International Standard ISO 2785

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Directives for selection of asbestos-cement pipes subject to external loads with or without internal pressure

Directives en vue du choix des tuyaux en amiante-ciment soumis à des charges extérieures avec ou sans pression intérieure

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ISO 2785-1986 (E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 2785 was prepared by Technical Committee ISO/TC 77, *Products in fibre reinforced cement*.

This second edition cancels and replaces the first edition (ISO 2785-1974), of which it constitutes a revision.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Directives for selection of asbestos-cement pipes subject to external loads with or without internal pressure

1 Scope and field of application

This International Standard gives rules for the selection of buried asbestos-cement pipes that are subject to external loads, with or without internal pressure.

It is based on the principles of calculation of external pressures due to earth and superimposed loads acting on buried pipes, considering the soil and pipe relative stiffnesses and their mechanical interaction.

These factors are applied to calculate the loads on asbestos-cement pressure pipes, and on asbestos-cement sewerage and drainage pipes.

Standard pipe-laying and bedding conditions are considered as detailed in ISO 4482 and the corresponding maximum ring-bending coefficients are fixed.

In applying this International Standard, numerical values for the specified parameters shall be selected. The pipe and soil parameters given have been established empirically so that calculated results are in close agreement with actual measurements. However, since in practice the exact values of these parameters are seldom known, it is the responsibility of the design engineer to select the most suitable values.

Safety factors against crushing of both pressure and non-pressure asbestos-cement pipes are recommended, and the procedure for choosing suitable pipes is described.

The safety factors for pressure pipes are established for combined stresses due to internal and external pressures without reducing the values given in ISO 160.

The steps in choosing suitable pipes are:

a) calculation of the total external load, including earth-load, superimposed vertical loads and water-load (see clause 4);

b) selection of an appropriate bedding angle and the respective maximum ring-bending coefficient (see clause 5);

c) for sewerage or drainage pipes, selection of one of the corresponding classes from ISO 881, so that the necessary safety factor is fulfilled;

d) when pressure pipes are to be chosen, specification of the minimum required ultimate crushing load and bursting pressure. The pipes so chosen shall comply at least with the requirements of ISO 160.

NOTE — The detailed procedure of choosing the necessary pipes is given in clause 7 for sewerage and drainage pipes and in clause 8 for pressure pipes.

2 References

ISO 160, *Asbestos-cement pressure pipes and joints.*

ISO 881, *Asbestos-cement pipes, joints and fittings for sewerage and drainage.*

ISO 4482, *Asbestos-cement pipelines — Guide for laying.*

3 Symbols and abbreviations

A	:	width of uniform surcharge of small extent, in metres
a	:	distance between two wheels on a single axle of a truck, in metres
B	:	width of trench at the crown of the pipe, in metres
B'	:	distance of the spring-line of a pipe from the wall of the trench in which it is buried, in metres
b	:	distance between two axles of a truck, in metres
c	:	diagonal distance between two wheels on two different axles of a truck, in metres
C, C_{90}	:	earth-load coefficient for a trench with vertical walls
C_c	:	load coefficient for superimposed concentrated moving loads
C_d	:	load coefficient for distributed surcharges of small extent
C_n	:	load coefficient for uniform surcharges of large extent
c_v, c_{v1}, c_{v2}, c_{v3}	:	coefficients of vertical deformation of pipe
c_h, c_{h1}, c_{h2}, c_{h3}	:	coefficients of horizontal deformation of pipe

d : nominal or internal diameter of pipe, in millimetres

D : external diameter of pipe, in metres

e : base of natural logarithms

E : modulus of elasticity, in newtons per square millimetre

E_p : modulus of elasticity of pipe, in newtons per square millimetre

E_s : modulus of compression of soil, in newtons per square millimetre

E_t : modulus of elasticity of road construction material, in newtons per square millimetre

E_1, E_2, E_3, E_4 : moduli of compression of soil and backfill in various zones of the trench, in newtons per square millimetre

H, H_1, H_2 : heights of earth cover of a pipe, in metres

H_e : equivalent height of earth cover over a pipe laid under a paved road, in metres

HT : heavy truck

I : modulus of inertia of the wall of pipe per unit length, in cubic millimetres

k : factor of ring-bending moment

k_v, k_h, k_{hp}, k_w : factors of ring-bending moments due to vertical, horizontal, horizontal reaction pressure and water-load respectively

K_1, K_2 : coefficents of lateral earth pressure

L : length of uniform surcharge of small extent, in metres

LT : light truck

m, m_0, m_1, m_m : concentration factors of vertical earth pressure over the pipe

M_e : ultimate ring-bending moment of pipe when tested in accordance with ISO 881 or ISO 160, in kilonewton metres per metre

M_m : maximum ring-bending moment in the wall of a buried pipe, in kilonewton metres per metre

M_1 : the ring-bending moment that will fracture the pipe when combined with an internal hydraulic pressure p_1

M_2 : the ultimate ring-bending moment when no internal pressure affects the pipe

n : concentration factor of lateral earth pressure on the sides of the pipe

p_d : intensity of distributed load, in kilonewtons per square metre

p_j : pipe projection ratio

p_w : hydraulic working pressure, in megapascals

p_1 : the internal hydraulic pressure that will fracture the pipe when combined with a ring-bending moment M_1

p_2 : the internal hydraulic pressure that will burst a pipe which is not exposed to any external load

P_e : crushing load of a pipe when tested in accordance with ISO 881, in kilonewtons per 200 or 300 millimetre lengths of pipe

P_v : maximum wheel load of a truck, in kilonewtons

P_{vc} : vertical pressure on a pipe due to moving concentrated surcharge, in kilonewtons per square metre

P_{vd} : vertical pressure on a pipe due to moving distributed surcharge, in kilonewtons per square metre

q_v, q_{v1}, q_{v2} : vertical earth pressure on the pipe, in kilonewtons per square metre

q_{vt} : total vertical pressure due to earth and moving load on the pipe, in kilonewtons per square metre

q_h, q_{h1}, q_{h2} : horizontal earth pressure on the pipe, in kilonewtons per square metre

q_{hp}, q_{hp1}, q_{hp2} : horizontal soil reaction pressure on the pipe, in kilonewtons per square metre

r : mean radius of pipe, in metres

s : wall thickness of pipe, in metres

S_p : stiffness of pipe, in newtons per square metre

S_{sh} : horizontal stiffness of soil backfill in the zone of the pipe, in newtons per square millimetre

S_{sv} : vertical stiffness of pipe bedding, in newtons per square millimetre

t_1, t_2 : thickness of layers in a road structure, in metres

V_s, V_{s1} : stiffness ratio

V_{ps} : pipe-soil system stiffness

w, w_1, w_2 : unit weight of backfill soil, in kilonewtons per cubic metre

W : crushing load per unit length of pipe when tested in accordance with ISO 160, in kilonewtons per metre

x_1, x_2, x_3 : auxiliary parameter defined in the text

α : half the bedding angle of pipe

β : slope of the wall of the trench

γ : specific weight of water, in kilonewtons per cubic metre

δ : deformation coefficient

ζ : correction factor

η_d : reduction factor of the resistance of the pipe to external load due to the action of internal pressure

η_z : reduction factor of the resistance of the pipe to internal pressure due to the action of external load

μ : safety factor against crushing of a pipe loaded externally without internal pressure

ν_d : safety factor against crushing of a pipe when an internal hydraulic pressure is applied together with a ring-bending moment

ν_z : safety factor against bursting of a pipe when a ring-bending moment is applied together with an internal hydraulic pressure

ϱ : angle of internal friction of backfill soil

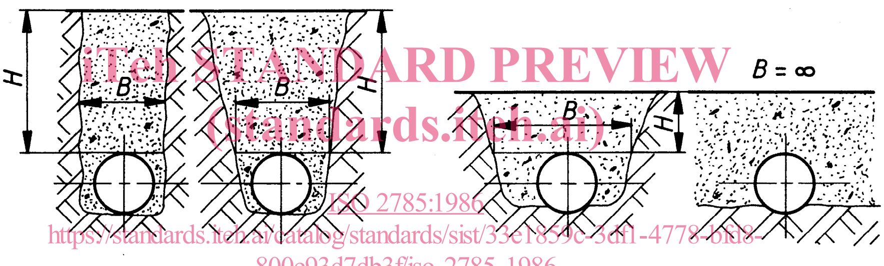
ϱ' : angle of friction between the backfill soil and the wall of the trench

ϕ : impact factor

4 Determination of external loads

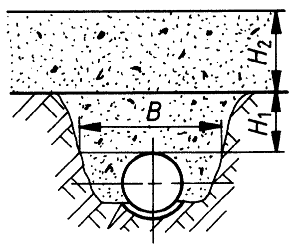
4.1 Calculation of earth pressure

The earth pressure on a pipe shall be calculated by the equations given in 4.1.1 to 4.1.3 appropriate to the following three types of pipe-laying conditions.



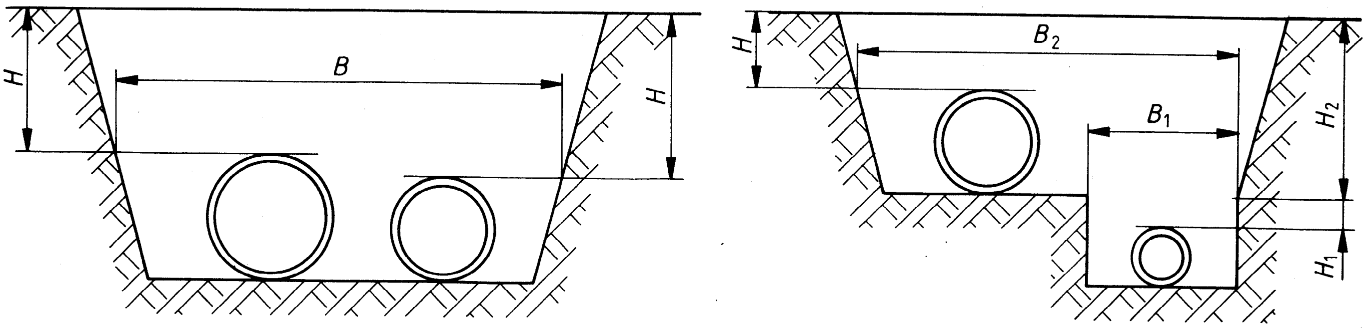
NOTE — Type 1 covers narrow trenches, wide trenches and positive projection embankment conditions.

Figure 1 — Type 1 of pipe-laying



NOTE — Type 2 covers negative projection conditions.

Figure 2 — Type 2 of pipe-laying



a) b)

NOTE — Type 3: two or more pipelines in a single trench.

Figure 3 — Type 3 of pipe-laying

4.1.1 Type 1 of pipe-laying (see figure 1)

4.1.1.1 Vertical earth pressure

The magnitude of the vertical earth pressure in type 1 pipe-laying conditions is given by the equation:

$$q_{v1} = m\,C\,w\,H \qquad \text{... (4.01)}$$

where

q_{v1} is the vertical earth pressure on the pipe, in kilonewtons per square metre;

m is the concentration factor of vertical earth pressure on the pipe calculated in accordance with equation (4.11);

C is the earth-load coefficient for a trench with vertical walls given by equation (4.02) and in annex A (see 4.1.1.1.1);

w is the unit weight of backfill soil, in kilonewtons per cubic metre (see table 1);

H is the height of earth cover above the crown of the pipe, in metres;

$$C = \frac{1 - e^{-2\,(H/B)\,K_1 \tan \varrho'}}{2\,(H/B)\,K_1 \tan \varrho'} \qquad \text{... (4.02)}$$

e is the base of natural logarithms;

B is the width of trench measured at the crown of the pipe, in metres;

K_1 is the coefficient of lateral earth pressure above the level of the crown of the pipe, according to the type of soil in this zone of backfill (see table 2);

ϱ' is the friction angle between the backfill soil and the wall of the trench, depending on the angle of internal friction of the soil (see table 1), and method of backfilling and compacting (see table 3).

Table 1 — Properties of soils for calculating earth-load

Group of soil	Types of soil 1)	Unit weight, w kN/m³	ϱ degrees	Moduli of compression E_s 2) at following proctor standard densities (%) achieved by self-consolidation or compaction N/mm²					
				85	90	92	95	97	100
1	Non-cohesive	20	35	2,5	6	9	16	23	40
2	Slightly cohesive	20	30	1,2	3	4	8	11	20
3	Mixed cohesive	20	25	0,8	2	3	5	8	14
4	Cohesive	20	20	0,6	1,5	2	4	6	10

1) The four types of soil are:

non-cohesive: gravel, sand;
slightly cohesive: binding non-uniform sand or gravel;
mixed cohesive: rock flour, weathered rock soils, clayey sand;
cohesive: clay, silt, loam.

2) The moduli of compression E_s of the soils are measured by applying the CBR (California Bearing Ratio) method using a round plate of an area of 700 cm².

The values of E_s are given by the expression:

$$E_s = \frac{1,5}{\pi R}\left(\frac{F}{y}\right)$$

where

R is the radius of the loading plate;

(F/y) is the slope of the load (F) settlement (y) curve obtained from the tests at the initial point, i.e. at $y = 0$.

Table 2 — Coefficients of lateral earth pressures

Group of soil	K_1	K_2
1	0,5	0,4
2	0,5	0,3
3	0,5	0,2
4	0,5	0,1

NOTE — K_1 and K_2 shall always be considered simultaneously.

Table 3 — Friction angles ϱ' corresponding to several laying conditions

Case No.	Laying conditions	ϱ'
1	Compaction of backfill according to the recommendations of ISO 4482. Unprotected trench walls or protected by withdrawable horizontal sheeting.	$\varrho' = \varrho$
2	Compaction of backfill according to the recommendations of ISO 4482 in the pipe zone. Uncompacted backfill above the pipe zone, or hydraulic backfilling or sheet-pile protection of trench walls.	$\varrho' = 2/3\varrho$
3	Trench wall protected by thick sheet piles or heavy planks, after their withdrawal.	$\varrho' = 0$

NOTE — The value of ϱ' should not exceed that of ϱ.

4.1.1.1.1 The influence of the slope of the trench wall

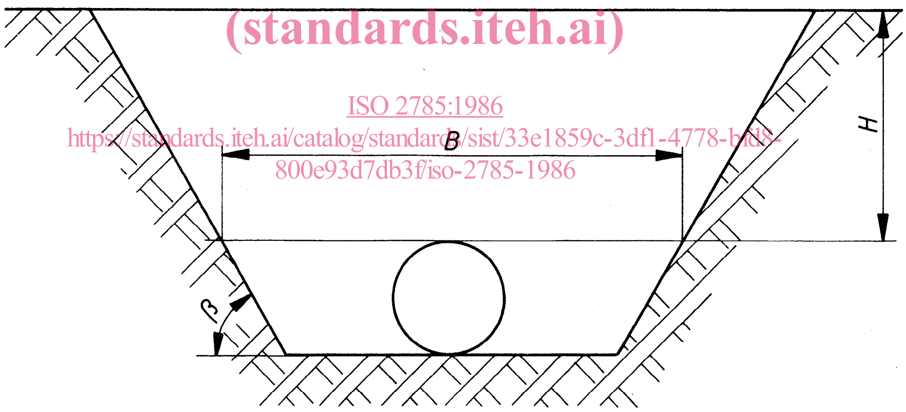


Figure 4 — Trench with sloping walls

At the same height of cover (H) and width (B) the vertical earth-load on a pipe is larger in a sloping-wall trench than in that with vertical walls. The slope of the walls, expressed by angle β, influences the value of the earth-load coefficient C as given by equations (4.03) and (4.04).

For $0 \leqslant \beta < \varrho$: $C = 1$ ... (4.03)

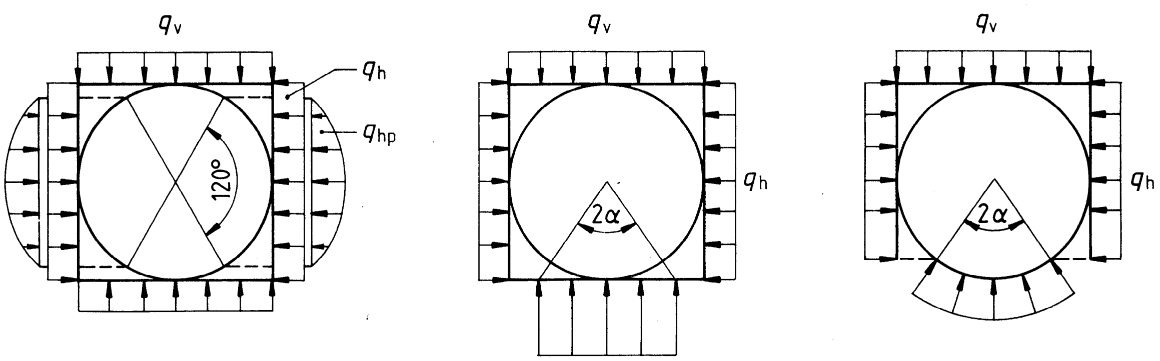
For $\varrho \leqslant \beta \leqslant 90°$: $C = 1 - \frac{\beta}{90}(1 - C_{90})$ ... (4.04)

where

ϱ is the angle of internal friction of the backfill soil;

C_{90} is given by equation (4.02).

4.1.1.1.2 The distribution of the vertical earth pressure and reaction



a) soil bedding, $V_{ps} \leqslant 0,1$ b) soil bedding, $V_{ps} > 0,1$ c) concrete bedding, $V_{ps} > 0,1$

Figure 5 — Distribution of earth pressures and reactions

For the calculation of ring-bending moments and deflections of the pipe, the vertical earth pressure is always assumed to be rectangularly distributed over its crown, as shown in figure 5. (The description of the various beddings is given in clause 5.)

The distribution of the reaction depends on the pipe-soil system stiffness V_{ps} [see 4.1.4 and equation (4.22)]:

Case 1: Pipe on soil-bedding and $V_{ps} \leqslant 0,1$, according to figure 5a), i.e. vertically directed reaction, rectangularly distributed over the full width D of pipe, regardless of the actual bedding angle.

Case 2: Pipe on soil-bedding and $V_{ps} > 0,1$, according to figure 5b), i.e. vertically directed reaction, rectangularly distributed along the bedding angle 2α.

Case 3: In the case of rigid bedding (for example a concrete cradle) and when $V_{ps} > 0,1$, according to figure 5c), i.e. radially directed and evenly distributed reaction along the bedding angle 2α.

4.1.1.2 Lateral earth pressure

The lateral earth pressure on the pipe is composed of the pressure q_h resulting from the vertical earth pressure and the lateral soil reaction q_{hp} due to deformation of the pipe.

The lateral earth pressure q_h is rectangularly distributed over the full height of the pipe in cases 1 and 2 [figures 5a) and b)] and in case 3 [figure 5c)] only above the rigid bedding.

The lateral soil reaction pressure q_{hp} is to be considered only in case 1 and as parabolically distributed along a central angle of 120° [figure 5a)].

The magnitudes of the two lateral earth pressures are given by the following equations:

$$q_{h1} = n K_2 C w H \qquad \ldots (4.05)$$

$$q_{hp1} = \delta (q_{v1} - q_{h1}) \qquad \ldots (4.06)$$

where

q_{h1} is the lateral earth pressure on the pipe, in kilonewtons per square metre;

q_{hp1} is the maximum ordinate of the lateral soil reaction pressure, at the height of the pipe centre, in kilonewtons per square metre;

q_{v1} is given by equation (4.01);

n is the concentration factor of lateral earth pressure calculated in accordance with equation (4.12);

K_2 is the coefficient of lateral earth pressure in the zone of the pipe, given in table 2 for different soils used in this zone;

δ is a deformation coefficient given by equation (4.21);

C, w, H are as defined in equation (4.01).

4.1.2 Type 2 of pipe-laying (see figure 2)

4.1.2.1 Vertical earth pressure

The magnitude of the vertical earth pressure in Type 2 of pipe-laying conditions (negative projection) is given by the equation:

$$q_{v2} = m (C w_1 H_1 + C_n w_2 H_2) \qquad \ldots (4.07)$$

where

q_{v2} is the vertical earth pressure on the pipe, in kilonewtons per square metre;

m, C, w, H are defined in equation (4.01);

indices 1 and 2 refer to the backfill below and above the level of the natural soil respectively (see figure 2);

C_n is given by equation (4.08) and in annex A:

$$C_n = e^{-2 (H_1/B) K_1 \tan \varrho'} \qquad \ldots (4.08)$$

H, B, K_1, ϱ' are defined in equation (4.02).

NOTE — If the trench has sloping walls (see figure 4), the coefficient C_n corresponding to a slope β should be corrected by applying equation (4.03) or (4.04).

4.1.2.2 Lateral earth pressure

The magnitudes of the two lateral pressures — q_h resulting from the vertical earth pressure and q_{hp} resulting from the deformation of the pipe — are given by the following equations:

$$q_{h2} = n K_2 (C w_1 H_1 + C_n w_2 H_2) \qquad \ldots (4.09)$$

$$q_{hp2} = \delta (q_{v2} - q_{h2}) \qquad \ldots (4.10)$$

where all the symbols are as defined for equations (4.05), (4.06), (4.07) and (4.08).

4.1.3 Type 3 of pipe-laying (see figure 3)

Two pipelines may be laid in a single trench either on the same level or on two different levels, as shown in figure 3.

The earth pressures on both pipes in figure 3a) and on the upper pipe in figure 3b) are calculated by equations (4.01), (4.05) and (4.06) considering for each pipe the corresponding value of backfill height H.

The earth pressures on the lower pipe in figure 3b) are calculated by equations (4.07), (4.09) and (4.10).

NOTES

1 The same procedure is applied if more than two pipes are laid in the same trench.

2 The procedure recommended in this clause may be applied only if the two (or more) pipelines are made of asbestos-cement.

3 When earth pressure on these pipes is calculated, the factor ζ should be calculated from equation (4.23a) and not read from figure 8 (see 4.1.4).

4.1.4 Soil-pipe stiffness ratio and earth pressure concentration factors

The concentration factor m of vertical earth pressures is given by the following equation:

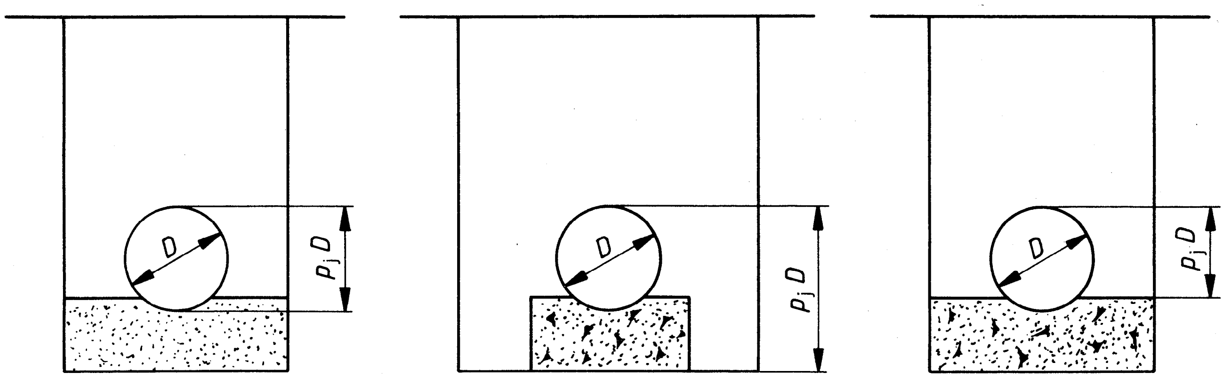
$$m = \frac{(m_1 - 1)}{3} \frac{B}{D} + \frac{4 - m_1}{3} \qquad \text{for } 1 < \frac{B}{D} < 4 \qquad \ldots (4.11a)$$

or

$$m = m_1 = \text{constant} \qquad \text{for } 4 < \frac{B}{D} < \infty \qquad \ldots (4.11b)$$

The concentration factor m shall not exceed the value m_{lim} given by the following expression:

$$m_{lim} = 1 + 4 K_1 \tan \varrho \qquad \ldots (4.11c)$$



a) soil bedding, $p_j = 1$ b) concrete bedding, $p_j > 1$ c) concrete bedding, $p_j < 1$

Figure 6 — Projection ratio p_j and pipe beddings

The concentration factor n of horizontal earth pressures is given by the following equation:

$$n = \frac{4 - m_1}{3} \quad \text{for } 1 < \frac{B}{D} < \infty \qquad \ldots (4.12)$$

In these equations:

B is the width of the trench at the crown of the pipe in metres;

D is the external diameter of the pipe, in metres;

K_1 is taken from table 2;

ϱ is taken from table 1;

m_1 is given by the following equations:

$$m_1 = \frac{m_m V_s + (m_m - 1)\, m_0 V_{s1}/(1 - m_0)}{V_s + (m_m - 1)\, V_{s1}/(1 - m_0)} \qquad \ldots (4.13)$$

$$m_0 = \frac{4 K_2}{3 + K_2} \qquad \ldots (4.14)$$

where K_2 is taken from table 2,

$$V_{s1} = \frac{1 - K_2}{1 - (0{,}25/p_j)} \qquad \ldots (4.15)$$

where K_2 is taken from table 2 and p_j is defined in figure 6,

$V_s = S_p / |C_v| S_{sv}$ when lateral reaction pressure q_{hp} is considered ... (4.16a)

$V_s = S_p / |C_{v1}| S_{sv}$ when lateral reaction pressure q_{hp} is disregarded ... (4.16b)

$$m_m = 1 + \frac{H}{D} \cdot \frac{1}{\dfrac{3{,}5}{p_j} + 2{,}2 \dfrac{E_1}{E_4} \dfrac{1}{(p_j - 0{,}25)} + \dfrac{H}{D}\left[\dfrac{0{,}62}{p_j} + 1{,}6 \dfrac{E_1}{E_4} \dfrac{1}{(p_j - 0{,}25)}\right]} \qquad \ldots (4.17)$$

In these three equations the various symbols are:

S_p is the stiffness of the pipe:

$$S_p = \frac{E_p}{12} \left(\frac{s}{r}\right)^3 \qquad \ldots (4.18)$$

s is the wall thickness of the pipe, in metres;

r is the mean radius of the pipe, in metres:

$$r = \frac{D - s}{2}$$

D is the external diameter of the pipe in metres;

E_p is the modulus of elasticity of the pipe, in newtons per square millimetre; (for asbestos-cement pipes, assume E_p = 25 000 N/mm²);

H is the height of backfill over the crown of the pipe, in metres;

S_{sv} is the vertical stiffness of the bedding;

$$S_{sv} = E_2 / p_j \qquad \ldots (4.19)$$

p_j is the projection ratio from figure 6;

$|C_v|$ is the absolute value of the factor of deformation of the vertical diameter (ΔD_v):

$$C_v = C_{v1} + C_{v3}\,\delta \qquad \ldots (4.20)$$

C_{v1} is the factor of deformation ΔD_v due to q_v (see table 4);

C_{v3} is the factor of deformation ΔD_v due to q_{hp} (see table 4);

$$\delta = C_{h1}/(V_{ps} - C_{h3}) \quad \ldots (4.21)$$

C_{h1} is the factor of deformation ΔD_h due to q_v (see table 4);

C_{h3} is the factor of deformation ΔD_h due to q_{hp} (see table 4);

V_{ps} is the pipe-soil system stiffness:

$$V_{ps} = S_p/S_{sh} \quad \ldots (4.22)$$

S_{sh} is the horizontal stiffness of bedding:

$$S_{sh} = 0{,}6\,\zeta\,E_2 \quad \ldots (4.23)$$

ζ is the correction factor calculated by the following expression or read from figure 8:

$$\zeta = \frac{1{,}662 + 0{,}639\left(\frac{B}{D} - 1\right)}{\left(\frac{B}{D} - 1\right) + \left[1{,}662 - 0{,}361\left(\frac{B}{D} - 1\right)\right]\frac{E_2}{E_3}} \quad \ldots (4.23a)$$

E_1, E_2, E_3, E_4 are the moduli of compression of the soil in different zones of backfill and trench (see figure 7), in newtons per square millimetre.

NOTE — Values of E_1 and E_2 can be taken from table 1 according to the compaction of the backfill. The values of E_3 and E_4 should be selected in accordance with the actual soil conditions. If E_3 and E_4 cannot be established, assume for usual soils $E_3 = E_2$ and $E_4 = E_s$ as given in table 1 at 100 % proctor density.

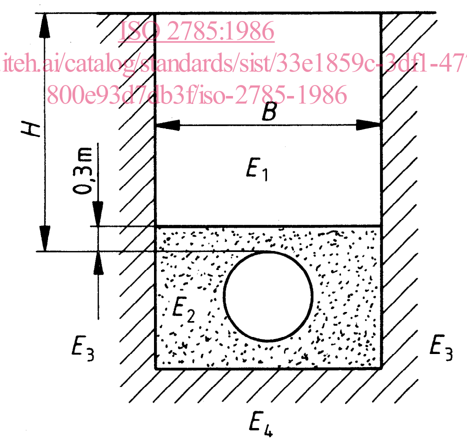


Figure 7 — Moduli of soil compaction in different zones of the trench