BRITISH STANDARD

BS EN
10298:2005

Steel tubes and fittings for on shore and offshore pipelines — Internal lining with cement mortar

The European Standard EN 10298:2005 has the status of a British Standard

ICS 23.040.10; 23.040.40; 25.220.99

BSI
British Standards

National foreword

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The UK participation in its preparation was entrusted by Technical Committee ISE/16, Protective coatings and linings of metal pipes and fittings, to Subcommittee ISE/16/-/10, Internal coatings and linings for steel pipes and fittings, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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English Version

Steel tubes and fittings for on shore and offshore pipelines - Internal lining with cement mortar

Tubes en acier et raccords pour canalisations enterrées et immergées - Revêtement interne au moyen de mortier de ciment

Stahlrohre und Formstücke für erd- und wasserverlegte Rohrleitungen Zementmörtel-Auskleidung

This European Standard was approved by CEN on 26 August 2005.

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Contents

Foreword

This European Standard (EN 10298:2005) has been prepared by Technical Committee ECISS/TC 29 “Steel tubes and fittings for steel tubes”, the secretariat of which is held by UNI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2006, and conflicting national standards shall be withdrawn at the latest by April 2006.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This European Standard specifies requirements for cement mortar linings for protecting the internal surface of steel tubes and pipeline components. It also specifies requirements for their application. It is applicable to the linings of tubes that have been welded longitudinally or spirally, seamless tubes and non-alloy steel components used for fluid transportation. This European Standard does not cover in situ applied or rehabilitation linings.

This type of lining is used in particular in the transport and distribution, under pressure or by gravity, of water intended for human consumption and industrial use, and also in fire extinguishing and waste water systems. The temperature of the water transported should not exceed 50 °C. Higher working temperature can be used by agreement of the parties.

The constituent materials of cement mortar lining, when used under the conditions for which they are designed, in permanent or temporary contact with water intended for human consumption, shall not change the quality of that water to such an extent that it fails to comply with the requirements of European regulations. For this purpose, reference shall be made to the relevant national standards transposing EN standards when available, dealing with the influence of materials on water quality.

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.

EN 196-1, *Methods of testing cement — Part 1: Determination of strength*.

EN 197-1, *Cement — Part 1: Composition, specifications and conformity criteria for common cements*.

EN 1744-1, *Tests for chemical properties of aggregates — Part 1: Chemical analysis*.

ISO 565, *Test sieves — Metal wire cloth, perforated metal plate and electroformed sheet — Nominal sizes of openings*.

ISO 2591-1, *Test sieving — Part 1: Methods using test sieves of woven wire cloth and perforated metal plate*.

ISO 3310-1, *Test sieves — Technical requirements and testing — Part 1: Test sieves of metal wire cloth.*

3 Terms and definitions

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

3.1
product manufacturer
manufacturer of lining material

3.2
coater
organisation responsible for lining of tubes and components

3.3
purchaser
buyer of the lined products

3.4
drinking water
water intended for human consumption

4 Classification of linings

The cement mortar linings shall be classified according to the cement type used, the additives used and the method of application.

The various possibilities are listed in Table 1.

Table 1 — Classification of linings

Cement type	**Blast furnace cement Portland cement**	**Blast furnace cement Portland cement sulphate resistant**	**Calcium aluminate cement**	
Symbol	CEM III A[a], CEM I [a]	CEM IIIB [a], CEM I-HS [b]	CEM CAC [b]	
Additives	**No additive**	**Liquefying additives**	**Resin dispersion**	**Mineral additives**
Symbol	N	L	R	M
Application sign	**Spinning method**	**Spraying method**	**Manual method**	
	I	II	III	

[a] Abbreviation according to EN 197-1.

[b] For cement CEM I HS (Sulphate Resistance) and CEM CAC (High Aluminium Cement) reference shall be made to European standards when available or to the relevant national standards.

5 Information to be supplied by the purchaser

5.1 Mandatory information to be supplied by the purchaser

The purchaser shall state in his enquiry and order the following minimum information:

— reference to this European standard EN 10298;

— type of water to be transported in the pipeline;

— type of cut-back (see annex A);

— transportation under pressure or by gravity for waste water application.

5.2 Options to be indicated by the purchaser

The purchaser may add the following optional information:

— type of cement;

— type of additives;

— method of application;

— service temperature;

— application of a pore sealer.

6 Standard designation

Designation of cement mortar lining in compliance with this European Standard shall contain the following:

— reference to this standard;

— type of cement;

— type of additives, if applicable;

— method of application.

EXAMPLE 1 5000 metres of tube - EN 10224 of 406, 4 x4, 0
- internal lining EN 10298 CEM I R I

EXAMPLE 2 8000 metres of tube - EN 10224 of 406, 4-4, 0
- internal lining EN 10298 CEM III M L II

7 Composition and application of the lining

7.1 Surface preparation

The internal surface to be lined shall be free from objects that can adversely affect the lining or impair its application. Loose rust, loose mill scale, dirt, debris, oil, grease, paint and other material that may have originated from an external coating process, scattered weld beads as well as blasting residues and/or chemical cleaning process residues shall be removed. However the presence of a light adhesive rust layer does not impair the performance of a cement mortal lining and may be left.

7.2 Composition of the lining

The mortar shall be a homogeneous mixture of cement, sand and water (certain additives, as given, in Table 1, may be added) of a suitable consistency for producing a regular lining on the internal surface of the tubes and fittings.

The mortar shall be free from foreign bodies, in particular lumps of hardened mortar.

In the cases of drinking water transportation lines, the organic impurities content shall not exceed the amount equivalent to 0,1 g $KMnO_4$/kg sand when determined as an extract in deionized water and to 0,3 g $KMnO_4$/kg sand when determined as an extract in 0,1 mol NaOH.

7.3 Constituent materials

7.3.1 Cement

The quality of cement shall comply with EN 197-1 or with European standards when available or the relelvant national standards (see Table 1).

NOTE Information in Annex B can be used as a guide in the selection of the cement type.

7.3.2 Sand

7.3.2.1 The sand shall be mainly composed of particles of siliceous material insoluble in alkali and shall not contain organic matter or visible traces of clay. It shall have a controlled particle distribution ranging from fine particles to coarser particles; it shall be clean and composed of hard, stable and resistant inert granular particles.

7.3.2.2 It shall be stored in a clean place in order to avoid any contamination by foreign bodies, and in particular by organic matter.

7.3.2.3 Sampling is carried out according to the requirements of ISO 2591-1.

7.3.2.4 The size-distribution curve of the sand shall be drawn using sieves complying with ISO 565. It shall meet the following requirements.

a) The fraction of fine particles passing through a sieve with 0,125 mm mesh aperture shall not exceed 10 % in mass. This is important in order to limit the error when determining *S*/*C* ratio of the mortar (see 8.2 and Annex C).

b) The fraction with particles diameters up to and including one third of the minimum thickness of the lining shall not be less than 50 % in mass.

c) The size of the coarsest particle shall neither exceed half the minimum lining thickness nor 3 mm except otherwise agreed upon by the parties.

7.3.2.5 The cleanness of the sand is evaluated according to the criteria of the contents of chlorides, organic impurities and clay matter.

a) The maximum chloride content shall be 0,02 %. The chloride content is determined according to EN 1744-1.

b) The amount of clay matter and other fine particles in the sand is determined by the separation method.This amount shall not exceed 2 % by mass.

7.3.2.6 Sands with a soluble and releasable alkali content of over 0,02 % shall not be used with CEM CAC.

7.3.3 Water

For drinking water systems, only water intended for human consumption shall be used.

For other applications, water of comparable quality, having a conductivity of less than 2 000 μS/cm and a $KMnO_4$ consumption of less than 10 mg/l, can be used. For the determination of these parameters the European standards shall be used when available and, if not, use relevant national standards.

7.3.4 Mortar additives

If the use of additives has been agreed and if they are not harmful to the quality of the water (in case of water intended for human consumption) or the performance of the lining they may be used for making up the mortar. For drinking water the additives shall comply with the national requirements in the country of use (see Clause 1).

Pozzolanic (hydraulic) fillers are allowed to be used up to a level of 10 % by mass of the cement and non-pozzolanic (non hydraulic) fillers up to 3 %. Fillers with a soluble and releasable alkali content of over 0,02 % shall not be used with CEM CAC.

All organic additives (liquifiers or resins dispersion) shall have a resistance to saponification greater than 45 ml when tested according to Annex D.

7.4 Method of application

7.4.1 The cement mortar is applied to the inside of tubes and fittings in such a way that the lining has maximum compaction and a surface condition that aids the flow of water.

Frozen material shall not be used and the mortar shall be applied at a temperature in excess of 5 °C; so as to permit its correct curing.

After application, the lining shall be kept damp, and the temperature of the substrate shall not be allowed to fall below 5 °C. To prevent the lining from drying too rapidly, the tube ends shall be capped or otherwise specified unless the lining is allowed to cure under moist/warm conditions or in a draught-free closed space. Curing may be speeded up and the regularity of the lining ensured by suitably adjusting the temperature and humidity of the lining in a regular treatment cycle. The curing period shall be sufficient to ensure that the tubes and fittings can be transported and stacked without the lining being damaged.

7.4.2 Cement mortar linings are mainly applied in three ways:

a) the centrifugation-method in which the mortar is spun at a high rotational speed after distribution along the length of the tube. Under the action of centrifugal force the solid components of the mortar are compacted to form a smooth lining, and part of the original water content is driven out. The partly dewatered lining withstands the transportation of the tube to the curing site;

b) the spinning-head-method in which the mortar is thrown at the wall of the tube or fitting, mostly through the centrifugal force exerted by a rotating throwing head. In this method the original water content of the mortar remains virtually unchanged in the process of application. Some additional smoothing of the mortar layer surface can be carried out by:

   — rotation of the tube;

   — mechanical trowelling or trowellings cones.

c) the manual-method in which the mortar is trowelled onto the steel surface. This is normally done in order to repair defects in a lining and often in order to line fittings.

7.4.3 The lining is applied at the factory to tubes and fittings. The ends are prepared according to the provisions of the order as applicable, so that jointing may be carried out on site (see Annex A).

7.5 Pore sealer (optional)

If the use of a pore sealer has been agreed, they may be used for covering or modifying the surface of the cement mortar lining. The pore sealer shall not be detrimental to the quality of the water (in case of water intended for human consumption) or to the performance of the lining.

For drinking water, the pore sealer shall comply with the national requirements in the country of use (see Clause 1).

Requirements pertaining to the performance and application of the pore sealer are not part of this standard.

8 Requirements for the applied lining

8.1 General

The required properties of the applied lining are given below:

— *S*/*C* ratio according to Annex C;

— *W*/*C* ratio according to Annex C;

— mechanical properties of the mortar;

— appearance and continuity;

— thickness of the lining system.

Other properties can be specified at the time of enquiry and order.

8.2 *S*/*C* and *W*/*C* ratios

NOTE 1 **determination of the sand cement ratio** (S/C ratio) according to Annex C;

NOTE 2 **determination of the water cement ratio** (W/C ratio) according to Annex C;

8.2.1 The *S*/*C* and *W*/*C* ratios of the wet mortar are determined since they have a major influence on the final properties of the cured mortar.

8.2.2 The composition of fresh mortar is such that the *S*/*C* is from 1,0 to 2,5.

8.2.3 In the case where the lining is applied by centrifugation-method, the fresh mortar after centrifugation shall have a *W*/*C* ratio less than or equal to 0,42.

8.2.4 In the case of application by spinning-head-method, the *W*/*C* ratio depends on the value of *S*/*C* within the limits in the following Table 2.

Table 2 — Relation between *S*/*C* ratio and *W*/*C* ratio for the spinning-head-method

S*/*C	2,5	1,7	1,0
W*/*C	≤ 0,42	< 0,40	< 0,37

NOTE For intermediate values interpolation is admitted.

8.2.5 For mortar applied by centrifugation-method, the determinations of *S*/*C* and *W*/*C* are carried out on samples of mortar taken from the tube within 15 min of the lining having been applied.

8.2.6 For mortar applied by spinning-head-method, the samples of mortar may be taken at the exit from the cement mixer. If during spinning, water is extracted from the mortar, sampling shall be according to 8.2.5.

8.2.7 The samples shall be representative of the total thickness of the layer of mortar. Refer to Annex C for the determination of the *S*/*C* and *W*/*C* ratio.

8.3 Mechanical properties of the mortar

For the mechanical properties of the mortar the following shall apply:

a) compressive strength after 28 days should be at least 50 N/mm^2 and the flexural strength 5 N/mm^2;

b) inspection of the mechanical strength of mortar is carried out on a prismatic specimen 40 mm x 40 mm x 160 mm prepared from fresh mortar taken from the lined tubes. If no water is removed during application the samples of mortar can be taken out of the mixer;

c) these specimens are prepared and their flexural and compressive strength are determined according to the provisions given in EN 196-1;

d) prisms for testing the mechanical properties of cement mortar mixes shall be cured under the conditions defined in EN 196-1 after 7 and 28 days.

8.4 Appearance and composition of the lining

The appearance of the lining is inspected visually and shall comply with the following:

a) mortar lining shall be uniformly smooth and free from cavities and any visible foreign bodies, though a few isolated particles of sand protruding from the surface are acceptable;

b) unless otherwise specified at the time of the inquiry and/or order isolated cracks with widths smaller than 1,5 mm are acceptable for drinking water application, provided that they are not deleterious to the stability of the lining;

c) for water of an aggressive nature (e.g. waste water, salt water,…), the crack width shall be limited to 0,5 mm;

d) should the cracks be larger, then pre-treatment with drinking water could be used until the maximum crack width has been reduced to 0,5 mm for water of an aggressive nature and 1,5 mm for drinking water; when pre-treatment with drinking water is not suitable, the cracks shall be repaired (see Clause 9);

NOTE Experience shows that isolated cracks generally close up on contact of the lining with drinking water through the swelling of the mortar and/or chemical plugging. However, the self-healing capability of the cement mortar decreases when stored for long periods in moist atmospheric conditions.

e) smoothing of defective areas of limited size is permitted. This may be carried out manually with a mortar compatible with the original mortar and if necessary containing an additive (see 7.3.4).

8.5 Thickness of the lining

8.5.1 The measured lining thickness shall comply with provisions in Table 3.

Table 3 — Lining thickness

Tube or fitting Outside diameter *D* [b] mm	Lining thickness [a] Nominal mm	 Minimum mm
$D \leq 273$	4,5	3
$273 < D \leq 610$	6	4
$610 < D \leq 914$	8	6 [c]
$914 < D \leq 1\,220$	10	8 [c]
$1\,220 < D$	14	12 [c]

[a] For acidic chalk dissolving water and for saline water (see Annex B), a minimum thickness of 6 mm shall be applicable.

[b] For fittings, e.g. reduction pieces, reducing T's, *D* refers to the largest outside diameter.

[c] The thickness given in Table 3 can be reduced by 10 % for submerged arc welded tubes, at the weld reinforcement.

8.5.2 The thickness of the fresh mortar is measured by using a graduated penetrometer, with an accuracy of ± 10 %.

8.5.3 The thickness of the hardened mortar is measured by:

— either using a comparator, with a maximum accuracy of ± 10 %;

— or another non destructive method e.g. by magnetic or electromagnetic measurement, with an accuracy of ± 10 %.

8.5.4 Measurements of thickness shall be made at more than 300 mm from each end of the tube and at four 90° diametrically opposed points in the same cross section. In addition measurements shall be made over weld seams for submerged arc welded tubes.

For fittings, the measurements shall be made at each end of the fitting at four 90° diametrically opposed points in the same cross section. In addition measurements shall be made over weld seams for submerged arc welded tubes.

9 Repairs

Tubes or fittings with defects as well as those which have been subjected to destructive control tests shall be repaired either by the coater or during installation.

The repair procedure may be agreed by the purchaser.

10 Marking

The marking on the coated tube or fitting shall be applied by a suitable method such as painting, stencilling or printing which provides clearly legible, indelible identification using durable materials.

The markings required shall be agreed between the parties concerned.

11 Handling, transport and storage

11.1 Handling

The lined parts shall be handled so that damage cannot be caused neither to the bevels nor to the linings. The direct use of steel hooks or other material, the shape or nature of which could damage the lining, is prohibited.

11.2 Transport to the storage area

During transport of the parts to the lining works storage site, all appropriate precautions shall be taken to avoid damage to the parts and linings.

11.3 Storage

Storage shall be controlled so that the lining shall be according to the requirements of 8.4 and 8.5.

During prolonged storage in dry or warm climate, it is advantageous to cap or cover the ends of tubes which have been lined to preclude the formation of cracks due to shrinkage and to maintain the self healing capability of the cement mortar.

Tubes for water intended for human consumption applications shall be capped during storage and transportation for hygienic reasons.

11.4 Loading of tubes and fittings for delivery

All appropriate precautions to avoid damage to parts and linings during loading and transport shall be taken at the lining plant.

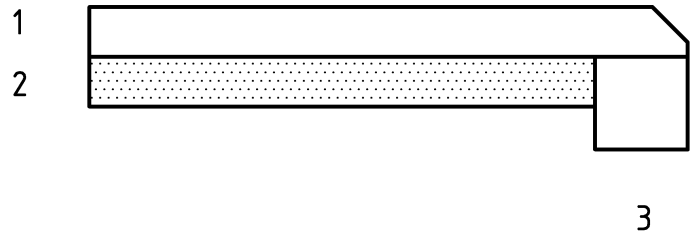
In general the coater is wholly responsible for the delivery of sound lined parts while they are in his hands.

Further handling, transportation and storage of lined components should be done in accordance to the instructions supplied by the coater.

Annex A
(informative)

Cut back types

A.1 Type C1



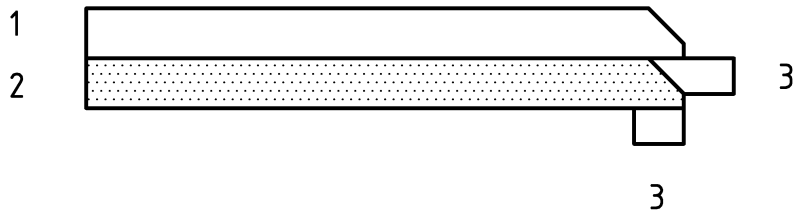
Key

1 Steel pipe
2 Cement mortar lining
3 ≈ 25 mm

NOTE A manual application of cement mortar lining is required on the joint.

Figure A.1 — End of End of pipes for butt welded joint for man-entry pipes bigger or equal than 600 mm

A.2 Type C2

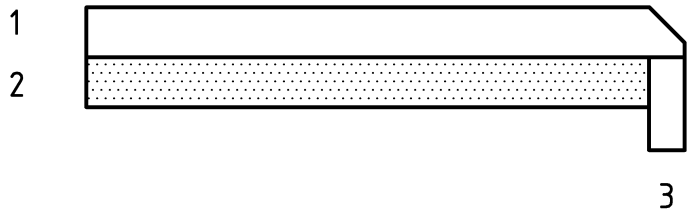


Key

1 Steel pipe
2 Cement mortar lining
3 3 mm to 5 mm

Figure A.2 — End of pipes for butt welded joint for man-entry and not man-entry pipes

A.3 Type C3

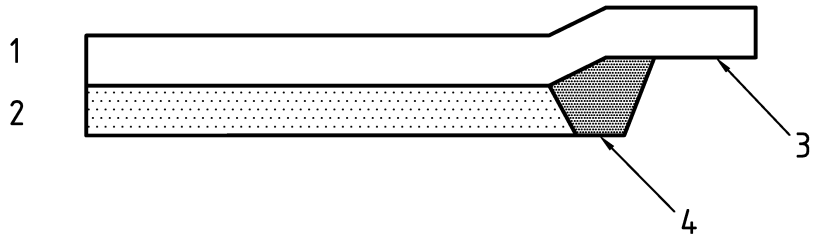


Key

1 Steel pipe
2 Cement mortar lining
3 3 mm to 5 mm

Figure A.3 — End of pipes for butt welded joint for man-entry and not man-entry pipes

A.4 Type C4

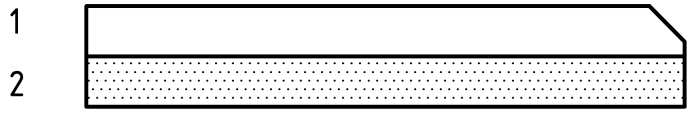


Key

1 Steel pipe
2 Cement mortar lining
3 Non lined end
4 Optional rubber ring

Figure A.4 — Steel pipe with spigot and socket joint

A.5 Type C5



Key

1 Steel pipe
2 Cement mortar lining

Figure A 5 — Steel pipe for welding collar or couplings

Annex B
(informative)

Guidance for the choice of the type of cement

B.1 Introduction

Pipes and fittings with cement mortar linings are used to build pipelines to transport e.g. drinking water, raw water, waste water, sea water, salt water and saline water. The cement mortar lining is a corrosion protection layer which is to be sufficiently resistant to the various media being transported within the pipes. This is achieved by using selected cement mortar types for the different media being transported.

B.2 Mechanism of destruction of internal cement mortar lining

B.2.1 General

The corrosion protection properties obtained by internal cement mortar lining is dependant on the achievement of a dynamic equilibrium between the lining and the media being transported. It is therefore essential to choose the cement type taking into account the media being transported.

B.2.2 Soft water

Very soft or demineralised water may dissolve out the calcareous components of the mortar. Dissolution is accelerated in the presence of Cl^- and Na^+ ions and retarded by Mg^{2+} and Ca^{2+} ions.

In soft water cement mortar linings are resistant if in compliance with equations (B1) and (B2) the minimum values of the concentration of calcium ions $c(Ca^{2+})$ and the concentration of carbon dioxide and its anions Q_c are complied with:

$$c(Ca^{2+}) > 0{,}02 \text{ mol/m}^3 = 0{,}8 \text{ mg/l} \quad \text{(B1)}$$

$$Q_c = c(CO_2) + c(HCO_3^-) + c(CO_3^{2-}) > 0{,}25 \text{ mol/m}^3 \quad \text{(B2)}$$

In the case of softer water and especially in the case of de-ionised water, slight dissolution of the cement mortar lining is to be expected which can lead to an inadmissible change in the composition of the water.

B.2.3 Acidic water

Besides excessive CO_2, other inorganic and organic acids may also adversely affect the cement mortar lining.

Dissolving chalk from cement mortar by acids leads to a softening of the cement mortar lining. In the case of great mechanical stress (erosion, go-devils), the softened mortar may be removed. Usually the concentration of these chalk dissolving acids and not the pH value is used to evaluate the acid attack. Experience has shown that at pH values of above 7.8, generally there are no chalk dissolving acids at a critical concentration present.

The extent of attack caused by acidic waters below pH 7 depends to a large extent on the solubility of the reaction salts formed. It should be noted that for a given pH weak acids are more concentrated than strong acids and are therefore more aggressive to the cement mortar.

NOTE 1 Strong acids such as hydrochloric and nitric acid dissolve calcareous aggregates and portlandite in the cement and give highly soluble reaction products. Sulphuric acid, in addition to dissolving the calcareous aggregates, may also, depending on the type of cement, give rise to attack through the formation of expansive ettringite.

NOTE 2 Attack by weak acids such as acetic, lactic and formic acid results in the formation of reaction products which are relatively soluble. However, weak acids have a tendency to dissolve reaction products which may act as diffusion barriers for strong acids. This then leaves the exposed mortar lining surface more susceptible to acid attack.

NOTE 3 Humic acid may be present in soft raw water. Even at relatively low concentrations, this can result in relatively low pH values. In waste water, in addition to a number of acids, ammonium ions can also occur, the concentration of which is to be evaluated.

NOTE 4 When there is a mixture of acids there will be a dominant acid type. Where the dominant aggressor is a weak acid it will tend to produce a reaction salt which is relatively soluble in that dominant weak acid. Similarly, where the dominant aggressor is a strong acid it will tend to produce a salt which is less soluble in that strong acid.

B.2.4 Alkaline water

The cement mortar lining is generally resistant to alkaline water at moderate concentrations.

B.2.5 Saline solutions

B.2.5.1 General

In addition to being attacked by chalk dissolving acids, the cement mortar lining can be destroyed by pieces breaking away due to specific ions in saline solutions.

In the terms of this standard, the following is applicable for saline solutions.

Table B 1 — Designation of saline solutions

Description of the water	**Salt content** [a] g/l
Water rich in salt	Approximately 3
Salt water, sea water	Approximately 30
Saline water or Brine	Greater than approximately 100
[a] see B.2.4.2 to B.2.4.6.	

B.2.5.2 Water rich in magnesium

Magnesium (chloride and sulphate) tends to dissolve the calcitic components of the cement and to form magnesium hydroxide.

B.2.5.3 Water rich in sulphates

Sulphates react with tricalcium aluminate to form expansive products, gypsum and ettringite which can lead to the destruction of mortar through cracking. For this reason, the tricalcium aluminate content of cements is limited when they are intended to come into contact with sulphates.

B.2.5.4 Water rich in nitrates

Apart from ammonium nitrate, nitrates are only weakly aggressive.

B.2.5.5 Water rich in chlorides

Chlorides are only slightly aggressive to cement, but are capable of reducing the pH of the cement matrix surrounding steel sufficiently to allow expansive rusting which goes on to cause cracking.

B.2.5.6 Water rich in sulphides

Sulphides give rise to sulphate in the presence of air and water, but the action of aerobic bacteria tends to turn sulphur, oxidised from hydrogen sulphide, to sulphuric acid which then attacks all cementitious materials, particularly in the upper parts of wastewater networks.

B.2.5.7 Sea water

The corrosive effects of sea water on cement are due to the combined action of sulphate and magnesium ion as described above. The presence of chloride ion reduces the action of sulphates, but has a corrosive effect on steel.

Whilst sea water has relatively little effect on submerged cement, attack in tidal zones can be severe.

B.2.6 Fatty and oily solutions

Depending on their viscosity and thus their ability to penetrate through mortar, fats and oils can cause damage through saponification.

B.2.7 Aggressive gaseous solutions

Gases may contain organic and mineral acids, which form aggressive solutions when the temperature falls under the dew-point.

Hydrogen sulphide (H_2S), particularly in wastewater networks can oxidise to sulphur which is converted by bacterial action to sulphuric acid. Hydrogen Sulphide is considered to be aggressive at a concentration of over 5 mg/l.

In the presence of water, carbon dioxide tends to carbonate cement, increasing its resistance to chemical corrosion. However carbonation contributes to depassivation of the cement matrix by lowering the pH close to the steel tube which allows expansive rust to form.

B.2.8 Abrasive waters

Cement mortar linings can be attacked by the water transported through the pipes. This can result in faults due to sanding which are to be expected especially when operating faults, while releasing the water from the pipes, are made, or in the case of strong turbulence in the region of the bends and especially when sending a pig through the pipes. In addition, over a period of time, the thickness of the cement mortar lining is eroded away by quite a considerable amount.

B.3 Dominant mechanisms relative to the type of water

The dominant mechanisms relative to the type of water can be summarised as in Table B.2.

Table B 2 — Dominant mechanisms relative to the type of water

	Pipelines for water intended for human consumption	Pipelines for waste water	Pipelines for salt, saline and sea water
Soft water	X	X	
Acidic water	X	X	
Alkaline water		X	
Water rich in magnesium		X	X
Water rich in sulphates		X	X
Water rich in nitrates		X	X
Water rich in chlorides		X	X
Water rich in sulphides		X	X
Sea water, Salt Water		X	X
Fatty and oily solutions		X	
Aggressive gaseous solutions	X	X	
NOTE The “X” denotes that this dominant mechanism is applicable.			

B.4 Application areas for cement mortar linings

B.4.1 The areas of application for the different transport media resulting from operating experience, field experiments and laboratory investigations are as described in Table B.3. Since in addition to the chemical composition of the water, the stationary and dynamic operating conditions have an effect of which the full extent is not yet known, this information is to be used for guidance purposes only.

Table B 3 — Overview of the areas of application

Water	Cement mortar types				
	CEM I CEM III A	CEM I-HS CEM III B	CEM CAC	-L (liquifier)	-R (resin dispersion)
Demineralised water	-	-	-	-	-
Soft water $CaCO_3$ < 55 mg/l	+	+	+	+	+
Water according to the Drinking Water Directive	+	+	-	+ [b]	+ [b c]
Raw water	+ [a]	+ [a]	+	+ [a]	+
Acidic chalk dissolving water	-	-	+	-	+
Alkaline water	+	+	+	+	+
Acidic water rich in magnesium and sulphate	-	-	+	(+)	+
Saline water rich in magnesium and sulphate	-	-	+	(+)	+
Water rich in sulphate	-	(+)	+	(-)	+
Alkaline saline water rich in chloride	+	+	+	+	+
Sea water	+	+	+	+	+
Waste water	-	(+)	+	(+)	+

NOTE + Suitable.
- Not suitable.
( ) with limitations.

[a] Suitable in the absence of chalk dissolving acids.

[b] To be used with pipes according to special agreements and only within specified limits.

[c] Only to be used with fittings and as repair mortar.

B.4.2 With the exception in the case of use in salt water and saline water, there is no large difference in resistance between the cement mortar types CEM I (Portland cement) and CEM III (Blast furnace cement). In salt water and saline water, cement mortar with cement CEM III may be advantageous.

B.4.3 Cement mortar types CM CAC have an especially high resistance to waters that attack concrete. Best results may be obtained by ensuring adequate curing immediately after application of the mortar.

B.4.4 Cement mortar with liquifiers (-L) with small water cement values has a high resistance to crack formation. In addition the resistance can increase especially against very salty concrete attacking waters.

B.4.5 The corrosion resistance of cement mortar types CEN CAC and cement with resin dispersion (-R) against concrete attacking acidic waters is determined according to the following method:

— sample: mortar prisms with a length of at least 2 cm made of fresh mortar or pieces of lining from the pipes with insulated cut and outer surfaces are used as samples. Composition and hardening conditions shall be equivalent operational conditions. The water cement value shall be equivalent to that of the mortar after it has been applied;

— chalk is removed from the samples using an acetate buffer solution with 0.1 mol l^{-1} acetic acid and 0.1 mol l^{-1} sodium acetate. To do this they are placed in the solution at ambient temperature where by the ratio between solution volume in cubic centimetres and sample surface area in squared centimetres should be 5 cm to 10 cm. The solution is renewed twice a week. The experiment takes 6 months;

— subsequently the de-calcified samples are dried in the air until they have reached a constant mass. After drying, the de-calcified upper mortar layer can break up in a mosaic fashion and sand. Loose sand and loose mortar parts are brushed off with a plastic brush. These loose parts and sand are weighed and the result is specified in grams per squared metre in relation to the sample surface.

If the specified area related abrasion volume is not reached, the sample is resistant to corrosion.

Table B 4 — Area related abrasion volume

Mortar type according to Table D.3	Area related abrasion amount g/m^2
CEM …. -R	< 100
CEM CAC without controlled curing	< 300
CEM CAC with controlled curing	< 100

B.4.6 Not all the water types have been included in the above table since the attack mechanism can vary considerably with the type of aggressive agent present.

B.5 Disinfection of drinking water pipes

Disinfection is a point of consideration when putting drinking water lines into operation. The different cement mortar linings may react to the disinfectants in different ways and this aspect should be taken into consideration. Also, the manner in which the disinfection water is to be disposed of shall be considered.

Annex C
(normative)

Wet mortar analysis

C.1 General

This annex describes the methods of calculation and analyses of the mixture ratio.

When organic or mineral additives are used, the nature and quantity of these materials shall be taken into account.

C.2 Sampling

When the wet mortar sample is taken, care shall be taken that a representative cross-section of the cement mortar compound is taken from across the whole cross-section of the cement mortar lining.

About 300 g of wet mortar is taken for the sample. This wet mortar sample is mixed well, so that two part samples of about 100 g (M_2) and 200 g (M_1), with the same compound for the analytical determination of the moisture ratio *S*/*C* can be obtained.

C.3 Method of calculation

The main components of wet mortar are sand, cement and water. Should any reagents, aggregates and synthetic materials be present for modification of the mortar they will not be determined in the wet mortar but calculated together with the cement part.

The ratio of the mortar *S*/*C* and the water cement ratio of the mortar *W*/*C* are calculated according to equations (C1) and (C2).

$$S/C = \frac{S_1/M_1}{1 - S_1/M_1 - W_2/M_2} \quad \text{(C1)}$$

$$W/C = \frac{W_2/M_2}{1 - S_1/M_1 - W_2/M_2} \quad \text{(C2)}$$

The following is applicable here:

S_1 Mass of sand in the wet mortar of mass M_1. The method of determination is described in C.4.

W_2 Mass of water in the wet mortar of mass M_2. The method of determination is described in C.5.

C.4 Determination of the mass of sand in the total mass

Given : M_1 mortar sample of about 200 g.

To be determined : ratio S_1/M_1.

Immediately after the sample has been taken and weighed (M_1) in a 2 000 ml beaker, the wet mortar is spread on and passed through a wire sieve according to ISO 3310-1 with a mesh size equivalent to *w* = 0,09 mm.

The sandy residue remaining on the sieve is then rinsed into a porcelain dish and treated with 20 ml to 30 ml of concentrated HCl. The residue is then poured onto the sieve again and rinsed with running water until the drain-off water is running acid free. Finally, the residue is dried in a drying cupboard at 105 °C until mass constancy is achieved.

Weighing: S_1.

The result S_1 is to be corrected using the numerical result of the blank test that occurs as a result of the fine and the lime contents of the sand.

C.5 Determination of the water part of the mass

Given: M_2 mortar sample of about 100 g.

To be determined: ratio W_2/M_2.

The water mass difference between the wet mortar sample taken and the dried mortar sample shall be determined. Scales and a hotplate with a sufficiently large-heated-surface area needed for the test.

The wet mortar sample is spread evenly over the pre-heated hotplate. The sample is dried quickly, whilst being stirred continuously, until no further formation of lumps can be observed. After cooling the sample is weighed once again. The mass loss determined corresponds to the water mass W_2.

Annex D
(normative)

Saponification resistance of organic concrete additives

D.1 General

This annex describes the method of determining the saponification resistance of organic concrete additives.

D.2 Sampling

Take a sample of organic additive with a mass of 5 g and mix it in 10 g of water.

The sample is adjusted to a pH value of 7,0 and 50 ml sodium hydroxide solution c(NaOH) = 0,1 mol.l^{-1} is added. This mixture is maintained at 60 °C for 48 h.

D.3 Method of testing

The sample is back titrated potentiometrically with hydrochloric acid c(HCl) = 0,1 mol.l^{-1} to pH = 7,0. The amount of hydrochloric acid used c(HCl) = 0,1 mol.l^{-1} given in ml is a measure of resistance to saponification.

Annex E
(informative)

Inspection

E.1 General

Inspection operations should be carried out by the coater as agreed at the time of enquiry and order. A representative appointed by the purchaser may witness these operations.

E.2 Document

The results of these inspection operations should be recorded by the coater and made available to the representative of the purchaser.

The coater should issue an inspection document assessing that the delivery conditions are according to the specification of the order.

E.3 Sampling

The purchaser's representative or the coater's inspection representative should select the tubes on which the specified tests should be carried out.

Mortar samples should be marked in order to be fully identifiable.

E.4 Nature and frequency of testing and control

The nature and the minimum frequency of the testing and control should conform to Table E.1.

Table E.1 — Nature and frequency of testing and control

Properties	Paragraph	Method of test	Minimum production control
Surface condition before lining	7.1	Visual	Each tube or fitting
Lining application conditions	7.4	--	Continuously
S/*C* and *W*/*C* ratio	8.2	Annex C	Once per week
Determination of the mechanical properties of the mortar	8.3	EN 196-1	Once per month
Cut back at the ends	7.4.3	Annex A	By agreement
Thickness on hardened lining	8.5.3	--	4 per shift

E.5 Retests

E.5.1 Test results which are unsatisfactory and not attributable to the quality of the coating could result:

— either from a defective sampling of the test piece;

— or from defective assembling or abnormal operation of the testing machine.

In such cases, the test should be disregarded and repeated.

E.5.2 During production control tests, if the results of one or more tests are incorrect or inadequate, the following steps should be taken:

— the tubes which are deemed defective should be taken back by the coater;

— the test that failed should be repeated on the 2 tubes before and after the tube that failed.

If the results from both tubes are satisfactory, the coating should be considered as acceptable. If not, the coating should be considered as unacceptable.

If the coating is rejected, the coater should recoat tubes and components according to a procedure approved by all parties and present the recoated tube or components for acceptance again.

Bibliography

[1] EN 10224, *Non-alloy steel tubes and steel fittings for the conveyance of aqueous liquids including water for human consumption — Technical delivery conditions.*

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