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Ductile iron pipes and fittings for pressure and non-pressure pipelines — Cement mortar lining

Tuyaux et raccords en fonte ductile pour canalisations avec et sans pression — Revêtement interne de mortier de ciment

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document 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 fourth edition cancels and replaces the third edition (ISO 4179:2005), which has been technically revised.

The main changes are as follows:

— definitions of additives and admixtures have been added;

— the following tests and performance requirements have been introduced:

  a) check for organic impurities;

  b) check for silt and clay;

  c) compressive strength of cement mortar lining;

  d) ring bending test for mortar disbanding;

— the requirement of internal diameter of pipe has been added;

— the list of performance test and routine tests has been added.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Ductile iron pipes and fittings for pressure and non-pressure pipelines — Cement mortar lining

1 Scope

This document specifies the nature, the method of application, the surface condition, performance requirements and the minimum thickness of internal linings of cement mortar for ductile iron pipes and fittings for pressure and non-pressure pipelines as defined in ISO 2531, ISO 7186 and ISO 16631.

It covers cement mortar linings which are used to improve the hydraulic properties of pipes and fittings compared to un-lined pipes and fittings and/or to prevent corrosion damage and includes special requirements for linings of gravity sewers operating partially filled.

It also covers linings used for the conveyance of particularly aggressive fluids, where the following solutions can be used either separately or in combination:

a) an increase in the thickness of the lining;

b) a change of the type of cement;

c) a coating over the lining.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 679, *Cement — Test methods — Determination of strength*

ISO 2531:2009, *Ductile iron pipes, fittings, accessories and their joints for water applications*

ISO 7186:2011, *Ductile iron products for sewerage applications*

ISO 10803:2011, *Design method for ductile iron pipes*

ISO 16132, *Ductile iron pipes and fittings — Seal coats for cement mortar linings*

ISO 16631:2016, *Ductile iron pipes, fittings, accessories and their joints compatible with plastic (PVC or PE) piping systems, for water applications and for plastic pipeline connections, repair and replacement*

ISO 21051:2020, *Construction and installation of ductile iron pipeline system*

ISO 20290-5, *Aggregates for concrete — Test methods for mechanical and physical properties — Part 5: Determination of particle size distribution by sieving method*

EN 545:2010, *Ductile iron pipes, fittings, accessories and their joints for water pipelines – Requirements and test methods*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
additives
finely divided mineral material (e.g. ground granulated blast furnace slag, coal fly ash, ground limestone, silica fume, mineral fillers and metakaolin, mineral pigments) or polymeric material used in order to improve certain properties of fresh mortar or hardened lining or that can be added to cement mortar in order to achieve specific properties

3.2
admixtures
organic or inorganic material added during the mixing process of mortar in a quantity not more than 5 % of dry matter by mass of the cement content of the mortar to modify the properties of the mix in the fresh and/or hardened state

Note 1 to entry: Admixtures in cement mortar is used to enhance properties of the mortar in terms of plasticizing, set accelerating, workability etc. meeting the requirements of this document.

4 Materials

4.1 Cement

The cement used for the lining shall comply with the cement standard(s) in application in the country of pipe manufacture or equivalent ISO standard.

Unless otherwise specified, the type of cement shall be selected by the manufacturer in order to be suitable for the nature of the fluid to be transported in accordance with ISO 2531:2009, Annex B, ISO 7186:2011, Annex B and ISO 16631:2016, Annex B.

4.2 Aggregates

The aggregate is a granular mineral constituent suitable for use in cementitious mortar. Aggregate can be natural, artificial or recycled from material previously used in construction. The aggregate shall have a controlled granulometric distribution from fine particles (sand) to coarser elements (gravel).

The aggregate shall meet requirements for materials in contact with drinking water when lining used for drinking water applications.

4.3 Mixing water

The water used for the preparation of the mortar shall be either potable water or water free from substances deleterious either to the mortar or to the water to be transported in the pipeline. The presence of solid mineral particles is, however, admissible provided that the above-mentioned requirements are still fulfilled. Existing national hygienic requirements shall be complied with.

4.4 Mortar

The fresh mortar of the lining shall be composed of cement, aggregates and water complying with 4.1, 4.2 and 4.3 respectively.

The respective proportions of aggregates and water to cement shall be selected and controlled by the manufacturer in order to achieve compliance with this document. The methods of determination of the ratios aggregates/cement and water/cement shall be specified by the manufacturer.

Manufacturers shall submit the hygienic certificate of mortar meeting the requirement of ISO 2531:2009, 4.1.4 for the material in contact with water intended for human consumption, in case the pipes are to be used for water application.

4.5 General requirements for using admixture and additives

In case the admixture(s) and additives have been used by the manufacturer, the same shall be declared along with the quality assurance plan and applicable hygienic certificate meeting the requirement of ISO 2531:2009, 4.1.4 for materials in contact with water intended for human consumption, in case the pipes are to be used for water application.

5 Application of lining

5.1 Condition of interior surface of pipe before application of lining

All foreign bodies, Ioose scale or any other material which can be detrimental to good adhesion between the metal and the lining shall be removed from the surface to which the lining shall be applied.

The inner surface of the pipe and fitting shall also be free of any metal projections, which can affect the thickness of the lining.

5.2 Method of application

The mortar shall be thoroughly mixed in order to achieve the appropriate consistency and homogeneity.

For pipes, the mortar is applied inside the pipes by depositing or spraying the mortar on the inner surface of the pipes, which are rotated at the required rpm to ensure the desirable centrifugal force for adhesion of the mortar onto the pipe surface (centrifugal method). Manufacturers may also use projection method or a combination of the two to achieve the desired properties meeting the requirement of this document. For fittings, the mortar is projected onto the wall by means of a rotating projection head or may be placed by hand or moulding using appropriate trowels.

Apart from the inner surface of the socket, the parts of the pipe or fitting coming in contact with the transported water shall be entirely covered with mortar.

The consistency of the mortar, the time and the speed of centrifugation, and the speeds of rotation and translation of the projection head shall be controlled so as to achieve a dense and continuous lining. The mortar shall be free of any cavities or visible air bubbles, so that minimum thickness and homogeneity are ensured at all points.

5.3 Curing

The fresh lining shall be cured at defined temperatures along with humidity requirements to be decided by the manufacturer in order to achieve the sufficient hardening of the cement mortar lining meeting the performance requirements of this document. However, manufacturer can decide to adopt natural curing or any other suitable curing method depending upon the climatic conditions in the manufacturing premises. Any loss of water from the mortar by evaporation shall be sufficiently slow that hardening is not impeded. This can be achieved, for example, by means of controlled atmosphere, closed pipe ends or by application of a seal coat to the still moist lining.

For high alumina cement lining, the requirements of ISO 7186:2011, 7.6 and 7.7 shall be met.

5.4 Seal coat

Unless otherwise specified, the manufacturer has the option of providing or not providing a seal coat. The seal coat shall not affect adversely the quality of the transported water.

When a seal coat is supplied, it shall be in accordance with ISO 16132.

The seal coat shall meet the requirement of ISO 2531:2009, 4.1.4 for materials in contact with water intended for human consumption, in case the pipes are to be used for water application.

5.5 Repairs

Repairs to damaged or defective areas are allowed. They should be carried out according to the manufacturer's instructions or instruction from a supplier of the repair material. The damaged mortar shall first be removed from these areas. Then the defective part shall be repaired by using, for example, a trowel with fresh mortar so that a continuous lining having a constant thickness is again obtained. If no instruction from a manufacturer or supplier for the repair material, it should be carried out in accordance with the ISO 21051:2020, 7.3.

For the repair operation, the mortar shall have a suitable consistency; if necessary, additives may be included to obtain good adhesion against the side of the existing undamaged mortar.

Sufficient curing shall be provided to the repaired areas.

6 Thickness of lining

6.1 Thickness requirements

The nominal thickness of the lining and the minimum thickness are given in Table 1. The lining thickness measured in the pipe shall not be lesser than the minimum value given in Table 1.

Table 1 — Thickness of cement mortar lining

DN group	Nominal size DN	Lining thickness		Maximum crack width and radial displacement (potable water)	Maximum crack width (partially filled sewage pipelines)
		nominal	minimum		
		mm		mm	mm
I	40	3	2	0,8	0,6
	50				
	60				
	65				
	80				
	100				
	125				
	150				
	200				
	250				
	300				
II	350	5	3	0,8	0,7
	400				
	450				
	500				
	600				

Table 1 *(continued)*

DN group	Nominal size DN	Lining thickness		Maximum crack width and radial displacement (potable water)	Maximum crack width (partially filled sewage pipelines)
		nominal	minimum		
		mm		mm	mm
III	700	6	3,5	1	0,8
	800				
	900				
	1 000				
	1 100				
	1 200				
IV	1 400	9	6	1,2	0,8
	1 500				
	1 600				
	1 800				
	2 000				
V	2 200	12	7	1,5	0,8
	2 400				
	2 600				

For partially filled sewage pipelines, by agreement between manufacturer and purchaser, the lining thickness may be increased, and/or high alumina cement mortar, polymer-modified mortar or suitably coated mortar may be used.

At the pipe ends, the lining may be reduced to values below the minimum thickness. The length of the chamfer shall be as per the manufacturer's recommendation.

6.2 Internal diameter

The nominal values of the internal diameter of centrifugally cast ductile iron pipes, expressed in millimetres, are approximately equal to the numbers indicating their nominal size, DN.

The internal diameter of cement mortar lined ductile iron pipes shall have limit deviation as per EN 545:2010, 4.3.2.2 to ensure the minimum bore of pipes.

6.3 Minimum internal diameter measurement

The internal diameter of the lined pipes shall be measured by means of suitable equipment by either of the following two methods:

a) two measurements shall be taken at right angles, at a cross section 200 mm or more from the end face; the mean value of these two measurements can then be calculated;

b) a system of pass/fail gauges shall be passed along the bore of the pipe.

6.4 Determination of lining thickness

The thickness of the lining is checked on the freshly applied mortar by the insertion of a steel pin, or on the hardened mortar by means of a non-destructive method of measurement.

The thickness of the lining shall be measured at both ends of the pipe in at least one section perpendicular to the pipe axis.

In each section, which shall be at least 200 mm from the pipe end, measurements shall be taken at four points spaced at 90° intervals.

The values for the thickness of the lining shall be reported to the nearest 0,1 mm.

The thickness of the lining shall be inspected on a statistical basis, as defined in the manufacturer's quality assurance plan, depending on the reproducibility of the lining process.

7 Surface condition of hardened lining

The cement mortar lining shall exhibit a generally smooth finish on its entire surface. However, the structure of the lining and its surface finish are related to the lining process; surface textures inherent in the method of manufacture (e.g. orange peel effects) shall be acceptable provided that they do not reduce the thickness of the lining to less than the minimum value as specified in Table 1. Only firmly embedded aggregate grains are allowed to appear on the surface of the lining.

For centrifugally applied linings, a thin laitance and cement rich layer, comprising fine aggregate and cement, can be formed on the inner surface of the lining. It can be extended up to approximately one-quarter of the total thickness of the mortar.

Due to the complex internal shape of the fittings and to the application process, the lining of fittings can show a corrugated surface provided that it does not reduce the thickness of the lining to less than the minimum value as specified in Table 1.

NOTE 1 The surface condition has comparatively lesser effect on the hydraulic characteristics, the main factors being the effective internal diameter of the pipes and the shape of the fittings.

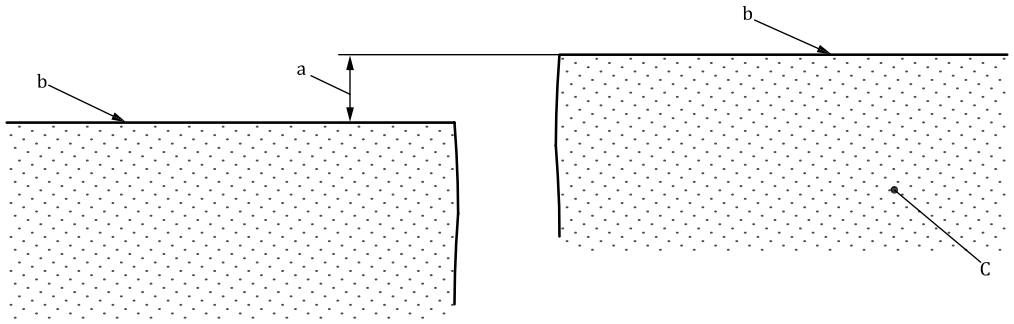
On contraction of the lining, the formation of hairline cracks, shrinkage cracks and radial displacements cannot be avoided (see Figure 1). These cracks and radial displacements, together with other isolated cracks which can result from manufacture or can develop during transportation, are acceptable if their width does not exceed the values in Table 1. Cracks shall not be detrimental to the mechanical stability of the lining. The cracks, radial displacement or disbondment of the cement mortar can occur due to the storage of the pipes and fittings in hot and dry environment particularly directly under the sun. The heat in the environment causes the expansion of the metal and at the same time shrinkage in the cement mortar, resulting in cracks, radial displacement or disbondment. When such pipes and fittings come in contact with water, due to absorption of moisture, the lining will swell, and the cracks will close and ultimately the cement mortar lining will heal due to autogenous process. If the crack width and radial displacement value exceeds the permissible limits, it shall be repaired as per the procedure prescribed by the manufacturer. Repair material are cement mortar of a similar type as the one used to line the pipe, or dedicated repair material made of mineral and organic finders.

NOTE 2 These cracks and radial displacements will close and heal when the lining comes into contact with water due to re-swelling of the lining and continued hydration of the cement.

For partially filled pipelines, crack widths and radial displacements shall not exceed the values given in Table 1, column "partially filled sewage pipelines".

Hollow areas, which are detectable by acoustic means (knocking), are related to the shrinkage of the lining in hot and dry climates and are acceptable.

NOTE 3 These hollow areas will disappear when the lining comes into contact with water.



a Radial displacement.
b Bore of Lining.
c Cement mortar lining.

Figure 1 — Radial displacement caused by cracking of cement mortar lining

8 Test conditions and performance requirements

8.1 General

The various checks specified in this document shall be carried out according to the manufacturer's quality plan, taking account of the following performance requirements. Annex A shall be referred for the performance tests and routine tests.

8.2 Aggregate

The check for organic impurities, clay-bearing substances and the determination of the granulometric curve of the aggregate on an average sample shall be carried out at the beginning for each supply source as per the requirements in 8.2.1. They shall then be checked at regular intervals as defined in the manufacturer's quality plan.

The frequency of these various checks may be changed depending on the regularity of the supplies. In particular, it shall be increased, at least temporarily, if supply sources are changed or if irregularities are noticed in supplies from the same origin. The manufacturer can use the supplier's quality certificate for the above quality requirements.

8.2.1 Check for organic impurities

8.2.1.1 Principle

Organic impurities are typically present in the fine aggregate such as sand. These impurities can interfere with the chemical reaction of hydration and can affect the strength of the mortar where the sands are used.

Colorimetric method is generally used to determine the presence of organic impurities based on the principle that such organic impurities reacts with sodium hydroxide (NaOH) producing a dark colour.

8.2.1.2 Sampling

The sample shall be taken, which is representative of the average properties of the batch and shall be reduced to an amount not less than the mass specified in the Table 2, appropriate to the upper size of the aggregate.

Table 2 — Minimum mass of preliminary sub-sample

Upper (D) sieve size of the aggregate mm	Minimum mass of sub–sample kg
63	50
45	35
31,50	15
22,4 or less	5

Dry the obtained sub–sample in drying oven at (40 ± 5) °C. Sieve the dried particles on a 4 mm sieve and retain the fraction that passes. The fraction that passes 4 mm sieve will be treated as test portion of aggregate.

8.2.1.3 Procedure of testing

Pour a 3 % sodium hydroxide (NaOH) solution into the glass bottle to a height of about 80 mm. Then, add some of the test portion obtained from the procedure in 8.2.1.2 into the glass bottle (a capacity of approximately 450 ml and an external diameter of approximately 70 mm) until the height of the aggregate and the solution is 120 mm. Shake the bottle to enable air bubbles to escape. Stopper the bottle and shake it vigorously for 1 min. Leave it to stand for 24 h. Compare the colour of the solution to standard colour solution contained in a similar clear cylindrical glass bottle. Record whether the colour of the solution is lighter or darker than the standard colour.

NOTE The standard colour solution is prepared by dissolving 45 g of $FeCl_3.6H_2O$ and 5,50 g of $CoCl_2.6H_2O$ in 279,5 g of water with 1 ml concentrated HCl.

8.2.1.4 Performance test results

The test result shall state whether the colour of the solution is negative test (lighter than the standard colour) or positive test (darker than the standard colour). Negative test indicates no presence of organic impurities meeting the requirement of this document.

The colorimetric tests of aggregate from an established source of supply shall be made once every six months. For aggregate from a new source, this test shall be made not less than once a month from a period of six months.

8.2.2 Check for silt and clay

8.2.2.1 Principle

The presence of silt and clay in aggregates with particle size lower than 63 microns, by more than 2 % (by mass) reduces the durability and the strength of the cement mortar.

8.2.2.2 Determination of fines

The determination of fines shall be done as per the procedure provided in ISO 20290-5. The percentage of fines passing 0,063 mm shall not exceed 2 %.

The above test of aggregates from an established source of supply shall be made once every six months. For aggregates from a new source, these tests shall be made not less than once a month from a period of six months.

8.3 Compressive strength of cement mortar lining

The compressive strength shall be determined by a test method in accordance with ISO 679, except that:

— the aggregate and the cement used for the prism samples are identical with those used for the mortar before application of the lining and the water shall conform to the requirements of 4.3;

— the aggregate/cement ratio used for the prism samples is equal to that used for the cement mortar before application of the lining;

— the water/cement ratio used for the prism samples is equal to that of lining immediately after the application to the pipe wall;

— the test samples are prepared either using an impact table or a vibration table (time 120 ± 5 s, frequency of vibrating mass 50 to 65 Hz) when the water/cement ratio is below 0,35.

The curing of prism samples shall be identical with the one used in the manufacturing process of cement mortar lining. The compressive strength of cement mortar shall not be less than 30 MPa.

NOTE 1 This takes into account the influence of the centrifugal spinning process which allows expelling the excess water.

NOTE 2 The compressive strength of lining is directly related to other functional properties such as high density, good bond and low porosity.

8.4 Ring bending test for mortar disbonding check

The test shall be carried out on a pipe section (500 ± 20) mm long, cut from the pipe barrel. The pipe section shall be placed on a support approximately 200 mm wide and 600 mm long, having a V shape with an angle between 170° and 180° (see Figure 2). The load shall be applied at the pipe crown through a loading beam approximately 50 mm wide and 600 mm long. Both the V support and the loading beam shall be covered with a sheet of elastomer with a thickness of (10 ± 5) mm and a hardness greater than or equal to 50 IRHD. Before the test, the pipe section shall be immersed in water at ambient temperature for approximately 24 h.

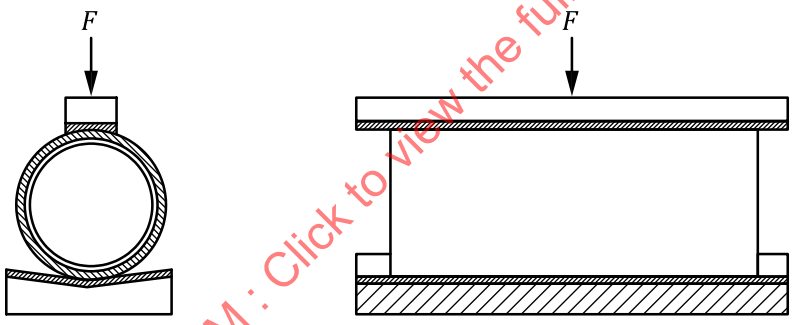


Figure 2 — Ring bending test

The load shall be increased steadily until the pipe deflection reaches the relevant value given in ISO 10803:2011, 6.4 and shall be kept for 1 min. The integrity of the lining shall be checked by visual inspection. There should not be any disbonding of cement mortar lining from the pipe. In addition, during visual inspection any damage in cement mortar lining should not be noticed.

The ring bending type test shall be done for DN groupings as per ISO 2531:2009, Table 9.

All cement mortar lined pipes shall comply with the requirements of ring bending test for mortar disbanding check. If the mortar is tested and documented by the manufacturer for this test and successfully used for a minimum of 10 years, the ring bending test for mortar disbonding check is only required for significant changes in formulation, which can adversely affect the performance mortar.

8.5 Appearance of lining

Each pipe and fitting shall be visually inspected for the appearance of the lining, with special reference to the surface condition and the finish of the ends.

Repairs considered necessary after this examination shall be carried out in accordance with the method described in 5.5.

8.6 Pipes for sewerage applications

Cement mortar lining for the pipes for sewerage application shall meet the requirements of ISO 7186:2011, 7.6 for chemical resistance to effluents and ISO 7186:2011, 7.7 for abrasion resistance.