

# STUDIES AND RESEARCH WORK ON THE REINFORCEMENT STEEL AND CONCRETE SURFACE CORROSION PROTECTION METHODS

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**Abstract.** Methods for reinforcement steel corrosion protection and concrete surface protection are analyzed. Knowing the corrosion process mechanism reinforcement steel can be protected by different protection methods even in the presence of crevices larger than those anticipated by design. The selection of the corrosion protection method depends on the reduction level of the reinforcement steel corrosion which in its turn is determined by the atmospheric conditions.

The selection of the accelerated corrosion test conditions was made revealing the mechanism of the processes that take place at the steel reinforcement surface under natural weathering conditions. Crevices ranging from 0.05mm to 1.00mm or larger were opened by bending reinforced concrete girders on special equipment and were maintained all over the period of the corrosion resistance study.

## Introduction

Long-term service life of reinforcement steel in concrete without any damage is possible if limiting the opening of the crevices. Knowing the corrosion mechanism, in certain cases reinforcement steel can be protected in the presence of crevices larger than those predicted by design (Astrova, 1987).

In principle, the following corrosion protection solutions can be applied:

1. Isolation of the reinforced concrete sections using synthetic elastic coatings;
2. Inhibiting the penetration by depolarisers of the protection layers in concrete;

3. Enhancing the concrete ohms resistance
4. Application of the cathodic protection.
5. The selection of the corrosion protection method depends on the reduction level of the reinforcement steel corrosion process, which in its turn is determined by the atmospheric conditions.

The size of the crevices during the concrete structure service life is not a constant value, as it varies depending on the loads, the dynamic actions, temperature variation, concrete contraction and creeping, reinforcement strain relief, etc. Under

such conditions, the application of creep-resistant coatings (paints and varnishes) is of great importance (Kariakina *et al.*, 1985).

In recent years, wear-resistant thiokol and chlorosulphonated polyethylene paints and varnishes are more and more often used. Elastomer-based varnishes and dyes with different filling materials (chalk and brick powder, Portland cement, etc.) (Rusu *et al.*, 1995) are also applied.

### Experimental Results. Interpretations

In order to investigate the action of the protection coatings on the reinforcement steel behaviour in the crevices of the reinforced concrete structures a number of specimens (10 × 10 × 100 cm beams with two PC 52 Ø 12 mm reinforcing bars with fragile (epoxy resins-based) and elastic (thiokol-based) coatings were prepared. The specimens were placed in HCl and

SO<sub>2</sub> environments (Table 1).

The accelerated corrosion test conditions were selected in order to point out the mechanism of the processes evolving at the surface of the reinforcement steel in atmospheric conditions. The time span of the accelerated corrosion tests, depending on the environment aggressiveness, ranged between 1 and 6 months.

Crevices, ranging from 0.05mm to 1mm or larger, were made by bending beams using special equipment and were maintained all over the investigation period of the reinforcement steel corrosion resistance.

Maintaining the reinforced concrete specimens under constant tensile stresses makes the experimental conditions similar to the *in-situ* service life conditions of the buildings subject to different loads in corrosive environments.

**Table 1.** The specimens were placed in HCl and SO<sub>2</sub> environments

Aggressive environment and exposure time	Protective coating type	Reinforcement steel's corrosion state	
		Corrosion depth	Corrosion spread
HCl = 0.1 mg/l; W = 70%, 6 months.	Vinyl- thiokol coating resistant to fracture	0	0
	Epoxy resin non-resistant to fracture	From 0.35 mm deep to reinforcing steel bar fracture	Where the size of the crevices was 0.3mm, rust extended to 40-80mm
	No coating	From 0.64mm deep to reinforcing steel bar fracture	All over the reinforcing bar surface
SO <sub>2</sub> , 3 months.	Vinyl-thiokol coating resistant to fracture	0	0
	Epoxy resin non-resistant to fracture	0.2 - 0.8 mm deep	Where the size of the crevices was 0.15mm - 20- 30mm deep; 0.3mm - rust spread over 40-45mm
	No coating	In the crevice area 0.6 - 0.9mm deep, in other segments up to 0.2mm deep	All over the reinforcing bar surface

This condition is particularly important, as according to the theory of the steel corrosion in the crevices of the reinforced concrete (Verbečki, 1985), the variation of the reinforcement steel tensile stress, along the crevice segment, favours the corrosion process

The application of surface hydrophobization of the porous concrete specimens indicates deep penetration of the silica-organic compounds into micropores and micro-crevices. The walls of the pores and crevices impregnate with thin hydrophobic films. Following this process, the air and vapour permeability of the material changes a little, accompanied by significantly increased ohms resistance of the hydrophobic layer, simultaneously with the decrease of the water absorption by the materials.

It can be assumed that under such conditions, the action of the macro-galvanic peers slows down and corrosion is determined by the galvanic micro-

peers only. A comparison of the reinforcement steel anodic polarization in the cracked concrete, before and after hydrophobization, indicates an almost complete isolation of the reinforcement steel anode sectors in the area of the crevices (Fig. 1).

It follows that the hydrophobization of the reinforced concrete elements surface provides a good reinforcement steel protection under normal atmospheric conditions and periodical wetness.

The reinforcement steel corrosion in the concrete crevices is the result of its passive state change under the action of the corrosion activators. Under normal atmospheric conditions, the major depassivation agent is carbon dioxide that binds with calcium hydroxide. In order to protect the reinforcement steel against corrosion, corrosion inhibitors that do not interact with the air compounds are used, ensuring passivation of the reinforcement steel in concrete.

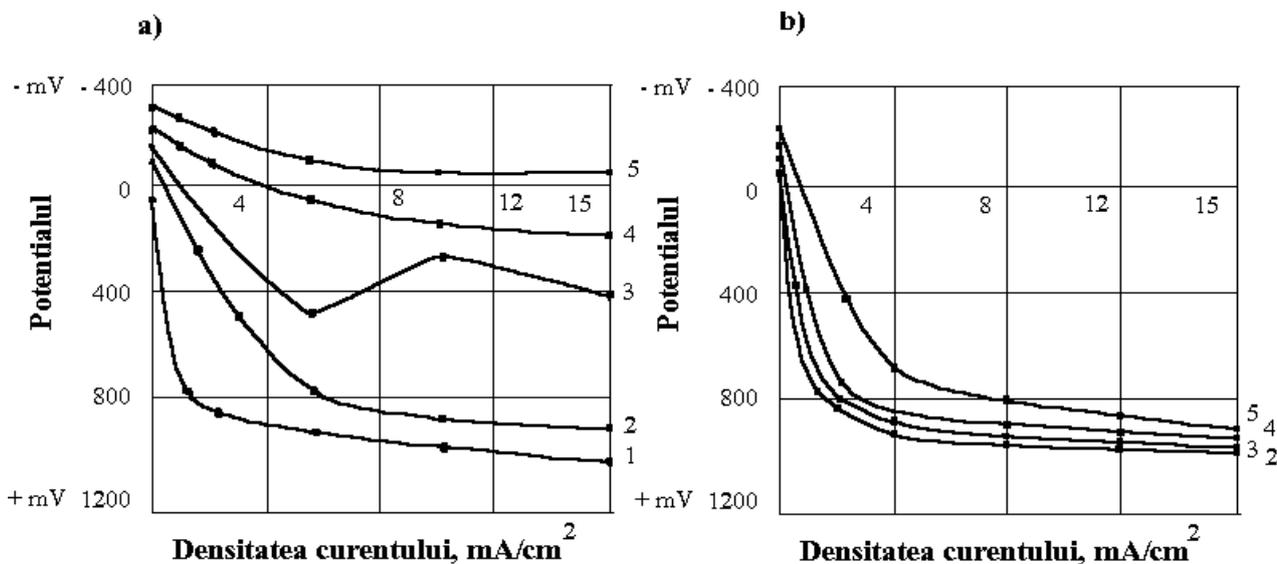


Fig. 1. Reinforcement steel anodic polarization curves in the concrete with crevices: a) – before hydrophobization; b) – after hydrophobization; 1 – no crevices; 2-5 – the crevice size varying between 0.1; 0.2; 0.5 and 1mm.

Such corrosion inhibitors as  $\text{CaOCl}_2$ , NaOH, superplasticiser C-3 (Rusu I. *et al.*, 1995), sodium nitride ( $\text{NaNO}_2$ ), organic substances, or natrium benzoate are mixed in the concrete in order to slow down the reinforcement steel corrosion. Other products including different superplasticisers are used to form a zinc carbonate layer (passivation) on the concrete steel (Rusu *et al.*, 1995), as well as different additives in the concrete under the form of aggregates that do not react chemically with the steel (Croitoru *et al.*, 1987).

The results of the electrochemical research are confirmed by the corrosion tests performed on the reinforced concrete elements with crevices (Fig. 2). The impact of the corrosion process inhibition in the reinforcement steel with crevices when corrosion inhibitors are used in concrete needs a long time investigation as there are data that attest the stoppage of their action in time even in the crevice-free concrete (Batracov, 1988).

Another method applied to avoid the penetration of the protective layer in the concrete by corrosion agents is the optimization of the grain size of the concrete components in order to obtain a concrete structure as compact as possible (Croitoru, 1987).

Reinforcement steel protection with metal and non-metal coatings is obtained by: surface treatments (Croitoru *et al.*, 1995), protection thin films, spatula applied material and thin sheets, corrosion inhibitors, etc.

Highly corrosion-resistant materials that do not need protection are also used.

Currently, thin film coatings are applied for reinforcement steel protection, adapted to the corrosion environment and including: oil- or bitumen-based varnishes and dyes; alkyd resin- or polymerization resin-based varnishes and enamels (co-polymer enamel, perchlorvinyl enamel, etc.), polycondensation resin-based varnishes (epoxy, polyurethane, silicone resins, epoxy resins with mix-in additives which provide high adhesion and chemical resistance, for instance ED-20 epoxy resin (Rusu *et al.*, 1995); emulsified dyes or polymerized resin emulsion-based dyes, etc.

One up-to-date and currently used method is zinc coating and dyeing. The role of the successive zinc coating of the metal support and dyeing of the deposited zinc coating is twofold:

- protection of the metal surface against corrosion
- protection of the porous zinc coating against oxidation.

For instance, in order to enhance the corrosion resistance of the profiled zinc coated steel sheets, epoxy resin thin films, consisting of perchlorvinyl resins or vinyl chloride-vinyl acetate co-polymers were applied. They impregnate the zinc porous coating, restrict the direct action on it and its penetration by the corrosion agents to the metal surface (Rusu *et al.*, 1994).

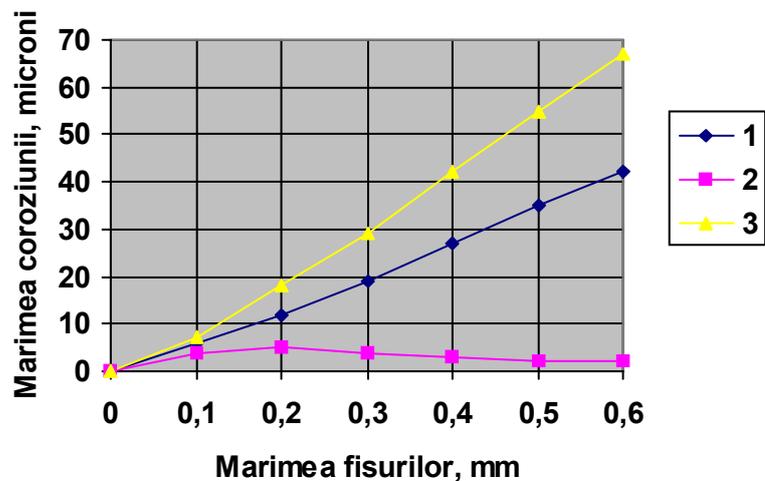


Fig. 2. Reinforcement steel corrosion in the crevice area in the concrete with corrosion inhibitors: 1 – concrete without corrosion inhibitors; 2 – 2% sodium nitrite; 3 – 2% natrium benzoate.

### Conclusions

Hydrophobization of the reinforced concrete elements provides a good protection of the reinforcement steel under normal atmospheric conditions and periodical wetness.

The corrosion of the reinforcement steel in the concrete crevice area is the result of the change in its passive state under the action of the corrosion activators.

Under normal atmospheric conditions, the major depassivation agent is carbon dioxide which binds with calcium hydroxide.

For reinforcement steel and the concrete surface protection corrosion inhibitors, super-plastifiers, varnishes and dyes, surface treatments, different epoxy resins, compaction of the protection layers, which do not interact with the air components, allowing passivation are used.

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