Analysis of self-healing potential of advanced cementitious composites – preliminary compositions and experimental results

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ABSTRACT

The imperative need for environmental sustainability generally leads to energy and resource saving measures, including in the construction branch, where concrete and cement based composites are the most used building material category and, as consequence, they induce significant costs for maintenance and repair works of their inherent, time dependent, degradation. The goal of concrete durability improvement, enhancing the service life of concrete structures, is clearly related to cracks appearance and evolution within the cementitious material and possible methods to ameliorate them, for failure prevention.

Along the time, there was noticed a certain ability of cementitious materials to autogenously heal themselves, which implies an economical and minimum invasive environmental approach to limit concrete structures degradation.

The improved self - healing potential of Engineered Cementitious Composites (ECC), a special category of High-Performance Fibre-Reinforced Cementitious Composites (HPFRCC), was considered to be the basic, inspiring nuclei for development of similar compositions, using local, Romanian or East-European raw materials (silica sand, powder type wastes and industrial by-products as additions, cement, etc.).

The paper presents the initial experimental procedure for evaluation of self - healing potential of the prototype compositions, considering both aspects: crack closing and also physical mechanical properties recovery after exposure to wet and dry conditioning cycles.

1. INTRODUCTION

The major goal of the undergoing the theoretical and experimental research carried out at URBAN –INCERC" National Research Institute, Romania, Cluj-Napoca Branch together with Civil Engineering Faculty of Technical University of Cluj Napoca, is obtaining cement-based composites with similar behaviour as Engineered Cementitious Composites (ECCs), regarding crack control under loading and also the efficiency of crack closing by autogenously means.

The first mix designs [1] proved good characteristics regarding tensile strength under three point bending, but they did not prove the expected multiple cracking behaviour, most probably due to poor compatibility between the used fibres and cementitious matrix.

Further mixes with different fibre type as dispersed reinforcement were developed.

2. MATERIALS

The basic raw components of the cementitious mixes, meaning the binding system and the aggregates, are of Romanian provenance materials, with availability on local construction market, as one of the major intent of this project is obtaining engineering materials or products that can be easily achieved locally.

The binding system contains Portland cement, namely HOLCIM CEM I 52.5 R and certified Govora fly ash with the index of pozzolanic activity of 78.59 % (at the age of 90 days), according to the product technical sheet. For all mixes the ratio of Cement to Fly Ash content (C/FA) is 1.2. Local silica sand, characterized by net dry density of 1410 Kg/m^3 and 500 μm maximum grain size, respectively 250 μm medium grain size, was used as aggregate for the cement-based composites.

A BASF High-Range Water Reducer (HRWR) admixture of polycarboxylate composition, selected as more effective for the fresh state characteristics of the previous Cement – Fly ash – Silica Sand mixes, was used. Polypropylene EUROFIBRES MF FINE + 1217 were added as disperse reinforcement in the mixes, 2% of volume, as recommended [2].

Several mixes were performed, considering as variables the mixing sequences and the total liquid content (water and admixture), as initial trials to improve the fresh state characteristics, respectively the workability. Fresh compositions were cast into 40 x 40 x 160 mm prismatic moulds, from which the corresponding specimens were removed after 24h.

3. METHODS

From all mixes that were evaluated as satisfactory from the fresh state point of view, one was selected for a preliminary determining the Self - Healing abilities of the composites. At the age of 20 days the three prismatic specimens were subjected to three points bending, with 2.4 N/s loading rate according to EN 196-1 specifications. The first specimen was loaded to the fracture force, leading to a corresponding bending bearing capacity of 5.0 MPa. The second and the third specimens were loaded to approximately 90% of the bearing capacity (4.4 MPa), which lead to a cracking state of the prisms. All specimens were then exposed to curing cycles consisting in water / air alternating exposure, in order to induce and eventually accelerate the healing mechanisms.

Evaluation of Self –Healing properties was classically performed: a) by visual analyse of crack self closing; b) by physical mechanical (bending) recovery (self-repairing)

4. RESULTS

The visual examinations of the specimens after 10, 30 and 50 curing cycles show a real and effective material potential of the crack self - closing by the means of simple exposure to wet and dry alternating conditions (Figure 1).

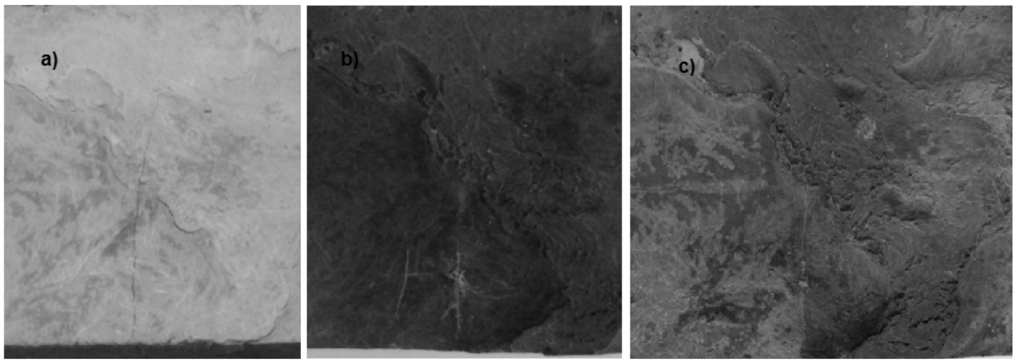

Figure 1: Visual evaluation of the first specimen major crack: a) Initial stage, after failure load; b) after 30 curing cycles; c) after 50 curing cycles

After specimen exposure to 50 curing wet and dry cycles, they were subjected to three points bending test, in the identical conditions as in the initial tests, meaning the loading rate and positioning the specimens in the testing machine. All specimens were loaded to failure. The results show complete recovery of flexural capacity of the material:

a) Specimen 1: the flexural strength developed after curing exposure is of 5.4 MPa, proving full repair of the specimen that was initially loaded to failure; the major crack developed under loading is overlaid to the initial one, sealed by curing and reopened in the second test, as expected;

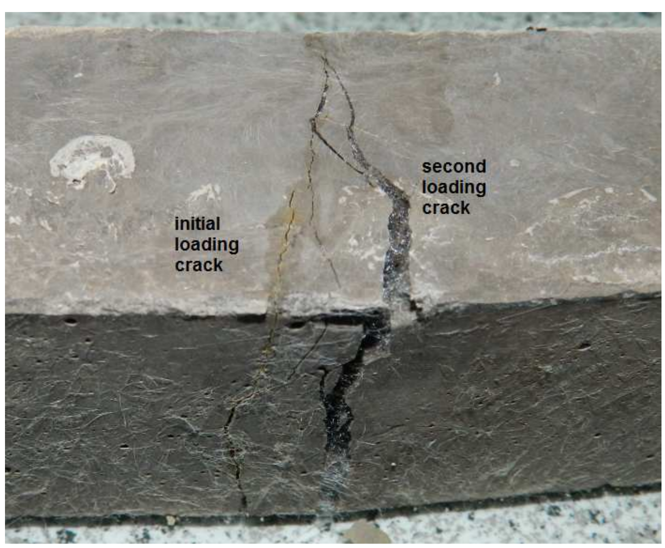

Figure 2: Cracking pattern of the second specimen

b) Specimen 2: the flexural strength developed after curing exposure is of 6.1 MPa, proving strong recovery of the specimen that was initially loaded to 90 % of its estimated bearing capacity; the failure major crack of the second test is distinct from to the initial one, indicating that strong hydration products were developed along the crack during the wet and dry cycles (Figure 2);
c) Specimen 3: the flexural strength developed after curing exposure is 4.7 MPa, sensitively less than its estimated bearing capacity; the major crack developed under loading is overlaid to the initial one, closed during the curing and reopened in the second test, as expected.

5. CONCLUSIONS

The preliminary tests performed on the composite, meaning visual evaluation of cracked specimen by three points bending test, curing and retesting of sample using identical loading conditions, show promising results concerning the autogenous healing ability of the cementitious materials, in terms of crack sealing of the and also recovery of initial bearing capacity.
Supplementary investigations are necessary for a realistic confirmation of initial results. Improvement of the mix design is considered mandatory, in terms of water amount reduction by using a more suitable reduction HRWR admixture and also regarding the improvement of matrix – fibres compatibility in accordance to Engineering Cementitious Composites (ECCs) design principles [3].

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