Chapter 1

Self-Healing Properties of Conventional and Fly Ash Cementitious Mortar, Exposed to High Temperature

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ABSTRACT

Direct stress and sub-stress caused by fire, temperature variation and external loading in a structure are most important for the development of cracks. The chemical reactions of natural healing in the matrix was not been established conclusively. The most significant factor that influences the self-healing is the precipitation of calcium carbonate crystals on the crack surface. The mechanism which contribute auto-genic healing are: (a) Continued hydration of cement at cracked surface as well as continued hydration of already formed gel and also inter-crystallization of fractured crystals; (b) blocking of flow path by water impurities and concrete particles broken from the crack surface due to cracking; (c) expansion of concrete in the crack flank (swelling) and closing of cracks by spalling of loose concrete particle are also reported as the sealing mechanism by researchers. The recovery of mechanical as well as physical property was discussed by different researchers. An experimental investigation was carried out to study the autogenic healing of fire damaged fly ash and conventional cementitious mortar samples subjected to steam followed by water curing at normal atmospheric pressure. The micro cracks are generated artificially by heating the 28 days aged mortar samples at 800 Deg. C. The effect of fly-ash replacing ordinary Portland cement by 0 and 20% was studied. Recovery of compressive strength and physical properties i.e. apparent porosity, water absorption, ultrasonic pulse velocity and rapid chloride ion penetration test confirm the self-healing of micro cracks. Such healing is more prominent for fly ash mortar mix. Optical as well as scanning electron microscopy With EDAX analysis and X-ray diffraction study of the white crystalline material formed in the crack, confirms formation of calcium carbonate.

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1. INTRODUCTION

Direct stress and sub-stress caused by fire, temperature variations and external loading in a structure are the most important reasons for the development of cracks. There are many literatures which demonstrate the degradation of concrete at different temperatures. At 100 to 200°C evaporation of the water starts, high steam pressure can lead to spalling of the cementitious composites. When the temperature reaches 250°C dehydration starts, degradation of concrete can be observed at this stage. On reaching the temperature at 400-550°C oxidation of volatile material starts and dehydration of CaCO₃ occurs (Georgali & Tsakiridis, 2005). Silica undergoes volume changes at different temperatures, specifically at 300°C there is a huge volume change of silica polymorph (Chu, 1978; Powers-Couche, 1994), this difference in thermal expansion/contraction of aggregate with rich silica, is one of the major causes for degradation of concrete, which eventually spread and may cause the failure of structure. It is reported that at 550°C reduction in compressive strength would typically range from 55% to 70% of its original value (Guise, 1999; Powers-Couche, 1992; Xu, Wong, Poon & Anson, 2003). At 800°C the shrinkage of hardened cement paste was found to be 2.2% by Y. Xu et al. (2003).

Fly ash is produced simultaneously in thermal power plant and is used significantly with cement clinker for structural applications. In India, as per IS 1489 (part-1): 1991 the code allows 10-25% of fly ash addition with cement clinker for making Portland pozzolana cement (Indian Standard, 1991). Addition of certain amount of fly ash with OPC was found to be resource-efficient, environment friendly, durable and economical (Crouch, Hewitt & Byard, 2007). The durability, workability and long term mechanical property has been found to be more for fly ash concrete than ordinary concrete (Sivasundaram, Carette & Malhotra, 1990; Mehta, 2004). Few literature deals with the self-healing property of fly ash-cement system. Pipat Termkhajornkit et al. reported that fly ash–cement system has the self-healing ability for cracks that occur from shrinkage (Termkhajornkit, Nawa, Yamashiro, Saito, 2009). In an experimental programme Mustafa Şahmaran et al. studied the self-healing ability of self-consolidating concretes incorporating high volumes of fly ash (HVFA–SCC) subjected to mechanical load for degradation (Sahmaran, Keskin, Özerkan & Yaman (2008). Both the articles concluded that the cracks were filled by newly formed C–S–H gels (secondary) because of the pozzolanic reactions.

Takeshi Watanabe et al. used ultrasonic pulse velocity to measure the self-healing of cement-fly ash system and concluded that fly ash has the ability towards self-healing (Watanabe, Fujiwara, Hashimoto & Ishimaru, 2011). In an experimental study Zong hui zhou et al. quantify the influence of slag and fly ash on the self-healing ability of concrete by strength measurement (Zhou, Li, Xu, Yu, 2011). Both the analytical processes were found to be important to quantify the self-healing of cementitious system.

The chemical reactions of self-healing process to heal the cracks was not been established conclusively. The most significant factor that influences the self-healing is the precipitation of calcium carbonate crystals on the crack surface (Mukherjee, Mandal & Adhikari, 2012; Heide, 2005; Edvardsen, 1999). The mechanism which contribute autogenic healing are:

1. Continued hydration of cement at cracked surface as well as continued hydration of already formed gel and also inter-crystallization of fractured crystals (Biscoping, 1998);
2. Blocking of flow path by water impurities and concrete particles broken from the crack surface due to cracking (Ramm & Biscoping, 1998; Saharam, Keskin, Özerkan & Yaman (2008);)
3. Expansion of concrete in the crack flank (swelling) and closing of cracks by spalling of loose concrete particle are also reported as the sealing mechanism by researchers (Guise, 1999).