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Change in Microstructure of Mortar due to Carbonation

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1. Introduction

Change in microstructure of mortar due to carbonation can be one of the most important factors that affects diffusivity of substances in mortar and physical properties of mortar (e.g. compressive strength). Therefore, experimental study has been performed to understand the phenomena more clearly and pave the way for modeling carbonation process in mortar and change in compressive strength of mortar due to carbonation.

2. Experimental work

Materials and Mix Proportions

Cements used in the experiments were OPC (ordinary portland cement) and blended cements/PBFSC (50% and 75% ground granulated blast-furnace slag). Chemical composition of both the OPC and ground granulated blast-furnace slag are given in Table 1. Standard Toyoura sand was used as fine aggregate. Mortar with water-binder ratio of 0.6 were prepared. Mix proportions of mortar are given in Table 2.

Specimen

All the specimens were cast as cylinders of diameter 5 cm and height 10 cm. After curing for one day in the moist room at 20°C, specimens were demolded. Slices with about 2 mm thickness were taken out from the middle portion of specimen (about 3 cm from top and bottom surface). Then, slices were either initially cured in water for 27 days or directly transferred to various environments (air with 0.07% CO_2, carbonation chambers with 1% or 10% CO_2) with constant humidity of 60% and temperature of 20°C. Porosity of sliced mortars, measured by mercury porosimetry, were obtained at the ages of 4, 12, 28 weeks.

Table 1. Chemical compositions and physical characteristics of OPC and GGBFS

	Ordinary Portland Cement	Ground Granulated Blast-furnace Slag
Ig. loss	1.2 %	---
Insol.	0.4 %	---
SiO_2	21.9 %	34.3 %
Al_2O_3	5.0 %	14.6 %
CaO	64.2 %	42.2 %
Fe_2O_3	2.8 %	0.2 %
MgO	1.7 %	6.4 %
Specific Weight	3.15	2.90
Specific Surface Area	3230 cm^2/g	4010 cm^2/g

Table 2. Mix proportions of mortar (60% W/C ratio)

% slag content	Cement	Water	Slag	Sand	Initial curing period
	(kg/m^3)				
0	598	359	------	1196	0 and 27 days
50	297	356	297	1187	
75	148	355	444	1178	

3. Results and Discussions

Effect of Water Curing

After exposing to various concentration of CO_2, it is shown in Fig. 1 that OPC mortar initially cured in water enlarges pore size although it decreases porosity (the same phenomena can also be seen in the case of blended cement mortar). However, OPC mortar which were not initially cured in water keeps the pore size constant (slightly increase in the case of blended cement mortar) with decrease in porosity (as shown in Figs. 2 and 3).

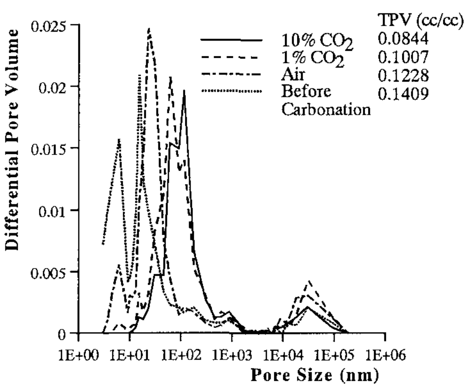

Figure 1. Pore Size Distribution of OPC Mortar initially cured in water after 12 weeks exposed to various concentration of CO_2

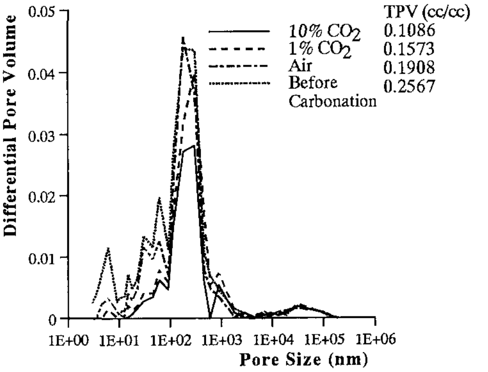

Figure 2. Pore Size Distribution of OPC Mortar without initially cured in water after 28 weeks exposed to various concentration of CO_2

Effect of Type of Cement

Carbonated mortar made of blended cement has higher porosity and larger pore size than those made of OPC (as shown in Fig. 4). This is more profoundly observed in the case of mortar which is not initially cured in water or exposed to high concentration of CO_2 (1% or 10% by volume).

Effect of CO_2 Concentration

Effect of CO_2 concentration on change of microstructure due to carbonation depends much on type of cement and water curing. In the case of mortar which were not initially cured in water, porosity of carbonated mortar made of OPC which in high concentration of CO_2 is lower than those exposed in air (as shown in Fig. 2). However, such kind of phenomena is not found in those made of blended cement (as shown in Fig. 5).

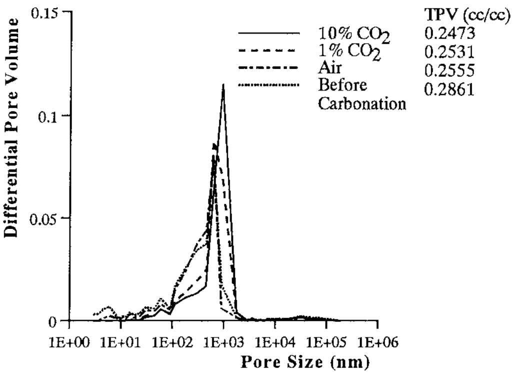

Figure 3. Pore Size Distribution of Mortar made of 75% PBFSC without initially cured in water after 12 weeks exposed to various concentration of CO_2

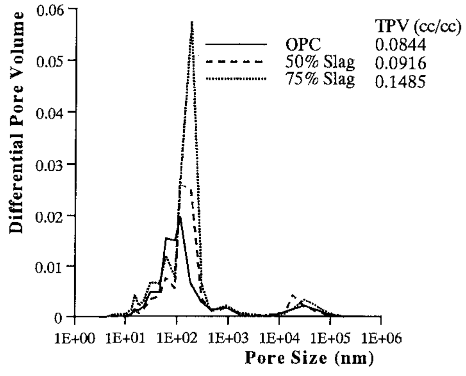

Figure 4. Pore Size Distribution of Mortar made of various type of cement initially cured in water after 12 weeks exposed to 10% CO_2

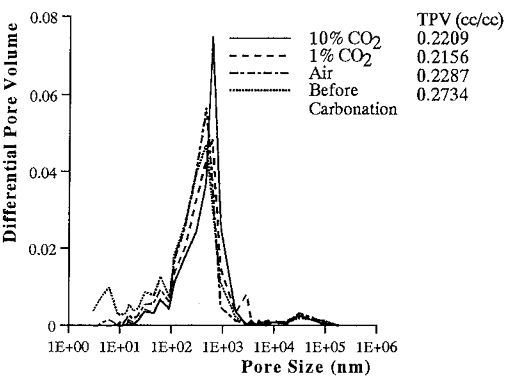

Figure 5. Pore Size Distribution of Mortar made of 50% PBFSC without initially cured in water after 12 weeks exposed to various concentration of CO_2

4. Conclusions

The experimental study allows the following conclusions:

1). The porosity of blended cement (50% or 75% Portland-BF Slag cement) mortar which were not properly cured in water increases due to carbonation. It may increase diffusivity of substances in mortar and decrease its compressive strength.

2). The change in microstructure of mortar, which is exposed to high concentration of CO_2, is quite different from those which are exposed to air. Moreover, it depends much on type of cement and initial water curing. Therefore, diffusivity of substances in mortar and its compressive strength of carbonated mortar in normal condition are quite different from those exposed to accelerated test.

Acknowledgment

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References

Bier, Th. A., "Influence of Type of Cement and Curing on Carbonation Progress and Pore Structure of Hydrated Cement Pastes," Material Research Society Symposium Proceedings, 1987, Vol. 85, pp. 123-134.