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Pore Refinement Action of GGBFS and Fly Ash on the Primary and Secondary Capillary Imbibition Rates of Concrete

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1 Introduction

Capillary imbibition depends on the volume and connectivity of pores. Anomalous imbibition (*i.e.* the lack of linearity between their water uptake and the square root of time) is generally reported for cementitious materials. For this reason, a novel approach considers an evolution with the fourth root of time (Villagrán Zaccardi *et al.*, 2017; Alderete *et al.*, 2019a). After long term exposure, water uptake further continues at a very low rate even after the capillary rise has covered the full height of samples. Then, a secondary imbibition period for the water ingress driven by diffusion into the finest pores of the cementitious matrix can be defined (Alderete *et al.*, 2019b). Primary and secondary imbibition coefficients are therefore convenient complementary descriptors of transport in cementitious materials.

In this paper, blended concrete mixes (Table 1) with substitutions of 20, 40 and 60 % of OPC by ground granulated blast-furnace slag (SB), or 20, 30 and 40 % of OPC by fly ash (FA). Samples were wet-cured for 28 and 90 days before testing. The pore refining action of these supplementary cementitious materials (SCMs) and consequent reduction of the capillary imbibition rate was assessed by mercury intrusion porosimetry and long-term capillary imbibition tests. For the first, the threshold diameter was determined by the tangent method, d_{tg} (Liu and Winslow, 1995), and the intrudable pore volume, ϕ_{in}, (Ma, 2014) was computed from the maximum intruded volume. For the second, primary and secondary imbibition rates were computed. For this, sections between 3 and 8 cm from the base of the 10 cm cylinders were used. Samples were laterally waterproofed to ensure one dimensional flow and preconditioned by drying them (at 50 °C until mass decrease was lower than a mass fraction of 0.1 % within 24 h). Dried samples were then put in contact with water, with an immersion depth of (3 ± 1) mm, and water uptake was periodically registered by weighting.

2 Results

Results are presented in Table 1. Pore refinement due to the action of the SCMs led to a decrease in the CIR, in connection with the reduction of d_{tg}. In contrast, values of ϕ_{in} and sCIR are not reflecting so well the refinement action of the SCMs. Results reveal the stronger refinement action of SB with time from 28 to 90 days, in comparison with FA mixes. A low water flow rate is in all cases correlated with the increased tortuosity of samples.

Table 1. Mix compositions and properties, and results from MIP and capillary imbibition.

	OPCc	SB20c	SB40c	SB60c	FA20c	FA30c	FA40c
CEM I 42.5 N / SCM (kg/m^3)	342/0	274/68	205/137	137/205	274/68	239/103	205/137
Water (kg/m^3)	154	154	154	154	154	154	154
Sand (kg/m^3)	865	860	860	860	860	860	855
Gravel (kg/m^3)	1040	1032	1030	1028	1032	1028	1020
Air content (%) / slump (mm)	2.1/70	2.4/70	2.1/100	2.3/120	2.8/70	2.3/100	2.4/150
Compressive strength 28d (MPa)	50.6	42.6	32.6	32.2	50.1	50.8	48.8
ϕ_{in} 28/90 d (mm^3/g)	13/nd	15.8/13.3	16.0/12.7	17.1/14.1	17.1/15.6	17.0/15.5	20.1/17.7
d_{tg} 28/90 d (μm)	0.3/nd	0.5/0.06	0.3/0.05	1.1/0.06	0.5/0.09	0.2/0.07	1.0/0.1
CIR 28/90 d (μg/mm^2/s$^{0.25}$)	64/54	43/37	57/36	65/43	54/36	56/34	57/44
sCIR 28/90 d (mg/mm^2/s$^{0.25}$)	11/16	8/17	11/10	9/11	16/19	10/15	11/15

3 Conclusions

During long-term exposure of unsaturated samples, the secondary water transport occurs at a much slower rate than the short-term capillary imbibition. Both primary and secondary periods display increasing water uptake proportional to $t^{0.25}$. The pore refinement action of ground granulated blast-furnace slag and fly ash was reflected in the comparable reduction of the CIR and d_{tg} parameters. In second term, ϕ_{in} values were reduced from 28 to 90 days, but the correlation is not very good with the capillary imbibition. The likely reason is that pore refinement causes an increase in tortuosity more than a reduction in porosity. Lastly, sCIR does not reflect so well the refinement action of the SCMs.

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References

Alderete, N. M., Villagrán-Zaccardi, Y. A. and De Belie, N. (2019a). Physical evidence of swelling as the cause of anomalous capillary water uptake by cementitious materials, *Cement and Concrete Research*, 120, 256–266. https://doi.org/10.1016/j.cemconres.2019.04.001

Alderete, N. M., Villagrán-Zaccardi, Y. A. and De Belie, N. (2019b). Mechanism of Long-Term Capillary Water Uptake in Cementitious Materials, *Cement & Concrete Composites*, submitted.

Liu, Z. and Winslow, D. (1995). Sub-distributions of pore size: A new approach to correlate pore structure with permeability.*Cement and Concrete Research*,25(4),769–778. https://doi.org/10.1016/0008-8846(95)00067-M

Ma, H. (2014). Mercury intrusion porosimetry in concrete technology: Tips in measurement, pore structure parameter acquisition and application. *Journal of Porous Materials*, 21(2), 207–215. https://doi.org/10.1007/s10934-013-9765-4

Villagrán Zaccardi, Y. A., Alderete, N. M. and De Belie, N. (2017). Improved model for capillary absorption in cementitious materials: Progress over the fourth root of time. *Cement and Concrete Research*, 100, 153–165. https://doi.org/10.1016/j.cemconres.2017.07.003