Development of self-healing cement pastes by long-term hydration

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Introduction

Optimizing material properties to ensure a minimal risk of service failure has become one of the major goals in construction industry. Cement based materials exhibit a natural capability to self-heal because of their long-term hydration process, resulting in some early age cracks to be spontaneously closed. The process is very slow though, with quite limited impact in the mechanical strength gain after 28 days. However, if this intrinsic ability to self-heal is complemented and enhanced with specific healing additives the final effect in crack sealing and repair can be substantially improved [1, 2]. This intrinsic self-healing ability can be boosted by using additives that react and bond chemically with the cement components. The combination of cement with additives with pozzolanic activity can trigger internal self-healing by closing microscopic cracks, preventing propagation and subsequent failure.

This work investigates the self-healing ability of engineered cement composites using specific additives with high pozzolanic activity, the paper focus on the influence of these additives in their final mechanical properties. Self-healing efficiency was evaluated by assessing the mechanical strength of damaged and healed samples. It has been demonstrated the benefit of using pozzolanic additives to extend cement and concrete durability via crack sealing.

Materials and methods

The cement composites were prepared using ordinary Portland cement (32.5 N) and a fine sand, with a binder-cement ratio of 1:3 and a water-binder content of 0.4. The fly ash has been supplied by CEMEX and its chemical composition is presented in Table 1. The samples were prepared with a 5, 10, 15 and 20 wt.% content of fly ash.

They were cured for 7 days under water and then, the control samples were tested to failure under compression. The samples for the self-healing assessment were damaged using 90% of the total compressive load, submerged and left to heal for 35 and 63 days.

Table 1 - chemical composition of the fly ash

Component	Weight %
SiO_2	45-51
Al_2O_3	27-32
Fe_2O_3	7-11
CaO	1-5
MgO	1-4
K_2O	1-5
Na_2O	0.8-1.7
TiO_2	0.1-1.1

Discussion

After 7 days, all the samples were tested to failure under compression loading. The samples with 5% of fly ash show an improvement in the early stage strength however, higher fly ash content caused a decrease in early strength (Figure 1). The low early compressive strength has been acknowledged by several authors [3], with different strategies being discussed to overcome the problem – the use of nanosilica or geopolymers for example [4, 5]. For this study, it was decided not to use any other additives to ensure that the analysis of the self-healing effect was not influenced by other components in the mixture.

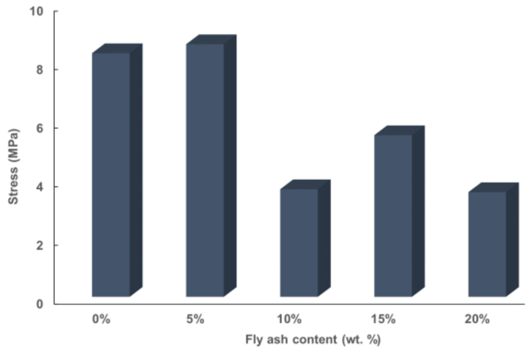

Figure 1 – Stress at failure under compression

Self-healing efficiency has been determined comparing the compression strength of the pre-damaged and the healed samples (Figure 2). Increasing amounts of fly ash had a positive effect on healing even after only 35 days but the best results are obtained after 63 days. Although the best performance was obtained with 20%, the 5% mixture is the one that shows the best compromise between compressive strength and healing efficiency.

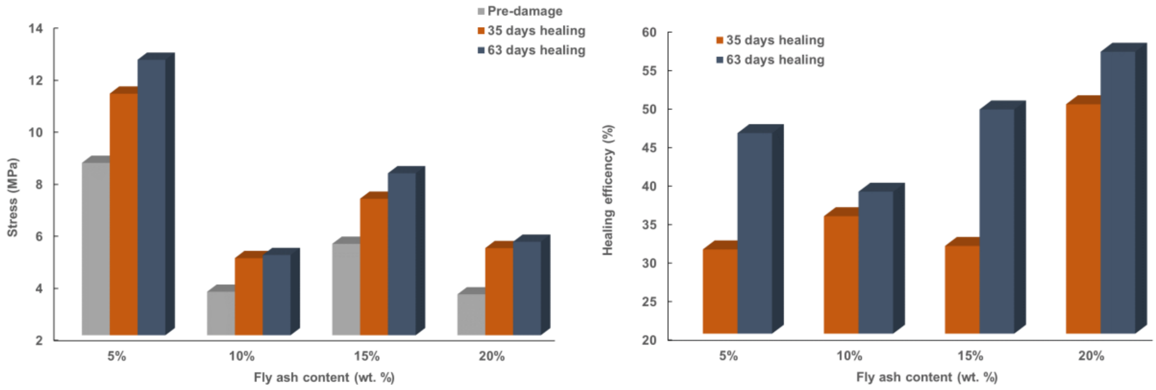

Figure 2 – Stress at failure a) and healing efficiency b) before damage and after the damage/healing cycle

Conclusion

This work shows that adding fly ash to cement composites, using self-healing effect by further hydration, can contribute to close internal cracks and prevent damage extension. This strategy requires the use of fly ash to be complemented with other additives, e.g. silica fume to compensate the loss in early strength. Self-healing obtained by further hydration in cement composites seems to be a sustainable and efficient strategy although further studies need to be conducted to fully understand this process.

References

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