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Abstract

Autogenous healing in 10-years aged cementitious samples containing microfibers and superabsorbent polymers †

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1. Overview and Novelty

Due to the interest to increase the durability and sustainability of concrete structures and construction techniques, a wide range of novel cementitious materials are being designed and investigated. One such recent material is a cementitious material containing superabsorbent polymers (SAPs) studied only from 1999 [1] onwards, mainly for its internal curing purposes with mitigation of autogenous shrinkage [2] and sealing characteristics [1]. Other positive influences are the change in rheology, the increase in freeze-thaw resistance, amongst others [3], [4]. From 2010 onwards [5], a combination of addition of synthetic microfibers and SAPs was studied, for their improved influence on autogenous healing in cementitious materials. It was found that optimal self-healing features were possible [6], [7], as the crack widths were limited and water was available during dry periods. Some of those first samples now have an age of over 10 years.

As the autogenous healing capacity is dependent on the age of the material, so will be the possible influence of added materials to promote this healing. The effects beyond one year [8] are not omnipresent in literature. The effect of the age cannot be investigated as long as the actual specimens do not reach the required maturity. In a previous study, the age was studied up to 8 years' time [9]. In this study, specimens from the same batch were studied after a decade of maturing in different storage conditions.

2. Methodology and Results

Samples containing CEM I 52.5 N (1:1), fly ash (1:1), fine quartz sand (0.7:1), water (0.6:1), superplasticizer (0.01:1), PVA fibers (0.04:1) were used as reference. The SAP samples contained additionally SAPs (0.01:1) and extra water (0.09:1) on top. The SAP is a bulk-polymerized cross-linked potassium salt polyacrylate having a d_{50} particle size of 477 µm and can swell up to 300 times its own weight in a liquid [7].

Samples were prepared and stored for 28 days at 20 ± 2°C and a RH > 95%. Three storage conditions up to an age of 10 years were used. These were *(1)* 20 ± 2°C and a RH > 95%, *(2)* a standard laboratory condition of 20 ± 2°C and a RH of 60 ± 5%, and *(3)* exposed outdoor storage in a Belgium climate 5 km from the weather station in Melle.

The effect of autogenous healing was investigated by four-point-bending loading at the age of 10 years. First, specimens were loaded to 1% strain. Second, the samples were stored in specific healing conditions. These were the same as pre-conditioning with one additional *(4)* wet-dry cycling with 1 h submersion in water at 20 ± 0.5°C and 23 h storage in standard laboratory conditions of 20 ± 2°C and a RH of 60 ± 5%. After this curing period, the samples were reloaded up to 1% strain. The results are given in Table 1.

Table 1. First-cracking-strength σ_{fc} [MPa], average crack width w [μm], number of cracks # [-], and healing ratio HR at high *RH+*, standard *RH-*, outdoor conditions *out* and wet/dry cycling *wd* [%].

Sample	σ_{fc}	w	#	*HR RH+*	*HR RH-*	*HR out*	*HR wd*
REF	6.5 ± 0.5 MPa	10 ± 7 μm	2-8	5 ± 1%	0 ± 1%	9 ± 6%	15 ± 9%
SAP	6.0 ± 0.8 MPa	8 ± 6 μm	4-12	16 ± 6%	6 ± 8%	27 ± 8%	33 ± 7%

Typical strengths and crack widths were obtained. Due to the stress initiator property of SAPs [10], the number of cracks increases. Due to the macro-pore formation, the strength is lowered. However, the healing ratios are always higher for SAP compared to REF samples. This is due to the water action by the SAPs during dry periods and the ability of SAPs to extract moisture from the ambient environment. This leads to better conditions for healing products to form as water is available [11]. The main visual appearance of the healing products was the whitish calcium carbonate crystallization.

3. Conclusions and Recommendations

The small crack widths after 10 years are still able to be partially healed. The main visual healing product is calcium carbonate. Further hydration was less likely as most binder already hardened during storage conditions. Generally, the samples containing SAPs show more prominent healing and they are still able to swell almost completely after a decade storage in an alkaline cementitious environment. This makes them a sustainable option for the future as less maintenance and repair will be required.

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