Chapter 8


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ABSTRACT

In this chapter, a deep analyse of a bio-inspired phenomenon starting with broad definitions of included mechanisms is provided. Since establishing an understanding starts with drawing the boundaries of a concept, foremost the definition of related terms are discussed in detail. Afterwards, the importance and history of self-healing phenomenon including the relevant concepts are presented. In order to facilitate the classification, the relevant sub-chapters present two main classes namely autogenic and autonomic healing. Nevertheless, the concepts and mechanisms under these two main topics are also discussed in detail. Finally, evaluation of self-healing mechanisms, tests conducted to determine whether self-healing took place, the indicators of measurement methods, using materials and test methods are given in full detail.

1. INTRODUCTION

Throughout its billions of years old history the nature has always found the best way by courtesy of natural selection. This continuous quality control process of nature results in evolution of biotic materials leading to continuous increase in quality and sustainability. Due to this natural tendency, the biotic materials have to show self-development along with the change in magnitude and type of the external forces and effects. Consequently, the tendency of living materials for maintaining their vitality enables all these alteration phases happen spontaneously.

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Nevertheless, regarding the engineering materials the development and quality control processes need to be controlled by an external mechanism. The physicochemical changes occur due to changing environmental conditions, however, it is not possible to mention about a natural tendency of self-development for abiotic materials. If some of the features of the biotic materials could be brought to abiotic engineering materials it would be a great chance of progress in materials science in terms of being more sustainable and having longer service life. Thus, bringing healing ability to abiotic materials can be considered as a method inspired by the nature itself for manufacturing materials having longer service lives with less repair works. In this context, the possible mechanism of self-healing in engineering materials are assessed in a variety of aspects in this chapter.

2. HISTORY

Almost two centuries ago a British brickmason Joseph Aspdin patented a hydraulic binder manufactured by calcining the slurry mix of lime and clay, afterwards grinding these lumps (clinker) into a blended powder, i.e. Portland cement. Today, due to its high compressive strength, resistance to water, relatively low cost, Portland cement concrete is the most preferred construction material. Particularly, during the last half century, concrete underwent considerable changes both in composition and in manufacturing techniques. As significant progress obtained in concrete researches the studies focused on improving the service life of this complex material (ICC 2006, Mehta 2006, Neville 2010).

Right after the invention of Today’s cementitious materials in 1824, the autogenic healing of concrete was first observed by French Science Academy in 1836 (Hearn, 1998). Some white crystal formations were observed on the end of water pipes and on some other structures in contact with water (Alahmad, 2009). Recrystallization of calcium hydroxide in concrete was found out as the main reason for healing mechanism. Although this information was not a new finding, along with the development in characterization and imaging techniques this topic attracted the interest of researchers (Hearn, 1998; Hyde & Smith, 1889). Regarding the studies conducted on these white precipitations it was concluded that the reaction of calcium hydroxide (Ca(OH)$_2$) either with carbon dioxide (CO$_2$) or calcium bicarbonate (Ca(HCO$_3$)$_2$) was considered as the main mechanism (Hearn, 1998; Loving, 1936; Wagner, 1974).

The first methodical studies on self-healing concept dates back to 1926 with Glanville’s studies (Glanville, 1931), right after the investigation of self-healing of cracks in bridges (Soroker & Denson, 1926; Brandeis, 1937). According to a study made in 1974 by Wagner, it was reported that cracks with 0.05 mm and 0.1 mm diameter healed in 60 hours and 1 year period of time, respectively (Wagner, 1974). Since moisture is the first requirement for autogenic healing the scope of the first studies investigating the water structures is not surprising in this promising research area. The inadequacy of mixing and placing of concrete in earlier times caused lack of quality in concrete structures, but a coincidental way to discover a natural characteristic of the concrete.

Until Dry’s (1994) first suggestion of autonomic healing of cementitious materials by polymers, the self-healing studies on cementitious composites were focused on autogenic healing which is uncontrollable, random and limited in capacity (Malinski et al., 1969; Wool, 1976, Wool & O’Connor, 1981, Tittelboom & De Belie, 2013). As this phenomenon attracted the concern of scientists for two decades, the research area has shown an increasing trend (Figure 1).