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Density and Strength Properties according to Alkali Activator Mixing Ratio of Non-cement Composite

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ABSTRACT---- ***In order to solve environmental and economical weakness of existing lightweight wall system, this study conducted a basic experiment to produce lightweight wall based on blast furnace slag and paper ash, which are industrial by-products, without using cement, and to check density and strength properties according to alkali activator mixing ratio of non-cement composite from the blast furnace slag and the paper ash. according to the outcome of an experiment to select optimal mixing ratio of alkali activator, density and water absorption ratio revealed semi-proportional correlation, and test specimen added with Na_2SiO_3 showed higher density and lower water absorption ratio than the replaced specimen. Meantime, as flexural strength and compressive strength, density and water absorption ratio showed the direct opposite, which means that strength of composite added with Na_2SiO_3 was generally weaker than that of replaced composite.***

Keywords--- Blast Furnace slag, Paper ash, Alkali activator

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1. INTRODUCTION

1.1 Background of research

Recently, interfloor noise in multi-unit dwelling buildings has emerged as a social problem, and a variety of studies have been conducted [1-4)] to resolve this problem. However, current wall-type structures are considered to have limitations in reducing interfloor noise occurring in multi-unit dwelling. The structural form of multi-unit dwelling would need to be shifted towards the type, such as Rahmen structure, which hinders transmission of noise through structures. This type of structure requires installation of partition walls. For conventional partition walls, there are secondary products that primarily use cement, such as sandwich panel, EPS cement composite panel, ALC panel, plasterboard composite panel, etc. Among them, sandwich panel and EPS cement composite are ultra-lightweight and provide both excellent thermal insulation properties and easy workability, but has disadvantage of vulnerability to fire and difficulty in extinguishing the fire due to the use of combustible material. Furthermore, ALC panel, which is manufactured under high temperature and pressure using the cement, is disadvantageous in terms of cost-effectiveness and energy efficiency. Meanwhile, plasterboard composite panel has the disadvantage that it has vulnerability to water. Thus, it is increasingly necessary to develop lightweight partition walls that provide high environmental and economic efficiency and reduce cement consumption. Studies that aim to reduce cement consumption have been conducted since long before. Among others, there is a study investigating the blast furnace slag and fly ash [5-6)]. Particularly, 12 million tons of blast furnace slags were reportedly generated in 2013. An increasing amount of blast furnace slag is expected to be generated, spurred by the upswing in the demand and advancement of steel industry. Meanwhile, paper ash, generated from paper production process in paper mill, is a by-product from incineration of paper sludge. The paper industry has witnessed rising production as a result of development of various multi-ply sheet forming technologies and chemicals for paper production. Approximately 1.5 million tons of wastes are generated yearly. However, about 90% of paper ash generated in paper mills end up being buried in landfill sites, causing environmental problems such as dust generation and lack of landfill sites.

1.2. Purpose of research

In this study, we conducted an experimental study to provide basic data for development of lightweight partition wall that was lightweight and did not use cement. For that, blast furnace slag, an industrial by-product, was used as binder. The hydration reaction of blast furnace slag was induced by adding alkali activator. Moreover, we examined weight-lightening of non-cement matrix which could be achieved by using the paper ash that generated hydrogen gas through reaction with alkali activator.

2. EXPERIMENTAL OVERVIEW

The experiment that aims to produce lightweight matrix using industrial by-product would need to derive optimal mixing ratio of alkali activator by considering the hydrogen gas formed through reaction among caustic alkali, paper ash, and alkali activator necessary to induce latent hydraulicity of blast furnace slag through hydraulic reaction. Thus, we intended to design the mixing ratio with a focus on hydrogen gas formation of paper ash, while aiming to induce latent hydraulicity of blast furnace slag with the mixing type alkali activator primarily based on NaOH, a caustic alkali.

2.1 Experimental plan and method

2.1.1 Experimental plan

In this experiment, paper ash was used as binder to induce formation of blast furnace slag and bubbles in order to develop the strength equal to or greater than that of cement. The ratio of blast furnace slag and paper ash was set to 95:5 based on 100g of binder weight. W/B was adjusted to 40% to ensure high water absorption ratio of paper ash and adequate supply of H_2O necessary for hydrogen gas generation. Alkali activator was set for three different cases: 1) When NaOH was used alone, 2) when the replacement ratio of Na_2SiO_3 was set to 10, 30, and 50 (%) for NaOH, and 3) when the addition ratio was set to 10, 30, and 50 (%). For measurement items, bulk specific gravity was measured by using the lightweight property as yardstick. Based on that, water absorption ratio, compressive strength and flexural strength were measured. The experimental factors and level are presented in Table 1.

Table.1 Experimental factor and level

Experimental factor	Experimental level	
Binder	Blast Furnace Slag, Paper Ash	2
Alkali activator	NaOH, Na_2SiO_3	2
Addtion ratio of Na_2SiO_3	10, 20, 30 (wt.%)	3
Addtion ratio of Alkali activator	12.5 (wt.%)	1
W/B	0.40	1
Curing conditions	Relative humidity 80±5 %, Temperature 20±2℃	1
Test items	Bulk Specific gravity, Water absorption ratio, Flexural strength, Compressive strength	4

2.1.2 Experimental methods

For the test of compressive strength and flexural strength in this study, both compressive strength and flexural strength were measured using the test piece with a dimension of 4×4×16cm in accordance with KS L ISO 679. The test piece for measurement of density was made in cylindrical form with a diameter of 100m and a height of 200mm in accordance with apparent specific gravity, moisture content, water absorption ratio, and compressive strength test methods(KS F 2459) for aerated concrete. The weigh and volume of the test piece were measured after curing until the age of 28 days to calculate the density.

For the test of water absorption ratio, the mass of test piece was measured with its surface in a dry state after completing the curing at the age of 28 days in accordance with KS F 2429. Then, the test piece was dried until the mass remained unchanged at temperature of 105±5℃to measure the mass. For the mixing method in experiment, blast furnace slag and paper ash were put into a mixer with a capacity of 18 L and underwent the first dry mixing at a speed of 20 rpm for 60 seconds. Then, NaOH and Na_2SiO_3 were mixed in water and added with the mixing water that had been stabilized for about a day, and underwent second mixing at a speed of 40 rpm for 90 seconds before being discharged.

2.2 Used Materials

3 types of Blast furnace slag used in this experiment had a density of 2.91 g/cm^3 and fineness of 4,464 cm^2/g. Magnesium oxide (MgO) content and sulphur trioxide (SO_3) content stood at 2.1% and 4.1 %, respectively. MgO content met the requirement of KS F 2563 regulation, but the blast furnace slag with slightly higher SO_3 content was used. As shown in Fig. 1, the paper ash was recovered from the paper ash discarded after incineration of paper sludge in paper mill and had a density of 2.70 g/㎤ and fineness of 3,600 cm^2/g. For chemical composition, the paper ash used in this study had CaO and SiO_2 molecules accounting for a combined 70% of whole molecules. The chemical nature of both blast furnace slag and paper are presented in Table 2.

Table 1. Chemical component of using materials

Materials	Chemical components (%)							
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	TiO_2
BFS	35.08	13.87	0.52	41.10	3.60	2.36	-	1.20
PA	13.00	10.10	0.90	65.70	4.40	1.70	-	0.40

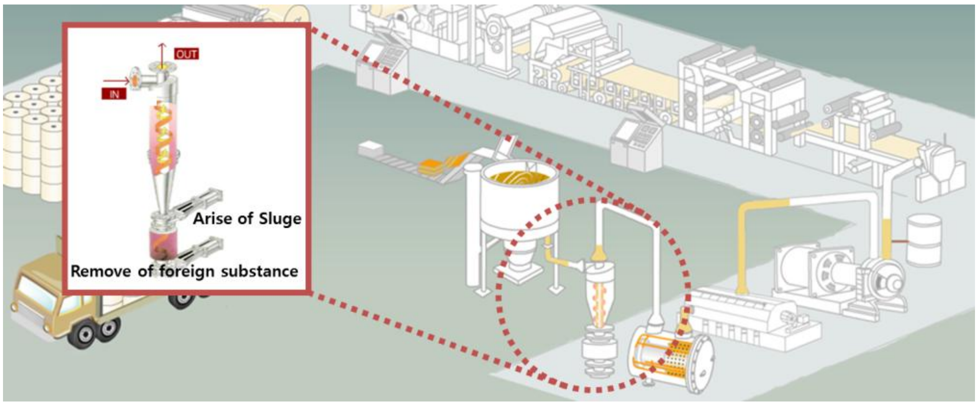

Fig.1 Paper ash manufacturing process

3 RESULTS OF EXPERIMENT & ANALYSIS

3.1 Density and absorb ratio

Figure 1 shows the bulk specific gravity and water absorption ratio based on replacement and addition ratio of NaOH and Na_2SiO_3. Bulk specific gravity was higher than that of Plain, regardless of replacement and addition of Na2SiO$_3$. Although the difference was negligible, the bulk specific gravity was higher in test piece added with Na_2SiO_3 than in the replaced test piece. Water absorption ratio was higher in all matrices than in the Plain when Na_2SiO_3 replacement was performed. Water absorption ratio was lower in all matrices added with Na_2SiO_3 than in the Plain.

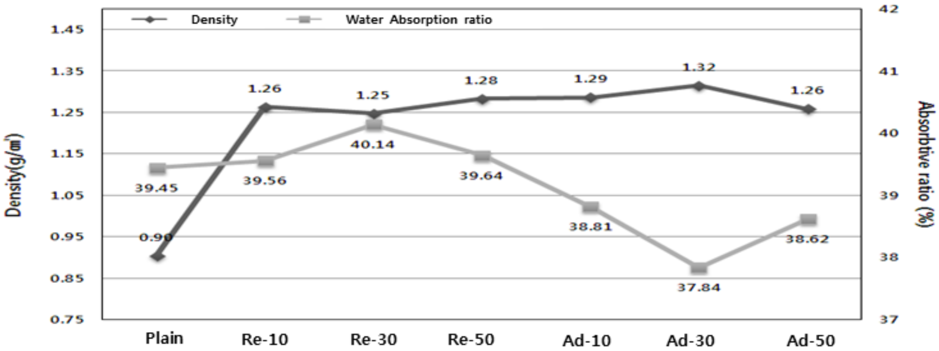

Fig. 1 Density and water absorption ratio

3.2 Flexural strength of lightweight matrix

Figure 2 shows the flexural strength based on addition ratio and replacement ratio of Na_2SiO_3. Test piece added with Na_2SiO_3 was found to develop slightly higher strength than Plain. As the addition ratio was higher, the strength improvement rate increased. Moreover, test piece replaced with Na_2SiO_3 was found to exhibit higher strength than the test piece added with Na2SiO3. Although the test piece added with Na_2SiO_3 showed higher density, the alkaline components not involved in hydration reaction were present in hardened structure, forming fine voids, and as a result, did not contribute to practical strength development.

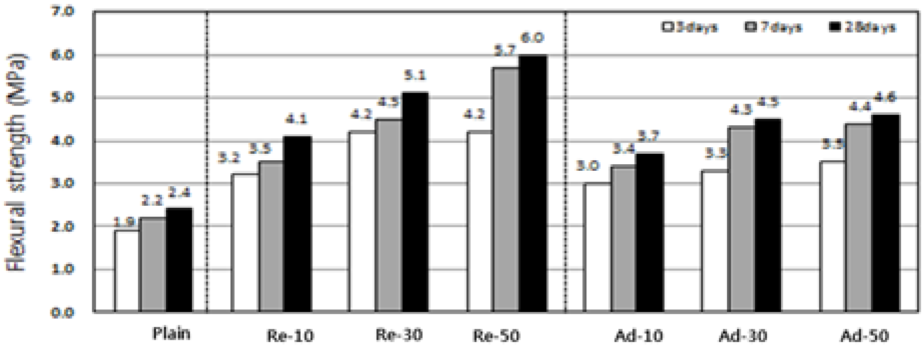

Fig. 2 Flexural Strength

3.3 Compressive Strength of lightweight matrix

Figure 3 shows the compressive strength based on addition ratio and the replacement ratio of Na_2SiO_3. As with flexural strength, compressive strength increased as the addition ratio of Na_2SiO_3 was higher. Matrix replaced with Na_2SiO_3 showed more excellent strength improvement rate than the matrix added with Na_2SiO_3. As with the analysis of flexural strength tendency, oversupply of accelerator led to formation of fine voids within the test piece added with Na_2SiO_3, resulting in failure to contribute to strength improvement.

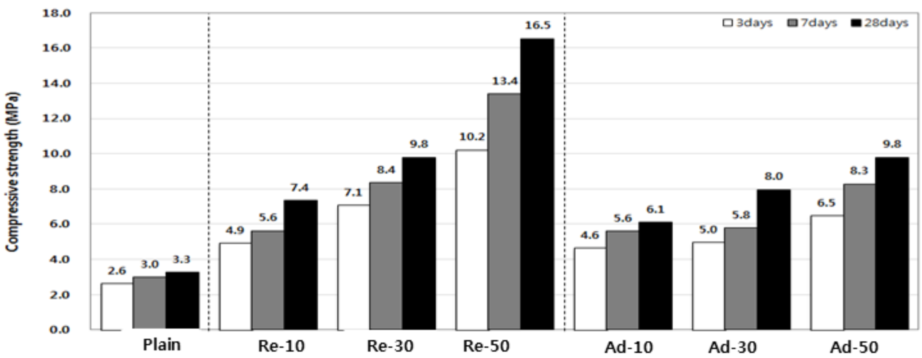

Fig. 3 Compressive Strength

4. CONCLUSIONS

In this study, we conducted an experiment to investigate the density and strength properties of non-cement matrix using industrial by-product based on mixing ratio of alkali activator, and reached the conclusion as stated below within the scope of this study. Based on the results of experiment that aimed to determine optimal mixing ratio of alkali activator, a correlation of inverse proportion was found to exist between density and water absorption ratio. Moreover, the test piece added with Na_2SiO_3 exhibited higher density and lower water absorption ratio than the replaced test piece.

For flexural strength and compressive strength, the matrix added with Na2SiO3 showed slower strength development than the replaced matrix, which contradicted the correlation between density and water absorption ratio. That is considered attributable to oversupply of alkali activator in connection with density and water absorption ratio, which resulted in the void to be filled by alkali which floated to the surface, consequently failing to contribute to practical strength development.

The results of this study are expected to help contribute to manufacture and application of inorganic binder that can resolve economic and environmental issues inherent in the use of conventional cement if systematic combination design of alkali activator and active use of paper ash are promoted on the basis of this experiment.

5. ACKNOWLEDGEMENT

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