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Performance Evaluation of Inter-Locking Block Using Fly Ash

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In this paper, the properties of inter - locking block using fly ash are discussed in order to provide economical advantages and improve quality, and protect environment and recycle resources. Fly ash is the by-product of coal in thermal power plant. The experimental parameters are fly ash content, the amount of AE water - reducing agent and mixing proportion of cement mortar. According to the experimental results, the improvement of quality in the side of strength, absorption ratio and freeze - thaw resistance for manufacturing inter - locking block and the curtailment of cost can be achieved in case of 15% of fly ash and 0.3% of AE water- reducing agent are mixed into mortar mixture of 1:6(C:S).

Key words : Inter-locking block, Flyash, Freeze-thaw resistance, Strength, Absorption

1. Introduction

Recently, in order to provide economical advantages and improve the quality, and protect environment and recycle resources, a plan of some replacement of admixture like fly ash including pulverized coal which is generated in a thermal power plant with cement in the manufacturing of inter-locking has been examined.

As regulation of interlocking block for side walk and road, however, KS F 4419 provides for 「In case of use of admixtures like AE agent, it shall not have adverse effect on the product」, implying that the use of admixtures is not recommended, and also it is not being activated in the field. Until now, researches on the manufacturing, and engineering properties of inter-locking block using mineral and chemical admixture have rarely been conducted in domestic and foreign country. Fundamental properties of inter-locking block were investigated by some researchers.[1~4)]

Therefore, this study is intended to expect the provision of economical advantages and improvement of the quality, and the protection of environment and the recycling of resources by positively using fly ash in the manufacturing of inter-locking block as well as to evaluate the performance of inter-locking block using fly ash by making a specimen of experimental inter-locking block through the change of mixing proportion of mortar in consideration of the addition of AE water-reducing agent and the practical conditions respecting the improvement of freeze-thaw resistance and by performing comparative analysis on all its characteristics.

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2. Design and Method of Experiments

2.1. Desig of Experiments

The design of experiments and the mixing conditions are as shown in Table 1 in this study. First, the mixing proportion of mortar considered two levels of 1:6 and 1:8 as C:S, while W/B considered two of 40% and 50% proper for the consistency of the mixing of each mortar. In addition, the substitution rate of fly ash considered three of 0%, 15% and 30%, and the addition of AE water-reducing agent considered four of 0%, 0.08%, 0.15% and 0.30%.

As experimental conditions, bending strength and compressive strength at 7 days and 28 days, respectively and were measured for 91 days, and absorption was measured for 28 days. And, for freeze and thaw test, Modulus of elasticity and weight loss

Table 1. Mixture Proportion and Experimental Results

Mix Ratio (C:S)*	W/B** (%)	Air Content (%)	FA/C (%)	AE/C (%)	Unit Water (kg/m³)	Absolute Volume(ℓ/m³) Cement	River Sand	Crushed Sand	Fly Ash	Flexural Strength (kgf/cm²) 7d	28d	91d	Compressive Strength (kgf/cm²) 7d	28d	91d	Absorption (%)
1:6	40	10	0	0	117	92	344	347	0	23	46	50	60	86	107	11.7
				0.08	117	92	344	347	0	25	36	43	50	87	100	11.1
				0.15	117	92	344	347	0	24	39	45	56	80	100	11.0
				0.30	117	92	344	347	0	20	35	39	50	75	96	11.5
			15	0	116	78	342	344	20	20	49	58	53	90	115	10.8
				0.08	116	78	342	344	20	21	35	52	50	88	108	9.1
				0.15	116	78	342	344	20	22	40	53	52	93	110	8.3
				0.30	116	78	342	344	20	15	33	49	46	80	100	8.4
			30	0	115	64	340	342	39	17	43	55	50	83	100	9.9
				0.08	115	64	340	342	39	17	36	45	40	80	95	7.3
				0.15	115	64	340	342	39	17	35	47	49	75	93	7.5
				0.30	115	64	340	342	39	14	31	39	40	70	90	7.5
1:8	50		0	0	113	72	356	359	0	20	30	40	50	68	88	10.0
				0.08	113	72	356	359	0	18	28	35	47	61	71	11.8
				0.15	113	72	356	359	0	16	27	30	41	46	63	12.7
				0.30	113	72	356	359	0	19	27	29	47	52	70	10.9
			15	0	112	61	354	357	16	17	32	44	47	70	90	9.8
				0.08	112	61	354	357	16	14	27	40	40	55	75	10.5
				0.15	112	61	354	357	16	12	28	30	35	50	70	10.0
				0.30	112	61	354	357	16	13	26	33	41	51	70	8.6
			30	0	111	50	353	355	31	13	30	40	37	60	82	9.6
				0.08	111	50	353	355	31	12	27	36	38	54	68	8.8
				0.15	111	50	353	355	31	10	25	30	29	40	63	9.0
				0.30	111	50	353	355	31	12	24	30	28	50	60	7.5

* cement:sand
** Water to cementitious ratio

were measured every 10 cycles after water curing for 2 weeks.

2.2. Materials

For materials used in this experiment, ordinary portland cement was used, and its physical properties are shown in Table 2.

Table 2. Physical Properties of Cement

Specific Gravity	Blaine (cm²/g)	Soundness (%)	Setting time(min.) Ini.	Fin.	Compressive Strength (kgf/cm²) 3d	7d	28d
3.15	3,564	0.06	241	460	226	303	396

For aggregate, river sand and crushed were used withmixing in the weight ratio of 1:1, and river sand from Gongju(公州) and crushed sand from Hwanhee, Chungbuk(忠北) of less than 13mm were used. The physical properties oaggregate are shown in Table 3. And, fly ash from Boryeong which was purified through gradation was used as admixture, and AE water-reducing agent from domestic D was used. Their physical properties are shown in Table 4, 5, respectively.

Table 3. Physical Properties of Aggregate

Kinds	Specific Gravity	Fineness Modulus	Voids Volume (%)	Absorption (%)	Unit Weight (kg/m³)	Solid Volume Percentage of Shape Variation (%)	Amount of Material Finer than No. 200 Sieve(%)
River Sand	2.54	2.68	38.6	2.61	1,559	57.4	1.86
Crushed Sand	2.52	3.30	29.0	3.25	1,787	54.1	15.4

Table 4. Physical Properties and Chemical Composition of Fly Ash

Specific Gravity	Blaine (cm^2/g)	Loss on ignition (%)	Chemical Components(%)					
			SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	MgO
2.2	3,218	5.9	60.4	24.7	4.6	3.2	0.2	0.8

2.3. Test Methods

Mortar mixing was conducted in accordance with KS L 5109. Moulds that a certain amount of mortar are customized after mixing is put into, and then it is vibrated with a table vibrator for 7 seconds and pressurized at 100kgf/cm^2 into a specimen (4×4×16cm).

For curing of the specimens, water curing was applied at 20±3℃. As experiment under hardened condition, the inter-locking block absorption test method in KS F 4419 was applied for absorption, and the standard test methods in KS F 2407 and ASTM C 349 were applied for bending strength and compressive strength test. In addition, freeze and thaw test in KS F 2456(procedure A) was applied. Relative dynamic modulus of elasticity was measured.

3. Results and Discussion

3.1. Compressive strength

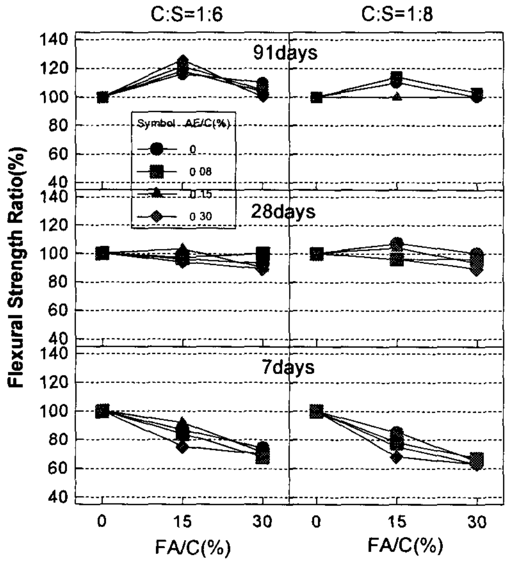

Fig. 1. Flexural Strength Ratio with the Variation of the Replacement of Fly Ash.

Table 5. Physical properties of AE water-reducing agent

Main Ingredient	Appearance	Specific Gravity(20℃)	Recommended Dosage C×(%)
Lignin	Brown Liquid	1.02	0.15

Fig. 1 and 2 show the bending strength and compressive strength by the change of substitution of fly ash into the mixing proportion of mortar, the days, and the addition of AE water-reducing agent under the condition that the non-substitution of fly ash is set to 100. First, the bending strength greatly decreases at the 7 days as the substitution of fly ash increases, while it is significantly recovered at the 28 days, showing somewhat irregular trend according tothe change in the substitution of fly ash, however, in general corresponding to the non-substitution of fly ash. The mixing proportion of mortar is 1:8 at the 91 days and the same strength is shown by the change in the substitution of fly ash at 0.15% of the addition of AE water-reducing agent, but, however, the strength more increased compared to the 28 days, and more strength was shown at 15% of the substitution than at non-substitution. It is judged that the strength was increased by the pozzolan reaction. The compressive strength shows generally similar trend to the bending

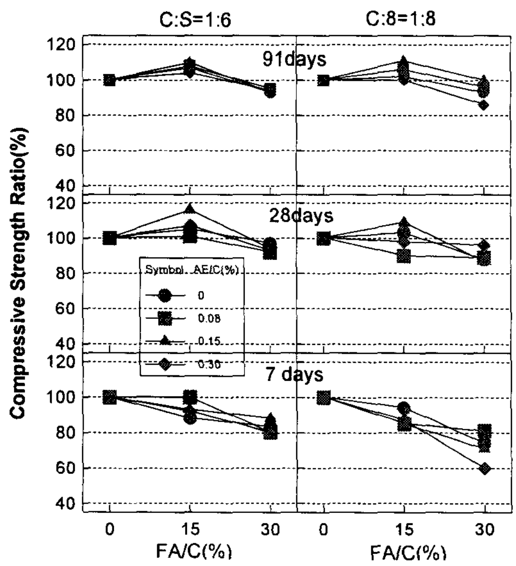

Fig. 2. Compressive Strength Ratio with the Variation of the Replacement of Fly Ash.

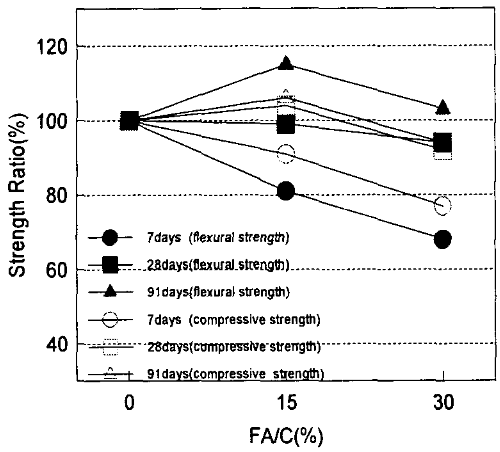

Fig. 3. Strength Ratio with the Variation of the Replacement of Fly Ash.

strength, and it was higher at 15% of the substitution of fly ash than of non-substitution at the 28 days and 91 days. Also, for the mixing proportion of mortar, higher bending strength and compressive strength were shown at 1:6 compared to 1:8, and the feature of appearance of both strength was similar.

Fig. 3, as analysis on Fig. 1 and 2 at a different angle, shows the bending strength ratio and the compressive strength ratio by the analysis on the addition of AE water-reducing agent and the mean of the mixing proportion of mortar. Same as the analyses in Figure 1 and 2, as the substitution of fly ash increases, the bending strength and the compressive strength at the 7 days greatly decreased compared to the non-substitution. However, at the 28 days, the bending strength increased 0.5% at 15% of FA/C and the compressive strength increased 4%, and decreased each 6%, 8% at 30% of FA/C. And, at the 91 days, the strength was greatly increased by the pozzolan reaction, such that the bending strength and the compressive strength increased each 15%, 6% at 15% of FA/C, and the bending strength increased 3% and the compressive strength decreased 6% at 30% of FA/C. As those results of bending strength and compressive strength in 3 months, the strength was highest at 15% of FA/C, implying that 15% substitution of fly ash is proper in manufacturing of inter-locking block. Fig. 4 and 5 show the bending strength and compressive strength by the change of addition of AE water-reducing agent into the mixing proportion of mortar, the days, and the substitution of fly ash. The bending strength and compressive strength by the change of addition of AE water-reducing agent showed somewhat irregular trend, but in general as the addition of AE water-reducing agent increased, they decreas For the mixing proportion of mortar, they were satisfactory at 1:6 compared to 1:8, and for days, as they went by,

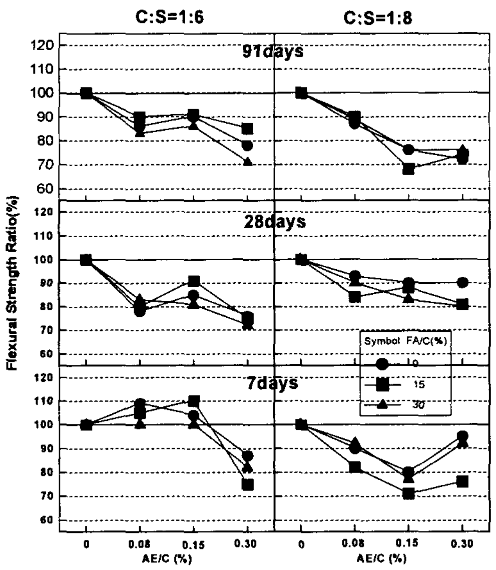

Fig. 4. Flexural Strength Ratio With the Variation of amount of AE water-reducing agent.

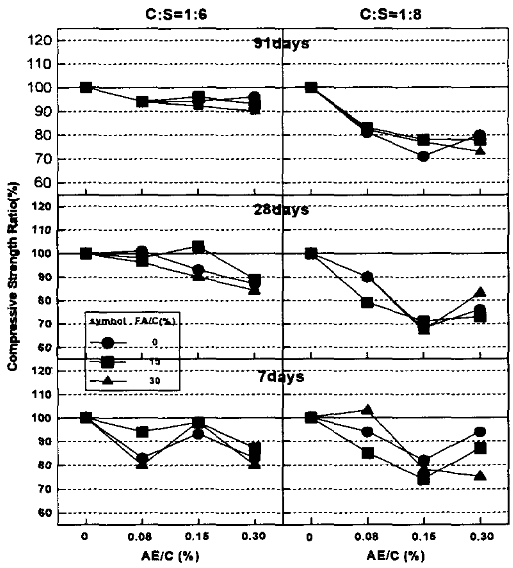

Fig. 5. Compressive Strength Ratio with the Variation of the amount of AE water-reducing agent.

the level of decrease of strength decreased as the addition of AE water-reducing agent increased.

3.2. Absorption

Fig. 6 shows the absorption into the mixing proportion of mortar and the addition of AE water-reducing agent according to the substitution and the non-substitution of fly ash. In general, as the substitution of fly ash increases, the absorption decreases, implying that a hydrate generated by the gap filling effect of fly ash and the pozzolan reaction blocks the capillary pore in the matrix and inhibits the flow of water and it accordingly causes the reduction in penetration. The absorption greatly more decreased as the substitution of fly ash increased at 1:6 of the mixing proportion of mortar compared to 1:8.

Fig. 7 shows the absorption by the change in the addition of AE water-reducing agent into the mixing proportion of mortar and the substitution of fly ash under the condition that the non-substitution of AE water-reducing agent is set to 100. At 1:8 of the mixing proportion of mortar, when the substitution of fly ash is small, as the addition of AE water-reducing agent increased, the absorption increased, as well. In general, as the addition of AE water-reducing agent increased, the absorption decreased, which implies that as the ball-shaped independent entrained air exists according to the addition of AE water reducing agent, it blocks water permeating into the capillary pore.

3.3. Freeze-thaw resistance

Fig. 8 shows the relative dynamic modulus of elasticity by the increase in the freeze-thaw cycle into

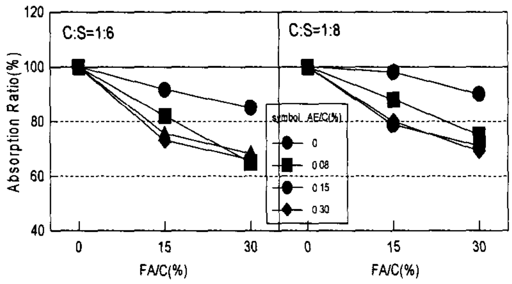

Fig. 6. Absorption Ratio with the Variation of the Replacement of Fly Ash.

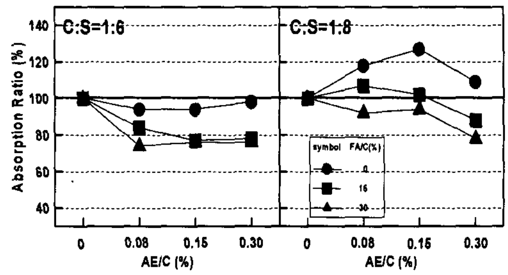

Fig. 7. Absorption Ratio with the Variation of the amount of AE water-reducing agent.

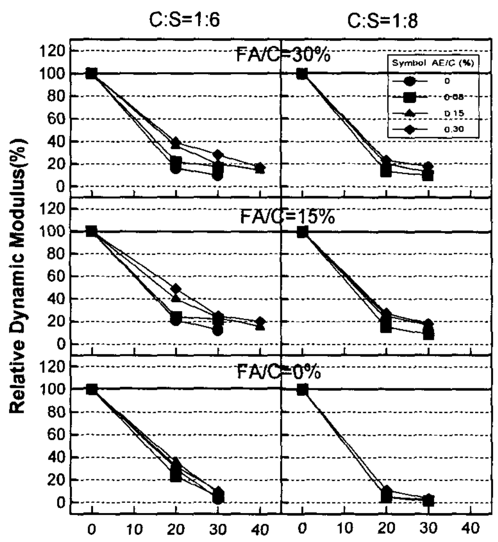

Fig. 8. Relative Dynamic Modulus of Elasticity with the Variation of the Cycle of Freeze and Thaw.

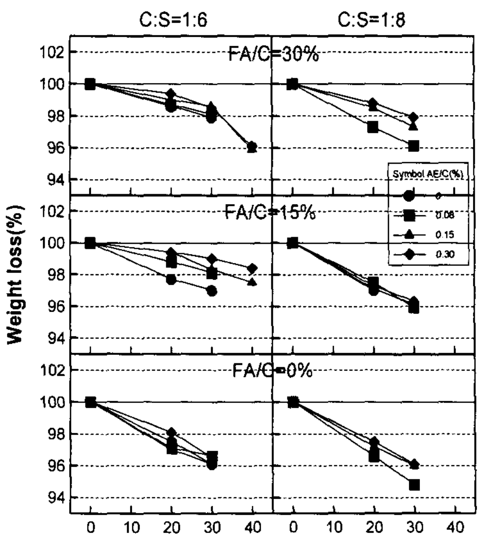

Fig. 9. Weight Loss with the Variation of the Cycle of Freeze and Thaw.

the mixing proportion of mortar, the substitution of fly ash and the change in the addition of AE water-reducing agent. First, for the substitution of fly ash, the case of the substitution of fly ash increased the relative dynamic modulus of elasticity by the increase of freeze-thaw cycle and caused higher freeze-thaw resistance contrary to existing theory. It is judged that such result is caused by the more strengthened mortar structure by the substitution of fly ash in continuous particle size distribution compared to the non- substitution.

For the change in the addition of AE water-reducing agent, as the addition of AE water-reducing agent, the freeze-thaw resistance increased, implying that the entrained air mixed by the addition of AE water-reducing agent relaxed the expansive pressure in freeze. For the mixing proportion of mortar, the freeze-thaw resistance was higher at 1:6(W/C=40%) compared to 1:8(W/C=50%).

Fig. 9 shows the mixing proportion of mortar by the increase of freeze-thaw cycleand the weight loss by the ratios of substitution of fly ash. In general, as fly ash is substituted, the addition of AE water-reducing agent is large, and the freeze-thaw cycle increases at 1:6 of the mixing proportion of mortar, the level of decrease of mass is small.

4. Conclusions

This study evaluated a series of performance to assess the performance of inter-locking block using fly ash. All the features of a specimen of inter-locking block made by change of the substitution of fly ash, the addition of AE water-reducing agent and the mixing proportion of mortar are as follows:

1) For strength, the bending strength and the compressive strength greatly decreased at the 7 days as the substitution increased, compared to the non-substitution of fly ash, but was similar at the 28 days, and increased 15%, 6% each at 15% of the substitution of fly ash at the 91 days due to the pozzolan reaction. Also, the bending strength and the compressive strength decreased as the addition of AE water- reducing agent increased.
2) The absorption decreased as the substitution of fly ash and the addition of AE water-reducing agent increased and the mixing proportion of mortar became rich(with lesser W/C).
3) As the result of freeze-thaw resistance experiment with the endurance evaluation index of inter-locking block, as the substitution of fly ash and the addition of AE water-reducing agent increased and the mixing proportion of mortar became rich, it exerted satisfactory performance by virtue of the increased amount of air.

Totally, 15% substitution of fly ash and 0.30% addition of AE water-reducing agent can manufacture more economic and quality inter-locking block than existing one as well as create higher value added in terms of prevention of environmental pollution and recycling of resources.

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