HEALCON – SELF-HEALING CONCRETE TO CREATE DURABLE AND SUSTAINABLE CONCRETE STRUCTURES

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ABSTRACT

Within the theme 'Self-healing materials for prolonged lifetime' (NMP.2012.2.1-3) of the Seventh Framework Programme, self-healing concrete is an important topic. The project HEALCON, which deals with self-healing concrete to create durable and sustainable concrete structures, is funded by EU-FP7 and started in January 2013. The coordinator of the project is Prof. Nele De Belie (UGent) and the consortium partners are UGent, Avecom, TU Delft, Acciona, TUM, TTI, VTT, COWI, DTI, CEINNMAT, Devan and Fescon.

Adequate perpetuation of the road, tunnel and bridge network, is crucial to preserving European cohesion and business operations; and around 70% of this infrastructure is made of concrete. In order to garantuee liquid tightness of concrete structures, and enhance durability of elements prone to bending cracks, smart concrete with self-healing properties will be designed.

Thanks to the existing expertise of the consortium in the field of self-healing concrete at a lab-scale, a thoughtful selection of promising techniques is possible.
- For early age cracks, a non-elastic repair material can be proposed, such as calcium carbonate precipitated by bacteria, or new cement hydrates of which the formation is stimulated by the presence of hydrogels.
- For moving cracks under dynamic load, an elastic polymeric healing agent is suggested.

Different healing agents and encapsulation techniques are tested and scaled up. Self-healing efficiency is evaluated in lab-scale tests using purposefully adapted monitoring techniques, and optimized with the help of suitable computer models.

Finally the efficiency is validated in a large scale lab test and implemented in an actual concrete structure. Life-cycle cost analysis will show the impact of the self-healing technologies on economy, society and environment compared to traditional construction methods.

1. INTRODUCTION

Reinforced concrete is designed to crack, but crack widths are limited to 0.2 to 0.4 mm depending on exposure class and type of concrete (reinforced or prestressed). Although these cracks do not impair structural stability, through-going cracks drastically affect liquid tightness. This is a major problem in tunnels and large underground structures, where cement hydration reactions and temperature/shrinkage effects in large concrete segments might result in the formation of early age cracks. Since liquid-tightness is necessary, expensive preventive measures are taken or repair works are needed right after construction. Furthermore, even if not through-going, cracks will allow faster penetration of aggressive liquids and gases. Certainly in case of chloride containing liquids or in case of high CO_2 concentrations (e.g. in urban environments), there will be a higher risk of reinforcement corrosion, which compromises the long-term durability of the structure. Current practice requires regular inspection, maintenance and repair, to ensure structural safety over the service life of the structure. These practices involve large direct and indirect costs, such as economic losses from traffic jams. Additionally, not all structures are easy to access for inspection and repair.

In their search to overcome these problems, researchers have been inspired by nature. Biological systems such as bones, skin or plants have the capacity to detect damage very quickly and have moreover the unique feature to repair the damage efficiently. It would be an enormous advantage if this concept could be translated to our engineering materials, such as concrete. The application of so-called “self-healing” concrete, which will in an autonomous way repair cracks, could reduce the maintenance costs drastically. Additionally, indirect costs such as due to traffic congestion, can be avoided.

The aim of HEALCON, a project funded by EU-FP7 and coordinated by Prof. Nele De Belie (Ghent University), is to design smart concrete with self-healing properties to create durable and sustainable concrete structures.

2. ENCAPSULATED HEALING AGENTS

Within the HEALCON project, the focus will be on two types of structures and damages where the use of self-healing concrete will have the largest benefit (Figure 1) :

- early age cracking in structures which demand liquid tightness
- bending cracks at concrete structural parts with a high risk of premature reinforcement corrosion.

Depending on the type of damage, another self-healing concept will be envisioned in the project. Early age cracks will be filled with a non-elastic material, while bending cracks in e.g. bridge beams will be filled with an elastic healing material to cope with the opening and closing movement of cracks under a dynamic load. This means that biogenic healing agents as well as polymeric healing agents (hydrogels and elastic healing agents) will be considered. Besides, suitable encapsulation techniques for each of the healing agents will be developed and the effect of the capsules on the fresh concrete properties will be investigated.

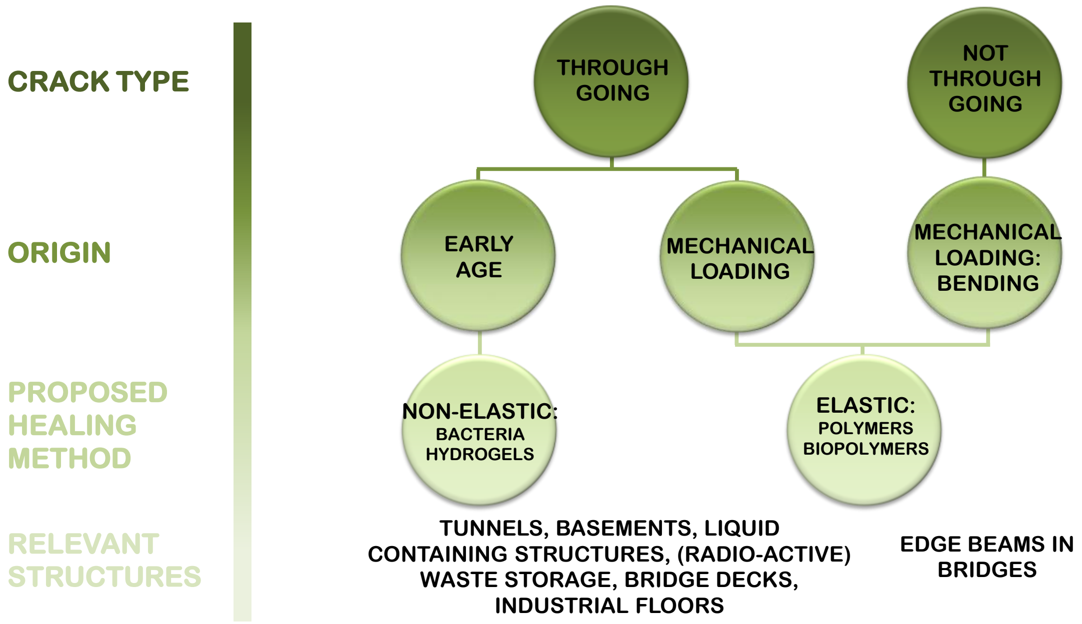

Figure 1: Overview of the self-healing applications envisioned in HEALCON

3. FROM LAB-SCALE TESTS TO FIELD TESTS

The efficiency of the different self-healing mechanisms with regard to mechanical behaviour, liquid-tightness and durability will be firstly quantified at lab-scale. Based on the outcome of these tests and the outcome of the developed computer models, which will simulate the fracturing and self-healing mechanisms, the mechanisms will be scaled to an industrial level. The production of self-healing agents will be upscaled and the developed self-healing methodologies will be experimentally validated in large-scale elements, under conditions close to reality. In the last stage, the new technologies will be demonstrated by their implementation in an actual concrete structure. Furthermore, a life cycle cost (LCC) analysis will be performed for the same structural element as used for the field test / demonstration and the LCC analysis will be supplemented by a life cycle assessment (LCA).
During the laboratory tests as well as during the field tests, non-destructive monitoring techniques will be used to charaterize healing.

4. END-USER MARKET NEEDS AND REQUIREMENTS

The technologies developed from the theoretical and laboratory experiments have to be functional and adaptable to engineering design and have to be implemented on real structures. Therefore, an end-user board is established from the beginning of the project to participate in defining technical and application requirements and to form a stakeholder group that will follow the project.

5. PROJECT OVERVIEW

To summarize, Figure 2 gives an overview of the different work packages within the HEALCON project and the interdependencies.

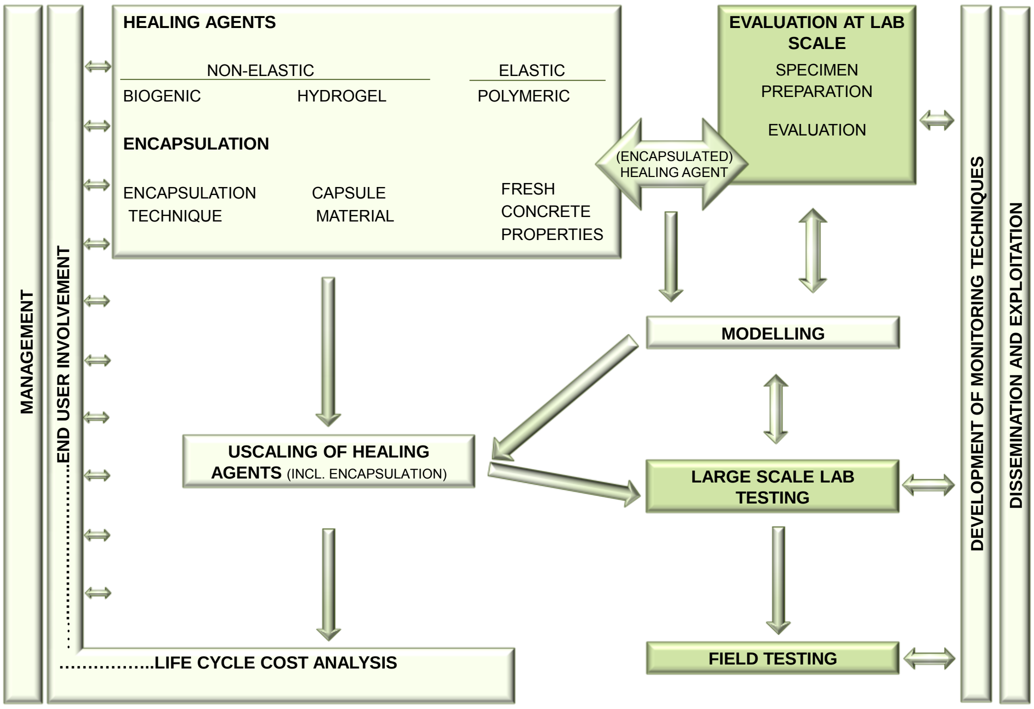

Figure 2: Work packages within HEALCON project and their interdependencies

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