International Standard 7336

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Asbestos-cement pipelines — Guidelines for hydraulic calculation

Canalisations en amiante-ciment — Principes directeurs pour le calcul hydraulique

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Foreword

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It has been approved by the member bodies of the following countries :

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Asbestos-cement pipelines — Guidelines for hydraulic calculation

1 Scope and field of application

This International Standard specifies the most common formulae and the corresponding head-loss coefficients to be applied for the calculation of the mean flow velocities in asbestos-cement pipelines, carrying potable water or sewage in full or partly full cross-section of pipeline, excluding piping systems in buildings.

The discharge of a pipeline is the product of the area of the fluid in the wet cross-section multiplied by the mean flow velocity.

2 Recommended formula

2.1 General

The following rational formula of Colebrook-White, based on the Prandtl-Karman theory of turbulence, is recommended for the calculation of flow velocity:

$$v = -2\sqrt{2gdJ}\,\log\left[(k/3{,}71d) + (2{,}51\nu/d\sqrt{2gdJ})\right] \ldots (1)$$

where

v is the flow velocity, in metres per second;

g is the constant of gravitation, in metres per second squared;

d is the (internal) nominal diameter of the pipe, in metres;

J is the hydraulic gradient, in metres per metre;

ν is the kinematic viscosity of the fluid, in square metres per second;

k is the linear measure of the effective roughness of the internal surface of the pipe, in metres.

NOTE — Formula (1) may be applied by using suitable tables, charts or special slide-rules.

2.2 Values of k and ν recommended for pipelines carrying potable[1] water

2.2.1 Linear measure of effective roughness k

2.2.1.1 The values of k recommended in this clause correspond to old as well as new asbestos-cement pipelines[1, 2]. The same values of k shall be applied in equation (1) for internally coated or uncoated pipes.

2.2.1.2 For discharge mains, in which the pipeline includes, except for joints, a relatively small number of fittings:

$$k = 25 \times 10^{-6}\ \text{m}$$

2.2.1.3 For distribution pipelines, which in addition to joints include fittings (for changing direction and diameter, for house-connections, valves, vents, etc.), in order to provide for all local head-losses:

$$k = 100 \times 10^{-6}\ \text{m}$$

2.2.2 Kinematic viscosity ν

The values of the kinematic viscosity ν to be applied in equation (1) depend on the temperature of the potable water. They are given in table 1.

Table 1 — Kinematic viscosity of water[3]

Temperature °C	$10^6\ \nu$ m^2/s	Temperature °C	$10^6\ \nu$ m^2/s
5	1,521	45	0,604
10	1,310	50	0,556
15	1,148	55	0,514
20	1,007	60	0,478
25	0,897	65	0,446
30	0,804	70	0,417
35	0,725	75	0,392
40	0,661	80	0,366

NOTE — For temperatures between those given above, the corresponding values of ν may be calculated by linear interpolation.

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[1] The same values are suitable for pipelines carrying any other type of clear water.

2.3 Values of k and v recommended for pipelines carrying sewage

2.3.1 Linear measure of effective roughness k

2.3.1.1 The values of k recommended in this clause correspond to asbestos-cement sewers slimed to about half-depth. The same values of k in equation (1) shall be applied for internally coated or uncoated pipes.

2.3.1.2 For sewers with no inlets and with no manholes:

$$k = 250 \times 10^{-6} \text{ m}$$

2.3.1.3 For sewers with inlets and with manholes:

$$k = 400 \times 10^{-6} \text{ m}$$

2.3.2 Kinematic viscosity v

The kinematic viscosity of sewage depends upon its temperature as well as the type and concentration of the impurities carried in it. At equal temperature the kinematic viscosity of sewage is usually higher than that of clear water.

For practical calculations of sewers, the value of the kinematic viscosity to be applied in equation (1) is:

$$v = 1{,}31 \times 10^{-6} \text{ m}^2/\text{s} \quad (T = 12 \text{ °C})$$

3 Other formulae

3.1 General

A number of empirical formulae of the general form

$$v = \mu d^x J^y \qquad \ldots(2)$$

are customary in the hydraulic calculation of full flowing pipes. These may be applied, provided that the corresponding friction coefficients μ suitable for asbestos-cement pipes are evaluated for each formula from equations (3) and (4):

$$\mu = (2g)^y \lambda^{-y} d^{(y-x)} v^{(1-2y)} \qquad \ldots(3)$$

$$\lambda^{-0{,}5} = -2 \log \left[(k/3{,}71d) + (2{,}51 v / d\sqrt{2gdJ}) \right] \qquad \ldots(4)$$

in which all the symbols have the same meaning as in equation (1). The most commonly used exponential formulae and the friction coefficients corresponding to the roughness indicated in 2.2 and 2.3 for the Colebrook-White equation are given in 3.2 and 3.3.

3.2 Empirical formulae for pipelines carrying potable water

3.2.1 General

The friction coefficients corresponding to the three formulae given in this sub-clause were calculated from equations (3) and (4) in which it was assumed that:

g = 9,81 m/s^2

v = 1,148 × 10^{-6} m^2/s (T = 15 °C)

k as according to 2.2.1.2 and 2.2.1.3

3.2.2 Formula of Hazen-Williams

$$v = 0{,}355\, C d^{0{,}63} J^{0{,}54} \qquad \ldots(5)$$

where

v is the flow velocity, in metres per seond;

d is the nominal diameter, in metres;

J is the hydraulic gradient in metres per metre;

C is the friction coefficient as given in table 2.

Table 2 — Hazen-Williams' coefficient C

Nominal pipe diameters mm	For discharge mains	For distribution pipelines
50 to 100	142	129
125 to 250	145	133
300 to 450	148	136
500 and over	150	140

3.2.3 Formula of Scimemi

$$v = k_{sc} d^{0{,}68} J^{0{,}56} \qquad \ldots(6)$$

where v, d, J are the same as defined in 3.2.2, and k_{sc} is given in table 3.

Table 3 — Scimemi's coefficient k_{sc}

Nominal pipe diameters mm	For discharge mains	For distribution pipelines
50 to 700	61,5	56,0
800 to 1 400	60,0	56,0
1 500 to 2 500	59,0	55,0

NOTE — It is also customary to replace in the formula of Scimemi the diameter d by the hydraulic radius $R (= d/4)$. If this is done, the coefficients of table 3 must be multiplied by 2,567.

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* National standards may specify higher values of k.

3.2.4 Formula of Strickler

$$v = k_{st} d^{2/3} J^{1/2} \qquad \ldots(7)$$

where v, d, J are as defined in 3.2.2 and k_{st} is given in table 4.

Table 4 — Strickler's coefficient k_{st}

Nominal pipe diameters mm	For discharge mains	For distribution pipelines
50 to 300	46,7	43,4
350 to 700	43,6	40,9
800 to 1 200	41,4	39,1
1 300 to 2 500	39,1	37,1

NOTE — Strickler's formula is sometimes given in terms of the hydraulic radius R ($= d/4$). In such a case, the coefficients of table 4 must be multiplied by 2,520.

3.3 Empirical formulae for pipelines carrying sewage

3.3.1 General

The friction coefficients corresponding to the three formulae given in this clause were calculated from equations (3) and (4) in which the diameter d was replaced by the hydraulic radius R ($d = 4R$) for full flowing sewers and it was assumed that:

g = 9,81 m/s^2

v = 1,31 × 10^{-6} m^2/s (see 2.2.2)

k as according to 2.3.1.2 and 2.3.1.3

The indicated friction coefficients correspond to flow velocities varying from 0,7 to 3,0 m/s.

3.3.2 Formula of Manning

$$v = R^{2/3} J^{1/2} / n \qquad \ldots(8)$$

where

v is the flow velocity, in metres per second;

R is the hydraulic radius of the wetted cross-section, in metres;

J is the hydraulic gradient, in metres per metre, equal to the slope of the pipeline in part-full flow;

n is the friction coefficient given in table 5.

Table 5 — Manning's coefficient n

Nominal pipe diameters mm	Pipelines with no inlets and no manholes	Pipelines with inlets and/or manholes
100 to 300	0,010	0,011
350 to 600	0,011	0,011
700 to 1 600	0,011	0,012
1 700 to 2 500	0,012	0,012

3.3.3 Formula of Manning-Strickler

Manning's formula when written in the following manner:

$$v = k_{ms} R^{2/3} J^{1/2} \qquad \ldots(8a)$$

is referred to as the formula of Manning-Strickler. The coefficient k_{ms} is equal to the reciprocal of Manning's coefficient n and is given in table 6.

Table 6 — Manning-Strickler's coefficient k_{ms}

Nominal pipe diameters mm	Pipelines with no inlets and no manholes	Pipelines with inlets and/or manholes
100 to 300	105	100
350 to 600	100	95
700 to 1 600	95	90
1 700 to 2 500	90	85

NOTE — The values of k_{ms} differ slightly from the reciprocals of n in table 5 due to rounding up of their precise values.

3.3.4 Formula of Chézy-Bazin

Chézy's formula for uniform flow in channels is given by the expression

$$v = C R^{1/2} J^{1/2} \qquad \ldots(9a)$$

in which R and J are as defined in 3.3.2, whereas C is the coefficient of flow defined by Bazin as follows:

$$C = 87/(1 + mR^{-1/2}) \qquad \ldots(9b)$$

where m is Bazin's friction coefficient given in table 7. Hence, Chézy-Bazin's formula

$$v = 87 R^{1/2} J^{1/2} / (1 + mR^{-1/2}) \qquad \ldots(9)$$

Table 7 — Bazin's coefficient m

Nominal pipe diameters mm	Pipelines with no inlets and no manholes		Pipelines with inlets and/or manholes	
	v = 0,75 m/s	v = 3,00 m/s	v = 0,75 m/s	v = 3,00 m/s
100 to 1 000	0,110	0,100	0,140	0,130
1 100 to 2 000	0,105	0,095	0,140	0,130
2 100 to 2 500	0,090	0,075	0,120	0,110

4 Flow in partly filled pipelines

4.1 General

The recommended formula (1) may be used for partly filled pipelines provided the results of the calculations are corrected in accordance with 4.2 and 4.3.

Formulae (8), (8a) and (9) may be used for calculating the flow in pipelines partly or completely filled without any corrections. The value of the hydraulic radius R will depend from the height to which the cross-section is filled with the flowing fluid ($R = A/p$ = area of the fluid in the cross-section divided by the wetted perimeter).

The following expressions permit the calculation of the different geometric and hydraulic characteristics of the flow in partly filled pipelines on the basis of those corresponding to the flow in full cross-sections and vice versa.

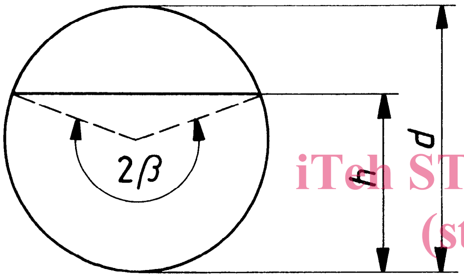

Figure — Partly filled cross-section of pipe

Let the degree of filling be expressed by

$$\eta = h/d \qquad \ldots(10)$$

Then the geometrical and hydraulic characteristics of the flow in a partly filled cross-section of a circular pipe are given in terms of the degree of filling η by the equations in 4.2 and 4.3.

Values of η to 0,85 apply to partially filled pipes; above this, values shall be considered flowing full.

4.2 Geometrical characteristics

Wetted area ratio:

$$\alpha = A_p/A_f = (\beta/\pi) - [(\sin 2\beta)/2\pi] \qquad \ldots(11)$$

Hydraulic radius ratio:

$$\varrho = R_p/R_f = 1 - [(\sin 2\beta)/2\beta] \qquad \ldots(12)$$

where

A is the area of the wetted cross-section of pipe;

p, f are the area indices for partly filled and full flowing pipe respectively;

R is the hydraulic radius of the wetted cross-section;

β is arc cos $(1-2\eta)$, in radians.

4.3 Hydraulic characteristics

Flow velocity ratio:

$$w = v_p/v_f = [(2\beta - \sin 2\beta)/2(\beta + \gamma \sin \beta)]^{5/8} \qquad \ldots(13)$$

Discharge ratio:

$$q = Q_p/Q_f = (2\beta - \sin 2\beta)^{13/8}/9{,}69(\beta + \gamma \sin\beta)^{5/8} \qquad \ldots(14)$$

where

$$\left.\begin{aligned} \gamma &= 0 \text{ for } \eta \leqslant 0{,}5 \\ \gamma &= [0{,}05\,(\eta - 0{,}5) + (\eta - 0{,}5)^3]/0{,}15 \end{aligned}\right\} \qquad \ldots(15)$$

NOTE — The coefficient γ given by Thormann's empirical equation (15) is a correction factor considering the friction between the flowing fluid and the air over its surface in a partly full section of a circular pipe [5].

The numerical values of the ratios given by equations (11) to (14) corresponding to several values of $\eta = h/d$ are listed in table 8.

Table 8 — Proportional area, hydraulic radius, flow velocity and discharge in part-full circular sections

$\eta = h/d$	$\alpha = A_p/A_f$	$\varrho = R_p/R_f$	$w = v_p/v_f$	$q = Q_p/Q_f$
0,10	0,052	0,254	0,425	0,022
0,15	0,094	0,372	0,539	0,051
0,20	0,142	0,482	0,634	0,090
0,25	0,196	0,587	0,716	0,140
0,30	0,252	0,684	0,789	0,199
0,35	0,312	0,774	0,852	0,266
0,40	0,374	0,857	0,908	0,339
0,45	0,436	0,932	0,957	0,418
0,50	0,500	1,000	1,000	0,500
0,55	0,564	1,060	1,030	0,581
0,60	0,626	1,111	1,053	0,660
0,65	0,688	1,153	1,068	0,735
0,70	0,748	1,185	1,075	0,804
0,75	0,804	1,207	1,073	0,864
0,80	0,858	1,217	1,064	0,913
0,85	0,906	1,213	1,050	0,951

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