UDK 669

TEST RESULTS OF THE COMPATIBILITY OF CONCRETE REPAIR MATERIALS

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Concrete deterioration

Nowadays concrete is one of the most popular building materials in many countries and contintnets. Its economy and durability made concrete widely spread in constrution and repair all over the world. Concrete is used in construction of industrial, civil, hydrotechnical, transport and other facilities as well as for production of reinforced concrete elements.

On the other hand, nowadays a big number of concrete and RC memebers and structures show significant deterioration, being not acceptable for their function and require urgent repair and rehabilitation works. Many newly repaired concrete members show serious damages only few years after repairs.

A big number of repeated defects of concrete structures take place either due to erroneous choice of the repair material or nonobservance of the appropriate methods of repair works.

Causes of concrete deterioration

Concrete buildings and structures are exposed to various natural and technological impacts which were considered in their design.

However in reality complex combinations of external nad internal impacts of variable intensity accelerate concrete deterioration.

These impacts act in the form of loads, environment, substances, energy and etc.

Common concrete defects

The most common concrete defects are:

- Cavities and spalling of concrete surface;
- damages of the concrete cover induces by rebar corrosion;
- concrete corrosion damages due to aggressive chemical and biological attack;
- concrete destrution caused by freeze-thaw cycles and etc.

Approach to concrete repair

European Standard BS EN 1504-9 gives an overall philosophy for repair work and framework for the whole process of repair from initial consideration of need for repair through to completion and maintenance of a repaired structure.

Part 9 adopts the following methodology:

a) assessment of the structure and of the extent of damage;

b) determination of the objectives of the repair work;

c) definition of the available principles for dealing with the identified deterioration in accordance with the stated objectives;

e) dentification of the specific properties required of the materials to be used in the repair.

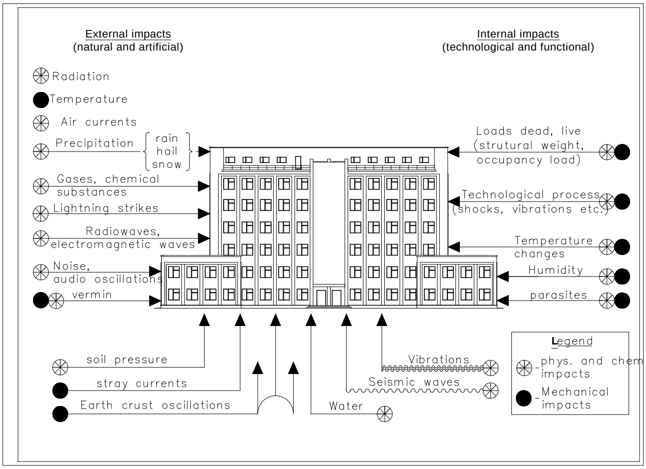

Fig.1. Impacts acting on the building.

<u>Principles and methods of protection and repair</u>

The principles and methods of protection and repair which can be adopted are divided into two groups; the first deals with defects in the concrete as a material and the second with reinforcement corrosion related defects.

Table 1.

Principles and methods for protection and repair of concrete: deteriorated concrete

Principle Number	Principle	Examples of Methods Based on the Principles
1[P1]	Protection against in-gress	1.1 Surface impregnation 1.2 Surface coating 1.4 Filling cracks
2 [MC]	Moisture control	2.1 Hydrophobic Impregnation 2.2 Surface coating 2.3 Overcladding 2.4 Electrochemical treatment
3[CR]	Concrete restoration	3.1 Hand-applied mortar 3.2 Recasting with concrete 3.3 Sprayed concrete
4[SS]	Structural Strengthening	4.1 Adding reinforcement by em-bedment of externally

Principle Number	Principle	Examples of Methods Based on the Principles
		4.2 Adding reinforcement in pre-formed or drilled holes 4.3 Plate bonding 4.4 Adding mortar or concrete 4.5 Crack injection
5 [PR]	Increasing physical resistance	5.1 Overlays or coatings 5.2 Impregnation
6[RC]	Increasing resistance to chemicals	6.1 Overlays or coatings 6.2 Impregnation

Table 2:

Principles & methods for protection and repair of concrete: reinforcement corrosion

Principle Number	Principle	Examples of Methods Based on the Principles
7 [P1]	Preserving or restoring passivity	7.1 Increasing cover with additional concrete or mortar 7.2 Replacing contaminated or carbonated concrete 7.3 Realkalisation 7.4 Chloride extraction
8 [IR]	Increasing resistivity	8.1 Reducing moisture content by surface coating or over-cladding
9 [CC]	Cathodic control	9.1 Reducing oxygen supply at the cathode by saturation or surface coating
10 [CP]	Cathodic protection	10.1 Applying an appropriate electrical potential
11 [CA]	Control of anodic areas	11.1 Applying coatings containing zinc to the reinforcement 11.2 Applying barrier coatings to the reinforcement 11.3 Applying inhibitors which penetrate to the reinforcement to the concrete surface

Compatibility of repair materials and concrete members

The problem of providing reliable protection to concrete building elements from external and internal impacts must be considered from the perpective of compatibility between cocnrete repair and protection materials with the concrete element.

General compatibility approach should provide a selection of such repair system that would provide uniformity of the new cover and substrate in terms of their chemical and physical properties.

Term «Compatibility» is defined as a balance of physical, chemical, electrochemical and deformation properties of repair material and concrete substrate which allows repaired structural member to resist stresses induced by volume changes, chemical and electrochemical impacts without failure for the specified lifetime.

Concrete repair system and concrete member under repair must have the following compatibility:

- Electrochemical.
- Adhesive
- Deformation
- Structural and mechnical.
- Chemical
- Penetration
- Durability

Adhesive compatibility. Adhesive compatibility is achievement of the sufficient bond between repair material and concrete substrtate and its comnsistency over time.

Deformation compatibility. Deformation compatibility − capacity of the repair layer to volumetric changes without cracks, loss of adhesion and spalling.

Repair material must possess stable volume without shrinkage or expansion at the initial maintenance stage. It must also have similar elastic modulus and thermal expansion coefficient with the substrate.

Structural and mechnaical compatibility. Requirements to strucural repairs are more challenging compared to surface or “make-up” repairs.

In addition to deformation compatibility requirements strutural repair works must also provide compatibility at the maintenance stage in terms of elastic modulus and creep between repair material and concrete substrate.

New concrete must possess mechanical properties similar to the “old” concrete: strength, elastic modulus, thermal expansion coefficient.

Table shows general requiremnts for selection of the repair materials for structural compatibility. First demand is that compression, bending and tension strength of the repair material must exceed the same properties of the concrete substrate.

Table 3.

General requirements for concrete repair materials to provide structural compatibility

Property	Correlation of the repair material (R) To substrate (C)
Compression, tension, bending strength	R ≥ C
Elastic modulus	R = C
Poisson ratio	Depends on elastic modulus and type of repairs
Thermal expansion coefficient	R = C
Bond under tension and shear	R ≥ C
Initial shrinkage or longterm	R ≥ C
Capacity to deformation	R ≥ C
Creep	May vary
Fatigue strength	R ≥ C

Extremely strong (hard) material may attract too much stress causing its failure by shear and debonding.

Strength of the new concrete should fall withing the limits of 0.7 to 1.6 of the existing concrete strength.

Following the second general requirement elastic modulus and thermal expansion coefficient of the repair material must be equal to the same of the concrete substrate.

Tests of the repair materials. Chair of Concrete and Masonry elements of PSACA carried out a series of tests of the proprietary repair materials compared to common cement and sand mortar.

Test were performed using Isomat brand materials, such as Megacret-40 (high strength cement mortar for repairs with polymer modifiers and PP fibres) and Rapicret (rapid curing repair cement mortar), and common portland cement and sand mortar.

Properties that allow to decide whether a repair material is acceptable for intended use that were tested in the lab are the following:

1.Workability, 2. Shrinkage, 3. Compression strength, 4.Bending strength, 5. Elastic modulus, 6. Shear bond strength, 7. Pull out strength.

Test results. Test results are presented in the table 4.

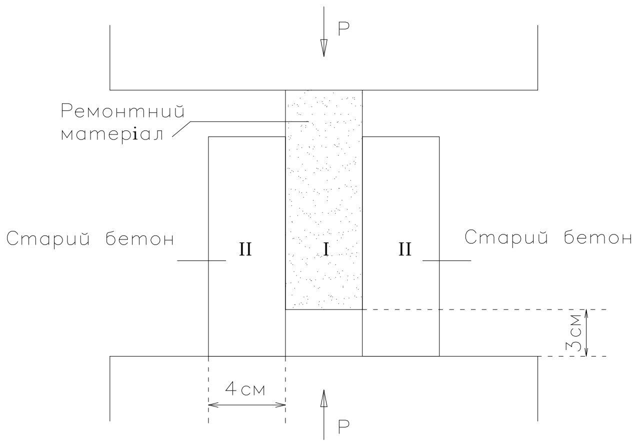

Fig. 2. Test on shear bond strength

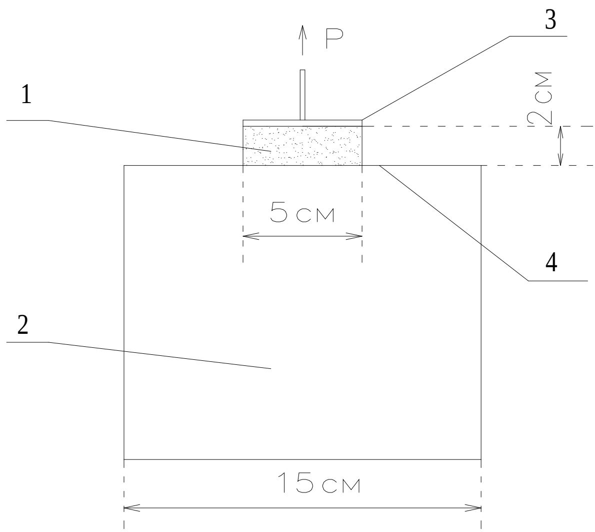

Fig. 3. Test on pull out strength

Table 4.

Test results

Property		№ composition		
		1) Rapicret	2) Megacrete-40	3) mortar
1. Density, kg/m^3		1956,7	1968,6	2301,8
2.Cone spread, mm		106	110	110
3. Shrinkage	lin-ear,%	0	0	1,76
4. Compression strength, N/mm^2		38,1	50,08	16,97
5. Bending strength, N/mm^2		5,39	8,44	1,014
6. Shear bond strength, N/mm^2		0,885	0,907	0,189
7. Pull out strength , N/mm^2		0,187	0,272	0,095
8. Elastic modulus,МПа		$10,45 \cdot 10^3$	$23,45 \cdot 10^3$	$22,97 \cdot 10^3$

Test results show that proprietary materials have better mechanical properties than common cement and sand mortar (compression, bending, shear bond and pull out strength).

Elastic modulus of all tested materials is lower than of concrete B20 (E_b=27,96·10^3 MPa) and therefore in order to use them for structural repair of concrete their composition must be adjusted (by modifying W/C ratio or addition of gravel).

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