EFFECT OF POZZOLANIC INDUSTRIAL WASTES ON DURABILITY OF ENGINEERED CEMENTITIOUS COMPOSITES (ECC)

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ABSTRACT
In this research 26 different compositions of an engineered cementitious composite with different percentages of Fly ash and Silica fume, as two pozzolanic industrial waste and by-product, were mixed. The effect of different percentage of the pozzolans on durability of ECC was studied. To evaluate the durability of the material, two tests, namely water absorption by immersion and water absorption by capillary, were performed. The results from both tests demonstrated the same trend regarding the influence of the wastes on durability. In other words, by increasing the amount of pozzolans, the water absorption after immersion and boiling, decreased more than 50% besides the significant reduction in the rate of absorption by capillary (sorptivity). The results also indicated that silica fume has a higher influence on the water-absorption reduction compared to fly ash however, in the case of absence of silica fume, fly ash plays a significant role on the improvement of durability of the material.

Keywords: Water absorption, Sorptivity, Durability, Engineered cementitious composite (ECC), Industrial Waste, Pozzolan, Fly ash, Silica fume.

INTRODUCTION
A very high-qualified type of ECC is Ultra-high performance concrete (UHPC). This type of ECC exhibit very special characteristics such as compressive strength higher than 150 MPa besides self-compactness [1, 2, 3, 4]. To meet the eco-efficiency criteria in the path of sustainable development, it seems necessary to replace materials such as cement, with a significant carbon footprint, with other pozzolanic materials particularly those having negative impact on environment such as industrial wastes. Silica fume, as the first pozzolanic waste in this research, is a byproduct of silicon metal or ferrosilicon alloys. The other industrial waste is fly ash available in huge quantities worldwide as a waste material with very low cost and environmental impacts since its application prevents the massive landfills use by this waste material from the thermal power plants [5]. In the first part of this research an Eco-efficient composition of UHPC was introduced [1, 6] and then the effect of fly ash and silica fume on the durability of the material through water absorption tests was investigated. The other durability-related tests were explained in other publications by the authors [7].

MATERIAL DEVELOPMENT AND TESTING PROCEDURE
All the process, including the mixing and curing procedure were explained in other publications by the authors [2]. For investigating the effect of waste quantity on durability, 26 compositions with various quantities of wastes were mixed and after curing period were divided into two pieces for water absorption by immersion as well as capillary tests. The water absorption by immersion and capillary were performed based on ASTM C642-97 and LNEC-E393 respectively [6, 7].

RESULTS AND DISCUSSION

The corresponding results are depicted in Fig. 1. The AAIB parameter in this figure is calculated based on Eq. 1 where A is the mass of oven-dried sample in air and C is the mass of surface-dry sample in air after immersion and boiling.

$$\text{Absorption after immersion and boiling (AAIB), \%} = 100(C-A)/A \quad (1)$$

Besides the AAIB, the rate of absorption, known as sorptivity, is shown on the right hand side of the diagram as well. Sorptivity is calculated through the water absorption by capillary formula shown in Eq. 2 where I is the absorption in mm, m_t is the change in mass of specimen in different time intervals in gram compared to the initial mass (Mi-M0), a is the area of exposed cross section of specimen to water in mm^2 and d is density of water in g/mm3 (0.001 g/mm3).

$$I=m_t/a.d$$

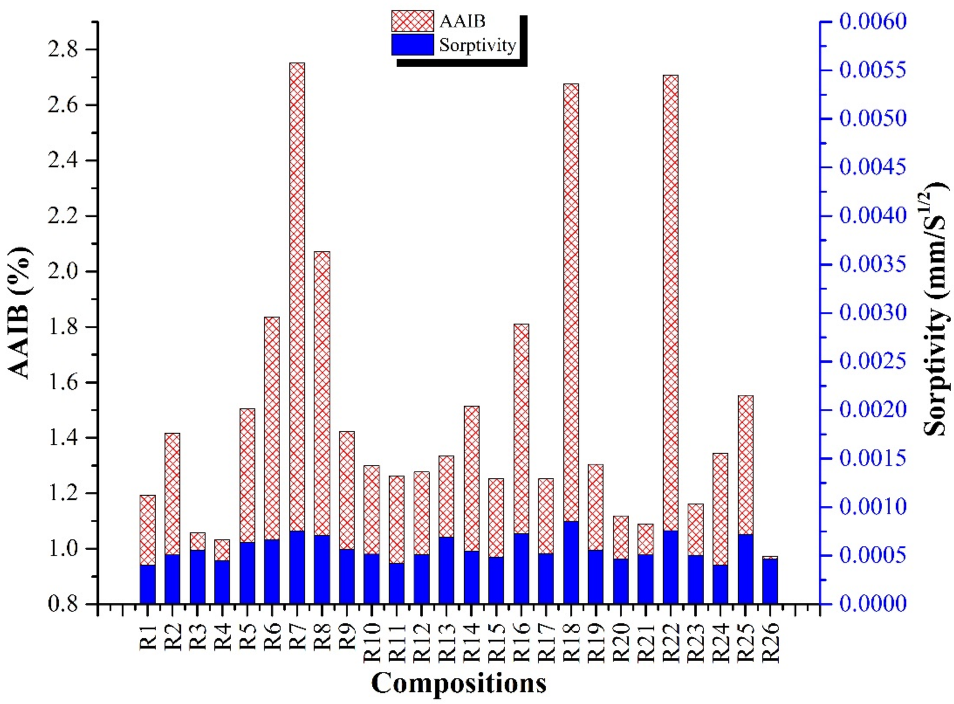

Figure 1:AAIB and sorptivity trends for different compositions.

As depicted in Fig. 1, both tests demonstrate almost the same trend. In other words, the compositions having highest quantities of silica fume and fly ash exhibited lowest water absorption and higher durability in both tests compared to other compositions with lower quantities of pozzolans.

CONCLUSIONS

By increasing the silica fume content, the water absorption reduces significantly. Fly ash up to around 50% of cement weight, improves the material with respect to lower water absorption. It was shown that R7, R18 and R22 demonstrated the worst behavior regarding water absorption in both tests. In other words, these three compositions with minimum silica fume and fly ash quantities, exhibited the highest water absorption. The next worst compositions as shown in Fig. 1 are R6, R8 and R16 again as the result of minimum level of pozzolans. On the other hand, compositions such as R4 or R26 with very high silica fume and fly ash content revealed very low water absorption in both tests compared to other mixtures. In other words, by increasing the amount of pozzolans, the water absorption after immersion and boiling, decreased more than 50%. This shows the importance of fine binders and possibility of using pozzolanic wastes in improvement of durability of materials.

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References

[1] I. Ferdosian, "Eco-efficient ultra-high performance concrete development by means of Response surface methodology," Cement and Concrete Composites, 2017.

[2] I. Ferdosian and A. Camões, "Effective low-energy mixing procedure to develop high-fluidity cementitious pastes," Matéria (Rio de Janeiro), vol. 21, no. 1, pp. 11-17, 2016.

[3] I. Ferdosian, A. Camões and M. Ribeiro, "High-volume fly ash paste for developing ultra-high performance concrete (UHPC)," Ciência & Tecnologia dos Materiais, 2016.

[4] M. Cheyrezy, V. Maret and L. Frouin, "Microstructural Analysis of RPC (REACTIVE powder concrete)," Cement and Concrete Research, vol. 25, no. 7, pp. 1491-1500, 1995.

[5] R. Kaufman, "Seeking a Safer Future for Electricity's Coal Ash Waste," National Geographic News, 2011.

[6] I. Ferdosian and A. Camões, "High-volume fly ash ultra-high performance concret," in Materiais 2015, VII International Materials Symposium/XVII Conference of Sociedade Portuguesa de Materiais, 2015.

[7] I. Ferdosian and A. Camões, "Ultra-high durable concrete: A way towards safe and durable structures," in 7th International Conference on Safety and Durability of Structures (ICOSADOS 2016), 2016.

[8] ASTM C642 – 97, Standard Test Method for Density, Absorption, and Voids in Hardened Concrete, West Conshohocken, PA 19428-2959, United States: ASTM International, 1997.

[9] LNEC E393, , Concrete. Determination of water absorption by capillarity, Lisbon: LNEC, 1993.

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