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PROPERTIES OF SURFACE PROTECTION COATINGS FOR CONCRETE BASED ON ACRYLIC AND EPOXY BINDERS

Abstract: Coatings are most frequently used products for concrete surface protection as they produce a continuous protective layer and prevent the ingress of substance that can damage the concrete like water, corrosive salts, vapor, gas chemicals, and biological agents. This paper includes comparison of different types of coating e.g. water-borne acrylic paint, solvent-based acrylic, high solids epoxy and water based epoxy (ECC). Testing of performance characteristics is done according to European standard "EN 1504-2: Surface protection systems for concrete". The results show the properties of each coating, and therewith the advantages and limitations of using a specific type of binder for protective coating formulation.

Key words: *Concrete, acrylic coatings, high solids epoxy, water-based epoxy, EN 1504-2*

PERFORMANSI ZAŠTITNIH PREMZA ZA BETON NA BAZI AKRILATNIH I EPOKSIDNIH VEZIVA

Rezime: Premazi (Coatings) su najčešće primenjivani produkti za površinsku zaštitu betona, koji formiraju kontinuirani zaštitni sloj koji sprečavaju prodor materijala koji mogu da degradiraju/razore beton kao što su voda, agresivne soli, vodena para, gasne hemikalije i biološki agenti. Ovaj trud predstavja poređenje preformansi različitih tipova premaza kao što su akrilati na vodenoj bazi, akrilatina bazi rastvarača, epoksidi i epoksidi na bazi vode (ECC). Testiranje performansi materijala je izvršeno prema Evropskom standardu EN 1504-2 za površinsku zaštitu betona. Rezultati ilustriraju performase svakog premaza, kao i prednosti i ograničenja upotrebe određenog tipa veziva za formuliranje premaza za zaštitu betona.

Ključne reči: *Beton, akrilni premaz, epoksidni premaz,, epoksid na vodenoj bazi, EN 1504-2*

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1. Introduction

Concrete substrates are exposed to mechanical and physical attack as well as chemical aggression which can cause damage and deterioration of the concrete matrix or corrosion of the reinforcement. These processes result in degradation and instability of the concrete structure. As concrete is porous material, carbon dioxide and other gases can diffuse in the capillary pores and dissolve in the pore water to form acidic solutions. They reacts with calcium hydroxide in the cement paste to form calcium carbonate: $CO_2+Ca(OH)_2 =CaCO_3+H_2O$. This reaction, known as carbonation, significantly reduces the pH of the concrete, from strong alkaline 13.0 to less alkaline 9.5. Concrete serves as passive layer for the steel rebar and when its destruction results in corrosion of the reinforcement. [1]

To slow down the process of carbonation the concrete can be protected in several ways, from which coating has been considered as most efficient. Coatings that are applied to concrete to slow down the carbonation process are known as anti-carbonation coatings. Treating the coating with a suitable type of protection coating makes its surface impervious to ingress of adverse agents like liquids, de-icing salts and gas chemicals.

In order to provide sufficient protection any type of coating must fulfill certain criteria. The European standard EN 1504-2 gives the requirements for performance characteristics which have to be met for each and every application.

Table 1- Obligatory performance characteristics for anti-carbonation coatings

Performance characteristics for all intended uses, principle 1.3	Test method	Minimum requirements (EN 1504-2, Table 5)
Permeability to CO_2	EN 1062-6	$S_d > 50$ m (Equivalent air layer thickness)
Permeability to water vapour	EN ISO 7783	Class I: Sd < 5 m Class II: 5 m ≤ Sd ≤ 50 m Class III: Sd > 50 m
Capillary absorption and permeability to water	EN 1062-3	$w < 0.1$ kg/(m^2 $h^{0,5}$)
Adhesion strength by pull-off	EN 1542	- for flexible system with trafficking ≥ 1.5 N/mm^2 - for rigid system with trafficking ≥ 2.0 N/mm^2

The demands for anti-carbonation coatings are high because the concrete structure must be durable and resistant to carbon dioxide, humid environment and various mechanical factors. Anti-carbonation coatings can be formulated with various types of binders, from which acrylics and epoxy play a dominant role. This study illustrates comparison of the performance characteristics of coatings based on these types binder. The results of the study that are reported in this paper show to which extent of carbonation exposure a certain binder provides sufficient protection.

2. Materials and experimental methods

To study of the effect of the binder on the performance properties of the coating, four types of anti-carbonation coatings based on acrylic and epoxy binder were formulated. Acrylic and epoxy binder were used in water-based and solvent-based formulations. All formulations include necessary amount of pigment, fillers, and additives. These ingredients can also affect the final properties to a certain degree. However the binder is the main constituent of every coating's formulation and as such it greatly influences the properties of the coating.

The tested coatings are part of ADING's product range for concrete protection (Antikorozin BB – water-based acrylic, Antikorozin BR – solvent-based acrylic, Adingpoks 1B – 2K epoxy coat and Adingpoks akva - 3K epoxy coat). These materials are certified according to EN 1504-2:2004.

The tests were carried out according to the EN methods given in Table 1. All samples were cured and conditioned prior to testing for 7 days at standard laboratory climate: T=23°C and RH=60%.

2.1 Single-component coating

The single-component coatings were formulated with acrylate copolymer dispersion as water-based coating and with methacrylic resin as solvent-based coating. The binders have very good weathering and UV stability, good water resistance and yellowing resistance. Both coating differ in flexibility and hardness. The water-based coating has density of 1.4 g/cm^3 and film thickness up to 150 µm. The solvent-based coating has density of 1.6 g/cm^3 and film thickness up to 250 µm.

2.2 Two-component coating

The two-component coating is produced on epoxy base using epoxy resin with EEW = 185 and modified polyamine hardener. The density of the material is 1.65 g/cm^3 and film thickness 300 µm.

2.3 Three component coating

The three component epoxy cement coating consist of water based epoxy and a cement-filler compound, with polymer-filler ratio of 25%, which enables formulation of a protective film higher in thickness for e.g. up to 3mm. The water from the epoxy resin serves as hydration medium for the cement, so the final film consists of two solid phases: epoxy and polymer.

3. Results and discussion

3.1 Carbon dioxide permeability

The diffusion coefficient for carbon dioxide shows how many times more resistant a coating is than air under equivalent conditions. The diffusion equivalent air layer thickness in meters is obtained from the product of diffusion coefficient and the dry film thickness of the coating.

The values for the carbon dioxide permeability listed in Table 2 give the main difference of the compared coatings. The higher the value of the equivalent air layer thickness, the greater is the resistance of the coating to carbon dioxide. [2]

Table 2- Permeability of carbon dioxide for anti-carbonation coatings

Coating type	Testing conditions	Minimum requirement	Test result
Water-based acrylic	T = 20°C, RH = 50%	> 50 m	60 m
Solvent-based acrylic			90 m
2K Epoxy coat			210 m
3K Water-based epoxy (ECC)			220 m

The water-based and solvent-based acrylic coatings show lower permeability resistance to carbon dioxide, compared with the epoxy coating and the modified epoxy that show extremely high resistance. The graph shows that coatings based on acrylics can last in environments that are not continuously exposed to high levels of gasses. Epoxy coatings will be durable even in severe conditions.

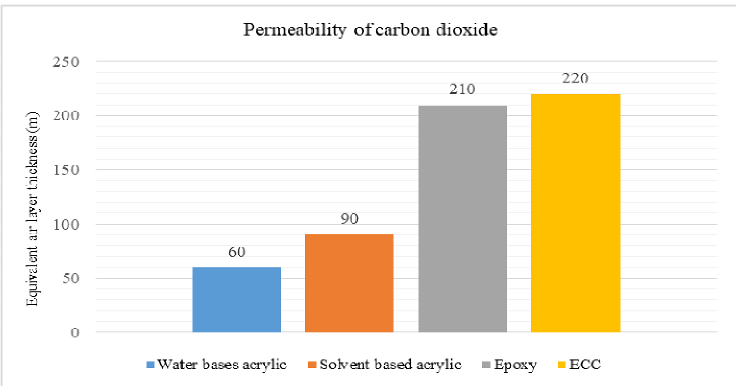

Fig. 1 Test result for carbon dioxide permeability

3.2 Permeability to water vapor

If vapor pressure build up behind the paint film it will cause it to blister. That is way it is preferable for the anti-carbonation coatings to allow free passage of water. Table 3 show that the water-based coating has highest permeability and is least susceptible to damage if exposed to pressure from trapped water. The solvent-based coating belongs also in the class of high permeability. In comparison with the thermoplastic polymer (acrylic polymer) the thermosetting (epoxy polymer) give much denser films which make them tight to water vapor. Nevertheless the tests for adhesion on wet concrete show that they can withstand much higher internal vapor pressure than the acrylic coatings. Even if the epoxy coating has low water vapor permeability, adequate surface preparation will allow the impervious film to be applied without subsequent loss of adhesion [3].

The combination of coating which has high impermeable to aggressive chemicals, and in the same time is permeable to water vapor is difficult to achieve, because in aggressive environments with high concentration of gases or corrosive solutions the paint films must be of lower porosity.

Table 3- Permeability of water vapor for anti-carbonation coatings

Coating type	Testing conditions	Water vapor transmission rate (g/m^2d)	Water vapor diffusion resistance factor μ	Equivalent air layer thickness Sd (m)
Water-based acrylic	T = 20°C, RH = 50%	134	30	0,15
Solvent-based acrylic		140	25	3.5
2K Epoxy coat		25	225	200
3K Water-based epoxy (ECC)		1,3	275	49

Fig. 2 gives a graphic display of the permeability of water vapor of the tested coatings and shows that the porosity and the permeability of the epoxy coat can be modified with the addition of fillers.

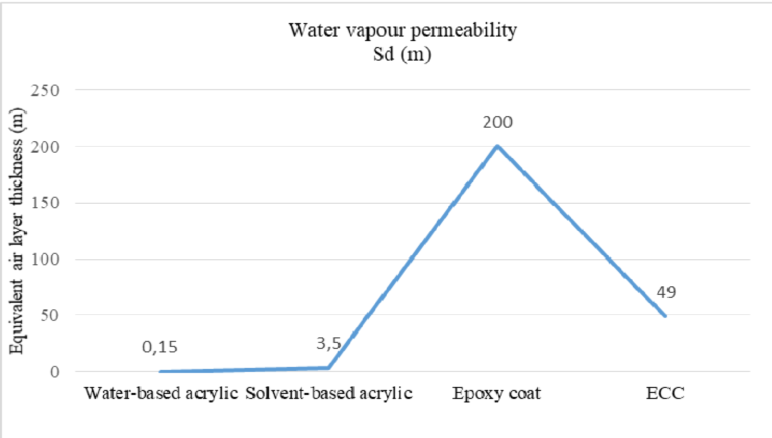

Fig. 2 Test result for carbon dioxide permeability

3.3 Water absorption

For comparison, vapor and water permeability shows that the results for water permeability of the coatings are inversely proportional to the water vapor permeability. In this case the water-based acrylic has higher water absorption, while the epoxy coating is impermeable to water. In spite of that, each tested coating has a water absorption coefficient much lower than the minimum required - so it can be referred and non-permeable to water.

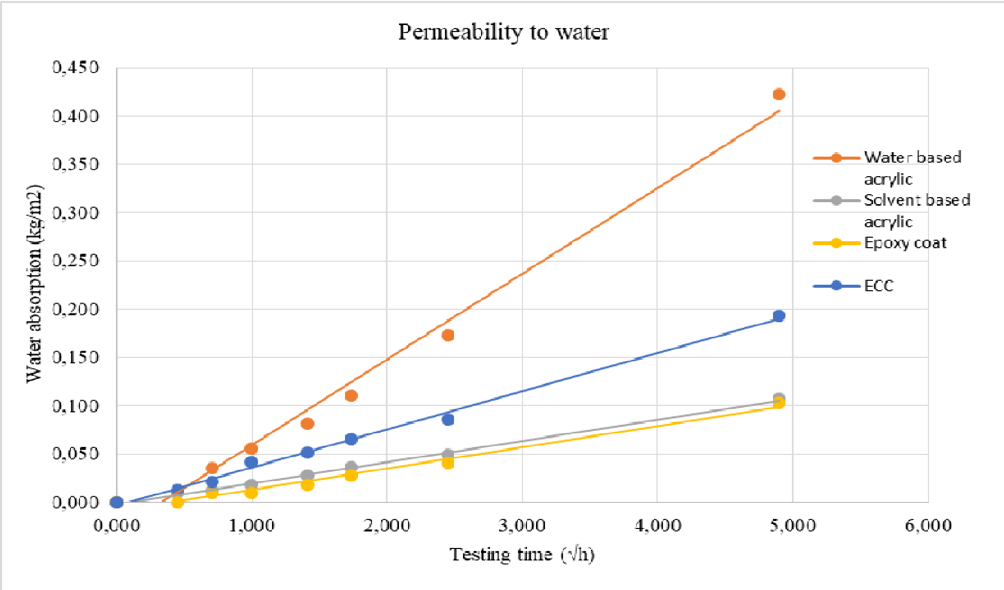

Fig. 3 Test result for water permeability

3.4 Adhesion

The adhesion criterion for the coatings ensures that the protective layer will stay adhered to the concrete despite all the mechanical and chemical influences it will be subjected to.

Table 4- Adhesion testing with pull-off test

Coating type	Testing conditions	Minimum requirement	Test result
Water-based acrylic	T = 20°C, RH = 50%	1,5 N/mm²	3.33 N/mm²
Solvent-based acrylic		2,0 N/mm²	3.75 N/mm²
2K Epoxy coat			3.52 N/mm²
3K Water-based epoxy (ECC)			3.83 N/mm²

The results in Table 4 show that acrylic coatings can be formulated both elastic for crack – bridging properties, and rigid for better impact resistance. The 3K epoxy cement coating has greater adhesion than the acrylic and the two component epoxy because of the high filler content. In the same time due to the polymer amount it has enough elastic strength to withstand movements in the concrete and temperature changes.

Fig. 3 Adhesion strength by pull-off test

4. Conclusion

The results of this study show that the more reactive the binder is (for two-component and three-component coating), the higher and long-lasting protection it will provide. Nevertheless based on the comparative results it follows that both acrylic and epoxy binder, either water and solvent borne, can be formulated in such way that will give sufficient concrete protection.
The tested materials have wide range of applicability and they can be used on variety of surfaces that are exposed to weathering, and are constantly under movement, vibrations and are overloaded like bridges, tunnels and pedestrian lanes.

The epoxy coating have disadvantage in terms of UV instability and restricted for usage in enclosed objects (e.g. tunnels). However, the 3K epoxy modified coating can be top-coated with another coating type which will provide long durability of the overall system. It also it can be applied on damp surface, before completed concrete curing. On the other hand for more flexible construction subjected to crack formation the acrylic coatings would be a better choice because they have bigger elasticity and crack bridging properties.

Reference objects

Acrylic-based coating
ANTIKOROZIN-BB

5. References

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