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Physical properties of cement composite with monoethanolamine

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Abstract: This study analyzed the fluidity, air content, flexural strength, compressive strength and carbon dioxide adsorption performance of cement, furnace slag and fly ash-based cement composite using appropriate substitution values of MEA derived from preliminary experiments. Fluidity and air content were found to increase as the fly ash substitution rate increases. It is believed that the increases are due to the fly ash ball bearing effect in combination with the creation of micropores by MEA. The compressive strength was found to decrease with lower furnace slag substitution ratios. This is believed to have resulted because the Pozzolanic reaction of the fly ash plays a more dominant role in determining the compressive strength than does the latent hydraulic activity of furnace slag as the furnace slag substitution rate is decreased. It is determined that the compressive strength was reduced because the Pozzolanic reaction reduces the density of the texture and pore structure of the interfacial transition zone. Carbon dioxide values increase as the furnace slag substitution rate was increased.
Keywords: *Blast furnace slag, Carbon dioxide, Fly ash, Pozzolanic activity, Monoethanolamine.*

1. Introduction

Global warming is a global problem, and according to the International Energy Agency (IEA), reaching carbon neutrality by 2050 will require an immediate stop to new investments into fossil energy and the accomplishment of carbon neutrality in power generation by 2040. Accordingly, each country is actively developing carbon dioxide reduction technologies, and among the various methods for carbon dioxide capture and isolation, studies into carbon dioxide reduction using MEA(Monoethanolamine) are being consistently conducted.

MEA absorbent used in CO_2 capture processes has many advantages such as excellent reactivity, commercialized processes and ample operational experience. Therefore, building on the carbon dioxide adsorption properties of concrete made with MEA, it is expected that combining the properties of long-term strength improvement due to the latent hydraulic activity and pozzolanic reaction properties to fly ash and fine furnace slag powder will yield the benefits of outstanding concrete strength and durability, potential use as a cement substitute, and reduction of carbon dioxide in the atmosphere[1, 2].

Therefore, the object of this study is to build on existing studies on the carbon dioxide adsorption properties of MEA by examining the improvement of strength through the addition of furnace slag and fly ash to the mix ratio.

2. Experimental plan and method

2.1. Experimental plan

The present experiment evaluates the physical and adsorption properties of cement-based composite using MEA. Based on the optimum substitutions rates of W/B and MEA derived from previous experiments, the properties of cement composite according to the mix ratios of cement, furnace slag and fly ash combination will be examined. The binder ratios are typically 30% Portland cement and 70% furnace slag and fly ash. Tests were carried out with five different furnace slag and fly ash ratios: 10:0, 7:3, 5:5, 3:7, and 0:10. The test items measured were fluidity, air content, flexural strength, compressive strength, and CO_2 adsorption performance. The specimens were cured at constant temperature and

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humidity of 20±2℃ and 60±5%, and the resulting experimental factors are as shown in Table 1. \

Table 1.
Experimental factors and level.

Experimental factor	Experimental level	Remarks
Binder	OPC1), BFS2), FA3)	3
W/B	30%	1
Absorbent conditions	MEA	1
Replacement ratio of MEA	5%	1
BFS:FA	10:0, 7:3, 5:5, 3:7, 0:10	5
Curing condition	Humidity (60±5)%, Temperature (20±2)℃	1
Experiment items	Fluidity, Air content, CO_2 adsorption Flexural strength, Compressive strength	5

Note: 1) OPC: Ordinary portland cement, 2) BFS: Blast furnace slag, 3) FA: Fly ash

2.2. Using materials

2.2.1. Monoethanolamine

MEA is an organic compound with the chemical formula $HOCH_2CH_2NH_2$ or C_2H_7NO and is a colorless viscous liquid with an ammonia odor. MEA is the most widely known of carbon dioxide wet absorbent amines. Chemically, an amine is a Lewis base, while carbon dioxide is a Lewis acid. The carbon dioxide adsorption mechanism is the formation of bicarbonate and carbonate through carbonation reactions. The mechanism is as expressed by Formula 1 below.

$$2RNH_2 + CO_2 \rightarrow RNHCOO^- + RNH_3^+ [R=CH_2CH_2OH] \quad (1)$$

Various methods are being studied for CO_2 capture using amines such as MEA, and methods used on an industrial scale include wet absorption methods using aqueous amine solution as the absorbent [3].

2.3. Experimental method

2.3.1. Fluidity

To examine the fluidity of uncured paste, the diameter was measured after striking 25 times according to KS L 5111 "Flow Table for Hydraulic Cement Testing"

2.3.2. Air content

To measure the air content of uncured paste, air measurements were taken in accordance with KS L 3136 "Method of for Measuring Air Content of Hydraulic Cement Mortar."

2.3.3. Flexural strength

The flexural strength test was performed using a specimen 40×40×160(mm). The strength at 3, 7, and 28 days of age was measured and compared. Bending strength tests were carried out on three specimens at each of these ages, calculating the arithmetic average for the three.

2.3.4. Compressive strength

Compressive strength tests were carried out using the method of KS L 5105 "Compressive Strength Test Method for Hydraulic Cement Mortar" using specimens of 40×40×160(mm). The strength at 3, 7, and 28 days of age was measured and compared. Compressive strength tests were carried out on six specimens at each of these ages, calculating the arithmetic average for the six.

2.3.5. CO_2 adsorption

Reduction of CO_2 was measured using the small chamber method proposed by Hanbat National University [4]. The cement composite to be measured was placed in a small, sealed chamber, with the fan

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continuously operating. Carbon dioxide is transported through convection by the wind from the fan, reaching the surface of the cured product. Here, while maintaining constant reference carbon dioxide concentration, a CO_2 concentration meter (NDIR-G150) was used to carry out measurements under the conditions shown in Figure 1 Measurements were carried out over 12 hours, measuring the change in carbon dioxide concentration every hour.

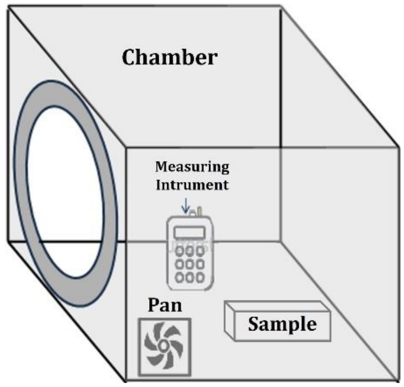

Figure 1.
Adsorption measurement.

3. Experimental result and analysis

3.1. Fluidity & Air content

Figure 2 shows the fluidity and air content test results for cement paste according to the mix ratios of furnace slag and fly ash. As the mix ratio of fly ash increases, both fluidity and air content tend to increase. This increase in fluidity and air content is determined to be due to the ball bearing effect of fly ash.

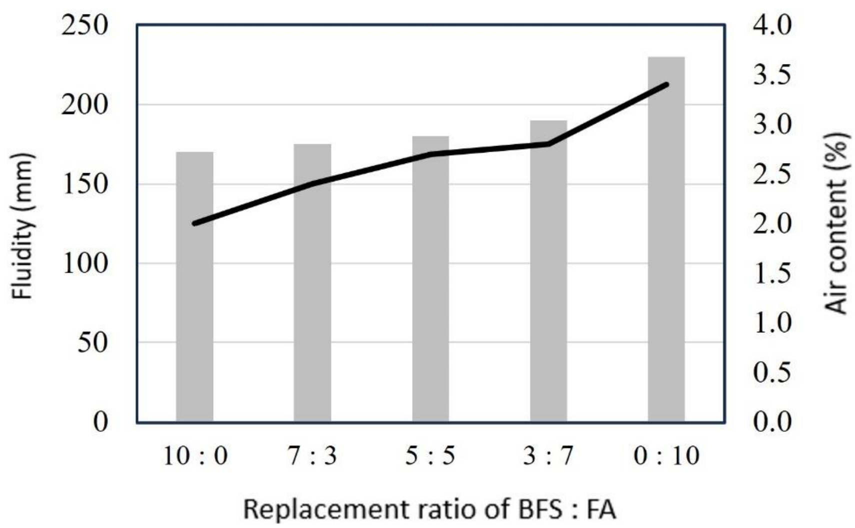

Figure 2.
Fluidity and air content in cement paste substituted MEA according to BFS and FA ratio.

3.2. Flexural strength

Figure 3 is a flexural strength graph according to the substitution rates of furnace slag and fly ash. The flexural strength measured at 28 days was 5.83, 5.77, 4.98, 5.11, and 5.01 (MPa) at furnace slag and fly ash substitution rates of 10:0, 7:3, 5:5, 3:7, and 0:10, respectively. Flexural strength tended to decrease with age. Whereas flexural strength tended to decrease as the substitution rate of fly ash increased, no large variance in the overall reduction of flexural strength was observed.

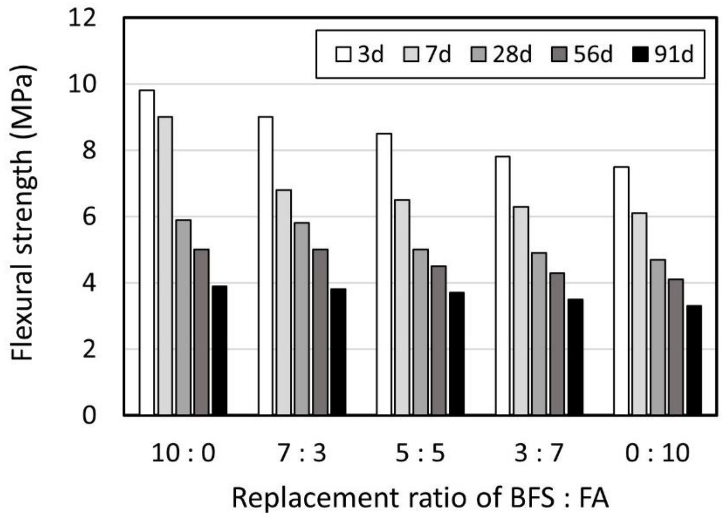

Figure 3.
Flexural strength of cement composite substituted MEA according to BFS and FA ratio.

3.3. Compressive strength

Figure 4 is a compressive strength graph according to the substitution rates of furnace slag and fly ash. The compressive strength measured at 28 days was 49.95, 47.51, 44.14, 36.46, and 33.04 (MPa) at furnace slag and fly ash substitution rates of 10:0, 7:3, 5:5, 3:7, and 0:10, respectively. Overall compressive strength tends to increase with age, but compressive strength tends to decrease as the fly ash substitution rate increases. This is believed to have resulted because the Pozzolanic reaction of fly ash plays a more dominant role in determining compressive strength than does the latent hydraulic activity of a furnace. It is determined that the compressive strength was reduced because the pozzolanic reaction reduces the density of the texture and pore structure of the interfacial transition zone.

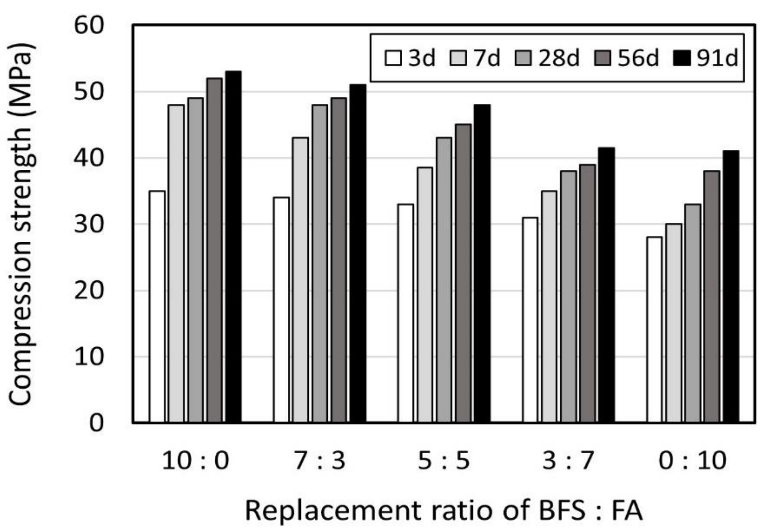

Figure 4.
Compressive strength of cement composite substituted MEA according to BFS and FA ratio.

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3.4. CO_2 adsorption

Figure 5 is a carbon dioxide reduction rates graph according to the substitution rates of furnace slag and fly ash. The concentration of carbon dioxide in the empty chamber was maintained at 3,000ppm, and CO_2 concentration decreased according to the furnace slag and fly ash substitution rate. Furthermore, the concentration of carbon dioxide tended to decrease as the furnace slag substitution rate decreases, and the maximum reduction was 23%.

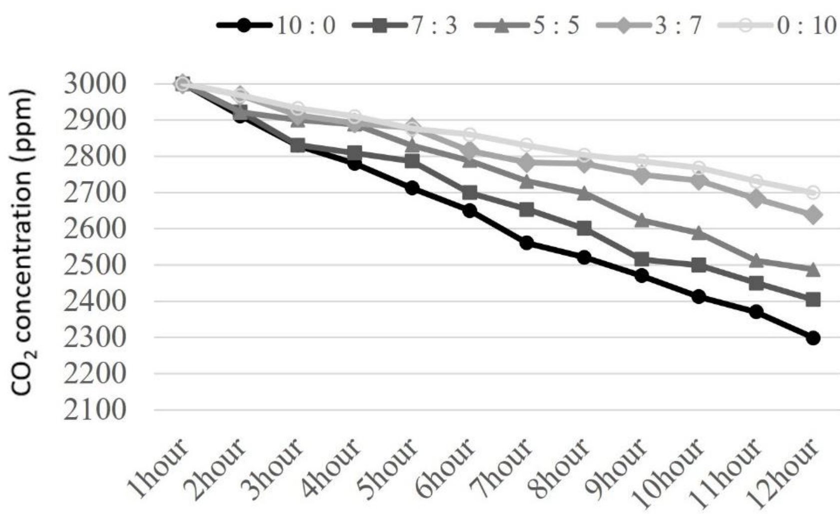

Figure 5.
CO_2 reduction ratio of cement composite substituted MEA according to BFS and FA ratio.

4. Conclusion

This study analyzed the fluidity, air content, flexural and compressive strength, and carbon dioxide adsorption performance of cement, furnace slag and fly ash-based cement composite using appropriate substitution values of MEA derived from preliminary experiments. Fluidity and air content were found to increase as the fly ash substitution rate increases. It is believed that the increases are due to the fly ash ball bearing effect in combination with the creation of micropores by MEA. The compressive strength was found to decrease with lower furnace slag substitution ratios. This is believed to have resulted because the Pozzolanic reaction of the fly ash plays a more dominant role in determining the compressive strength than does the latent hydraulic activity of furnace slag as the furnace slag substitution rate is decreased. It is determined that the compressive strength was reduced because the Pozzolanic reaction reduces the density of the texture and pore structure of the interfacial transition zone. Carbon dioxide values increase as the furnace slag substitution rate was increased.

This positive effect on adsorption is determined to owe to CO_2 adsorption by MEA and increases in microporosity as the substitution rate is increased, due to the larger particle size of furnace slag than that of fly ash. These results may be useful as basic research data for studies on carbon dioxide adsorption by cement composite using MEA.

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