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Porosity and Pore Size Distribution of Well Hydrated Cement-Fly Ash-Gypsum Pastes

[1]J.M. Khatib, [2]L. Wright, [3]P.S. Mangat and [4]E.M. Negim

[1]School of Technology, University of Wolverhampton, Wulfruna Street, Wolverhampton, WV1 1LY
[2]Pick Everard, Halford House, Charles Street, Leicester, LE2 7DQ, UK
[3]Centre for Infrastructure Management, MERI, Sheffield Hallam University, Howard Street, Sheffield, S1 1WB, UK
[4]School of Chemical Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia

Abstract: This research is a part of a wide range investigation on the use of flue gas desulphurisation (FGD) in construction applications. It reports some results on the porosity and pore size distribution of cement paste containing varying amounts of fly ash-gypsum blends as partial replacement of cement. The cement was replaced with 25% of different blends of fly ash and gypsum. The gypsum content ranged from 0 to 100% the fly ash-gypsum blend. All the pastes were cured for 365 days. Increasing the amount of gypsum increases the pore volume and the tendency of obtaining coarser pore structure.

Key words: FGD waste · Fly ash · Gypsum · Desulphurised waste · Porosity · Pore size distribution

INTRODUCTION

The porosity and pore size distribution of construction materials determine the performance of such materials in construction applications. The performance covers the mechanical properties such as strength and durability properties including the ingress of chloride and sulphate ions [1-5].

The total porosity in the system has a noticeable effect on the mechanical properties of construction materials [1-3], whereas the pore size distribution will mainly affect the durability properties [4, 5]. This is highlighted when correlation was made between the porosity and pore size distribution and the various mechanical and durability properties [6, 7].

The effects of mineral admixtures such as fly ash and ground granulated blafurnace slag on porosity and pore structure of cement paste is well established [8-9]. This paper presents the results on the effect of fly ash-gypsum blend on the porosity and pore size distribution of cement paste at 365 days of curing. The results at 28 days of curing were reported elsewhere [10]. The reason for blending fly ash and gypsum is to simulate flue gas desulphurisation (FGD) waste.

MATERIALS AND METHODS

The materials used for the pastes were Portland cement (C), fly ash (FA), gypsum (G) and water. Mix M1 represents the reference paste containing 100% C. Mixes M2 to M5 contain different simulated desulphurised wastes blended from fly ash and gypsum (FA-G blends). The cement was replaced with 25% fly ash and/or gypsum. The gypsum content in the FA-G blends ranged from 0 to 100%. The water/binder was kept constant at 0.5. The binder consisted of cement, fly ash and gypsum.

Table 1 shows the binder proportion of the mixes.

Table 1: Constituents of binder

		Proportions (% weight of binder)		
Mix No	Mix ID	Cement (C)	Gypsum (G)	Fly Ash (FA)
M1	REF(100_C)	100	0.00	0.00
M2	$100_{FA}0_G$	75	0.00	25.00
M3	$85_{FA}15_G$	75	3.75	21.25
M4	$50_{FA}50_G$	75	12.50	12.50
M5	$0_{FA}100_G$	75	25.00	0.00

Corresponding Author: J.M. Khatib, School of Technology, University of Wolverhampton, Wulfruna Street, Wolverhampton, WV1 1LY.

Paste specimens were placed in a mist curing room at 20°C for 24 hours until demoulding. After that demoulding took place a nd specimens were placed in water at 20°C for a total period of 365 days. After that a suitable sample was taken from the middle of specimen. The samples were dried in an oven at 70°C to remove the moisture. After drying, the samples were placed in an airtight bottle until testing. Mercury intrusion porosimetry was used to determine total porosity and pore size distribution. Further information on the testing technique is found elsewhere [11].

RESULTS AND DISCUSSION

The total pore volume (TPV) of paste containing different fly ash-gypsum blends at 365 days of curing is plotted in Figure 1. Most paste containing a blend of fly ash and gypsum as cement replacement show higher total pore volume than the reference paste (i.e. mix M1). Paste containing 85% fly ash and 15% gypsum blend yielded the lowest total pore volume compared with all other pastes including the reference. The combination of 85% fly ash and 15% gypsum showed the highest strength [11].

The particle size distribution for pastes M1, M2, M3, M4 and M5 at 365 days of curing is shown in Figures 2 to 6. There exists a noticeable difference in the pore size distribution curves for pastes with and without gypsum. The reference paste exhibits a single peak for the particle size distribution curve. As the gypsum content in the paste increases there is a shift from a single peak to a double peak (bimodal), which becomes distinct when the cement is partially replaced with 25% gypsum (i.e. paste M5). The threshold diameter for the various pastes at 365 days of curing is plotted in Figure 7.

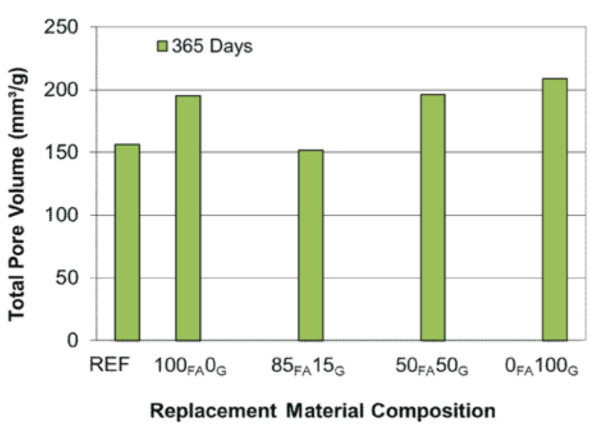

Fig. 1: Influence of FA-G composition on the TPV of pastes

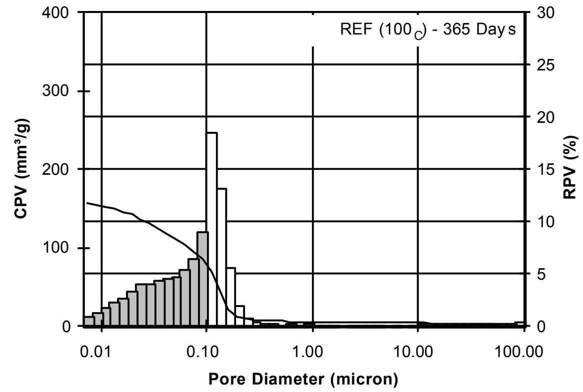

Fig. 2: Pore size distribution of the reference paste (M1)

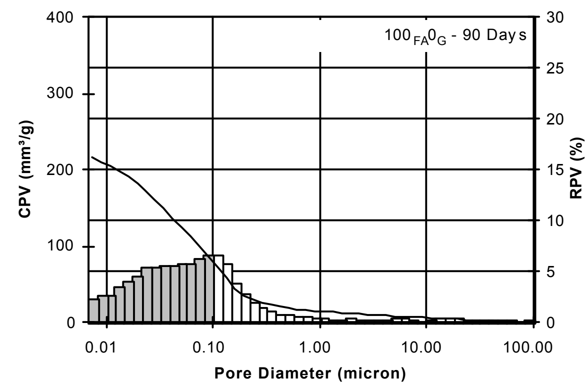

Fig. 3: Pore size distribution of paste M2

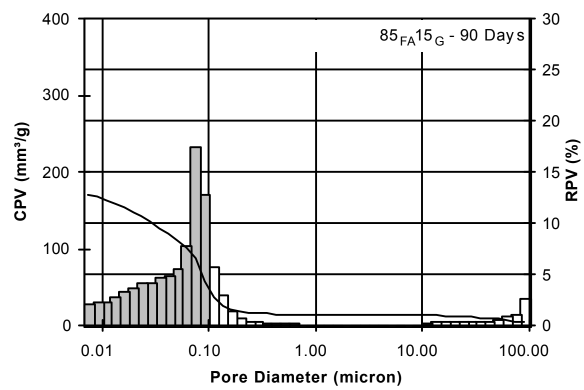

Fig. 4: Pore size distribution of paste M3

Using high proportion of gypsum as in paste M4 shows an increase in the threshold diameter compared with the other pastes. A larger threshold diameter indicates a coarse pore structure. This is further supported in Figure 8 where the percentage of large pores (pores whose diameter are larger than 0.1µm) is shown for the various pastes. An increase in the gypsum content results in an increase in the percentage of large pores. The maximum increase in the percentage in large pores occurs in paste M5 where the gypsum forms 25% of the total cement content.

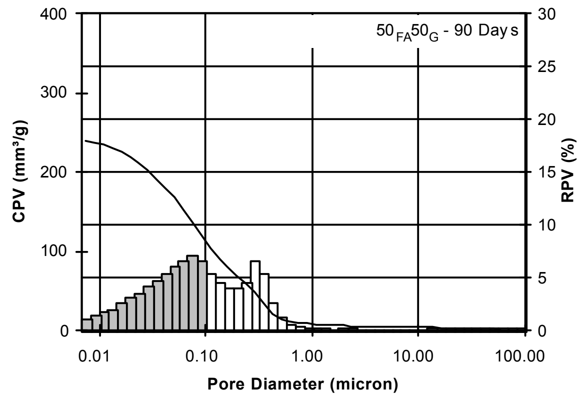

Fig. 5: Pore size distribution of paste M4

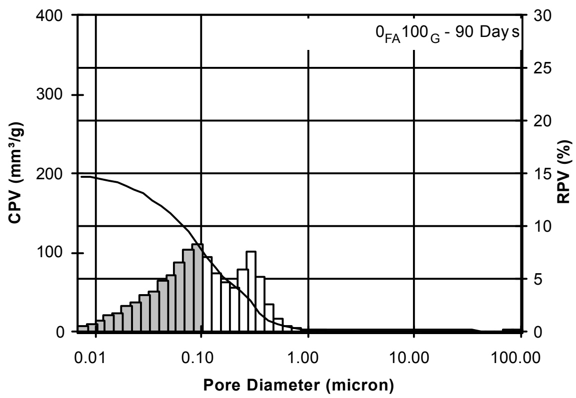

Fig. 6: Pore size distribution of paste M5

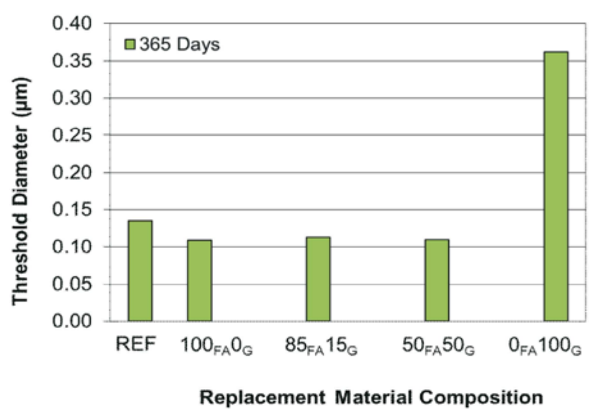

Fig. 7: Influence of FA-G composition on the threshold diameter (TD) of pastes

Due to the pozzolanic reaction, using fly ash in cement-based system is deemed to improve the pore structure of cement paste [12]. The products of cement hydration react with silica and alumina in the fly ash to produce additional hydration products, which fill the open capillary pores and improve the pore structure [13, 14]. Adding sulphate to the fly ash is reported to improve the reactivity of the fly ash [1, 2].

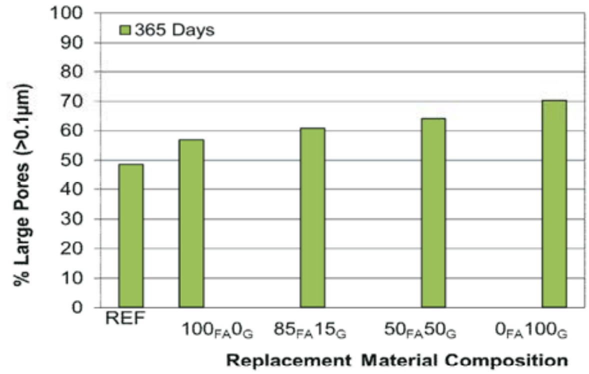

Fig. 8: Influence of FA-G composition on the percentage of large pores (>0.1μm) of pastes

Excessive gypsum replacements can result in a retardation of the hydration process as the ettringite formed on the fly ash particles increases, which temporally retards the reaction with lime [2].

CONCLUSIONS

At long-term curing period (i.e. 365 days of curing), replacing 25% of cement with different amounts of fly ash and gypsum increased the total pore volume unless the right amount of gypsum is introduced. For example when 25% of the cement is replaced with a combination of 15%gypsum and 85% fly ash, the total pore volume is lower than the control. There is tendency for the pore structure to become coarse when increasing amounts of gypsum is introduced into the system.

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