HIGH-VOLUME FLY ASH ULTRA-HIGH PERFORMANCE CONCRETE

Iman Ferdosian[1, *], Aires Camoes[1]

[1] Center of Territory, Environment and Construction (C-TAC), Civil Engineering Department, University of Minho, 4800-058 Guimarães, Portugal;
[*]corresponding author: iman_fn2007@yahoo.com

Keywords: Ultra-high performance concrete, UHPC, Fly ash, high volume fly ash, Eco-efficient, composite material, Workability, Compressive strength.

Abstract

Ultra-high performance concrete (UHPC) is a kind of high-tech composite material which shows superb characteristics compared to other kind of concrete such as self-compactness, compressive strength higher than 150 MPa and exceptional durability performances. This new composite material consists of an optimized gradation of granular ingredients, water/binder ratio less than 20% in weight and a high content of steel fiber. This material offers variety of sustainable applications with respect to long-term cost and environmental aspects as an eco-efficient material. It enables the designers to have slim sections with higher strength, ductility and durability for applications such as bridge decks, shell structures and elements in high-rise structures even in aggressive environments.

The main goal of this research was to develop a more eco-efficient UHPC. In this regard, cement and silica fume, as two main constituents of the prevalent UHPC compositions, were replaced by fly ash (FA), as a waste material, which brings about both economic and ecological efficiency in construction industry. According to the fact that this material should demonstrate high workability, in the first phase the effect of various kind of superplasticizers (SP) and their best addition time and method were studied and in the next stage, cement and silica fume were substituted with fly ash.

With respect to the fact that W/C and W/B ratio in UHPC are less than 0.25 and 0.2 respectively, the role that superplasticizer plays in fluidizing the concrete is of paramount importance. This role is attributed to the dispersion of cement particle those are confined with a positive layer of Ca^{2+} ions from dissolution of cement particles in water. As time passes and C-H and C-S-H gels are formed, the positive cement particles loss their tendency to adsorb the anionic SP particles. So, the addition time of SP to the binder has an important effect on fluidity of paste and concrete as well. The obtained results show that the best procedure for water and SP addition time is watering the binders with 60% of the whole water and mixing for 3 minutes, i.e. the time that cement gel formation starts, adding SP and mixing for 5 minutes and finally addition of the rest of water which seems to remain as free water which has great effect on fluidity of paste.

The second phase of this research, as mentioned above, was to develop a type of UHPC with lower cement and silica fume content. The preliminary tests prove the applicability of fly ash to be used in UHPC. However the samples demonstrate lower strength in early ages, the long-term strength goes beyond that of the reference mixture just with cement. Based on the results, the best percentage of FA, with respect to fluidity and strength of paste, is 15% of the cement weight.

Furthermore, according to the fact that packing density of the whole mixture has a great influence on both fluidity and strength of paste and UHPC as well, FA in different particle size was tested and finally an eco-efficient UHPC with best particle size and optimum dosage of SP, as shown in the following table, with compressive strength of 150 MPa and flow diameter of 20 cm was developed.

Table 1 - Composition of UHPC in weight ratio to cement

Cement	1
Silica fume	0.2
Fly ash	0.4
Micro Sand	1.4
Quartz powder	0.1
Steel fiber (%v)	0.02
Water	0.25
SP	0.04