Mohd Nasim et al. International Journal of Recent Research Aspects ISSN: 2349-7688, Vol. 4, Issue 4, Dec 2017, pp. 402-405

Self-Healing Capability of Various Synthetic Fibers – A Review

[1]Mohd Nasim, [2] U.K Dewangan

[1] Research scholar, NIT Raipur, [2] Professor, Department of Civil Engineering, NIT Raipur
[1]mohdnasim8@gmail.com, [2] ukdewangan.ce.nitrr.ac.in

***Abstract*— This paper reviews the self-healing capability of Fiber-reinforced cementitious composite (FRCC) using various synthetic fibers. Cracks are a common occurrence in concrete due to various combinations of reasons and its low tensile strength. The occurrence of cracks and micro cracks in hardening concrete endangers the durability and mechanical properties of concrete. Prevention of cracks is essential and significant for extending the service life of concrete structures and to check its maintenance costs. Self-healing is being looked upon as a future technology in concrete, to control and heal cracks. So, the use of synthetic fibers in FRCC to controls the crack width and the fibers bridge the cracks and thus to promote the self-healing efficiency. Self-healing studies on FRCC using synthetic fibers are still limited. Therefore, the main aim of the review is to identify the research gap for further studies in the emerging field of self-healing concrete using different synthetic fibers and to summarize the effect of synthetic fibers on various vital properties of concrete such as workability, strength, and durability. Finally, the scope of future research work is identified and discussed.**

***Index Terms*— Concrete, Cracks, Fibers, Self-Healing**

I. INTRODUCTION

The self-healing concrete is developed in the belief for “crack-free” concrete structures, which is one of the most proficient solutions, especially in the last decade, by a lot of researchers[1]. The self-healing method might be a proper measure against cracks. So, the self-healing phenomena can be likely to be more effective in fiber reinforced cementitious composites (FRCC) than in conventional concrete. Fiber reinforced cementitious composite (FRCC) has a good capability for self-healing of cracks because of it control the crack width[2]. FRCC with synthetic fibers, one of the key mechanisms for self-healing is calcium carbonate precipitation in the crack. It was revealed that fibers act not only to control the crack width but also as the cores of chemical precipitation sites [3]. In specific, synthetic fibers can promote effective precipitation of self-healing products due to its high polarity[4]. Thus, the self-healing capability of FRCC largely depends on the features of the employed fibers, i.e., FRCC with high polarity fibers such as polyvinyl alcohol (PVA) has greater self-healing capability than polypropylene fibers (PP) due to its no polarity because the fiber polarity can attract calcium ions and accelerate the calcite precipitation.

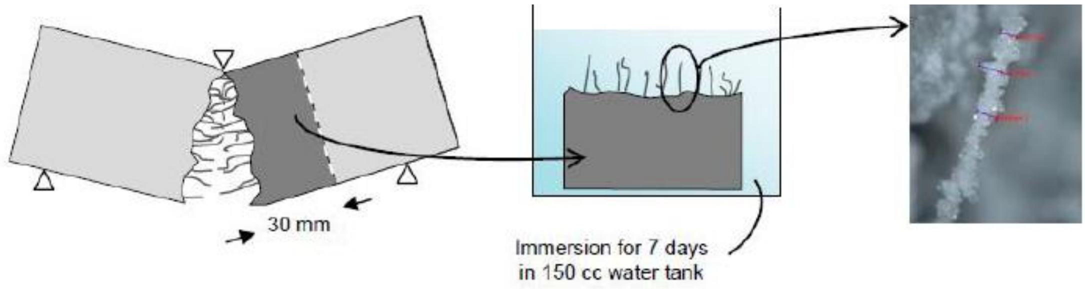
In this paper, the self-healing capability of FRCCs using two synthetic fibers are used for review namely polyvinyl alcohol (PVA) and polypropylene (PP) fibers on different properties of concrete such as workability, strength, and durability.

II. SELF-HEALING CAPABILITY OF SYNTHETIC FIBERS

Lawler, et al.[5] showed the relationship between displacement and flow rate of water in fiber-reinforced mortar specimens depending on the type of reinforcement. They compared the behavior for three types of fiber (long steel, short steel and polyvinyl) combined in different percentages. Their results reveal the effect of the fibers type and volume on the flow rate on cracked specimens, since higher volume of fibers and the combination of macro steel fibers and PVA fibers (both added at 0.5% by volume) achieved the lowest water flows.

Desmettre and Charron [6] compared the behavior of normal strength concrete (w/c ratio of 0.6) and fiber-reinforced concrete (with silica fume, w/b = 0.43), showing that autogenous healing overcame the crack propagation effect in fiber-reinforced concrete the, which did not occurred in normal strength concrete.

Homma, et al. [4] compared the performance of two types of polyvinyl alcohol (PVA-I and PVA-II), ethylene vinyl alcohol (EVOH), polyacetal (POM) and two polypropylene (PP and C-PP) fibers with similar procedures (Nishiwaki, et al.)[7]. When measuring the permeability of precracked specimens, those with PP and EVOH fibers did not present a permeability decrease after healing under water, while the rest of types of fibers (including C-PP) had a significant decrease. However, the only type of fiber that allowed a recovery of permeability coefficient values to that of uncracked specimens, were PVA fibers.



(a) Three-point bending test to split a specimen into 2 pieces

(b) Immersion of a cut specimen in water

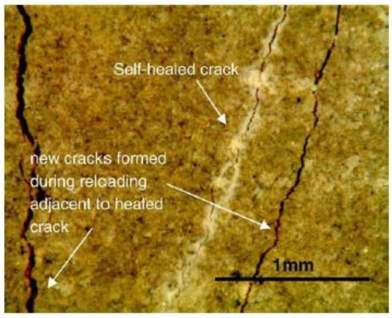
(c) Measurement of the diameter of fibers with precipitated crystals

Fig. 1: Methodology followed to measure the thickness of the precipitates (Nishiwaki, et al., 2012).

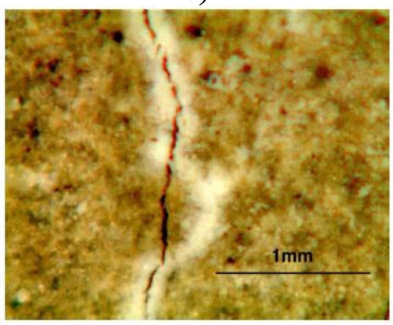
By 14 days of healing exposure 0.3 mm cracks were visually closed, except for the PP fibers. However, permeability tests showed that most of the specimens were reacting even at 20-30 days of exposure. They also measured the thickness of the crystal precipitates in the different types of fibers, in one concrete surface, in order to measure their potential healing effect, as shown in Fig 1, achieving better results for PVA fibers.

Snoeck & de Belie [8] analyzed the self-healing properties of cementitious composites reinforced with flax and cottonised flax in order to compare with PVA fibers. According to their results, the self-healing of cracks after exposing specimens to wet/dry cycles, was independent of the fiber type: cracks smaller than 0.03 mm healed completely but cracks around 0.15 mm only partly healed.

Li, et al. [2] analyzed the enhanced autogenous healing properties for ECC containing Fly Ash and PVA fibers pre-cracked at the age of 6 months, under five different healing exposures (Ying-zi, et al., 2005; Yang, et al., 2011). CR1 and CR2 were two exposures consisting on cycles of water immersion and drying, CR4 was water immersion, and finally CR3 and CR5 were two regimes with different moist conditions. Neither CR3 nor CR5 got significant healing measuring by resonant frequency, confirming the need of direct contact with water. Because of that, only CR4 was compared in terms of recovery of tensile stiffness to the two exposures with cycles (Yang, et al.)[9]. Their results show that for small preload tensile strain, the three exposures achieved recoveries higher than 80%, and cycles around 100%, while for moderately damaged specimens the differences between these exposures were not as clear. After 20 days of exposure, the achieved recoveries of resonant frequency were around 87-100% for the exposure CR1 while 77-90% for CR2. Their results showed that self-healing is possible and healed cracks could be of an enough strength (see Fig.2). However when testing to tensile load and comparing the pre-cracking curve with re-loading after healing, their final stiffness were hardly recovered (Yang, et al.)[10]. The maximum load was generally recovered but this could be caused by the ECC behavior, with high volumes of fibers.



a)



b)

Fig. 2 : a) New crack paths and b) old healed crack s (with white precipitates) (Yang, et al., 2009).

Herbert & Li [2] analyzed if ECC was able to heal under real conditions. In their study, concrete specimens were exposed to environmental conditions in Ann Arbor in Michigan for 12 months, being exposed to a range of temperatures of 11.7 to 32.8ºC. They concluded that specimens under a natural exposure could heal; and also that cyclic loading could deteriorate the stiffness recovery, but specimens were still able to heal a certain percentage of the damage.

Qian, et al [11] analyzed the self-healing behavior of SHC incorporating blast furnace slag and limestone powder, in a relatively high water/binder ratio (0.31 to 0.60). Their results show that water curing had always better results than air curing, with recoveries of the deflection capacity about 65-105% in the case of water curing and 40-60% for the latter. The smaller crack widths and low water/binder ratio enhanced the self-healing reactions. In their study, cracks up to 30 µm width were completely healed, but cracks with relatively large width (around 60 µm) showed only partial healing, as shown in Fig.3. This suggests that small crack widths are preferable, since less healing products are needed to fill the crack and it is easier for the products to grow and bridge the crack.

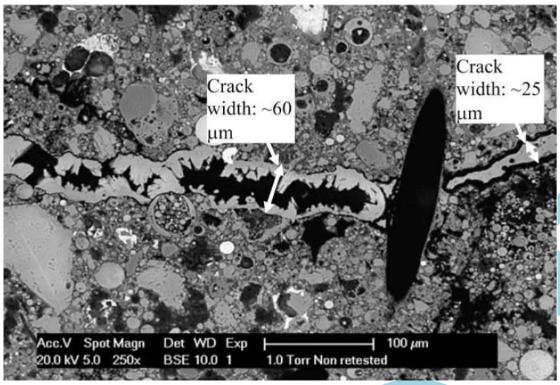


Fig.3: Partial crack healing after water curing (Qian, et al., 2009).

Ma, et al. [12] studied the autogenous healing of medium early-strength ECC for different pre-damage levels and different exposures. The results showed faster self-healing occurred in the healing condition of water/air cycle but the higher stiffness recovery was achieved combining cycles with different moist contents. The self-healing product were a mixed system consisting of C-S-H and CaCO3 with predominance of calcite.

Kim, et al. [13] compared the mechanical behavior of HPSFRC mostly with very small cracks (20 µm) in water or air with the standard curve for two exposures. Their results showed that increase stiffness and load recovery healing in water in comparison to healing in air. At reloading stiffness were lower than original stiffness, but it was somewhat enhanced for specimens healed 14 days underwater. Smaller cracks (< 50 µm) healed completely while medium cracks (around 0.2 mm) remained opened after 28 days of water immersion.

CONCLUSION

The PVA fiber had thick precipitation on the other hand, in the PP fibers had no precipitation. PVA allowed for a greater recovery than PP. In addition to promoting composite self-healing, cementitious repair materials mixed with PVA fibers displayed a good performance in improving concrete strength. In future research, self-healing capability of FRCC using synthetic fibers will be enhanced by chemical admixture.

References

[1] S. Report, H. Mihashi, and T. Nishiwaki, “Development of Engineered Self-Healing and Self-Repairing Concrete Report Development of Engineered Self-Healing and Self-Repairing Concrete-,” vol. 7, pp. 171–186, 2012.

[2] V. C. Li and E. N. Herbert, “Self-healing of microcracks in engineered cementitious composites (ECC) under a natural environment,” *Materials (Basel).*, vol. 6, no. 7, pp. 2831–2845, 2013.

[3] Y. Chan, V. C. Li, Y. Mook, and Y. Chan, “Feasibility Study of a Passive Smart Self-Healing Cementitious Composite Feasibility study of a passive smart self-healing cementitious composite,” vol. 8368, no. November, pp. 819–827, 1998.

[4] D. Homma, H. Mihashi, and T. Nishiwaki, “Self-Healing Capability of Fibre Reinforced Cementitious Composites,” vol. 7, no. 2, pp. 217–228, 2009.

[5] J. S. Lawler, T. Wilhelm, D. Zampini, and S. P. Shah, “Fracture processes of hybrid fiber-reinforced mortar,” *Mater. Struct. Constr.*, vol. 36, no. 257, pp. 197–208, 2003.

[6] C. Desmettre and J. Charron, “Water Permeability of Reinforced Concrete Subjected to Cyclic Tensile Loading,” no. 110, 2013.

[7] T. Nishiwaki, M. Koda, M. Yamada, H. Mihashi, T. Kikuta, T. Nishiwaki, M. Koda, M. Yamada, H. Mihashi, and T. Kikuta, “Experimental Study on Self-Healing Capability of FRCC Using Different Types of Synthetic Fibers Experimental Study on Self-Healing Capability of FRCC Using Different Types of Synthetic Fibers,” vol. 10, pp. 195–206, 2012.

[8] D. Snoeck and N. De Belie, “Mechanical and self-healing properties of cementitious composites reinforced with flax and cottonised flax , and compared with polyvinyl alcohol fibres,” *Biosyst. Eng.*, vol. 111, no. 4, pp. 325–335, 2012.

[9] Y. Yang, E. Yang, and V. C. Li, “Cement and Concrete Research Autogenous healing of engineered cementitious composites at early age,” *Cem. Concr. Res.*, vol. 41, no. 2,

pp. 176–183, 2011.

[10] Y. Yang, M. D. Lepech, E. H. Yang, and V. C. Li, “Autogenous healing of engineered cementitious composites under wet-dry cycles,” *Cem. Concr. Res.*, vol. 39, no. 5, pp. 382–390, 2009.

[11] S. Qian, J. Zhou, M. R. de Rooij, E. Schlangen, G. Ye, and K. van Breugel, “Self-healing behavior of strain hardening cementitious composites incorporating local waste materials,” *Cem. Concr. Compos.*, vol. 31, no. 9, pp. 613–621, 2009.

[12] H. Ma, S. Qian, and Z. Zhang, “Effect of self-healing on water permeability and mechanical property of Medium-Early-Strength Engineered Cementitious Composites,” *Constr. Build. Mater.*, vol. 68, pp. 92–101, 2014.

[13] D. J. Kim, S. H. Kang, and T. H. Ahn, “Mechanical Characterization of High-Performance Steel-Fiber Reinforced Cement Composites with Self-Healing Effect,” *Materials (Basel).*, vol. 7, no. 1, pp. 508–526, 2014.

