CEOCOR
COMITE D'ETUDE DE LA CORROSION
ET DE LA PROTECTION DES CANALISATIONS

COATING SELECTION CRITERIA FOR CAST IRON PIPES

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SECTOR C, MATERIALS
GT2 COATINGS

CONTENTS

COATING SELECTION CRITERIA FOR CAST IRON PIPES

1 AIMS

This guide is intended for use by anyone who uses cast iron pipes, operators or specifiers, to allow selection of the correct coating protection (type of use, cost, ease of application, ease of use) of cast iron pipes, joints and cast iron accessories for protection against mechanical and/or corrosive action :

a) From external sources (soil, atmosphere, water..)
b) From the transported fluid (potable water, waste water, raw water, gas)

2 SCOPE

The internal and external coatings that are the subject of this recommendation can be applied to cast iron pipelines (pipes, fittings and accessories) :

- For the transport and distribution of potable water or for irrigation
- For the distribution of gas
- For sewerage or removal of waste water

Installed in buried networks, above ground or inside buildings.

3 REFERENCES

3.1 STANDARDS

The general standards for pipes and joints in cast iron (application, material type, thickness and mechanical properties, pressure rating and water tightness, joints..) are given in four european standards :

- EN 545 Ductile iron pipes, fittings, accessories and their joints for water pipelines. Requirements and test methods.December 1994
- EN 969 Ductile iron pipes, fittings, accessories and their joints for gas pipelines. Requirements and test methods. December 1995
- EN 598 Ductile iron pipes, fittings, accessories and their joints for sewerage pipelines. Requirements and test methods.December 1994
- prEN 877 Cast iron pipes and fittings, their joints and accessories for the evacuation of water from buildings. Requirements, test methods and quality assurance. February 1998

These europeans standards are applicable, without amendment, in all the EEC and EFTA countries, where they are enforced as national standards.

Other than standards the main references that relate more specifically to coatings are :

- International standards :
  - ISO 4179 Ductile iron pipes for pressure and non-pressure pipelines. Centrifugal cement mortar lining. General requirements.
  - ISO 8179 Ductile iron pipes. External zinc coating
    Part 1 : Metallic zinc with finishing layer. 1995
    Part 2 : Zinc rich paint with finishing layer. 1995
  - ISO 8180 Ductile iron pipes. Polyethylene sleeving. 1985

- Draft european standards:
  - pr EN 12 501-1 Protection of metallic materials against corrosion. Corrosion likelihood in soil. Part 1 General.
  - pr EN 12 501-2 Protection of metallic materials against corrosion. Corrosion likelihood in soil. Part 2 Low-alloyed and non-alloyed ferrous materials.
  - pr EN 50 162 Protection against corrosion by stray current from direct current systems
  - pr EN xxx Ductile iron pipes, fittings and accessories. External coatings for pipes in highly agressive soils (WI 00203017 of CEN/TC203)
  - pr EN xxx Ductile iron pipes, fittings and accessories. Epoxy coatings for fittings and accessories (WI 00203018 of CEN/TC203)

- Existing national European standards:
  - DIN 30674 Coating of ductile iron pipes
    Part 1 : Polyethylene coating. 1982
    Part 2 : Cement mortar coatings. 1992
    Part 3 : Zinc coating with protective covering. 1982
    Part 4 : Bitumen coating. 1983
    Part 5 : Polyethylene sleeving. 1985
  - NF A 48851 Tuyaux en fonte à graphite sphéroïdal pour canalisation avec pression. Revêtement extérieur en polyuréthanne. 1985
  - BS 6076 Polymeric film for use as a protective sleeving for buried iron pipes and fittings (for site and factory application). 1996
  - DIN 3475 Korrosionsschutz durch Innenemaillierung. 1993
  - DIN 3476 Korrosionsschutz durch EP-Innenbeschichtung aus Pulverlack bzw. Flüssiglacken. 1996

- Existing CEOCOR recommendations:
  - Recommandations pour le revêtement intérieur en mortier de ciment des conduites métalliques neuves en acier et en fonte. Trib. Cebedeau N°461 1982
  - Recommandations pour le revêtement interne des canalisations en fonte ductile et en acier au moyen de résines thermodurcissables. Trib. Cebedeau N°493 1984

3.2 REGULATORY DOCUMENTS

Council Directive 98/83/CEE of the European Communities on the quality of water intended for human consumption, 3 november 1998

3.3 BIBLIOGRAPHY

1) M. PARIS " Zinc based coating for protecting gray and ductile iron pipes against corrosion "
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2) R. MARCHAL " Protection of buried ductile iron pipelines with a zinc based coating : healing power and coating damages ", 4ème Conf. Int. Sur la protection intérieure et extérieure des tuyaux. Sept 1981 – BHRA
3) M. LANGENFELD " La protection externe des canalisations en fonte ductile : expérience acquise sur le revêtement zinc ". Juin 1984. Journées d'Etude de l'ANSEAU.
4) DIPRA " Test site report : zinc clad pipe studies of 1979, with bituminous overcoating ".
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6) W. WOLF and M. LANGENFELD. " Technologie-Report über duktile Gussrohre mit Zinkspritzüberzug und Deckbeschichtung " FGR 21, 1986, pp 36-43.
7) MILLER. " Durability of cement mortar linings in cast iron pipes ", Journal AWWA, juin 1965
8) POURBAIX. " Atlas of electrochemical equilibria in aqueous solutions ". Pergamon Press, Oxford 1966
9) P.SOUKATCHOFF. " Etude de résistance à l'eau douce de quelques ciments " Matériaux et Constructions (RILEM), n°104, mars-avril 1985
10) P.SOUKATCHOFF. " Résistance des mortiers aux eaux agressives " TSM-L'EAU Avril 1990, pages 197 à 201
11) J.M.HOFMANN. " Zinc coatings for the external protection of ductile iron water mains ". PHD thesis, UMIST. April 1990.
12) " Guide de protection des canalisations d'eau et de gaz " Editions Techniques & Documentation Lavoisier. 1987

4 DIFFERENT TYPES OF COATINGS

Nowadays cast iron pipes are routinely coated. The coatings used are :

a) " standard " coatings, used in the majority of cases

b) " special " coatings, used instead of the " standard " coatings when the internal or external corrosion conditions are severe.

Table 1 gives a list of the main external coatings used for cast iron pipes.

Note : It should be noted that cathodic protection is not normally used on buried cast iron pipes. This is because of the electrical discontinuity at joints and accessories caused by the rubber gasket. Unlike buried structures that are electrically continuous (steel pipelines with welded joints) cast iron pipelines do not create macro cells of great extent (several tens to several hundred metres, or possibly kilometres) against which cathodic protection is indispensable. Metallic zinc coatings provide protection against mini and macro galvanic cells of limited extent.[12] *It is also because of the electrical discontinuity of cast iron pipes that they are less susceptible to the effects of stray currents (in the vicinity of d.c. traction systems such as trams and railways, or in the vicinity of other cathodic protection systems)*

Tables 2 and 3 show respectively the list of interior coatings for pipes and fittings.

TABLE 1. **EXTERNAL COATING OF BURIED, IMMERSED OR ABOVE GROUND PIPES**

Coatings	Constitution	Minimum thickness
NORMAL CONDITIONS (" standard " coating)		
Zinc + seal coat	A metallic layer A bituminous or epoxy coating	130 g/m2 70 microns
CORROSIVE CONDITIONS (" special " coatings)		
Zinc + seal coat **+ polyethylene sleeve**	A metallic layer A coating of paint A film	130 g/m2 70 microns 200 microns
Polyethylene	An extruded layer on a thermofusible adhesive	1,8 mm (DN ≤ 100) 2,0 mm (DN ≤ 250) 2,2 mm (DN ≤ 450) 2,5 mm (DN ≤ 700) 3,0 mm (DN > 700)
Polyurethane	A spray coating on a shot blasted surface	700 microns
Zinc +adhesive **+ fibre cement**	A metallic layer A brushed layer A sprayed layer	130 g/m2 0,1 mm 4,0 mm (DN ≤ 300) 5,0 mm (DN ≤ 600) 6,0 mm (DN > 600)
Plastic anti-corrosion tape	One layer with a 50% overlap	1,6 mm
INSIDE BUILDINGS		
Undercoat of acrylic or glycerophtalic	A spray coating	30 microns

TABLE 2. **INTERNAL COATING OF PIPES**

Coatings	Constitution	Minimum thickness
POTABLE WATER (" standard " coating)		
BFC (1) **or OPC** (2) **Cement mortar**	A layer either spray or centrifugally applied	2 mm (DN≤ 300) 3 mm (DN ≤ 600) 3.5 mm (DN ≤ 1200) 6 mm (DN ≤ 2000)
SEWERAGE (" standard " coating)		
High Alumina Cement mortar lining	A layer either spray or centrifugally applied	2 mm (DN≤ 300) 3 mm (DN ≤ 600) 3.5 mm (DN ≤ 1200) 6 mm (DN ≤ 2000)
DRAIN AND SOIL PIPES		
Epoxy Coating	A spray coating	50 microns
GAS		
Bituminous coating	A spray coating	50 microns
AGGRESSIVE POTABLE WATER (" special " coating) (3)		
High Alumina Cement mortar lining	A layer either spray or centrifugally applied	2 mm (DN≤ 300) 3 mm (DN ≤ 600) 3.5 mm (DN ≤ 1200) 6 mm (DN ≤ 2000)
Cement mortar + seal coat (4)	See above + a spray coat	See above + 100 microns
CORROSIVE EFFLUENT (" special " coating)		
Polyurethane	A layer on a shot blasted surface	1,5 mm
Liquid epoxy	A layer on a shot blasted surface	250 microns

(1) Blast furnace cement
(2) Ordinary Portland cement
(3) Aggressive water : water that attacks limestone. Corrosive water : water that attacks iron
(4) Semi-permeable bituminous or epoxy coatings

TABLE 3. **COATING OF FITTINGS AND ACCESSORIES**

Coating	Constitution	Minimum thickness
POTABLE WATER OR GAS		
Internal and External		
Bituminous coating	Dip or spray process	100 microns
Epoxy coating	An electrostatically applied layer	70 microns
Exclusively Internal		
Cement mortar	Spray by turbine	3 mm
Enamel	Application then heating	150 microns
SEWERAGE or CORROSIVE ENVIRONMENTS		
Internal and External		
Epoxy powder	Spray or liquid bed	250 microns
Liquid epoxy	Spray	150 microns
SOIL and DRAIN		
Internal and External		
Fusion bonded epoxy	Spray or liquid bed	150 microns
Epoxy coating	An electrostatically applied layer	70 microns

5 MAIN CHARACTERISTICS OF " STANDARD " COATING

5.1 External zinc coating :

External zinc coatings are normally specified and used for cast iron pipes. The protection mechanism is described in the Annexe 1.
The zinc coating is always coated with a seal coat, which usually consists of a layer of bitumen or epoxy paint, the paint thickness should not be less than 70 microns.
Zinc coating provides effective protection against corrosion in soils, with the following exceptions :

- soils with low resistivity (less than 1500 or 2500 ohm.cm)
- acid soils (pH less than 5.5 to 6)
- areas of stray current influence
- polluted ground, or ground containing industrial waste (coal, slag)

5.2 Internal coating of cement mortar

Cement mortar linings are usually specified and used in cast iron pipes carrying potable water or domestic effluent. The protection mechanism is described in the Annexe.

The limitations of cement mortar linings are as follows :

a) in potable water

Cement mortar linings are generally used with potable water that conforms with the EU drinking water directive, which states that water intended for human consumption must not be aggressive or corrosive. In practice this water must be of average mineralisation (hardness of at least 8 French degrees, i.e. 32 mg/l of calcium), close to the pH equilibrium (within 0.2 pH units) and moderately conductive (conductivity less than 400 µS/cm) in order to take into account the presence of metallic materials with no -or poor- coatings in the networks. The use of mortar cement may be limited when :

- the water is exceptionally soft and aggressive and remains in the pipe for long periods. The durability and corrosion prevention qualities of the coating are not in question, as demonstrated by long term testing. But this transported water in contact with the cement mortar lining tends to recover its equilibrium, thus showing an undesirable pH increase.
- the mineral content of the water must not change during the course of its passage through the pipe. In practice there are always exchanges of mineral salts between the cement mortar and the water.

b) in waste water

In general terms the regulations prohibit effluent in public networks where the pH is less than 5 and whose temperature is greater than 35°C. High alumina cement, whose resistance lies within a band of pH4 to pH12 inclusive (peaks up to pH 3.5) is therefore suitable. These limits can be reached :

- when the waste is of a special composition (industrial waste). An examination for each case is required.
- when septic fermentation conditions exist in a sewer, which, by a bacterial process, leads to the generation of hydrogen sulphide and then sulphuric acid. These conditions, which are hazardous in general terms, can be the consequence of original waste water system design mistakes (time the effluent is in the pipeline, lack of aeration, stagnation) and are located at specific places in the network (at the outlets of pressurised pipe sections, for example).

6 COMPARISON BETWEEN DIFFERENT COATING TYPES

Tables 4 and 5 provide a qualitative comparison of internal and external coatings for cast iron pipes.

The tables should be used with care :

- Only qualitative assessments have been used in the tables. The reference documents should be consulted for detailed specifications for the coatings.
- The characteristics of the coating to be considered may change depending on the conditions of use. It is necessary, in each case, to analyse the requirements in order to select the most important characteristics for the particular application. The optimum coating selected for a given condition is not necessarily the one with the best total score from the table.
- The performance of different coatings, for a certain application, cannot always be directly compared, or measured in the same way. For example, the resistance to impact damage for an active coating (e.g. zinc externally and cement internally) cannot be measured in the same way as for a passive coating (polyethylene or epoxy) by verifying the absence of porosity after the impact of a given intensity.
- The scale of values provided in tables 4 and 5, which uses 4 levels is arbitrary. It represents the general opinion of the experts who have produced this document.

TABLE 4– **COMPARISON OF EXTERNAL COATINGS FOR BURIED CAST IRON PIPES**

CHARACTERISTICS	PIPES						FITTINGS		
	Zinc	Zinc + MPE (1)	Polyethylene	Polyurethane	Fiber Cement	Anti corrosive tape	Bitumen Paint	Epoxy Paint	Epoxy Powder
Mechanical									
- Impact	++	+	+	+	++	+	+	+	+
- Puncturing	++	-	+	+	++	+	+	+	+
- Adherence	+	-	+	++	++	-/+	+	+	-
Installation									
- Cutting and jointing(2)	+++	+	+	++	+	+	NS	NS	NS
- Connections	+++	+	++	++	+	+	NS	NS	NS
- Pipe bed (buried)	++	-	+	+	+++	-	+	+	+
- Storage / Transport	++	-	+	+	++	-/+	+	+	+
Anticorrosion									
- $\rho > 2500\ \Omega.cm$	+	+	++	++	+	++	+	+	++
- $1500 < \rho < 2500\ \Omega.cm$	-	+	+	+	+	+	-	-/+	+
- $\rho < 1500\ \Omega.cm$	-	-	+	+	+	+	-	-	
- polluted ground	-	-/+	++	++	+	+	-	-/+	++
- stray currents	-	-/+	++	++	-	++	-	-	++
- macro cells (3)	++	++	++	++	++	++	-	+	++
Temperature (°C)									
- Cold (Tmin)storage	- 30	- 20	- 20	- 20	- 20	- 20	- 30	- 30	- 20
- Hot (Tmax)service	+ 50	+ 50	+ 50	+ 60	+ 50	+ 40	+ 30	+ 40	+ 60

(1) Polyethylene sleeve
(2) Jointing after cutting
(3) Risk of corrosion concentrated at coating defects

Coating suitability
- - : insufficient
- + : sufficient
- ++ : superior
- +++ : excellent
- NS : not applicable

TABLE 5 – COMPARISON OF INTERNAL COATINGS OF CAST IRON PIPES

CHARACTERISTICS	PIPES						FITTINGS	
	Bitumen Paint	Cement Mortar OPC (1)	Cement Mortar BFC (2)	Cement Mortar HAC (3)	Cement Mortar +S.C. (4)	Polyurethane	Epoxy Powder Paint (5)	Epoxy Powder
Mechanical								
- Impacts	+	++	++	++	++	+	+	+
- Adherence	+	+	+	+	+	++	+	++
Installation								
- Cutting	+	+	+	+	+	+	NS	NS
- Connections	+	+	+	+	+	+	NS	NS
- Storage/transport	++	+++	+++	+++	++	+	+	+
Raw or potable water								
- Potability(6)	-	+	+	-/+	- (7)	-/+	+	+
- Aggressive water (8)	-/+ (9)	-	-/+	+	+	++	++	++
Treated water								
- Public effluent	-	+	+	++	+	++	+	++
- Industrial effluent	-	-	-	-/+ (10)	-	+	-	+
- Abrasion	-	+	+	++	-	++	-	+
- Septic fermentation	-	-	-	-/+ (10)	-	++	-	++
Temperatures (°C)								
- Cold (T min) storage	- 30	- 30	- 30	- 30	- 30	- 20	- 30	- 20
- Hot (T max) service	+ 40	+ 60	+ 60	+ 60	+ 40	+ 50	+ 40	+ 60

(1) Ordinary Portland Cement
(2) Blast Furnace Cement
(3) High Alumina Cement
(4) seal coat
(5)Potable or raw water : 70 microns
Sewerage : 50 microns

(6) Compatibility with drinking water, according to national regulations
(7) only if epoxy or acrylic seal coat
(8) Hardness < 8°F
(9) according to water corrosivity
(10) limited to pH 4 continuously

Coating suitability : NS : not applicable
- : insufficient + : sufficient
++ : superior +++ : excellent

ANNEXES

Protection mechanism of the external zinc coating

Protection mechanism of the internal cement mortar lining

EXTERNAL ZINC COATING

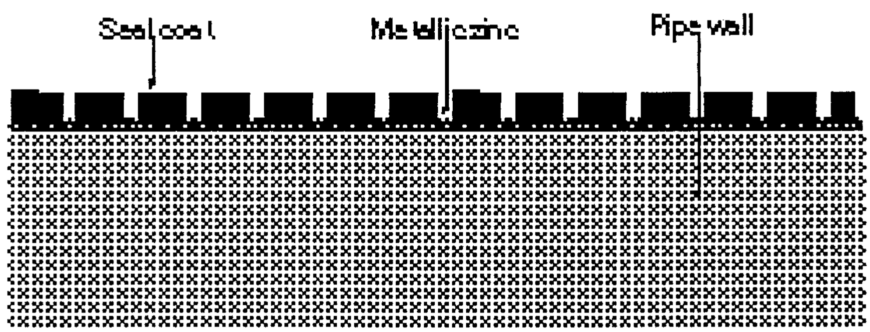
This coating is specified for buried ductile iron pipes by EN545, EN598 and EN969 (Chapter 442) for, respectively, water, sewerage and gas pipelines. It is also specified by ISO8179.

History

Zinc coatings were perfected in the fifties, mainly by long-term laboratory and field testing. They were first introduced in Europe on grey iron pipes in 1958. Today it is provided by all the European pipe producers and also offered by the Japanese, American and Indian manufacturers.

Constitution

The figure below shows the constitution of the coating.



The zinc is factory applied to a clean and dry pipe surface, usually just after the ferritisation heat treatment of the pipe. The zinc coating is generally applied by the technique of electric arc guns, in other words the molten metal is sprayed on the pipe after an electric arc is drawn between two zinc wires. Other techniques can be used to obtain an equivalent coating : flame spray, spray of molten zinc from a bath.

The minimum specified thickness for the zinc coating is 130 g/m² on the surface. However, several manufacturers offer 200 gm/² as a standard.

The zinc coating is always coated with a bituminous or epoxy seal coat, the thickness of which should not be less than 70 microns. This coating serves two functions :

- for corrosion prevention it controls the activity of the zinc and allows the formation of a stable layer of complex zinc salts
- it provides the pipe with a finished appearance, in particular the colour (as a rule black for potable water and gas, red for waste water)

Notes:

- the application of zinc by galvanization is not state of the art for ductile iron pipes
- ISO 8179 also permits the use of a zinc rich paint (not less than 85% of zinc by mass) whose binder is organic (epoxy) or mineral (silicate), as an alternative to metallic zinc.

Protection Mechanism

The external zinc coating is an " active " type of protection, as opposed to " barrier " coatings, which isolate the iron from the ground.

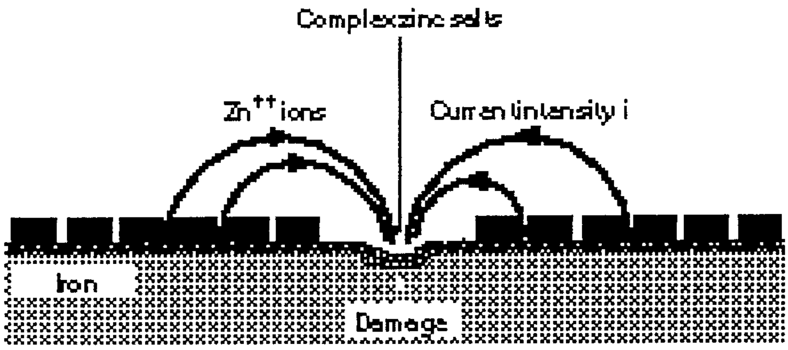
The protection mechanism has been studied in the laboratory and in field trials and has been covered in several publications (1) (2) (3) (4) (5) (6) (11)

Two mechanisms are in operation :

- The formation of a stable protection layer on the surface of the pipe, which is the result of the slow transformation of zinc into complex zinc salts (oxides, carbonates, oxychlors) in contact with the soil. These salts are insoluble and the layer, when it is well formed, is dense, impermeable, and adheres to the surface.

- The healing of coating defects. One of the unique principles of zinc coatings is the ability to protect adjacent coating damage (caused by impact or transportation). This is due to the galvanic action of the zinc, which enables the coating defect (small area) to become cathodic to the pipe surface, preventing the development of anrapid local corrosion.

The figure below illustrates the corrosion protection mechanism



Additional protection using a polyethylene sleeve

A correctly applied polyethylene sleeve will extend the areas where zinc coating can be used. The sleeve provides a confined area around the pipe which prevents renewal of the ground water and hence limits its corrosive action. It removes, by virtue of its position between the zinc and the earth, the effects of inhomegenous soils, which in turn makes the zinc less vulnerable to geological macro elements or to differential aeration corrosion cells. Finally, the sleeve is adequate for deflecting stray currents, except in areas of steep potential gradients (see prEN 50162), and ensures that the pipeline is not the lowest electrical resistance path.

The effectiveness of this addition to the zinc coating depends entirely upon the quality of application (usually on the contractor who installs it). It is particularly important that the polyethylene sleeve is in good contact with the pipe, and that the ends are properly sealed (pipe to pipe and joint to joint) to avoid circulating water between the pipe and the sleeve and also pockets of soil or water.

INTERNAL CEMENT MORTAR LINING

This coating is specified by EN545 (chapter 442) and EN598 (chapter 443), also by ISO 4179.

For potable water the standards specify that the main cement are of the Portland type (OPC), or containing large amounts of slag (Blast Furnace Cement : BFC). For public waste water the standards specify the use of High Alumina Cement (HAC).

Background

The first references to the use of cement mortar linings are found in the United States in 1920.

It is generally applied on potable water iron pipes built since the 1950s, replacing the conventional " black "coatings .

Constitution

Cement mortars are made up from clean sand, potable water, and cement. They are applied in the pipes by two types of process :

a/ the centrifugal method, which enables a high mechanical compaction and the removal of excess water
b/ the spray method, where the mortar (usually with a higher cement content) is applied by a turbine rotating inside the pipe.

After application the mortar is cured in a controlled atmosphere (temperature, humidity) long enough to achieve the required resistance.

Protection mechanism

The cement mortar lining is porous and functions like an " active " protection. It neutralises the potential aggressivity of the water that penetrates it by changing its pH value to between 11 and 13, before it makes contact with the iron pipe. For such high values of pH, the iron is located in a passive region of the pH-potential diagram where it is passivated . Passivation is when the iron is covered with a thin and stable oxide film which prevents corrosion (8).