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Protection and Maintenance of Concrete Bridges

Protection et entretien des ponts en béton

Schutz und Instandhaltung der Betonbrücken

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SUMMARY
The article deals with protection of concrete bridges against corrosion and deterioration. Protection is understood as being a series of successive measures starting from design and ending in repair. The in-service maintenance measures like coating and crack filling are specially treated. Results from tests for protective coatings and injection resins carried out in Finland are included.

RÉSUMÉ
L'article présente la protection des ponts en béton contre la corrosion et la destruction. Ici, la protection exprime toute la série des mesures prises depuis la conception jusqu' à la réparation. On a spécialement étudié la protection des surfaces de constructions en béton et le plombage des fissures du béton. Certains résultats ont été obtenus en Finlande après des recherches sur la protection et les injections.

ZUSAMMENFASSUNG
Dieser Artikel behandelt die Schutzmassnahmen bei Betonbrücken gegen Korrosion und Verwitterung. Die Schutzmassnahmen bedeuten hier eine Serie von nacheinander folgenden Massnahmen von der Projektierung bis zu den Reparaturen. Besonders werden Reparaturmassnahmen wie der Schutz von Betonaussenflächen mit Beschichtungen und die Füllung der Risse mit Injektionsmitteln behandelt. Einige Ergebnisse der in Finnland durchgeführten Versuche, bei welchen die obengenannten Reparaturmethoden zur Anwendung kamen, werden erläutert.

1. PROTECTION MEASURES IN GENERAL

In the general meaning protection of bridges is understood to cover all the measures taken to prevent deterioration and to extend service life of bridges. Accordingly, the protection of bridges starts from design.

Parallel to structural design durability design is carried out. In the case of bridges an automatic adaptation of solutions in codes and standards may not be enough for durability design. In addition to observing rules a careful evaluation of different optimal solutions with special attention to the probable service life is needed. The decisions made in the design stage pertaining to the quality of concrete, concrete cover, draining systems of bridge deck, quality of water membrane etc. are most significant in regard to the prevention of deterioration of bridges.

The purpose of quality control is to insure that quality requirements for materials and structures will be met. Some control measures must be taken at the time fo concrete cast. In Finland, for example, where salt-frost scaling of concrete is one of the most severe problems in bridges, it is essential to insure by tests before and during construction that the required air content of concrete is attained. The poor frost resistance of concrete due to lack of air in concrete is difficult to be replaced by other protective measures. Another critical point is the concrete cover of reinforcement. The supervision of the construction site must check before casting of concrete that the required concrete cover is provided for reinforcement to prevent too early corrosion.

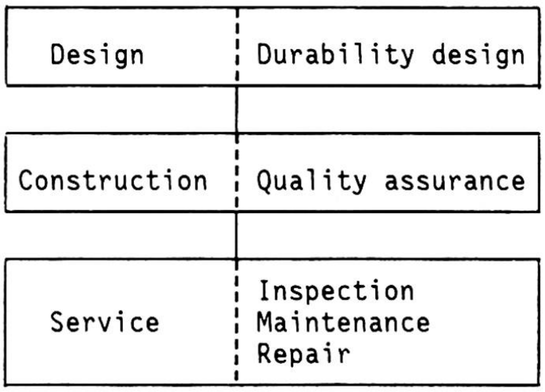

Fig. 1 General protection scheme of bridges.

The inspection and maintenance of bridges belong to the protection of bridges and are an essential part of it. The purpose of the inspection activity is to follow the condition of bridges so that extensive deterioration can be prevented by right time maintenance. The parts of bridges which normally are invisible such as submerged structures and bridge decks under pavement should be taken under control by special inspections.

Maintenance and repair follow inspections when defects or damage are discovered. By maintenance we understand here preventive measures such as sealing concrete with protective coatings or filling cracks.

2. PROTECTION WITH COATINGS

2.1 General remarks on coating

Although coating of bridges has not been very extensively used in Finland it is obvious that in many cases the service life of bridges can be extended with special protective coatings which retard the chloride penetration and carbonation processes in concrete. Also by setting a barrier to moisture ingress the frost-salt deterioration can be diminished.

The performance of a protective coating depends on its adhesion. It is essential that the concrete surfaces to be coated are throughly clean and sound. The moisture content of the concrete at the time of coating is also important. Most coatings require a dry substrate.

In the following description protective coatings are classified into three groups: surface sealers, polymer coatings and cement based coatings.

2.2 Surface sealers

Surface sealers partly penetrate into the capillary pores of concrete and leave a thin water repellent film on concrete surface. They do not significantly change the appearance of concrete. Surface sealers produce an effective barrier to water from outside but they are relatively permeable to water vapour from inside of concrete. By the chemical composition surface sealers are usually silanes, siloxanes or silicone resins.

Due to the water repellent property of surface sealers they can be used to prevent frost damage in concrete. They can also be used as a barrier against chlorides from outside and as a protective agent against staining. However, the rate of carbonation cannot be reduced by surface sealers.

Some of the surface sealers (especially silanes) are more effective in preventing the moisture ingress than thicker polymer coatings. It is due to their ability to impregnate all cavities and voids on the concrete surface as opposed to normal polymer coatings which leave pin holes. In Fig. 2 typical water absorption and desorption curves for specimens (100 mm cubes) with different coatings are presented. Very little moisture is absorbed into the silane impregnated specimen compared to the other coated specimens. The good vapour-permeability of silane can also be noted.

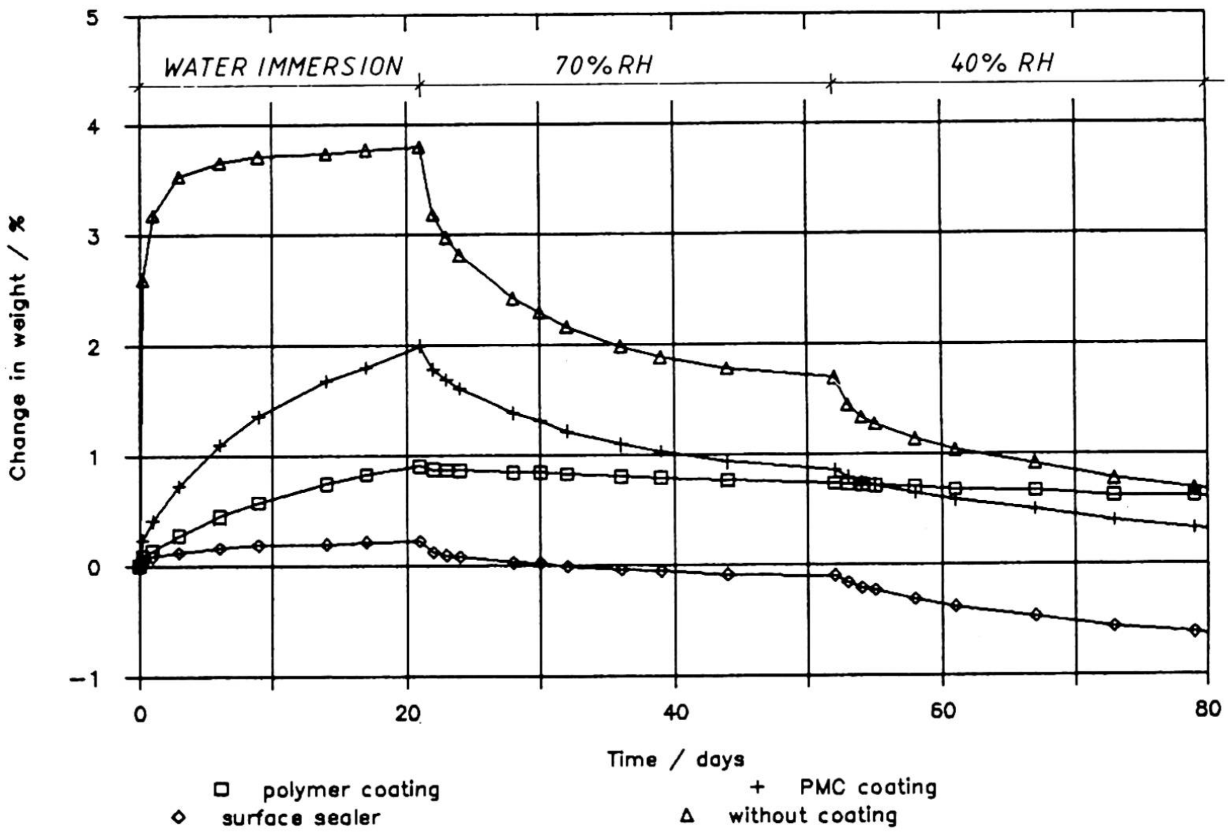

Fig. 2 Absorption and desorption of coated 100 mm cubes.

2.3 Polymer coatings

By the chemical composition polymer coatings are usually epoxy resins, polyurethanes, acrylics, polyester resins or copolymers [1]. They consist of one or two components being reactive, water based or solvent based. For better appearance polymer coatings are often pigmented.

Polymer coatings can be compiled of several treatments. Thin coatings classified in the range of (0.15 - 1 mm) produce a rather effective barrier to carbonation. However, they do not normally seal the concrete completely because of the pin holes left in the coating. Water from outside can easily penetrate into concrete through pin holes but drying is slow because of the relatively vapour-impermeable coating. That is why thin polymer coatings are susceptible to loosen from the substrate when not sheltered from rain.

Thick polymer coatings (1 - 3 mm) are normally completely water-impermeable. Most of them can also bear heavy mechanical loading. Accordingly they can be used as a water membrane on a bridge deck without protective concrete. Some modifications of epoxy and polyurethane-based thick coating have elastic properties being deformable enough to bridge living cracks.

2.4 Cement-based coatings

The binding agent of cement based coatings usually consists of cement such as portland cement and polymer (polymer modified cement). The polymer may be styrene butadiene rubber, acrylic or modified acrylic or other polymer latex.

Cement based coatings of normal thickness (< 2 mm) are spread by brush or spray. Mortars of the thickness (2...5 mm) can also be trowelled. Carbonation or penetration of chlorides cannot be effectively retarded by cement based coatings but their resistance to freeze-thaw cycles may be rather good.

In Table 1 results of the tests on polymer and cement based coatings carried out in Finland are presented. The evaluation of each coating is made using the scale (++, +, -, --) with respect to every test. The variation in compositions and properties of different coatings can be noted.

Polymer coatings No.	Specification	Barrier against chlorides	Barrier against carbonation	Resistance to freeze-thaw cycles Type of concrete surface: non-carb no chlorides	non-carb chlorides	carbonated no chlorides	carbonated chlorides
	thin coatings						
1	2 c primer + 1 c copolymer	++	++	++	++	++	+
2	2 c primer + 2 c polyurethane	++	++	++	--	++	--
3	2 c epoxy	+	+	++	++	++	-
4	2 c epoxy	+	+	++	+	++	-
5	2 c epoxy (water based)	-	-	++	++	++	++
6	silane + 1 c acryl-polymer	++	-	++	++	++	-
7	2 c epoxy (water based)	-	+	++	++	++	+
8	2 c epoxy	++	+	++	++	++	--
9	1 c primer + 1 c copolymer	--	-	+	--	--	--
10	1 c polyester (elastic)	-	+	--	--	++	--
11	2 c primer + 2 c epoxy (water based)	++	+	++	++	++	++
12	primer + acrylpolyester	+	+	--	--	++	--
13	siloxane + 1 c acryl-polymer	++	-	+	++	+	--
	thick coatings						
14	2 c epoxy bitumen	+	++	++	++	++	++

(continued)

Cement based coatings		Barrier against chlorides	Barrier against carbonation	Resistance to freeze-thaw cycles Type of concrete surface			
No.	Specification			non-carb no chlorides	non-carb chlorides	carbonated no chlorides	carbonated chlorides
	normal coatings						
15	PMC-coating + acryl resin	+	+	+	-	-	-
16	styreneacrylic + PMC-coating	--	-	++	++	--	--
	mortars						
17	PMC mortar (2 c copolymer)	--	--	++	++	++	++
18	cement based mortar	--	-	++	++	++	++

Table 1 Summary of results of tests for coated specimens (++ very good, + good, - not good, -- poor).

3. CRACK FILLING

Concrete structures are designed in such a way that controlled cracking may occur in some circumstances. However, unfavourable cracks also appear causing a risk to the durability of reinforcement or structural integrity. Such cracks must be repaired as soon as possible.

In the Finnish recommendations for bridge structures all cracks exceeding the width of 0.3 mm should be filled by resin. In the filling of structural cracks injection techniques are used. Small surface cracks can be also filled by manual gravity feeding.

In the manual feeding of small cracks latex polymers may be advantageous because of their good capillary suction properties. However, complete filling of the crack is not expected when manual feeding is used.

Filling a crack by injection involves introducing low viscosity resin into the crack by due pressure and holding it there while it sets to a non-flowing state. A number of different sealing methods are used (putties, sealing tapes etc.). In case it is impossible to seal the outlet of the crack thixotropic epoxy resins can be used. Thixotropic resins do not easily flow out of an open crack.

One of the most important properties of injection resins is the bond to concrete. In Fig. 3 the results of a slant shear test carried out in Finland are presented. The bond at the slant joint is evaluated by crushing the prism in a compression testing machine and recording the failure load. The results show the variation in bond strengths on dry and moist concrete surfaces.

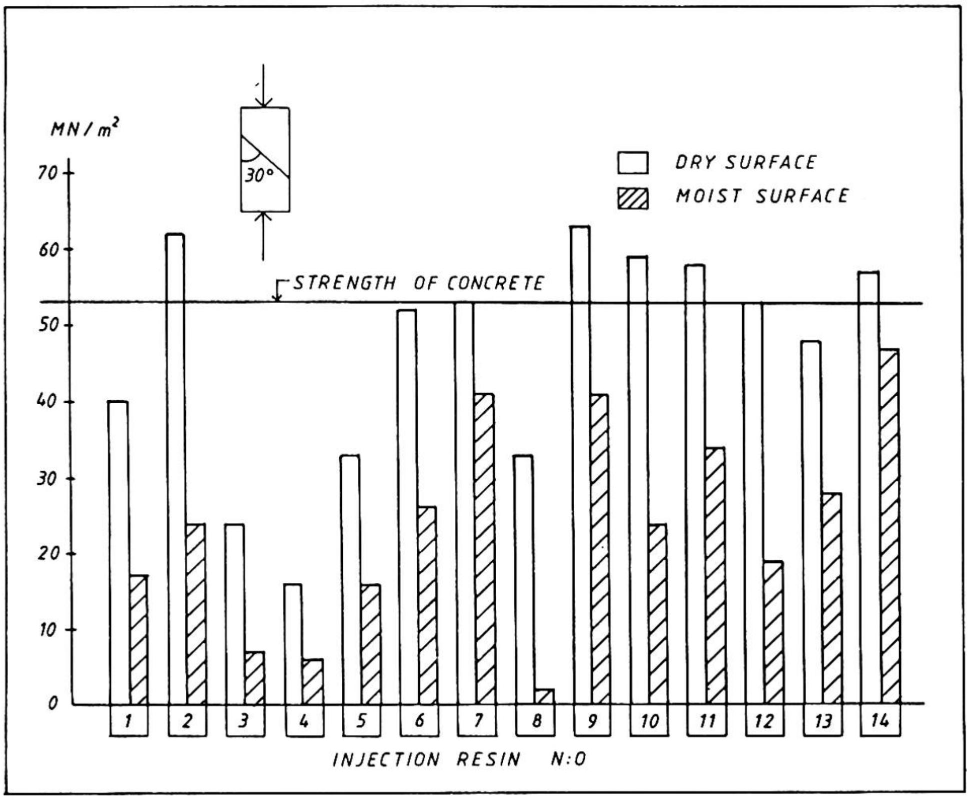

Fig. 3 Test results of bond (slant shear) test for 14 injection resins.

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