Commission 1

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Ductile iron pipes with cement mortar coating according EN 15542

Mr Steffen Ertelt – Dipl.-Ing. (FH) – Head of Applications Engineering

Duktus Rohrsysteme Wetzlar GmbH, Sophienstr. 52 – 54, 35576 Wetzlar, Germany

Abstract

Since 1978 the first pipes made of ductile iron with a cement mortar coating have been delivered. There was not a standard for the cement mortar coating at that stage. It was only in November 1982 that the draft version of DIN 30674-2 [1] – “Cement mortar coating for ductile iron pipes; requirements and testing” appeared. The definitive version was issued in July 1984. At that stage of development, a zinc coating was not applied below the cement mortar coating (ZMU) because it was not clear at that point whether the alkaline ZMU was compatible with a zinc coating. From the early 80’s, a zinc coating was applied before the pipes were coated with cement mortar.
This paper presents the results of excavations carried out to examine the pipe conditions of pipes with cement mortar coating after three decades with and without zinc coating.

1.) Zinc coating with cement mortar coating (ZMU) to EN 15542

The field of use of coatings of this type is defined in Annex D.2 of EN 545 [2] and is described in detail in section 3 of this paper.
The external protection for pipes formed by a zinc coating (providing active protection for the pipes) plus a plastic-modified cement mortar coating to EN 15542 [3] (Figs. 1 and 2) has proved highly satisfactory when there have been external mechanical loads of the kind which may occur in direct installation in coarse-grained native soils of grain sizes up to 100 mm. The fibres admixed in the cement mortar and the open-weave polyethylene bandage makes the cement mortar coating extremely resistant to mechanical stress. This is why pipes with this external protection are also being used for trenchless installation.

Figs. 1 and 2: Ductile iron pipes with a zinc coating and a cement mortar coating to EN 15542, to EN 545 (blue) for drinking water and to EN 598 (reddish-brown)

2.) The self-healing process produced by a zinc coating

a. Until the pipes are installed, the finishing layer protects the zinc against the effects of the weather. In the pores in the finishing layer (epoxy, bitumen or a cement mortar coating), reactions of the zinc with rainwater and with carbon dioxide in the air, produce zinc carbonates which seal off the pores. Once the pipes have been installed in the ground, in time and by a process whose progress is slow the zinc converts into a dense, firmly adhering, impermeable, crystalline layer of insoluble compounds consisting mainly of zinc oxides, hydrates and zinc salts [4].

b. If damage occurs to the surface of a pipe and if the ductile iron surface of the pipe is exposed, this surface is protected by a protective electrochemical action produced by zinc. The exposed surface of the ductile iron pipe becomes the small cathode and the zinc-coated surface of the pipe becomes the anode, which is of a large surface area. Zinc goes into a solution, is transported by an ion flow to the damaged surface of the pipe and forms a covering layer composed of products of reaction of zinc. This produces fresh and durable corrosion protection at the point of the damage [4],[5].

3.) Bedding of ductile iron pipes in the pipeline zone

The fields of use and bedding criteria for ductile iron pipes depend on the particular external protection the pipes have and are laid down in Annex D of EN 545 [2] and in Germany in the domestic standards DIN 30675-2 [6] and DVGW Arbeitsblatt W 400-2 [7].

Ductile iron pipes having external protection based on a zinc coating with a cement mortar coating to EN 15542 [3] can be installed directly in soils of aggressiveness class III without an anode backfill and without any further investigation [see Fig. 3].

Under DIN 50929 part 3 [8], the meanings of soil aggressiveness classes I, II and III are as follows:

- Soil class I;
  - I a – not aggressive
  - I b – of low aggressiveness

- Soil class II
  - II – aggressive

- Soil class III
  - III – of high aggressiveness

Table 14.1:
Fields of use for underground pipelines of ductile iron with coatings to EN 14628 [14.3], EN 15189 [14.4], EN 15542 [14.6], DIN 30674-3 [14.9] and -5 [14.10], EN 14901 [14.5], DIN 51178 [14.14] in conjunction with DIN 30675-2 [14.8] for pipes, and EN 14901 [14.5] and DIN 51178 [14.14] for fittings and valves.

No.	Coating on pipes	Thickness of coating	Coating recommended for joints	Suitable bedding for corrosion protection	Fields of use in the form of soil classes
1	Zinc coating with finishing layer (cover coating), to DIN 30674-3 [14.9]	130 g/m² of zinc with finishing layer to EN 545 [14.1]	None	Not provided Provided	I, II I, II, III [2]
2	Zinc coating with finishing layer, to ÖNORM B 2560 [14.11]	200 g/m² of zinc with ≥ 100 µm polyurethane finishing layer	None	Not provided Provided	I, II I, II, III [2]
3	Cement mortar coating to EN 15542 [14.6]	5.0 mm	Heat-shrinkable material or B-50M[1] coating to DIN 30672 [14.12] or rubber collars	Not provided	I, II, III
4	Polyethylene coating to EN 14628 [14.3]	1.8 to 3.0 mm	Heat-shrinkable material or B-50M[1] coating to DIN 30672 [14.12]	Not provided	I, II, III
5	Polyurethane coating to EN 15189 [14.4]	≥ 700 µm	None	Not provided	I, II, III
6	Polyethylene sleeving to DIN 30674-5 [14.10] in conjunction with DIN 30674-3 [14.9]	0.2 mm	Same as pipes	Provided[3]	I, II, III

[1] At sustained temperatures of T ≤ 330 °C, the B-50M coating to DIN 30672 [14.12] or the C-30M coating to DIN 30672 [14.12] may be used for joints.
[2] Not suitable when there is constant exposure to eluates of pH < 6 and in peaty, boggy, muddy and marshy soils
[3] The directions given in section 4.1 need to be followed.
Note: By agreement, materials for corrosion protection covered by DIN 30672 Part 1 [14.12] may be used for coating ductile iron pipes away from the joints

Fig. 3: Table 14.1 – Taken from the FGR/EADIPS E-Book of 07/2011

The maximum grain sizes of the pipe bedding materials used in the pipeline zone, as a function of the nature of the external coating, are defined for cement mortar coated pipes as follows in DVGW Arbeitsblatt W 400-2 [7]:

- zinc coating with cement mortar coating to EN 15542
  - round-grained material: 0 – 63 mm (individual grains up to a max. of 100 mm)
  - fragmented material: 0 – 63 mm (individual grains up to a max. of 100 mm)

The greatest potential for the economical installation of pipes is offered by the external protection formed by a zinc coating plus a cement mortar coating. The reason for this is its ability to withstand high mechanical loads and the resulting possibility of re-using native soils of grain sizes up to 100 mm for the bedding for the pipes. The economy comes not only from the avoidance of any need for suitable pipe bedding material to be brought in, but because the excess spoil excavated from the trench in the pipeline zone does not have to be transported away and possibly deposited on a dump.

The coating types formed by a zinc or zinc-aluminium coating with a finishing layer and a zinc coating with a cement mortar coating are classified as active

coatings and in the event of any unwanted damage to the external protection of pipes in the course of transport and/or installation, they have a self-healing action [5] produced by the zinc coating applied.

4.) Examination of pipes after three decades in operation

Users often ask how well the ZMU stands up in practice. These questions prompted test digs to be made on the pipelines laid using the first ductile iron pipes with ZMU in order to check on the coatings. Three sections of pipeline were examined. Pits were dug to expose the pipelines at each of these points.
A window was cut out of the ZMU. The surfaces of the pipes were checked, and samples of the respective native soils and the bedding materials used were examined under DIN 50929-3 [8].

a) Heilbronn, Böllinger Höfe, Wannenäckerstr.

- DN 400 ductile iron potable water pipes to DIN 28600 [9] and DIN 28610 [10] with a cement mortar coating (ZMU) to DIN 30674-2 [1]
- Year of installation: 1985

A pipe having been exposed, its ZMU showed itself to be firmly adhering, undamaged and in a good as new state (Fig. 4). The exposed surface of the pipe had a zinc coating and an epoxy bonding layer (Fig. 5). No evidence was found of any corrosive attack. The native soil was examined under DIN 50929-3 [8]. The result was a rating figure of 0 points corresponding to soil class I (not aggressive). With a rating figure of –3, the embedding material resting directly against the pipe was of soil class Ib (of low aggressiveness). In this part of the route, the pipeline had been installed in not aggressive or slightly aggressive native soil. The native soil had been used as an embedding material.

After a period of 25 years in use, the state of the pipeline at the test dig was found to be as good as new. A technical operating life of 100 to 140 years will certainly be achieved.

Fig. 4 Excavation – exposed ZMU

Fig. 5 Zinc coating with epoxy bonding layer

b) Heilbronn, Böllinger Höfe district, lengthened part of Grundäckerstrasse

- DN 500 ductile iron drinking water pipes to DIN 28600 [11] and DIN 28610 [12] with a cement mortar coating (ZMU)
- The pipeline was installed in 1979 in an anode backfill (a bedding of neutral sand).

The pipeline having been exposed (Fig. 6), its ZMU showed itself to be firmly adhering, undamaged and in a good as new state. The exposed surface of the pipe did not have a zinc coating at that time but did have an epoxy bonding layer. No evidence was found of any corrosive attack (Fig. 7). In this part of the route, the pipeline had been installed in not aggressive or slightly aggressive native soil with chemically neutral sand as an anode backfill (Fig. 6).

After a period of 32 years in use, the state of the pipeline at the test dig was found to be as good as new. The assumed technical operating life of 100 to 140 years will certainly be achieved.

Fig. 6 Excavation – exposed ZMU

Fig. 7 Epoxy bonding layer without zinc

c) Zweckverband Mittelhessiche Wasserwerke ZMW supply utility, connection to Gladenbach, Lohra section

- DN 300 ductile iron drinking water pipes to DIN 28600 [11] and DIN 28610 [12] with a cement mortar coating (ZMU)
- Year of installation: 1978/1979

The DN 300 ductile iron pipeline having been exposed (Fig. 8), its ZMU showed itself to be firmly adhering, undamaged and in a good as new state. The exposed surface of the pipe had an epoxy bonding layer but not a zinc coating; no evidence was found of any corrosive attack (Fig. 9). In this part of the route, the pipeline had been installed in highly aggressive native soil. The embedding material used had been the native soil or, in the region of the bottom of the pipe, gravel (Fig. 10). The pipeline was also below the water table in this part of the route. The vertical inhomogeneity (gravel at the bottom of the pipe, corrosive cohesive soil as backfill at the sides and over the top of the pipe) resulted in differential aeration cells (corrosion cells) forming.

Although the conditions encountered at installation had been highly adverse, no evidence was found of any external attack after a period in use of 32 years. A technical operating life of 100 to 140 years will certainly be achieved.

Fig. 8 Excavation – exposed ZMU

Fig. 9 Epoxy bonding layer without zinc

Fig. 10 Embedding in highly aggressive soil

5.) Summary

At all three of the points checked, the pipelines were found to be in an impeccable, good as new, state. At all of these points the ductile iron pipes had been installed under different soil conditions. The properties of ductile iron as a material do not change and the coatings were examined so it is safe to say that the whole of the pipes examined are still as good as new even after being in operation for three decades. The main results are listed in Table 1 (Fig. 11). [13]

Table 1:
Overview of the results of test digs made for the projects:
Assessments of the state of the ZM-U on the ductile iron pipes exposed and of their surfaces

Test dig	Project 1	Project 2	Project 3
Town	Heilbronn	Heilbronn	Gladenbach
Street	Wannenäckerstrasse	Lengthened part of Grundäckerstrasse	Lohra section
Year of installation	1985	1979	1978/1979
DN nominal size	400	500	300
Soil along the route			
B_o/class	0/Ia	–5/II	–11/III
Nature	Not aggressive	Aggressive	Highly aggressive
Soil in contact			
B_o/class	–3/Ib	8/Ia	–11/III (gravel only at bottom of pipe)
Nature	Of low aggressiveness	Not aggressive	Highly aggressive
Heterogeneity	No	No	Yes
Ground water	No	No	Yes
Results of examination of pipe			
Exterior of ZM-U	Not attacked	Not attacked	Not attacked
Adhesion	Good	Good	Good
Surface of metal	Not attacked	Not attacked	Not attacked

Fig. 11: Table 1 – Overview of the results

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