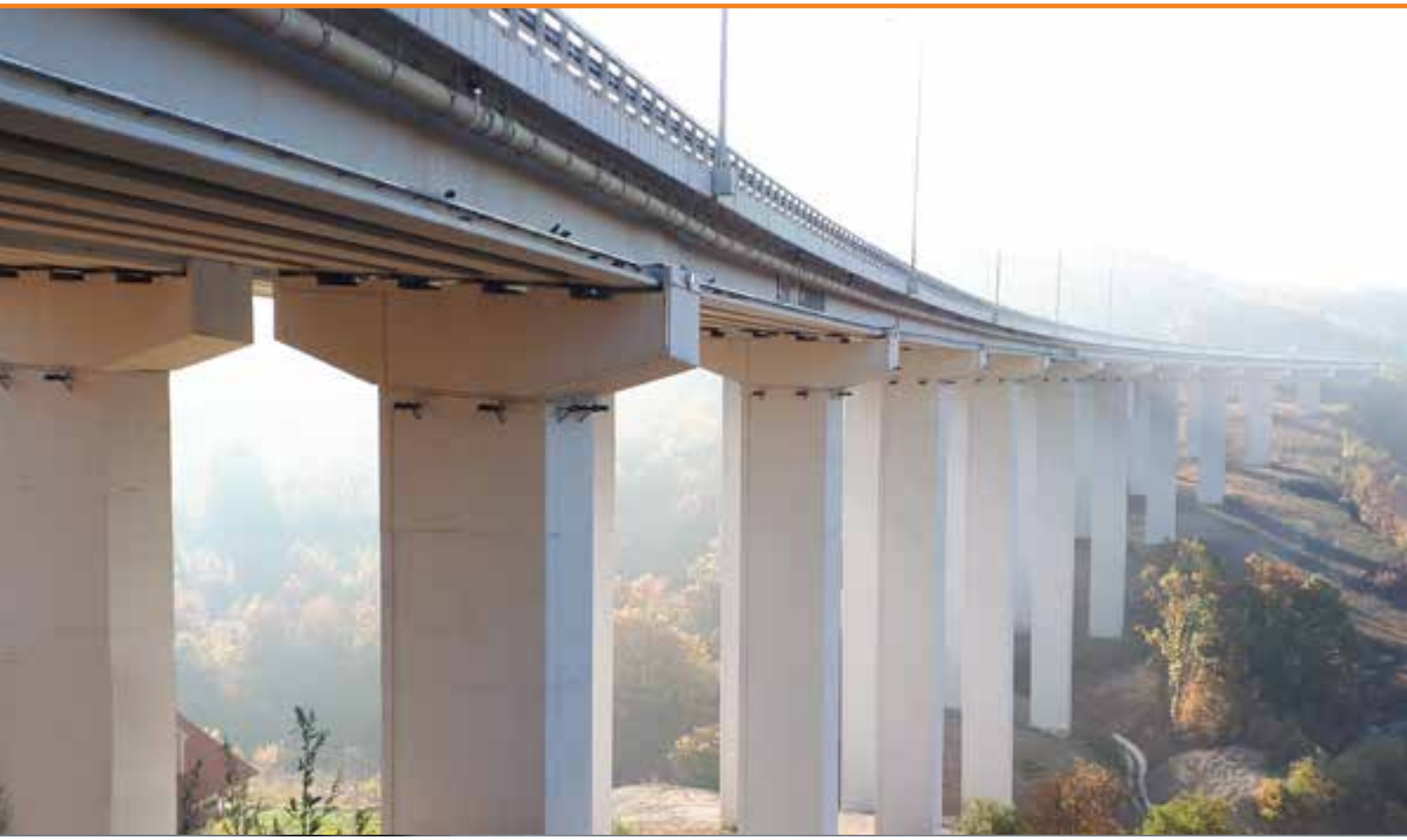
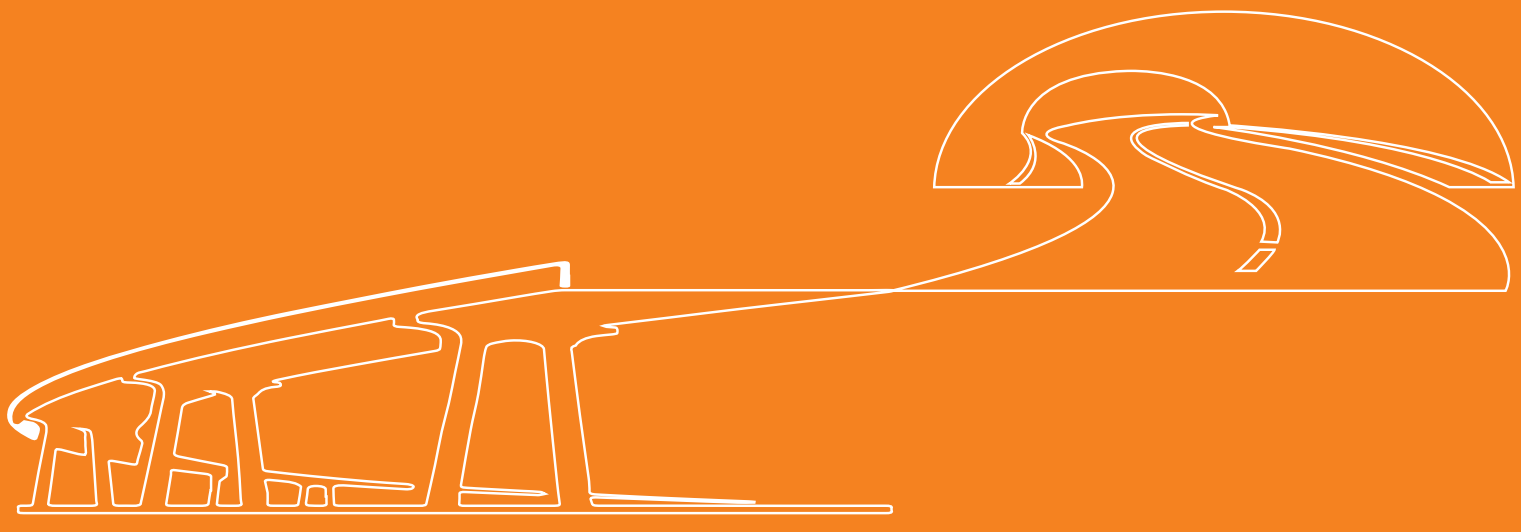
ADING
ingredient of every structure

PROTECTION OF REINFORCED CONCRETE STRUCTURES AND TRAFFIC INFRASTRUCTURE EXPOSED TO CARBONATION





EN 1504-2

ADINGPOKS AKVA 1B

$$H_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2H_2O$$

ANTIKOROZIN BB

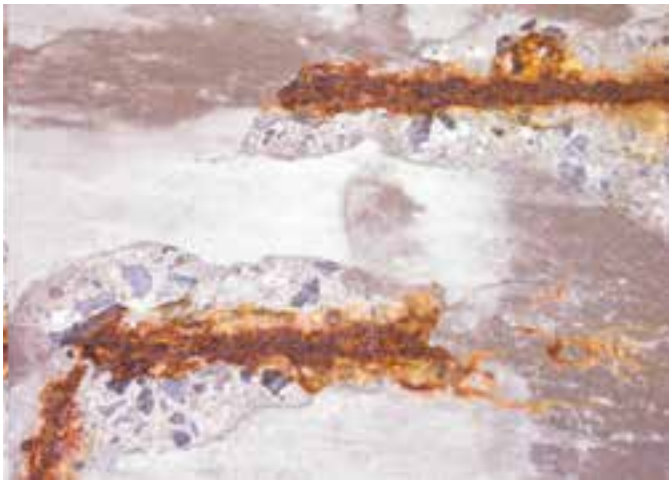
RC constructions

ANTICARBONATION PROTECTION

INTRODUCTION

Reinforced concrete as construction material provides high durability of buildings due to the properties of concrete to improve its strength characteristics over time and to protect steel reinforcement from corrosion. However, due to design and performance flaws, impact from external aggression during exploitation, damages and structural degradation can occur. Therefore, it's necessary to take additional measures for protection of concrete structures. Climate change, industrial development and expansion of urban areas contribute to increasing the aggressiveness of the environment – pollution of the atmosphere with CO_2, sulfates, chlorides, etc. Exposure to high concentrations of CO_2, due to increased traffic in the urban areas and road infrastructure (tunnels, bridges), lead to the process of carbonation.

Carbonations process of concrete is one of the basic factors responsible for damage and degradation of reinforced-concrete structures, especially in environments where there is a high concentration of carbon dioxide. As a consequence of carbonation, concrete alkalinity reduces, therefore causes loss of protection and occurrence of corrosion of the steel reinforcement in RC constructions.



1. CARBONATION OF CONCRETE

In order for carbonation to occur in concrete, carbon dioxide from the atmosphere must form a chemical bond with water, that results in formation of Carbonic acid.

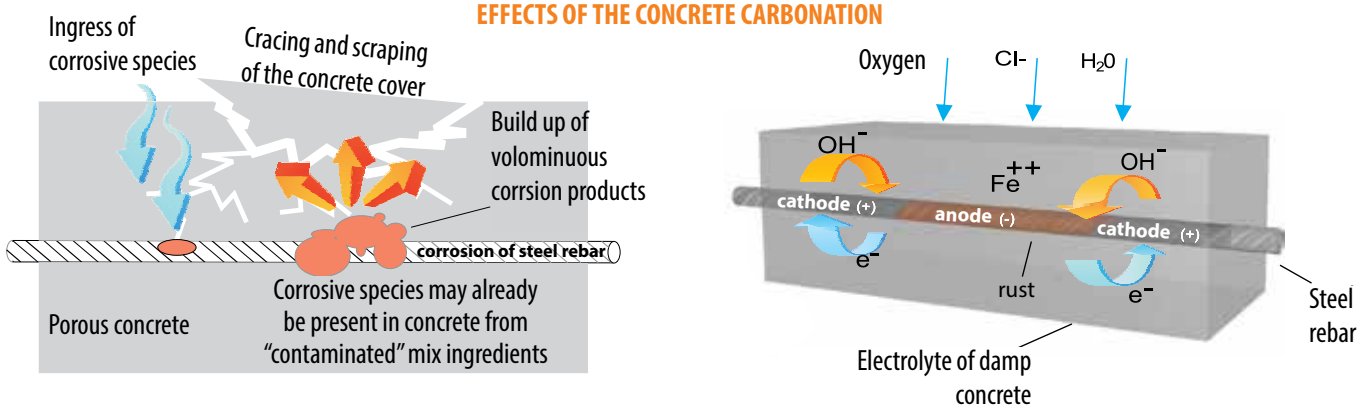
$$CO_2 + H_2O \rightarrow H_2CO_3$$

The formed Carbonic acid reacts with the alkaline calcium hydroxide present in the concrete matrix, creating insoluble calcium carbonate. Such a process is called **CARBONATION OF CONCRETE** and results in a drop of the concrete pH value from 12,5 to approximately 8,8

$$H_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2H_2O$$

In reinforced concrete structures the danger is that in an environment where the concrete pH value is lower than 11, steel is prone to corrosion. When the carbonation process reaches the steel reinforcement, the protective coating around the reinforcement bars can no longer perform its function and the steel bars begin to corrode. Additionally, the "rust" formed on the steel expands causing stresses in the concrete, resulting with cracks in which water infiltrates and causes greater degradation.

Another negative effect of carbonation is that by reducing the alkalinity of the concrete corrosion exposure of the reinforcement increases. This type of corrosion most often occurs due to the presence



of sodium chloride (sea salt), which is present in seawater, soils or when using salts for defrosting pavements of bridges and parking lots.

2. EXPOSURE CLASSES AND REQUIREMENTS FOR PERFORMANCE OF CONCRETE EXPOSED TO CARBONATION, IN ACCORDANCE WITH THE EUROPEAN STANDARD EN 206-1

Depending on the purpose of the buildings and their exposure to atmospheric impacts, water and CO_2, RC constructions can be exposed to different carbonation intensity during exploitation period.

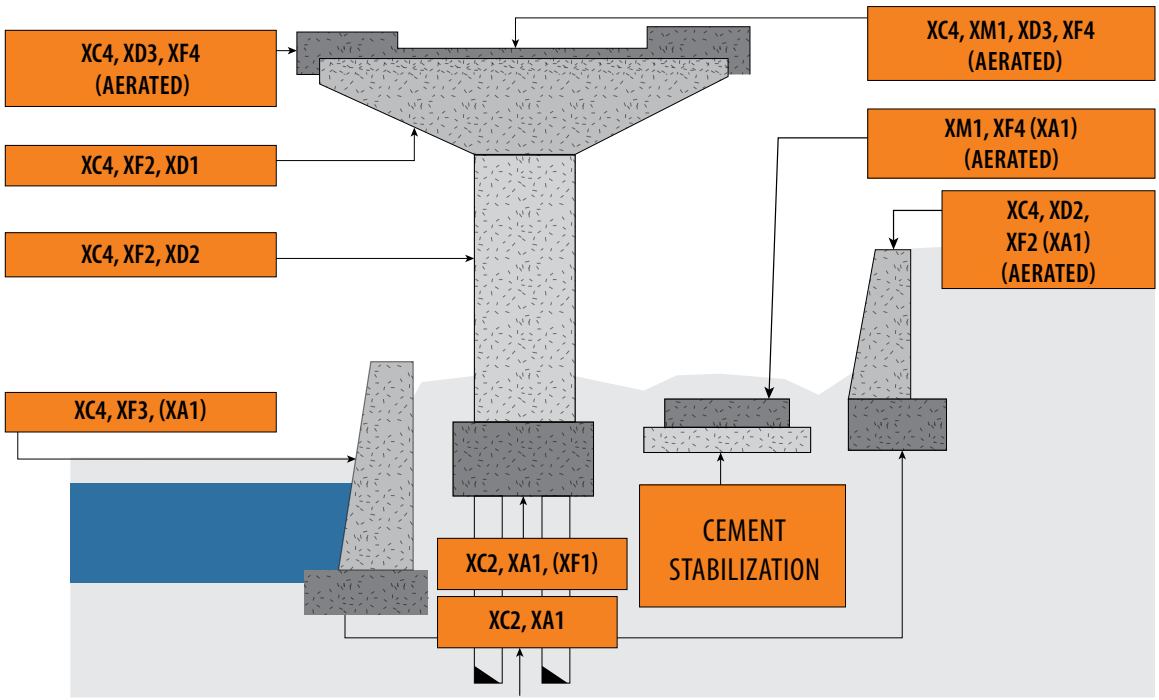
European standard for concrete *EN 206 Concrete: specification, performance, production and conformity* define the following classes of concrete exposure to carbonation:

XC1 – XC4 CORROSION INDUCED BY CARBONATION	
Class designation	**Example of constructions**
XC1 – Dry or permanently wet	Concrete permanently submerged, building in a low humidity environment
XC2 – Wet, rarely dry	Foundation construction
XC3 – Moderate humidity	Exterior concrete surfaces, protected from rain
XC4 – Cyclic wet and dry	Horizontal RC surfaces exposed to atmosphere impacts, pavements, parking lots.

As a part of the same standard EN 206-1, recommendations are given for preparation of concrete depending on the class exposure (designation). Recommendations define the basic conditions for the concrete design according to its exposure class which includes: minimum concrete strength, minimum cement amount, maximum W/C factor, type of cement and air content.

RECOMMENDED LIMITING VALUES FOR COMPOSITION AND PROPERTIES OF CONCRETE				
	CARBONATION			
Exposure class	XC1	XC2	XC3	XC4
Max W/C	0, 66	0, 6	0, 55	0, 5
Min. strength class	C20/25	C25/30	C30/37	C30/37
Min. cement content (kg/m^2)	260	280	280	300
Min. air content (%)	-	-	-	-

Poor assessment of the exposure class for the design of a structure can lead to degradation of concrete during exploitation. For illustration, a schematic representation of typical concrete exposure of road infrastructure is given below.



Typical concrete exposure of infrastructure constructions

3. RECOMMENDATIONS FOR PROTECTION OF CONCRETE STRUCTURES EXPOSED TO CARBONATION

In order to increase the durability of reinforced concrete structures located in environments with a high exposure to carbonation, in addition to the implementation of the recommendations for the concrete design, it is necessary to apply materials that will provide an anticorrosive protection of the concrete. In this way, the parts of the constructions with defects (ex. segregations, cracks, thin protective layer of concrete, etc.), will also be protected.

Additionally, some existing RC objects during their construction they weren't built with concrete that has the appropriate characteristics, appropriate protective layers of concrete, etc. In such buildings, carbonation and damages are often present in the concrete and steel reinforcement.

Corroded reinforcement as a consequence of concrete carbonation

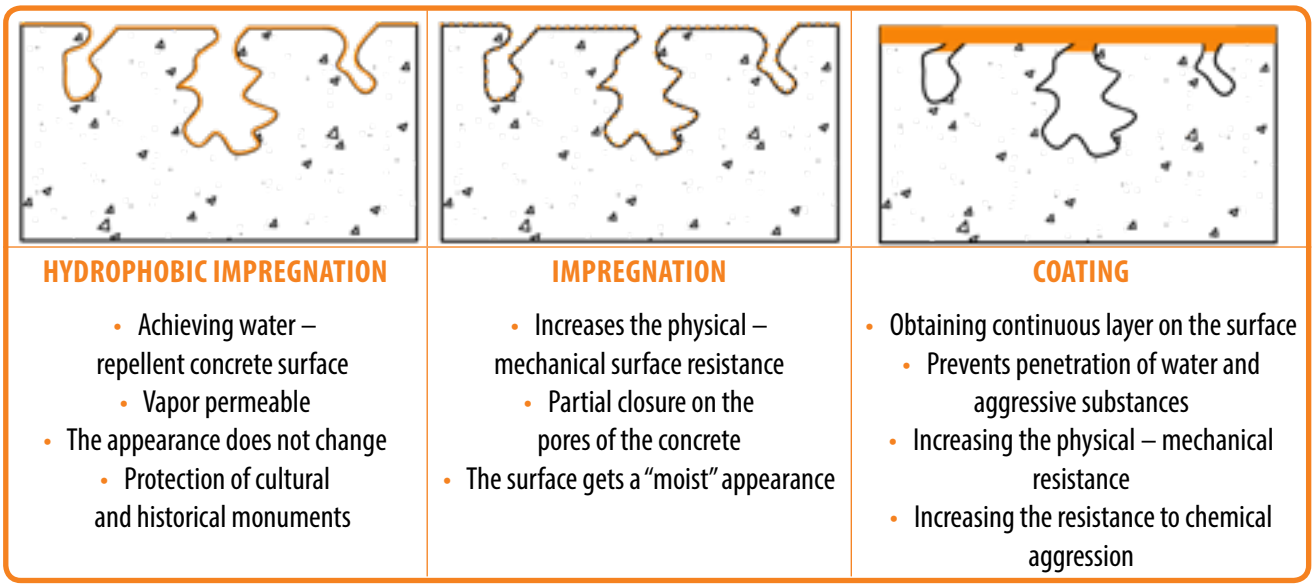
By applying the systems for reparation and protection of RC constructions, objects can restore their functionality and can ensure durability during further exploitation in conditions of high level of aero-pollution.

The basic principles and methods for surface protection of concrete are defined by European standard for protection and rehabilitation of concrete and RC concrete constructions – *EUROPEAN STANDRAD EN 1504 Products and systems for the protection and repair of concrete structures*.

In accordance with the standard EN 1504, for the protection of RC constructions exposed to carbonation, the following principles and methods are applied:

PRINCIPLE 1	Protection against ingress	Hydrophobic impregnation
		Impregnation
		Coating
PRINCIPLE 2	Moisture control	Hydrophobic impregnation
		Impregnacija
PRINCIPLE 5	Increasing physical resistance	Impregnation
		Coating
PRINCIPLE 6	Resistance to chemicals	Coating
PRINCIPLE 8	Increasing resistivity	Hydrophobic impregnation
		Coating

There are three basic methods for surface protection of concrete structures: impregnation, hydrophobic impregnation and coating.

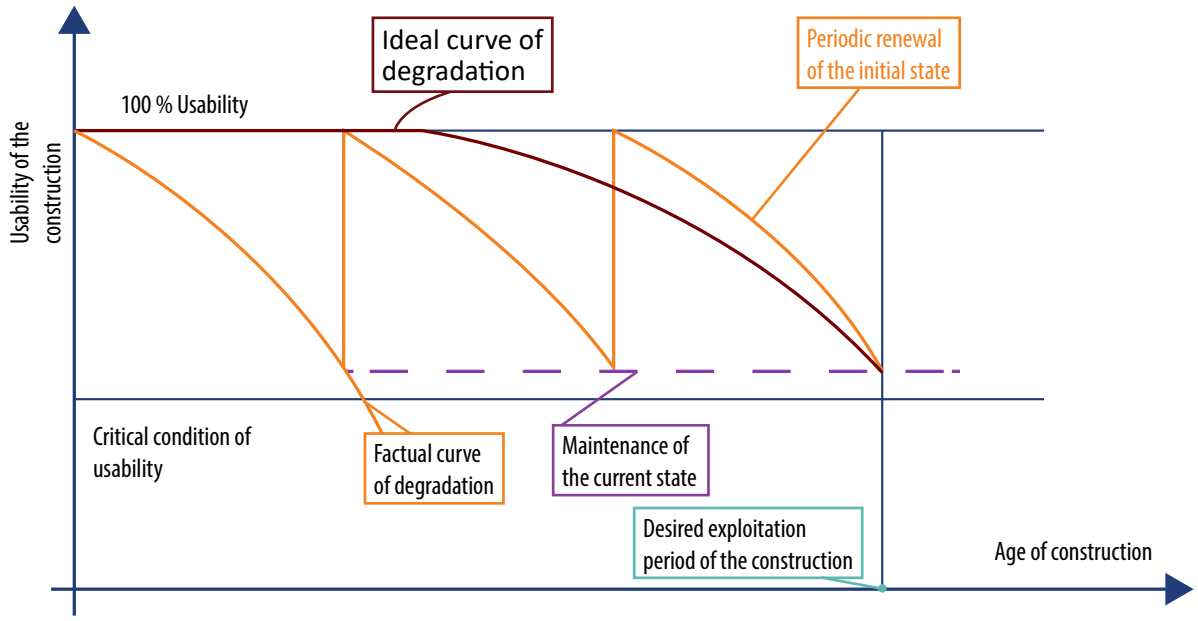


HYDROPHOBIC IMPREGNATION	IMPREGNATION	COATING
• Achieving water – repellent concrete surface • Vapor permeable • The appearance does not change • Protection of cultural and historical monuments	• Increases the physical – mechanical surface resistance • Partial closure on the pores of the concrete • The surface gets a "moist" appearance	• Obtaining continuous layer on the surface • Prevents penetration of water and aggressive substances • Increasing the physical – mechanical resistance • Increasing the resistance to chemical aggression

The most appropriate and permanent method for protection of road infrastructure objects and prevention of the concrete carbonation is application of anti-corrosion coating for protection of concrete surfaces.

In cases when at existing objects process of carbonation is formed deep in the concrete section, and the corrosion of the steel reinforcement has started, first it is necessary to repair the RC construction and after that to apply protection on the construction surface.

*The European Standard EN 1504 includes recommendations for the possibilities of managing infrastructure facilities during their period of operation. They are illustrated by the following graph:



In order to achieve functionality of the building close to the ideal curve of usability, without the need to perform complex (and expensive) remediation work, it is necessary for the constructions to be subjected to continuous monitoring and maintenance throughout the entire period of use. Such practice is of particular importance for constructions located in areas where they are exposed to intense aggressive impact from the environment.

In long-term, the most economical and safest way to increase the durability of RC constructions in aggressive environments is the application of appropriate products for protection of constructions. The price cost of such materials is minor compared to the investment value, and it allows significant extension of the life of the construction, as well as retaining 100 % of its functionality. Regular and proper application of protective materials on RC constructions makes them remain functional for unlimited period of exploitation.

4. REQUIREMENTS AND PERFORMANCES OF THE MATERIALS INTENDED FOR ANTI–CARBONATE PROTECTION OF CONSTRUCTIONS

The selection of a suitable product or system for surface protection of concrete is made considering the purpose of the construction, as well as the conditions and exposure of the construction during exploitation.

The most important characteristics that are taken into account when choosing the material are:

- Elasticity and the ability to cover (bridge) micro – cracks
- Adhesion to dry and wet concrete substrate
- CO2 permeability
- Water vapor permeability
- Capillary absorption and waterproofing
- Resistance to frost and chlorides
- Resistance to UV radiation
- Chemical resistance
- Other specific properties (fire resistance, wear and slip resistance, impact resistance, etc.)
- Conditions related to protection of human health and protection of the human environment

Depending on the conditions of the building and the exposure, for protection of RC constructions from carbonation different coatings can be used made with synthetic resins based on acrylic resin, epoxy or polyurethane reactive resins.

BASIC REQUIREMENT FOR PERFORMANCE OF COATINGS FOR CONCRETE PROTECTION FROM CARBONATION

Characteristic performance	Test method	Minimum requirements (EN 1504-2, Table 5)
Permeability CO_2	EN 1062-6	$S_d > 50$ m (Equivalent layer of air)
Permeability of water vapor	EN ISO 7783	Class I: $S_d < 5$ m Class II: 5 m $\leq S_d \leq$ 50 m Class III: $S_d > 50$ m
Capillary absorption and water permeability	EN 1062-3	$w < 0.1$ kg / (m^2 $h^{0,5}$)
Strength adhesion pull - off	EN 1542	- For a flexible system with traffic ≥ 1.5 N/mm^2 - For rigid system with traffic ≥ 2.0 N/mm^2

In situ examination of the properties of the protective coating Anticorozin BB

*Illustration: Comparative performance analysis 3 types of protective coatings from the production program of Ading.

Material	Type of coating	Permeability of CO^2	Permeability of water vapor	Strength adhesion pull - off
ANTIKOROZIN BB	Acrylic – water based	60 m	0, 15	3.33 N/mm^2
ANTIKOROZIN BR	Acrylic-base with solvents	90 m	3, 5	3.75 N/mm^2
ADINGPOKS AKVA 1B	2C – epoxy coating on water base	220 m	49	3.83 N/mm^2

Laboratory tests of the properties of protective coatings

Examination of the adhesion of protective coatings *Pull – off* method

Examination of depth of carbonation

5. SYSTEM FOR ANTI – CARBONATIVE PROTECTION OF RC CONSTRUCTION FROM THE PRODUCTION PROGRAM OF ADING SKOPJE

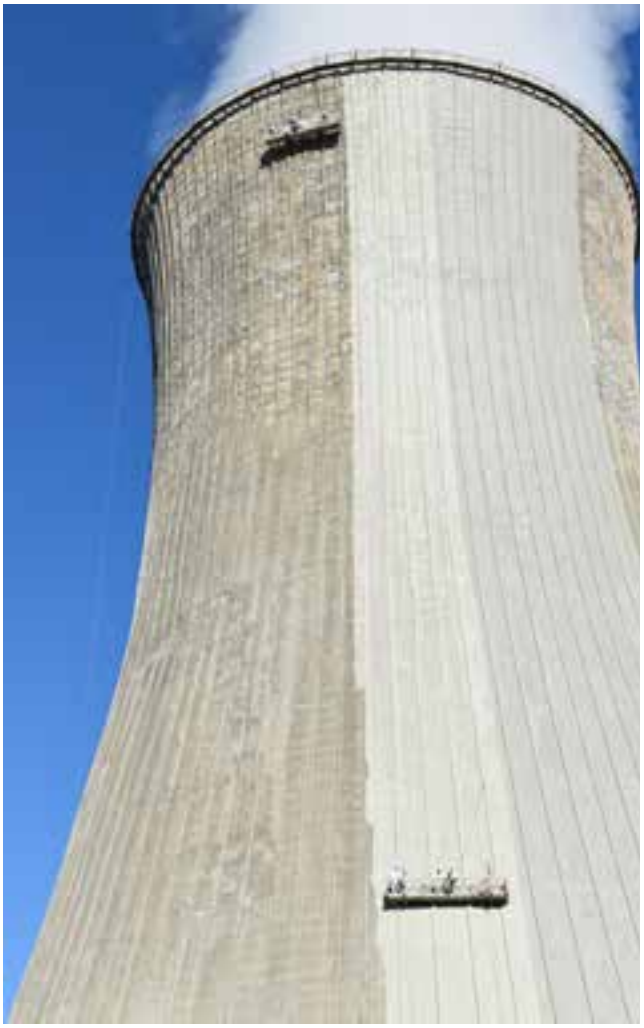
ADING production program offers several systems intended for protection of RC constructions present at road traffic infrastructure (bridges, tunnels, supporting structures), RC constructions in urban areas, industrial buildings, electric power plants (ex. exterior surface of cooling towers at thermal power-plants), hydro technical constructions, etc. Depending on the purpose of the construction and the degree of exposure, it is necessary to choose an appropriate system – material for protection of the structures, taking into account the conditions of application (temperature, humidity of the air and the substrate, accessibility, etc.) It is also necessary to choose the appropriate material that will not have a harmful impact on the environment and human health.

For protection of RC buildings exposed to intense carbonation, from the production program of ADING it is recommended application of the following products and systems for the protection of concrete constructions.

SYSTEM 1 based coating **ANTIKOROZIN BB** and primer for hydrophobic impregnation **FASIL V**. The system is specially designed to protect infrastructure constructions with high exposure to carbonation of concrete, impacts from ice, de-frosting salt, atmosphere influences and UV radiation. It is applied as a decorative finish to old, new and repaired reinforced concrete surfaces.

Product	In accordance with EN standard	Properties
ANTIKOROZIN BB	According to EN 1504 – 2 anti – corrosion coating for surface protection of concrete ingress and moisture control: - Surface protection against ingress (Method 1.3 according to EN 1504 – 9) - Moisture control (Method 2.2 according to EN 1504 – 9) - Increased resistance (Method 8.2 according to EN 1504 – 9)	✔ Ready – 1 Component ✔ Waterproof ✔ Vapor permeable ✔ Resistant to ice ✔ UV stable ✔ Ecological ✔ Does not contain solvents ✔ Economical ✔ Decorative (in color)
FASIL V	EN 1504 – 2 hydrophobic impregnation for surface protection of concrete: - Protection against ingress (Method 1.1 according to EN 1504 – 9); - Moisture control (Method 2.1 according to EN 1504 – 9); - Increased resistance (Method 8.1 according to EN 1504 – 9)	✔ Water – repellent (forms water – repellent surfaces) ✔ Vapor permeable ✔ Waterproof ✔ Does not change the surface appearance ✔ Increases the resistance to treated surfaces with ice and salts ✔ Reduces capillary absorption of water on concrete section ✔ Simple application with brush / roller or spray

Application examples and reference constructions with
ANTIKOROZIN BB I FASIL V



SYSTEM 2 Coating for anti-corrosion protection of concrete surfaces **ANTIKOROZIN BR**, produced on the basis of synthetic resins and solvents. It is used for traffic signalization marking, decorative finish and protection of infrastructure objects. It has a high mechanical strength and resistance to wearing. System is resistant to oil and petrol derivatives.

Product	In accordance with EN standard	Properties
ANTIKOROZIN BR	According to EN 1504-2 anti-corrosion coating for surface protection of concrete ingress and moisture control: -Surface protection against ingress (Method 1.3 according to EN 1504 -9) - Moisture control (Method 2.2 according to EN 1504 – 9) - Increased resistance (Method 8.2 according to EN 1504 – 9)	✔ 1 Component ✔ Waterproof ✔ Vapor permeable ✔ Resistant to ice ✔ UV stable ✔ Resistant to petrol derivatives ✔ Economical ✔ Decorative (in color)

It is applied on a concrete or cement substrate in two working procedures, manually or with a spraying machine (*airless*). When applying the first layer, the material is diluted with additional 5 – 8 % **RASTVORUVAC P**. It is applied on a concrete or cement substrate in two working procedures, manually or by spraying machine (airless pump). When applying the first layer, the material is diluted by adding 5 – 8 % of RASTVORUVAC P, while subsequent layers are diluted to a maximum of 5 %.

Traffic signaling
Application examples and reference objects with ANTIKOROZIN BB and FASIL V

SYSTEM 3

Two-component epoxy coating on water base **ADINGPOKS AKVA 1B** and primer for hydrophobic impregnation FASIL V. The system is intended for surface protection of concrete exposed to mechanical and chemical impacts.

ADINGPOKS AKVA 1B has a light reflection degree (gloss units), in compliance with European standards for traffic safety. When applied on road tunnels, **ADINGPOKS AKVA 1B** allows adjustment of the reflection degree of light (*gloss units*), according to the European standards of traffic safety. It is also recommended as a finish coating in objects with high requirements for hygiene. Other examples of building where the same system is applied for concrete protection are constructions exposed to mild chemical aggression (eg. the interior of tanks and cooling towers at thermal power plants).

Product	In accordance with EN standard	Properties
ADINGPOKS AKVA 1B	EN 1504-2 epoxy water based coating for surface protection from concrete ingress, for increased physical and chemical resistance of concrete surfaces: - Surface protection against ingress (Method 1.3 according to EN 1504 – 9) - Moisture control (Method 2.2 according to EN 1504 – 9) - Increase resistance (Method 8.2 according to EN 1504 – 9) - Physical resistance (Method 5.1 according to EN 1504 -9) - Chemical resistance (Method 6.1 according to EN 1504 – 9)	✔ Protection from concrete carbonation ✔ Waterproof ✔ Vapor permeable ✔ Resistance to dilute acids, solutions of salts and mineral oils ✔ Good adhesion to the substrate ✔ Abrasive resistance ✔ Mechanical resistance ✔ Non-toxic in a bound state ✔ Easy for application ✔ Easy for maintenance

ADINGPOKS AKVA 1B is a 2 – component material, based on reactive epoxy resin which dissolves in water. It is prepared by mixing two components, after which is applied in two working procedures, manually or by spraying machine (*airless*). Before applying, it is recommended to treat the concrete substrate with a hydrophobic impregnation primer **FASIL V** applied with a brush, roller or a spraying machine, in one working procedure. In case of very weak or very porous concrete substrate, it is recommended pre-impregnation with a primer on epoxy base **ADINGPOKS AKVA PRAJMER** or **ADINGPOKS 1PV**.

Application examples and reference objects with ADINGPOKS AKVA 1B

SYSTEM 4

Three-component cement/epoxy based mortar **ADINGPOKS AKVA**, used for surface protection of concrete exposed to intensive mechanical and chemical impacts. When applied in road tunnels, **ADINGPOKS AKVA** provides protection from carbonation, ice and chlorides, protection against mechanical wearing caused by spraying of water and abrasion from sand thrown out by vehicle tires. Other examples of constructions where this system is applied are reservoirs and sedimentation tanks at the waste water treatment plants, buildings in the chemical industry, etc.

Product	In accordance with EN standard	Properties
ADINGPOKS AKVA	According to EN 1504 – 2 and EN 1504 – 3 epoxy cement coating for surface protection of concrete: - Epoxy based polymer (RS) mortar - Surface protection against ingress (Method 1.3 according to EN 1504 -9) - Moisture control (Method 2.2 according to EN 1504 -9) - Increased resistance (Method 8.2 according to EN 1504 -9) - Physical resistance (Method 5.1 according to EN 1504 -9) - Restoration of concrete by hand plastering (Method 3.1 according to EN 1504 -9) - Protection or passive restoration by increasing the protective layer of reinforcement with mortar (Method 7.1 according to EN 1504 – 9).	✔ Protection of concrete and reinforcement in aggressive environment ✔ High mechanical strength and wear strength ✔ Protection of concrete from carbonation ingress ✔ Waterproof ✔ Water vapor permeable ✔ Excellent adhesion to dry and wet concrete ✔ Improves the adhesion bond between old and new concrete or repair mortar ✔ Available in gray and white

ADINGPOKS AKVA is a three – component system, produced on the base of reactive epoxy resin and cement filler. It is prepared by mixing two pasty components of the resin, after which the powder component is gradually added and mixed until complete homogenization. The material is applied in one or more working procedures, manually (with a trowel) or by a spraying machine (airless) in layers with a thickness of 1 -3 mm. In case of weak or very porous concrete substrate, it is recommended to use a pre-impregnation epoxy base primer **ADINGPOKS AKVA PRAJMER** or **ADINGPOKS 1PV**.

Application examples and reference objects with ADINGPOKS AKVA

SYSTEM 5

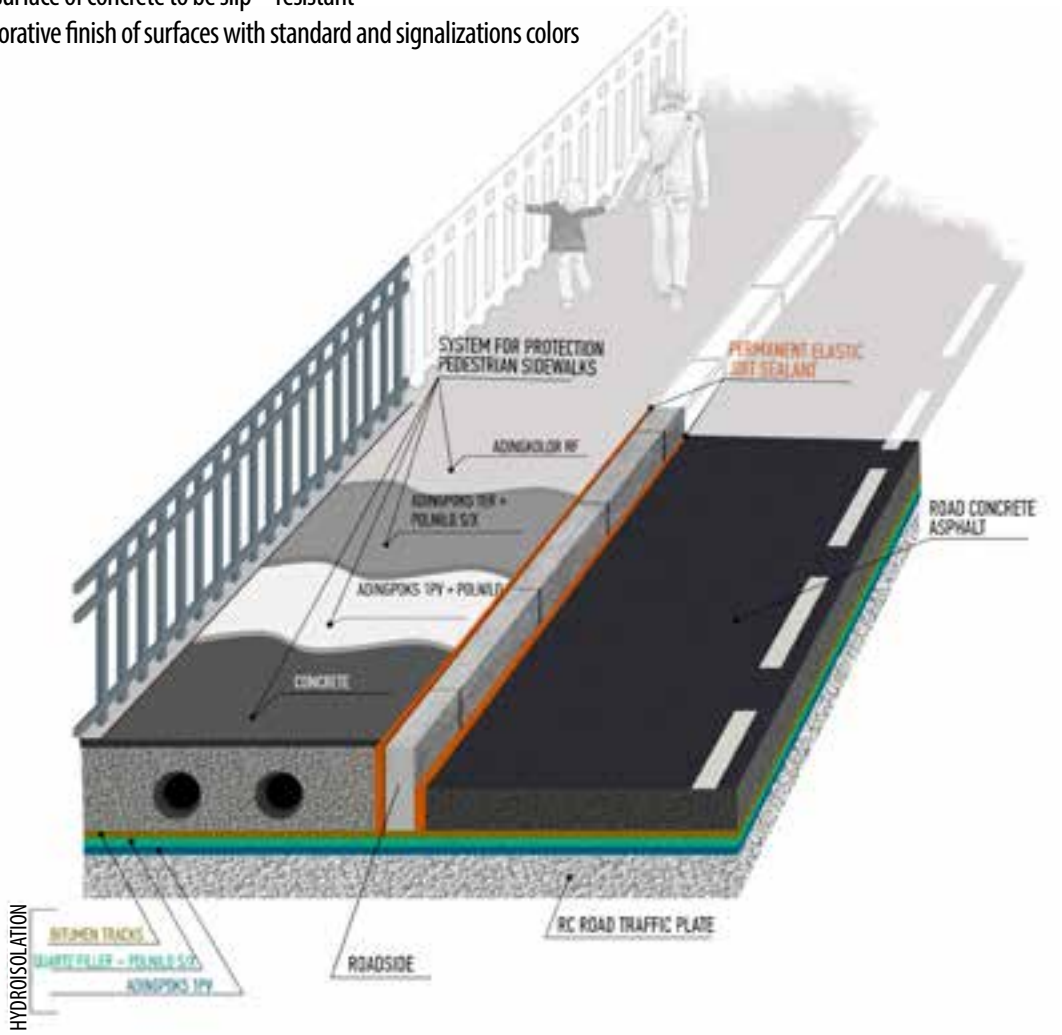
Skid-free systems for protection of pedestrian sidewalks on bridges and other constructions exposed to light pedestrian traffic, atmosphere influences and chemical aggression. Ading's system for protection of pedestrian sidewalks is based on epoxy and methacrylate coatings.

- Epoxy primer **ADINGPOKS 1PV**
- Quartz filler **POLNILO C/X** – one layer
- Epoxy based coating **ADINGPOKS TER**
- Quartz filler **POLNILO C/X** (0,3 – 0,8 mm)
- Metacrylate finish **ADINGKOLOR RF** – two layers

Product	In accordance with EN standard	Properties
ADINGKOLOR RF	EN 1504 – 2 coating for surface protection and increased physical resistance of concrete surfaces: - Physical resistance (Method 5.1 according to EN 1504 -9)	✔ Excellent adhesion to the substrate ✔ Closes the surface structure of the substrate ✔ Resistance to salts, oil and petroleum derivatives ✔ Resistance to Atmospheric influences ✔ Waterproof ✔ Wear resistant, at normal industrial exploitation ✔ UV stable ✔ Available in multiple color ✔ Simple and fast application ✔ Easy maintenance
ADINGPOKS 1PV	According to EN 1504 – 2 and EN 13813 SR – B2.0 – IR4 – epoxy primer for wet concrete substrates - Moisture control (Method 2.2 according to EN 1504 -9) - Increased resistance (Method 8.2 according to EN 1504 -9) - Preparation of synthetic resin screed mortars	✔ Transparent, low viscosity two – component epoxy resin ✔ Excellent adhesion for dry and wet concrete substrate ✔ Water – repellent and waterproof ✔ Bacteriological resistance ✔ Good resistance to mild acids, solutions of salts and mineral oils ✔ Resistant to oil and oil derivatives
ADINGPOKS TER	EN 1504 – 2 two component epoxy coating for surface protection of concrete and steel surfaces exposed to mechanical and chemical influences: - Surface protection against ingress (Method 1.3 according to EN 1504 -9) - Physical resistance (Method 5.1 according to EN 1504 -9) - Chemical resistance (Method 6.1 according to EN 1504 -9)	✔ Extremely high chemical resistance ✔ Resistant to oil and oil derivatives ✔ High mechanical resistance ✔ High adhesion to concrete and metal surfaces ✔ Waterproof ✔ Non – toxic in cured state ✔ Bacteriological resistance ✔ Easy maintenance

SYSTEM PROPERTIES:

- Protects of exposed concrete to mechanical impacts and wear – pedestrian traffic, bicycles, wheelchairs, etc.
- Protects of exposed concrete to aggressive physical – chemical impacts
- Protection of exposed concrete to direct atmosphere impacts on a horizontal surface – rain, snow, frost, direct sunlight and UV radiation
- Protection of exposed concrete to impacts from salts, cyclically exposed environment from chloride, for ex. parts of construction from bridges, sidewalks, parking lots – Protection of concrete exposed to carbonation
- Cyclically humid environment, for ex. external surfaces of buildings that are directly exposed to atmosphere impacts
- Ensures the surface of concrete to be slip – resistant
- Provides decorative finish of surfaces with standard and signalizations colors



PROTECTIVE COATINGS

EN 1504-2

ADINGPOKS AKVA 1B

$$H_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2H_2O$$

ANTIKOROZIN BB

RC constructions

ANTICARBONATION PROTECTION

ADING
ingredient of every structure

Company for production of chemical materials for construction industry, since 1969

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