# INTERNATIONAL STANDARD

# ISO
# 10803

# Design method for ductile iron pipes

*Méthode de calcul des tuyaux en fonte ductile*

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# Contents

Page

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# 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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 10803 was prepared by Technical Committee ISO/TC 5, *Ferrous metal pipes and metallic fittings*, Subcommittee SC 2, *Cast iron pipes, fittings and their joints*.

This second edition cancels and replaces the first edition (ISO 10803:1999), which has been technically revised.

# Design method for ductile iron pipes

## 1  Scope

This International Standard specifies the design of ductile iron pipes used for conveying water, sewerage and other fluids

—  with or without internal pressure, and

—  with or without earth and traffic loading.

## 2  Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2531, *Ductile iron pipes, fittings, accessories and their joints for water applications*

ISO 7186, *Ductile iron products for sewerage applications*

ISO 7268, *Pipe components — Definition of nominal pressure*

ISO 10802, *Ductile iron pipelines — Hydrostatic testing after installation*

## 3  Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7268 and the following apply.

**3.1**
**allowable operating pressure**
**PFA**
maximum internal pressure, excluding surge, which a component can safely withstand in permanent service

**3.2**
**allowable maximum operating pressure**
**PMA**
maximum internal pressure, including surge, which a component can safely withstand in service

**3.3**
**allowable site test pressure**
**PEA**
maximum hydrostatic pressure that a newly installed component can withstand for a relatively short duration, when either fixed above ground level or laid and backfilled underground, in order to ensure the integrity and leaktightness of the pipeline

NOTE    This test pressure is different from the system test pressure, which is related to the design pressure of the pipeline.

**3.4**
**embedment**
arrangement and type(s) of material around a buried pipeline, which contribute to its structural performance

See Figure D.1.

**3.5**
**bedding**
lower part of the embedment, composed of the lower bedding (if necessary) and the upper bedding

See Figure D.1.

**3.6**
**bedding reaction angle**
conventional angle used in the calculation model to account for the actual soil pressure distribution at pipe invert

**3.7**
**compaction**
deliberate densification of soil during the installation process

**3.8**
**standard Proctor density**
degree of soil compaction, as defined in AASHTO T99 using a 2,5 kg rammer and a 305 mm drop

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# 4   Design procedure

**4.1**    The pipe wall thickness shall provide adequate strength against the internal pressure of the fluid and against the effects of external loads due to backfill and surcharge, i.e. traffic loadings.

Ductile iron pipes in compliance with ISO 2531 are classified according to their allowable operating pressure for use in water applications. Ductile iron pipes in compliance with ISO 7186 are for sewerage applications either under pressure or under gravity. Using the equations given in Clauses 5 and 6, the design of buried pipes is performed by determining

a)   the minimum pipe wall thickness for the allowable operating pressure (PFA), and

b)   the depths of cover as given in Annexes B and C.

**4.2**    The design procedure for the pipes is the following:

a)   from the allowable operating pressure of the pipeline, select the class of pipe as appropriate from ISO 2531 or ISO 7186 [the minimum pipe wall thickness of these pipes has been calculated from Equation (1)];

b)   calculate the allowable depth of cover in accordance with Clause 6;

c)   if the allowable depth of cover is not adequate, select higher a pressure class of pipe and repeat steps 4.2 a) and b) until the allowable depth of cover is acceptable.

NOTE 1    In practice, in most cases, the pressure class and the allowable depth of cover for the pipes can be selected from the appropriate tables in Annexes B or C without carrying out the detailed calculations as explained above.

NOTE 2    When installed and operated under the conditions for which they are designed, ductile iron pipes, fittings, accessories and their joints maintain all their functional characteristics over their operating life, due to constant material properties, to the stability of their cross-section and to their design with high safety factors.

NOTE 3    In certain countries, national standards or regulations can specify other design procedures.

## 5 Design for internal pressure

### 5.1 Design equation for wall thickness

The minimum wall thickness of pipes, $e_{min}$, shall be not less than 3 mm (as specified in ISO 2531) or 2,4 mm (ISO 7186) and shall be determined using Equation (1):

$$e_{min} = \frac{PFA \times SF \times DE}{20 R_m + (PFA \times SF)}$$ (1)

where

$e_{min}$     is the minimum pipe wall thickness to resist hoop stress due to internal pressure, in millimetres;

PFA     is the allowable operating pressure, in bar[1]) (see 5.2);

SF     is the design safety factor (see 5.2);

DE     is the nominal pipe external diameter, in millimetres (see Annex A);

$R_m$     is the minimum ultimate tensile strength of the ductile iron, in megapascals ($R_m$ = 420 MPa in ISO 2531 and ISO 7186).

Nominal wall thickness, $e_{nom}$, of the pipe is calculated as given by Equation (2):

$$e_{nom} = e_{min} + (1,3 + 0,001 DN)$$ (2)

where DN is the nominal diameter of pipe as defined in ISO 2531 and ISO 7186, in millimetres.

Nominal pipe wall thicknesses for various classes in accordance with ISO 2531 are given in Table A.1 and nominal pipe wall thicknesses for pressure and gravity pipe classes in accordance with ISO 7186 are given in Table A.2.

### 5.2 Design safety factors

The minimum pipe wall thickness, $e_{min}$, shall be calculated with a design safety factor of 2,5 for the maximum allowable operating pressure (i.e. PMA as indicated in ISO 2531 and ISO 7186) and a design safety factor of 3 for the allowable operating pressure (i.e. PFA as indicated in ISO 2531 and ISO 7186).

NOTE      This allows field testing of installed ductile iron pipelines in compliance with ISO 10802 by application of test pressures up to the allowable test pressures given in ISO 2531 and ISO 7186.

## 6 Design for external loads

### 6.1 Design equation

$$\Delta = 100 \frac{K_x q}{8S + 0,061 E'}$$ (3)

or

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1)     100 kPa = 1 bar = 0,1 MPa; 1 MPa = 1 N/mm$^2$.

$$q = \frac{\Delta\left(8S + 0{,}061E'\right)}{K_{\text{x}} + 100} \qquad (3)$$

where

$\Delta$    is the pipe diametral deflection, in percent of external diameter, $D$;

$K_{\text{x}}$    is the deflection coefficient depending on bedding reaction angle;

$q$    is the vertical pressure at pipe crown due to all external loads, in megapascals;

$S$    is the pipe diametral stiffness, in megapascals,

$$S = \frac{EI}{(D)^3}$$

where

$E$    is the modulus of elasticity of the pipe wall material, in megapascals (170 000 MPa for ductile iron);

$I$    $= \left(\dfrac{e_{\text{stiff}}{}^3}{12}\right)$ is the second moment of area of the pipe wall per unit length, in millimetres to the third power;

$D$    is the mean diameter of pipe $\left(\text{DE} - e_{\text{stiff}}\right)$, in millimetres;

DE    is the nominal pipe external diameter as specified in ISO 2531 and ISO 7186, in millimetres;

$e_{\text{stiff}}$    is the average of the minimum pipe wall thickness of the pipe and nominal wall thickness of pipe, in millimetres;

$E'$    is the modulus of soil reaction, in megapascals.

Pipe material stiffness values, $S$, may be taken from the relevant annexes of ISO 2531 and ISO 7186.

The values of $E'$ and $K_{\text{x}}$ are given in Table 1 for each trench type and soil group.

NOTE      The design equation is based on the Spangler model (see Figure 1), where the vertical pressure, $q$, is acting downward and:

—   is uniformly distributed at the pipe crown over a diameter;

—   is in equilibrium with a pressure, acting upward at the pipe invert, uniformly distributed over the bedding reaction angle $2\alpha$;

—   causes a pipe deflection, which gives rise to a horizontal reaction pressure at pipe sides, parabolically distributed over an angle of 100°.
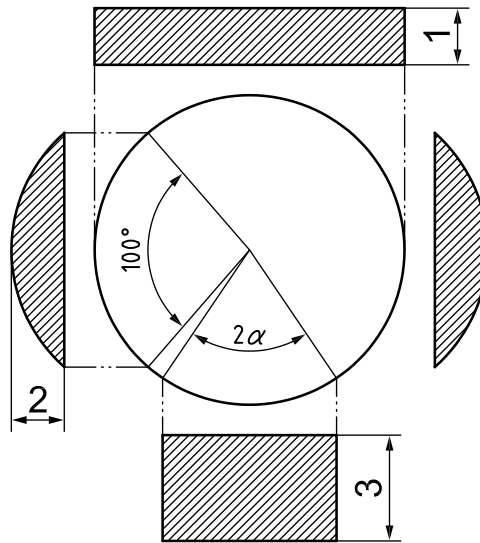
**Key**

1  vertical pressure, $q$
2  lateral reaction pressure = 0,01 $\Delta E'$
3  vertical reaction pressure = $q/\sin\alpha$

**Figure 1 — Spangler model**

## 6.2  Loads applied to the pipe and calculation for the allowable depth of cover

### 6.2.1  General

The total vertical pressure, $q$, acting at pipe crown is the sum of the following components:

$$q = q_1 + q_2 \tag{4}$$

where

$q_1$  is the pressure from earth loads;

$q_2$  is the pressure from traffic loads;

NOTE  The pressure from traffic loads, $q_2$, is greater than that from normal static loads applied to the ground surface; however, any abnormal surface loading can require special consideration.

The value of $q$ obtained from Equation (4) is basically a function of $H$ (allowable depth of cover), i.e.

$$q = f'(H) \tag{5}$$

Equating this to Equation (3) (see 6.1):

$$f'(H) = \frac{\Delta \times (8S + 0{,}061E')}{(K_x) \times (100)} \tag{6}$$

The value of allowable depth of cover, $H$, may be determined after calculating the value of $q$ as given in 6.2.2 and 6.2.3 and other parameters as defined.

### 6.2.2 Pressure from earth loads

Equation (7) shall be used to calculate $q_1$ from the weight of the earth prism immediately above the pipe:

$$q_1 = 0,001 \gamma H \tag{7}$$

where

$q_1$    is the pressure at pipe crown, in megapascals;

$\gamma$    is the unit weight of the backfill, in kilonewtons per cubic metre;

$H$    is the height of cover (distance from pipe crown to ground surface), in metres.

In the absence of other data, the unit weight of the soil is taken as being equal to 20 kN/m$^3$ in order to cover the vast majority of cases. If a preliminary geotechnical survey determines that the actual unit weight of the backfill is less than 20 kN/m$^3$, the actual value may be used for determining $q_1$.

If, however, it appears that the actual value is more than 20 kN/m$^3$, the actual value should be used.

### 6.2.3 Pressure from traffic loads

The value of $q_2$ shall be calculated using Equation (8), based on wheel load taken from national and/or local applicable standards and regulations.

$$q_2 = 0,04 \; \frac{\beta}{H} \; (1 - 2 \times 10^{-4} \; \mathrm{DN}) \tag{8}$$

where

$q_2$    is the pressure at pipe crown, in megapascals;

$\beta$    is a traffic load factor; the following are the given values:

— 1,5: this is the general case, except access roads;

— 0,75: roads where truck traffic is prohibited;

— 0,50: all other cases;

$H$    is the height of cover, in metres;

DN    is the nominal size.

NOTE 1    Equation (8) is not applicable when $H < 0,3$ m.

In the case where a national standard exists for the traffic loadings, the value of $\beta$ may be given as follows:

$$\beta = \frac{P}{100} \tag{9}$$

where $P$ is the wheel load, in kilonewtons, for a particular type of road according to the respective national standard.

All pipelines shall be designed for at least $\beta = 0,5$ and pipelines laid adjacent to roads shall be designed to withstand the full road loading.

NOTE 2    For pipelines under railroads or airports or subjected to heavy construction traffic, special requirements can apply according to the respective national standard and regulations.

## 6.3  Soil and pipe interaction

The bedding reaction angle depends on the installation conditions (bedding, sidefill compaction) and on the pipe diametral deflection (especially for large sizes).

The modulus of soil reaction, $E'$, of the sidefills depends on the type of soil used for the embedment and upon the trench type (see Annex D). In the absence of applicable standards or other data, the values of $E'$ indicated in Table 1 may be used at the design stage for five typical trench types and for six soil groups (see Annex E for the classification of soils).

These data are valid for pipes laid under embankments as well as in trenches.

A preliminary geotechnical survey should be carried out to facilitate identification of the soil and proper selection of $E'$ values.

$E'$ values given in Table 1 apply when trench shoring is left in place or removed in such a way as to allow compaction of sidefill against the native trench wall; otherwise, reduced $E'$ values should be applied.

In very poor ground conditions, it may be necessary to use soil stabilization matting to prevent migration of embedment with resultant loss of soil reaction modulus, $E'$.

**Table 1 — Modulus of soil reaction, $E'$**

| Trench type | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Placement of embedment | Dumped | Very light compaction | Light compaction | Medium compaction | High compaction |
| Standard Proctor density of sidefill, % | a | >75 | >80 | >85 | >90 |
| Bedding reaction angle ($2\alpha$) | 30° | 45° | 60° | 90° | 150° |
| $K_x$ | 0,108 | 0,105 | 0,102 | 0,096 | 0,085 |
| $E'$ (MPa) | | | | | |
| Soil group A | 4 | 4 | 5 | 7 | 10 |
| Soil group B | 2,5 | 2,5 | 3,5 | 5 | 7 |
| Soil group C | 1 | 1,5 | 2 | 3 | 5 |
| Soil group D | 0,5 | 1 | 1,5 | 2,5 | 3,5 |
| Soil group E | b | b | b | b | b |
| Soil group F | b | b | b | b | b |

a    Depending on the type of soil and its moisture content, a standard Proctor density of 70 % to 80 % should normally be achieved by simply dumping the soil in the trench.

b    Use an $E'$ value of 0 unless it can be ensured that a higher value is achieved consistently.

## 6.4  Allowable pipe diametral deflection

The allowable pipe diametral deflection, $\Delta_{max}$, may be taken from relevant annexes of ISO 2531 and ISO 7186. These values provide sufficient safety against yield bending strength of the pipe wall, lining deformation, joint leak tightness and hydraulic capacity of the pipe. However, national standards and/or the manufacturer's catalogues may introduce more stringent limitations, for instance 3 % for cement mortar linings.

For each DN, the allowable pipe diametral deflection, $\Delta_{max}$, is the lowest of the following:

a) $\Delta_1$, which provides a safety factor of 2 against irreversible damage of the lining:

— for cement mortar linings (DN $\geq$ DN 300):

$$\Delta_1 = 3 + \frac{DN - 300}{500}, \text{ with a maximum of 4 \%;}$$

— for flexible linings:

$$\Delta_1 = 5 \text{ \%;}$$

b) $\Delta_2$, which provides a safety factor of 1,5 against the yield bending strength of the ductile iron pipe wall:

$$\Delta_2 = 100 \times \frac{R_f \times (DE - e_{nom})}{SF \times E \times e_{nom} \times DF} \tag{10}$$

where

$R_f$ is the yield bending strength of the pipe wall material ($R_f$ = 500 MPa for ductile iron);

DE is the pipe external diameter as defined in ISO 2531 and ISO 7186, in millimetres;

$e_{nom}$ is the nominal pipe wall thickness, in millimetres;

SF is the safety factor (= 1,5);

$E$ is the modulus of elasticity of the pipe wall material ($E$ = 170 000 MPa for ductile iron);

DF is the deformation factor which depends mainly on the pipe diametral stiffness (for ductile iron pipes, DF = 3,5).

# Annex A
(informative)

# Dimensions of preferred and other class pipes

## A.1 Dimensions of preferred and other class pipes for pipes conforming to ISO 2531

Dimensions of preferred and other class pipes with flexible joints classified by the allowable operating pressure, in bar (PFA), prefixed by the letter C, i.e. C20, C25, C30, C40, C64 and C100 are given in this annex. These are derived from Equation (1) and the data of Clause 5, and are in compliance with ISO 2531.

**Table A.1 — Dimensions of preferred and other class pipes for pipes conforming to ISO 2531**

| DN | DE[a] mm | Nominal iron wall thickness, $e_{nom}$ mm[b] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | C20 | C25 | C30 | C40 | C50 | C64 | C100 |
| 40 | 56 | | | | 4,4[c] | 4,4 | 4,4 | 4,4 |
| 50 | 66 | | | | 4,4[c] | 4,4 | 4,4 | 4,4 |
| 60 | 77 | | | | 4,4[c] | 4,4 | 4,4 | 4,4 |
| 65 | 82 | | | | 4,4[c] | 4,4 | 4,4 | 4,4 |
| 80 | 98 | | | | 4,4[c] | 4,4 | 4,4 | 4,8 |
| 100 | 118 | | | | 4,4[c] | 4,4 | 4,4 | 5,5 |
| 125 | 144 | | | | 4,5[c] | 4,5 | 4,8 | 6,5 |
| 150 | 170 | | | | 4,5[c] | 4,5 | 5,3 | 7,4 |
| 200 | 222 | | | | 4,7[c] | 5,4 | 6,5 | 9,2 |
| 250 | 274 | | | | 5,5[c] | 6,4 | 7,8 | 11,1 |
| 300 | 326 | | | 5,1 | 6,2[c] | 7,4 | 8,9 | 12,9 |
| 350 | 378 | | 5,1 | 6,3[cd] | 7,1 | 8,4 | 10,2 | 14,8 |
| 400 | 429 | | 5,5 | 6,5[cd] | 7,8 | 9,3 | 11,3 | 16,5 |
| 450 | 480 | | 6,1 | 6,9[c] | 8,6 | 10,3 | 12,6 | 18,4 |
| 500 | 532 | | 6,5 | 7,5[c] | 9,3 | 11,2 | 13,7 | 20,2 |
| 600 | 635 | | 7,6 | 8,7[c] | 10,9 | 13,1 | 16,1 | 23,8 |
| 700 | 738 | 7,3 | 8,8[cd] | 9,9 | 12,4 | 15,0 | 18,5 | 27,5 |
| 800 | 842 | 8,1 | 9,6[c] | 11,1 | 14,0 | 16,9 | 21,0 | |
| 900 | 945 | 8,9 | 10,6[c] | 12,3 | 15,5 | 18,8 | 23,4 | |
| 1000 | 1 048 | 9,8 | 11,6[c] | 13,4 | 17,1 | 20,7 | | |
| 1100 | 1 152 | 10,6 | 12,6[c] | 14,7 | 18,7 | 22,7 | | |
| 1200 | 1 255 | 11,4 | 13,6[c] | 15,8 | 20,2 | | | |
| 1400 | 1 462 | 13,1 | 15,7[c] | 18,2 | | | | |
| 1500 | 1 565 | 13,9 | 16,7[c] | 19,4 | | | | |

**Table A.1** (*continued*)

| DN | DE[a] mm | Nominal iron wall thickness, $e_{nom}$ mm[b] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **C20** | **C25** | **C30** | **C40** | **C50** | **C64** | **C100** |
| **1600** | 1 668 | 14,8 | 17,7[c] | 20,6 | | | | |
| **1800** | 1 875 | 16,4 | 19,7[c] | 23,0 | | | | |
| **2000** | 2 082 | 18,1 | 21,8[c] | 25,4 | | | | |
| **2200** | 2 288 | 19,8 | 23,8[c] | | | | | |
| **2400** | 2 495 | 21,4 | 25,8 | | | | | |
| **2600** | 2 702 | 23,1 | 27,9[c] | | | | | |

a  A tolerance of +1 mm applies.

b  For pipes with weld beads, see ISO 10804.

c  Preferred classes.

d  For preferred classes, thicknesses are greater than the thicknesses calculated for "smoothing" between C40 and C30, and also between C30 and C25.

## A.2  Dimensions of pressure and gravity sewer pipes conforming to ISO 7186

**Table A.2 — Dimensions of pressure and gravity sewer pipes conforming to ISO 7186**

| DN | DE[a] mm | Nominal iron wall thickness, $e_{nom}$ mm | | Pressure pipe: corresponding preferred pressure class of ISO 2531 |
|---|---|---|---|---|
| | | **Pressure pipe** | **Gravity pipe** | |
| **80** | 98 | 4,4 | 3,4 | C40 |
| **100** | 118 | 4,4 | 3,4 | C40 |
| **125** | 144 | 4,5 | 3,4 | C40 |
| **150** | 170 | 4,5 | 3,4 | C40 |
| **200** | 222 | 4,7 | 3,4 | C40 |
| **250** | 274 | 4,9 | 4,1 | C30 |
| **300** | 326 | 5,1 | 4,8 | C30 |
| **350** | 378 | 5,7[b] | 5,5 | C30 |
| **400** | 429 | 6,3[b] | | C30 |
| **450** | 480 | 6,4 | | C25 |
| **500** | 532 | 6,5 | | C25 |
| **600** | 635 | 7,5 | | C25 |
| **700** | 738 | 8,5[b] | | C25 |
| **800** | 842 | 9,6 | | C25 |
| **900** | 945 | 10,6 | | C25 |
| **1000** | 1 048 | 11,6 | | C25 |
| **1100** | 1 152 | 12,6 | | C25 |

**Table A.2** (*continued*)

| DN | DE[a] mm | Nominal iron wall thickness, $e_{nom}$ mm | | Pressure pipe: corresponding preferred pressure class of ISO 2531 |
|---|---|---|---|---|
| | | **Pressure pipe** | **Gravity pipe** | |
| **1200** | 1 255 | 13,6 | | C25 |
| **1400** | 1 462 | 15,7 | | C25 |
| **1500** | 1 565 | 16,7 | | C25 |
| **1600** | 1 668 | 17,7 | | C25 |
| **1800** | 1 875 | 19,7 | | C25 |
| **2000** | 2 082 | 21,8 | | C25 |
| **2200** | 2 288 | 23,8 | | C25 |
| **2400** | 2 496 | 25,8 | | C25 |
| **2600** | 2 702 | 27,9 | | C25 |

a    A tolerance of +1 mm applies.

b    For preferred classes, thicknesses are greater than the thicknesses calculated for "smoothing" between C40 and C30, and also between C30 and C25.

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