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Development of cost-efficient UHPC with local materials in Colombia

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1 Introduction

Compared with normal strength concrete, ultra-high-performance concrete (UHPC) is characterized by high particle packing density, combined with the use of superplasticizer to reduce the water-to-cementitious materials ratio. These extremely low porosity and low permeability characteristics of UHPC give it improved durability and mechanical properties over other types of concrete [1] [2].

However, in terms of sustainability and cost, this class of material must still be evaluated regarding its value of the higher average dosage of binder compared to regular concrete.

The research program reported on herein was aimed at detemining eco-friendly UHPC dosages in which the cement content was kept as low as possible while reaching compressive strength al 28 days (R28) over 150 MPa using local avalible components in the Colombian market and without using any heat treatment.

2 Materials

The materials used to manufacture the concrete were local available in Colombia. In all dosages, ASM Type HE cement (C), 100 kg/m^3 of silica fume (SF), silica sand (SS) with maximum particle size of 600 µm, tape water and polycarboxylate-ether-superplasticizer (HRWR), were used. As suppelemtary cementitious materials (SCM) several options were tested: Electric Arc Slag Furnace (EASF), Ground Granulated Blast Slag Furnace (GGBSF), Limestone Powder (LP), Micro-Limestone Powder (MLP), Recycled Glass Powder (RGP), Recycled Glass Flour (RGF), local high unburned carbon fly ash (FA), and fluid catalytic cracking catalyst residue (FC3R), as partial substitution of cement and silica fume. A reference dosage without restrictions in the amount of silica fume which doesn't use any of the SCM aforementioned, was used as reference.

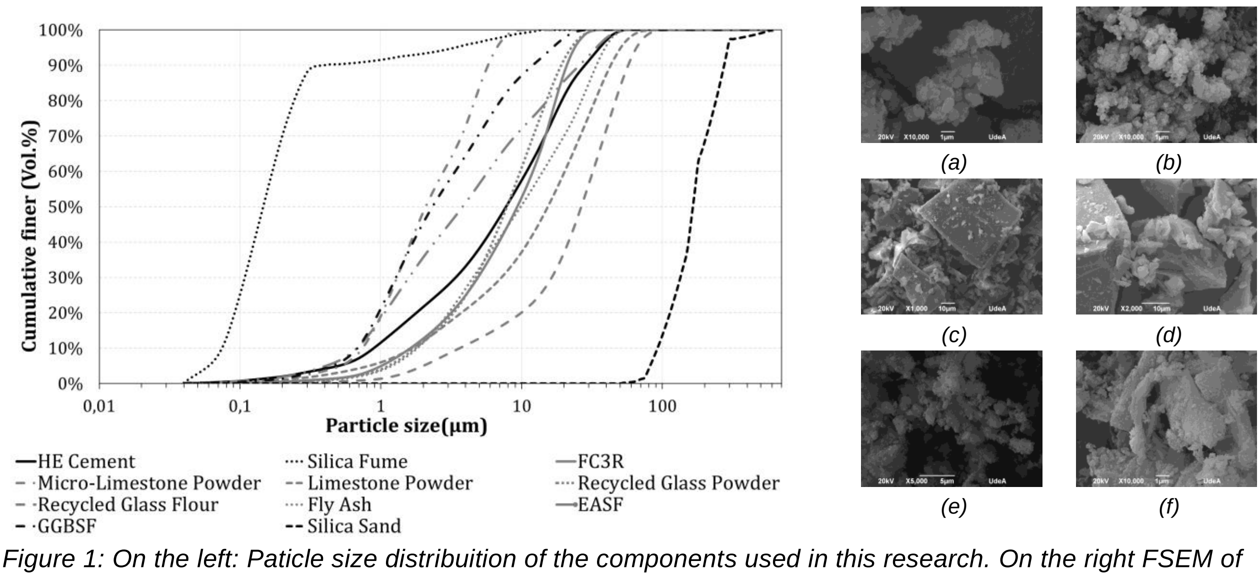

Figure 1: On the left: Paticle size distribuition of the components used in this research. On the right FSEM of several supplementay cementitious materials used: a)FC3R, b)MLP, c)RGP, d)RGF, e)EASF, and d)FA.

3 Mixture design and results

Statistical tools such as Design of Experiments (DoE) and multiobjectiove optimization were used to better adjust the goal of compressive stgrength while using the less amount of cement and maintining the mixture in a reasonable cost. The factors analysed in each combination of components were cement content in kg/m^3 (Factor A), water to binder ratio (Factor B) and percentage of superpasticizer in volume used (Factor C). The rest of components were adjusted to the A&Amod curve using q=0.264 [3]. The optimization was based on the desirabilities approach developed by Derringer and Suich [4]. In every combination a 18-run DoE was used. The combinations analysed are depicted in Table 1 as well as their mathematical optimization and the respective experimental verification.

Table 1: Combinations analysed in the research. COP = Colombian Pesos. R28 in MPa. Cement in kg/m^3

DoE	**SCM**	**Cement**	**w/b**	**HRWR**	**Model R28**	**Experimental R28**	**Cost/m^3** *(x1000COP)*
REF	-	870	0.191	3.05%	174	170	1350
DoE01	LP+MLP+EASF	651	0.161	2.62%	155	152	900
DoE02	RGF+MLP+EASF	621	0.164	2.55%	158	156	848
DoE03	RGP+MLP+FC3R	654	0.172	2.83%	153	150	900
DoE04	RGF+RGP+MLP	603	0.165	2.05%	155	152	809
DoE05	MLP+RGF	590	0.163	2.11%	157	155	806
DoE06	MLP+FA	711	0.168	2.86%	151	148	890
DoE07	GGBFF+RGF	674	0.164	2.57%	153	157	841
DoE08	GGBSF+RGP+RGF	681	0.166	2.28%	152	151	876

4 Conclusions

Based on the obtained results from this analysis, the following conclusions can be drawn: (i) Partial substitution of cement and silica fume is possible with different options, however there is a drop in the resistance in all cases;(ii) limestone powder and especially recycled glass allow to reduce the superplasticizer content which has a notable impact on the final cost;(iii) local fly ash dogage presents the greater need for cement due to the high unburned carbon over 12%;(iv) lower final cost an cement content is achieved when blending micro-limestone powder and recycled glass flour as partial substitution of cement and silica fume.

References

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