	0·154	0·162	0·168	0·178	0·186	0·192	0·194	0·195	0·196	0·196	0·196
1·0	0·028	0·055	0·079	0·101	0·120	0·136	0·149	0·160	0·168	0·175	0·185	0·193	0·200	0·202	0·203	0·204	0·205	0·205
1·2	0·029	0·057	0·083	0·106	0·126	0·143	0·157	0·168	0·178	0·185	0·196	0·205	0·212	0·215	0·216	0·217	0·218	0·218
1·5	0·030	0·059	0·086	0·110	0·131	0·149	0·164	0·176	0·186	0·193	0·205	0·215	0·223	0·226	0·228	0·229	0·230	0·230
2·0	0·031	0·061	0·089	0·113	0·135	0·153	0·169	0·181	0·192	0·200	0·212	0·223	0·232	0·236	0·238	0·239	0·240	0·240
2·5	0·031	0·062	0·090	0·115	0·137	0·155	0·170	0·183	0·194	0·202	0·215	0·226	0·236	0·240	0·242	0·244	0·244	0·244
3·0	0·032	0·062	0·090	0·115	0·137	0·156	0·171	0·184	0·195	0·203	0·216	0·228	0·238	0·242	0·244	0·246	0·247	0·247
5·0	0·032	0·062	0·090	0·115	0·137	0·156	0·172	0·185	0·196	0·204	0·217	0·229	0·239	0·244	0·246	0·249	0·249	0·249
10·0	0·032	0·062	0·090	0·115	0·137	0·156	0·172	0·185	0·196	0·205	0·218	0·230	0·240	0·244	0·247	0·249	0·250	0·250
α	0·032	0·062	0·090	0·115	0·137	0·156	0·172	0·185	0·196	0·205	0·218	0·230	0·240	0·244	0·247	0·249	0·250	0·250

3.4.2.2 In case of a long transverse load or having concentration on a moderately sized area, the loaded area shall be subdivided into unit squares and the load on each square treated as a separate concentration.

3.4.2.3 *Total vertical load due to superimposed distributed loads of fiinte extent* — If the superimposed load of P_d N/m² is uniformly spread over an area of $2\ A \times 2\ B$ on the top surface directly above the conduit, divide the area into four parts each equal to $A \times B$ and find the influence coefficient from Table 2. The vertical load on the top of the conduit per metre run shall be computed by equation (7).

$$P_{vd} = 4\ C_s\ P_d\ B_c$$

where

P_{vd} = total vertical load on top of conduit in N/m due to superimposed distributed load;

C_s = the influence co-efficient to be read from Table 2 corresponding to $A = \frac{B_c}{2}$, $B = \frac{1}{2}$ and the height of fill H in m above top of conduit;

P_d = distribution load in N/m²; and

B_c = outside width of conduit in m.

3.4.3 *Effect on Lateral Pressure* — The effect of concentrated loads and surcharge on the lateral pressure due to backfill on the conduit shall be computed as under:

a) Determine the unit vertical pressure as discussed in **3.4.1** and **3.4.2**,

b) Convert this vertical pressure into an equivalent height, and

c) Increase H_p in equation (3) by the amount of equivalent backfill height as calculated in (b).

3.4.4 *Impact Factors* — In order to account for the impact effect of the moving loads, the values calculated in **3**, **3.4.1**, **3.4.2** and **3.4.3** shall be multiplied by an impact factor for highways I given by the following relation:

$$I = 1 + 0{\cdot}3/H$$

where

H = the height of fill in m above the top of conduit.

4. SEISMIC EFFECTS

4.1 General — The underground conduits should not be cast directly against rock or any rock ridge within the soil, but shall be provided with at least half metre-excavation filled with soil or aggregate backfill to prevent discontinuities during seismic activity. This would, however, need further study in case of important structures.

4.2 Curvature Requirements

4.2.1 *Curvature Distortion* — The underground conduits shall be designed to conform to ground curvature imposed by seismic waves in soils. The combined maximum strain ε resulting from an oblique wave shall be taken as:

$$\varepsilon = \frac{5{\cdot}2\,A}{L} \qquad \ldots\ldots(8)$$

where

A = amplitude in cm corresponding to wavelength L to be obtained from Table 3. Table 3 gives horizontal amplitude. For vertical amplitudes use two-thirds of these values, and

L = critical wavelength in m, taken as 6 times the maximum width of structure in the plane of bending.

4.2.1.1 The values of A not covered in Table 3 may be computed from equation (9):

$$A = CL^{n} \qquad \ldots\ldots(9)$$

The values of constants C and n are as under:

	Soft Soil	*Firm Soil*
C	$277{\cdot}8 \times 10^{-7}$	$30{\cdot}56 \times 10^{-7}$
n	1·86	1·95

4.2.1.2 If ε from equation (8) is less than 1×10^{-4}, the distortion shall be assumed elastic and no special provision need be made.

4.2.1.3 If ε calculated from equation (8) exceeds 1×10^{-4}, the structure shall be articulated with transverse joints designed to absorb the calculated strain rate multiplied by the spacing of the joints.

4.2.1.4 Except for very unusual structures or soils, curvature distortion shall be well within the elastic range.

TABLE 3 WAVE AMPLITUDE

(*Clause* 4.2.1)

SL No.	WAVE LENGTH L, m	AMPLITUDE A, cm	
		Soft Soil	Firm Soil
(1)	(2)	(3)	(4)
i)	10	$20{\cdot}2 \times 10^{-4}$	$2{\cdot}7 \times 10^{-4}$
ii)	20	$73{\cdot}1 \times 10^{-4}$	$10{\cdot}5 \times 10^{-4}$
iii)	30	$155{\cdot}0 \times 10^{-4}$	$23{\cdot}1 \times 10^{-4}$
iv)	40	$266{\cdot}5 \times 10^{-4}$	$40{\cdot}6 \times 10^{-4}$
v)	50	$401{\cdot}5 \times 10^{-4}$	$62{\cdot}7 \times 10^{-4}$
vi)	60	$562{\cdot}5 \times 10^{-4}$	$90{\cdot}2 \times 10^{-4}$

4.2.2 *Shearing Distortion*

4.2.2.1 The underground conduits shall be designed for racking as the structure should conform to the shearing of the soil due to earthquake. The magnitude of this distortion (*see* Fig. 5) shall be determined from equation (10):

$$\theta = 0{\cdot}76 \frac{H}{V^2} \qquad \text{......(10)}$$

where

θ = the angle of shearing distortion in radians,

H = the depth of overburden in m (Fig. 5), and

V = average velocity of propagation of the design earthquake wave through the overburden. The values given in Table 4 are recommended for design purposes.

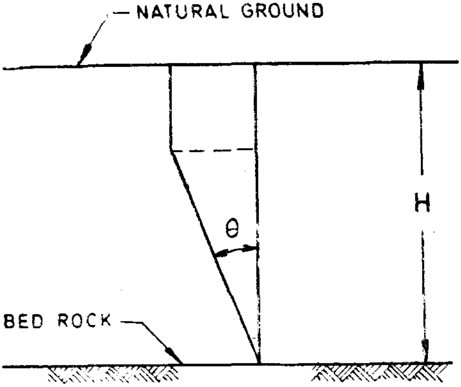


FIG. 5 SHEARING DISTORTION OF GROUND

TABLE 4 VELOCITY OF PROPAGATION OF EARTHQUAKE WAVES

(*Clause* 4.2.2.1)

SL No.	SOIL CLASSIFICATION	VELOCITY m/s
(1)	(2)	(3)
i)	Compact granular soil	300
ii)	Silty sand	150
iii)	Medium clay	60
iv)	Soft clay	30

4.2.2.2 For layer soils θ shall be taken as the greater of the values computed for: (a) the layer encompassing the structure, considered by itself; and (b) the entire overburden thickness, using the average V for all soil layers.

4.2.2.3 *Elastic distortion capacity* — The capacity of a continuous framed structure to absorb racking distortion within the elastic range is the rotation capacity of the most rigid exterior corner joint and shall be computed using equation (11):

$$\alpha = \frac{1}{1\,000}\left\{\frac{L_f}{5\,t_f} + \frac{L_w}{5\,t_w}\right\} \qquad ......(11)$$

where

α = elastic rotation capacity of the joint in radians,

L_f = clear length of floor slab between points of bending restraints,

t_f = structural thickness of floor slab,

L_w = clear length of wall slab between points of bending restraints, and

t_w = structural thickness of wall slab.

4.2.2.4 If the elastic rotation capacity α of the most rigid corner joint exceeds the imposed shearing distortion θ, no further provisions need be made.

4.2.2.5 The imposed shearing distortion in competent soils is generally less than 2×10^{-3}. If the thickness of the exterior floor and wall slabs is kept less than one-fifth their clear span, the shearing distortion requirement is satisfied.

4.3 Earth Pressures

4.3.1 In case the underground conduits, located in seismic zones are designed for 'at-rest' earth pressures, no increase in pressure during or subsequent to an earthquake need be considered.

4.3.2 In case these structures are designed for active earth pressures based on **3.1.2**, these should be checked for 'at-rest' pressures allowing one-third increase in unit stresses (for calculation of earth pressures in earthquake zones, *see* IS : 1893-1984*).

5. PERMISSIBLE STRESSES

5.1 The permissible stresses in concrete and steel reinforcement shall conform to IS : 456-1978†.

5.2 The crack width in concrete face shall normally be restricted to 0·2 mm.

---

*Criteria for earthquake resistant design of structures (*third revision*).

†Code of practice for plain and reinforced concrete (*second revision*).

(*Continued from page* 2)

Members	*Representing*
Chief Engineer	Irrigation Works, Government of Punjab, Chandigarh
Director (Canals) (*Alternate*)	
Shri O. P. Datta	Bhakra Beas Management Board, Chandigarh
Shri N. L. Goel (*Alternate*)	
Shri Narendra Singh	Irrigation Department, Government of Uttar Pradesh, Lucknow
Shri N. N. Singhal (*Alternate*)	
Superintending Engineer (PH)	Central Design Organization (Irrigation Department), Government of Maharashtra, Nasik
Executive Engineer (PH) (*Alternate*)	
Shri G. D. Tyagi	National Hydroelectric Power Corporation Ltd, New Delhi

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	Unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	Unit	Symbol	Definition
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

INDIAN STANDARDS INSTITUTION

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002

Telephones: 331 01 31, 331 13 75 **Telegrams: Manaksanstha**
(Common to all Offices)

Regional Offices:	*Telephone*
*Western : Manakalaya, E9 MIDC, Marol, Andheri (East), BOMBAY 400093	6 32 92 95
†Eastern : 1/14 C.I.T. Scheme VII M, V.I.P. Road, Maniktola, CALCUTTA 700054	36 24 99
Northern : SCO 445-446, Sector 35-C, CHANDIGARH 160036	2 18 43 3 16 41
Southern : C.I.T. Campus, MADRAS 600113	41 24 42 41 25 19 41 29 16
Branch Offices:	
'Pushpak', Nurmohamed Shaikh Marg, Khanpur, AHMADABAD 380001	2 63 48 2 63 49
'F' Block, Unity Bldg, Narasimharaja Square, BANGALORE 560002	22 48 05
Gangotri Complex, 5th Floor, Bhadbhada Road, T. T. Nagar, BHOPAL 462003	6 67 16
Plot No. 82/83, Lewis Road, BHUBANESHWAR 751002	5 36 27
53/5, Ward No. 29, R. G. Barua Road, 5th Byelane, GUWAHATI 781003	—
5-8-56C L. N. Gupta Marg (Nampally Station Road), HYDERABAD 500001	23 10 83
R14 Yudhister Marg, C Scheme, JAIPUR 302005	6 34 71 6 98 32
117/418 B Sarvodaya Nagar, KANPUR 208005	21 68 76 21 82 92
Patliputra Industrial Estate, PATNA 800013	6 23 05
Hantex Bldg (2nd Floor), Rly Station Road, TRIVANDRUM 695001	7 66 37
Inspection Offices (With Sale Point):	
Pushpanjali 205-A West High Court Road ,Bharampeth Extension, NAGPUR 440010	2 51 71
Institution of Engineers (India) Building, 1332 Shivaji Nagar, PUNE 411005	5 24 35

---

*Sales Office in Bombay is at Novelty Chambers, Gran tRoad, Bombay 400007 89 65 28

†Sales Office in Calcutta is at 5 Chowringhee Approach, P. O. Princep Street, Calcutta 700072 27 68 00

Printed at Arcee Press, New Delhi, India