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A STUDY OF THE COMPOSITION OF CEMENT MORTAR LINING IN WATER AND SEWAGE PIPELINES

SPRAWDZENIE SKŁADU POWŁOKI CEMENTOWEJ W RURACH WODOCIĄGOWYCH I KANALIZACYJNYCH

Abstract

Cementation of iron water and sewage pipes is a standard procedure that is used to ensure internal protection against corrosion. In order to reduce leaching of chemical elements from coating to water, the neutral impact of cement coating on the water is of major importance. In the present study, the elemental composition of the cement mortar lining, taken from the new cast iron pipes with a diameter of 100 and 150 mm, has been investigated. A reference sample was made from Portland cement. Studies using scanning electron microscopy revealed an increased contents of titanium in the sewage pipes coating and also aluminum and alkali in water pipe coatings.

Keywords: ductile iron pipe, blast furnace cement, Portland cement, centrifugal lining, energy dispersive spectroscopy

Streszczenie

Cementowanie żeliwnych przewodów wodociągowych i kanalizacyjnych jest standardowym zabiegiem stosowanym w celu zapewnienia wewnętrznej ochrony przewodów przed korozją. W celu ograniczenia stopnia ługowania zanieczyszczeń z wykładziny do wody szczególne ważne jest, aby powłoka zachowywała się neutralnie w stosunku do wody, z którą ma kontakt. W obecnej pracy zbadano skład pierwiastkowy powłok cementowych pobranych z nowych rur żeliwnych o średnicy 100 i 150 mm. Próbkę porównawczą wykonano z cementu portlandzkiego. Badania z użyciem skaningowego mikroskopu elektronowego ujawniły podwyższoną zawartość tytanu w powłokach w przewodach kanalizacyjnych oraz glinu i alkaliów w powłokach w rurach wodociągowych.

Słowa kluczowe: rury żeliwne, cement hutniczy, cement portlandzki, cementowanie wirowe, spektrometria dyspersji energii

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1. Introduction

Ductile iron pipes used in water and wastewater are supplied as standard with cement-mortar lining [1–4]. The function of cement-mortar lining is to reduce the susceptibility to corrosion and the frictional resistance of pipelines. Cement coating must meet a number of standard requirements [3, 4] for example, have the appropriate thickness, cracks width, compression resistance. Due to the quality of drinking water and coating durability, numerous studies are devoted to the investigation of chemical elements leaching from coating to water [5–7].

Recently [8], more attention has been paid to the structural characterization of factory cement coatings. In contrast to the cement-mortar applied on construction site, they exhibit not only better density, but also a gradient distribution of the components across the coating thickness. The mortar is poured into pipe spinning with high rotation velocity. This causes separation of the coarse concrete components on the wall of the pipe and on the coating surface – solidification of dense and very smooth layer consisting of cement laitance. Because the cement binder is a critical component of the concrete, it can be expected that under the same operation conditions of cemented iron pipes, changes of technological properties of cement coating will be different for a homogeneous and layered structure.

Regardless of whether the concrete mixture was applied on the new iron pipes, or the renovation of old pipes was performed, the corrosion resistance of coating is determined by the type of cement used and the tightness and strength of hardened concrete (properties varying considerably over time) [9]. For factory cement lining of iron water pipes, the blast furnace cement is used, as its chemical and mineral composition have a smaller impact on the quality of tap water than Portland cement mortar [7]. The wastewater pipes are used with alumina cement mortar lining, which has better resistance to fermentation tanks and certain acids, as well as increased wear resistance under normal flow conditions [10]. The use of aluminous cement for water pipes is not recommended, as it may cause a dangerous increase in the concentration of alumina dissolved in water [5–7].

The aim of this study was to investigate the chemical composition of the coating cement for water pipes supplied by different manufacturers and compare the results with studies lining for a typical sewer pipe.

2. Experimental method

The materials for the study consisted of three cast iron pipes from different suppliers, lined with standard cement mortar coating. The collected samples were determined as follows: *E* and *S* – coating of water pipes with a diameter 150 mm, *B* – a coating of sewer pipe with a diameter 100 mm. Macroscopic inspection included visual inspection of the appearance and colour of the lining surface (Fig. 1) and measurement of coating thickness using a micrometer screw (Table 1). It was assumed, that the comparative test will be made with Portland cement. The sample M was taken from the pipes, which are part of the laboratory equipment, as described in Ref. [6]. Concrete mix was prepared from cement CEM I 42.5R and fine sand in relation 1:1 with the addition of water, which guaranteed water-cement ratio $w/c = 0.3$. The coating was applied manually in the laboratory, hence the lack of segregation of components in its cross section.

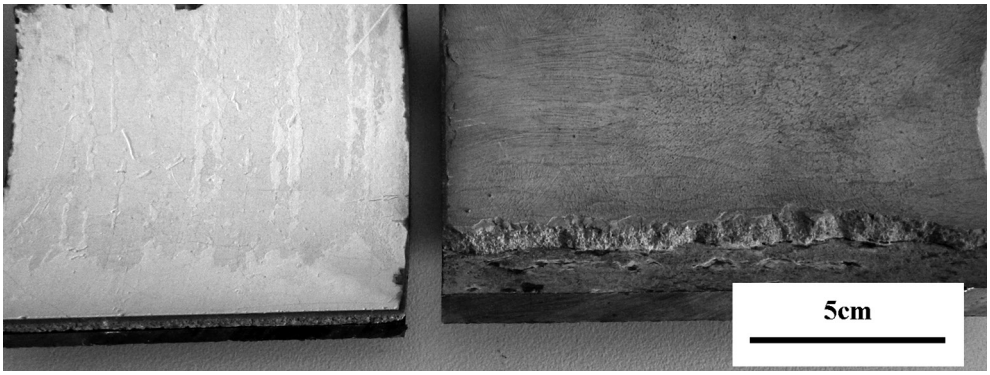


Fig. 1. Image of the factory cement lining: specimens S (on the left) and B (on the right)

Table 1

Dimensions of investigated material: DN – nominal pipe diameter; G_1 – lining thickness; G_2 – laitance thickness

Specimen	DN	G_1, mm	G_2, mm
M	–	6.0	–
E	150	8.2	1.8
S	150	5.3	2.0
B	100	5.0	1.4

The chemical composition of the surface of the cement-mortar lining has been analyzed using a scanning electron microscope HITACHI S-3400N, equipped with an energy dispersive X-ray spectrometer (EDS) manufactured by *ThermoScientific*. Microscope mode is variable vacuum, allowing to test the natural state of surface of an electrically non-conductive specimen. A single area of analysis was 2.5 × 1.5 mm. A similar study was carried out for the comparative coating *M*.

3. Results and discussion

For various cements based on Portland cement clinker, the difference in the composition of the upper layer of the cement coating surface has been expected, due to differences in the composition and the respective proportions of clinker minerals, undergoing binding and hardening. Table 1 shows that the estimated thickness of the cement laitance (G_2) does not depend on the overall thickness of the coating (G_1). Microscopic photographs of the Surface coating (Figs. 2–5) disclosed qualitatively different characteristics: open porosity (*M* and *S*), small cracks (*E* and *S*) and roughness (*M* and *B*). On the Surface of the sample *E* showing a part of the slag, which confirms the use of cement of CEM III class. For comparison only of the Surface of the sample – the typical spectrum is given in the next picture to the structure from Fig. 2 to Fig. 5. More particularly, for spin-coating applied, it is the cement laitance.

Comparative coating *M* matured in different natural conditions than factory-allied, but according to the literature [11, 12], should show typical composition of clinker: 62–68% CaO, 18-25% SiO_2, 4–8% Al_2O_3, 2–4% Fe_2O_3, 0.5–0.6% MgO, 0.8–3.0% SO_3, 0.4–3.0% N_2O+K_2O. For Portland cement, hydrated silicates, aluminates and ferrites calcium proceeds to form ettringite-like compounds, portlandite (called "slaked lime"), and tobermorite silicate phase (gel substance with high fineness) [9]. It is known that, in contrast to Portland cements (*M*), blast furnace cement contain less lime, more silica and generally more alumina [9]. The calculation of the composition of the oxide phase in Portland cement clinker is pointless here, since the analysis of coatings was carried out by semi-quantitative method – the results are compared in Table 2.

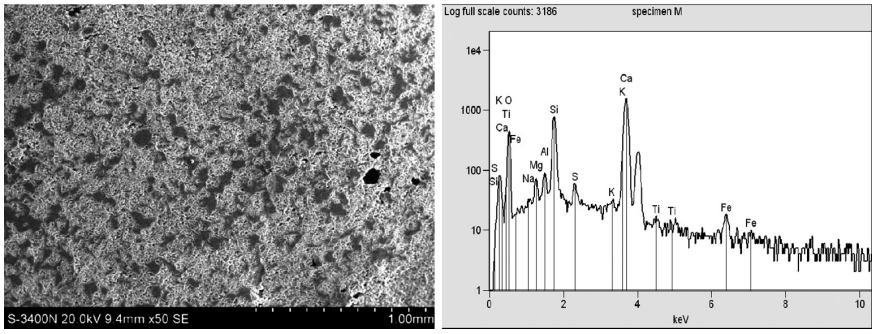


Fig. 2. Surface analysis of a reference Portland cement lining (specimen M)

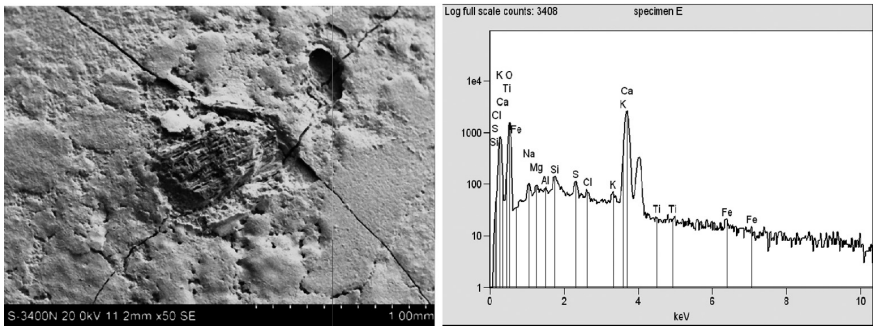


Fig. 3. Surface analysis of a cement-mortar lining from water supply pipe (specimen E)

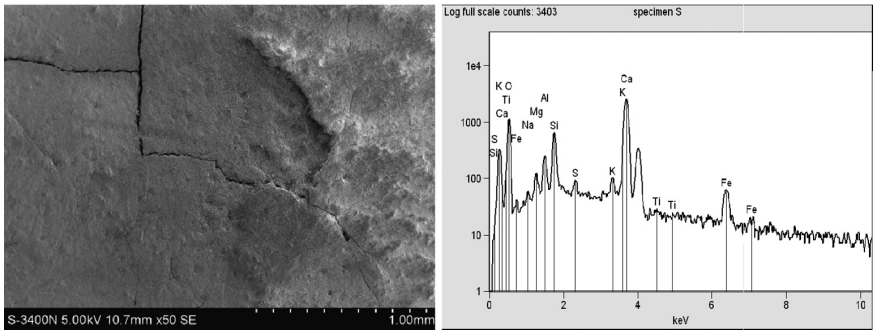


Fig. 4. Surface analysis of a cement-mortar lining from water supply pipe (specimen S)

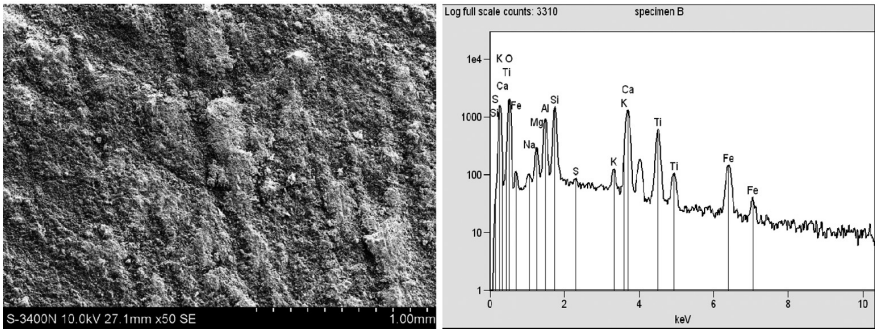


Fig. 5. Surface analysis of a cement-mortar lining from sewage pipe (specimen B)

Table 2

Results of quantitative EDS analysis of cement-mortar lining surface

Specimen	Elemental composition [weight %]										
	Ca	*Si*	*Al*	*Fe*	*Ti*	*Mg*	*Na*	*K*	*S*	*Cl*	*O*
M	32.0	9.5	0.8	0.8	0.2	0.7	0.2	0.1	0.6	0.0	55.1
E	26.8	1.3	0.5	0.5	0.0	0.4	0.8	0.5	0.6	0.2	68.2
S	27.6	4.2	1.7	1.6	0.1	0.8	0.3	0.5	0.3	0.0	63.0
B	10.7	7.5	4.9	2.9	7.4	1.5	0.7	0.5	0.1	0.0	63.7

The results for water pipe linings showed that specimen (*S*) contains more silica and iron-aluminate than the specimen (*E*); the linings have also different content of magnesium, sodium and sulfur. The composition of cement lining (*B*) shows a large amount of aluminate phases, higher concentration of Mg and, above all, the presence of Ti in quantities equal to Si. According to [13] titanium dioxide is „self-cleaning" on concrete surfaces, neutralizes organic compounds and prevents the emergence of fungi and lichen on the air.

4. Conclusions

The composition of the various cement-mortar linings applied internally to ductile iron pipes has been examined by means of scanning electron microscope. It was found by comparative method that:

– Centrifugally lined in a factory cement-mortar linings have a significantly lower open porosity and better surface smoothness, than those applied by projection method (on site, in the lab), through macroscopic separation of the cement-laitance layer;
– Sewerage coating is different from water coating not only in color and absence of cracks; in addition to higher aluminum content, a high concentration was measured for titanium, which in the form of nanooxide acts as a photo catalyst in special concretes;

– Factory cement-mortar lining of water pipes exhibit several-fold differences in aluminum and iron content. In both specimens chromium and lead were not detected;
– In contrast to Portland cement, the factory coatings exhibited higher alkaline content.

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