pISSN 1598-2033
eISSN 2233-5706
Journal of the Korea Institute of Building Construction, Vol. 12, No. 5
http://dx.doi.org/10.5345/JKIBC.2012.12.5.468
www.jkibc.org

Bond Strength of Mortar mixed Activated Hwangtoh

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Abstract

This study aimed to mix and test mortar incorporating activated Hwangtoh to improve the Hwangtoh brick bond strength of brick structures. To do this, the bond strength correlation of mortar was analyzed by means of materials and experiment factors and levels, and the optimum conditions were suggested after analyzing the physical properties of brick and the mix ratio of mortar and additive. Furthermore, the compressive strength and bond strength were found to be in inverse proportion, and in terms of the materials and mixing level, W/C ratio, substitution ratio of activated Hwangtoh, and fine aggregate grading were shown to have a considerable influence on the strength. In conclusion, the optimum mixing conditions to improve the bond strength are found to set W/C ratio at 65% and replacmenet ratio of activated Hwangtoh at 10%.

Keywords : activated hwangtoh, mortar, hwangtoh brick, brick bond strength, compressive strength

1. Introduction

1.1 Research background and objective

To address issues such as the natural resources crisis, the destruction of the natural environment and the ecosystem, the depletion of natural resources, and the emission of pollutants from construction materials, environmental preservation and green building construction have been given much attention recently[1,2]. In addition, the sustainable construction movement has been accelerated, with environment-related government agencies and organizations, construction-related associations, construction companies and construction material manufacturers working together in advanced countries and making efforts to limit the use of pollutant-emitting construction materials, utilize natural resources, develop non-polluting construction materials, and recycle construction waste[3]. In addition, a variety of environmental and functional construction materials are currently being used to enhance the eco-friendly features, including structures mainly built with Hwangtoh bricks, boards and finishing materials, to name a few.

Unlike general sintered bricks, Hwangtoh bricks are manufactured through a process of natural drying after pressing, and are known to have good eco-friendly features, including a high absorption rate, humidity control, and deodorization performance. For this reason, Hwangtoh bricks have become popular in building construction as material for internal and external walls as the demand for suburban houses rises. Since Hwangtoh bricks are mostly used in a wet condition, the volume of adhesives used for masonry construction, including mortar and dry mortar, is also increasing accordingly. To expand the use of Hwangtoh in construction, studies are being conducted on the

Received : October 24, 2011
Revision received : August 22, 2012
Accepted : August 29, 2012
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application of sintered Hwangtoh for mortar; however, there are restrictions in using ordinary cement mortar as an adhesive for Hwangtoh-brick masonry, and the strength problem of dry mortar made of ordinary Hwangtoh has been raised as an issue. Therefore, an adhesive material that is more appropriate for Hwangtoh-brick masonry should be developed, and bond strength should also be improved. In addition, if the pozzolanic property and reaction of activated Hwangtohis used to replace mortar, a non-structural element for cement brick masonry and plastering, it is expected that bond strength of Hwangtoh brick masonry will be improved, and the environmental load arising from cement production reduced.

With these facts in mind, the mortar was mixed using activated Hwangtoh to improve bond strength of Hwangtoh brick masonry and reduce environmental load of cement use. The properties of mortar were analyzed by mix proportion, and a bond strength test was performed to analyze the correlation between application condition and strength, and ultimately provide appropriate guidance for the use of mortar in a Hwangtoh brick structure.

1.2 Research method and scope

Literature was reviewed to understand the properties of Hwangtoh, and appropriate test factors and mix proportion were set for activated Hwangtoh mortar mix after a preliminary test. Absorption rate, replacement ratio of activated Hwangtoh, aggregate, grading of fine aggregate, polymers, etc. were determined as factors influencing the properties of activated Hwangtoh mortar. The research scope was limited in order to analyze basic properties of the activated Hwangtoh mortar such as flow and compressive strength by mix proportion, the bond strength at application to Hwangtoh bricks, and the correlation between the bond strength and each influencing factor.

2. Theoretical review

2.1 Components and formation of Hwangtoh

Hwangtoh, an indigenous natural loess, is mostly composed of minerals with the exception of the water and air in the pores. There might be a small amount of amorphous substance in thesolid that has not yet turned into mineral, such as plant roots, and microorganisms like bacteria, but the proportion of such elements is very small, and the main components of Hwangtoh can be considered as minerals, mostly consisting of particles weathered from granite, diorite, quartz porphyry, felsophyre, and alunite before and after the end of the Cretaceous period. Hwangtoh can be found all over Korea but is especially plentifulin kaolin production districts. A large amount of high quality Hwangtoh is produced from the surface layer of kaolin in Hadong, Goseong and Sancheong, Gyeongsangnam-do, Korea. The Hwangtoh produced in the districts is made in the course of decomposition of quartz trachyte, andesite and granite by weathering and hydrothermal process.

The particles of Hwangtoh include a variety of minerals such as quartz, feldspar, mica, and calcite. A light-yellow sediment, it can be divided into yellow and red soil. It consists of the following minerals, in the following ratios: 50-60% of silica (SiO_2) with large pore size, 8-12% of alumina (Al_2O_3), 5-12% of lime (CaO), 2-6% oxide of magnesium (MgO), 2-4% ferric oxide (Fe_2O_3), 0.8-1.1% ferric oxide (Fe_2O_3), and 0.5% each of titanium dioxide (TiO_2) and manganese oxide (MnO). The chemical components and formation of Hwangtoh have much in common with those of kaolin, and contain relatively more iron oxide. Iron oxide is one of the transition metal oxides, andis reported to have 95 percent far-IR emissivity. The properties of

Hwangtoh may vary slightly depending on factors in the district in which the Hwangtoh was formed, such as the geologic environment, hydrologic environment, geological features and climate. Hwangtoh is classified as halloysite, one of the kaolin sub group of minerals, and it contains SiO_2, Al_2O_3, and Fe_2O_3 as main components, which are similar to concrete admixture, and also has a pozzolanic property. It is also known as an eco-friendly material with advantages such as thermal storage, self-cleaning power, deodorization, anti-bacterial function, and far-IR emissivity, and is generally known to be good for the human body[4,5]. In addition, when sintering at a high temperature, SiO_2 and Al_2O_3 of the activated organics have a pozzolanic reaction with $Ca(OH)_2$, generating CSH gel and CASH gel. For this reason, it is also highly evaluated as a possible concrete admixture[6].

2.2 Bond strength of mortar

The general properties of mortar may vary depending on mix proportion, initial flow and use of admixture. The masonry unit is a large rectangular wall made through acombination of bricks and mortar. It has been found in many studies [7,8] that the stronger the combination between bricks and mortar, the higher the strength of the brick wall. Hence, it is noted that the bond strength of mortar in the masonry unit has a great impact on permeability and structural preservation. If the bond strength improves with the strength of masonry wall kept at a required level, it can contribute to the safety and durability ofthe concrete wall. For this reason, advanced countries have already established the criteria for bond strength test of mortar[9], and many studies have been conducted in compliance with the criteria. Based on the W/C theory that it is best to mix mortar with the minimum amount of water that satisfies the workability requirements, mortar is made for masonry work. Considering the bond strength and compressive strength ofmortar, bond strength should be considered more than anything else in the properties of mortar used in masonry work. In terms of flow, compressive strength of mortar should first be secured, and then the compressive strength should be taken into account[10]. That is, the water in the mortar is absorbed by the upper and lower masonry bricks, and it is important to secure flowability of mortar for integrity of the masonry wall. Thisis why the bond strength is considered important in the masonry unit.

3. Test plan and method

3.1. Test materials and properties

The cement used in this test is ordinary Portland cement with relative density of 3.15kg/m^3 and Blaine fineness of 3,466 cm^2/g. The fine aggregate is river sand with fineness modulus (FM) of 2.56mm and up to 5mm. The aggregate was classified into 4 types based on the standard grading scale through the test for sieve analysis (see Figure 1). The Hwangtoh used is natural Hwangtoh powder with an average particle size of 13㎛. Hwangtoh was activated after sintering it for 1 hour at 800℃, and then it was cooled rapidly. Fly ash (FA) and blast furnace slag (BFS) were used as admixture, and SBR latex and epoxy resin were used as polymer. The absorption rate of Hwangtoh bricks used in the test was 15% at room temperature. When dampened, the absorption rate of the bricks improved to be 18% at 15 minutes and 20% at 30 minutes. Table 1 indicates the property of materials used in the test. Tables 2 through 6 indicate the chemical composition of Hwangtoh, and the physical properties of cement, aggregate, and LBR latex and epoxy resin, respectively.

Table 1. Properties of materials

Material	hwangtoh brick	Cement	Fine aggregate	Activated Hwangtoh	Admixture	Polymer(density)
Property	compressive strength 16.279MPa absorption 5.7%	specific gravity :3.15 fineness:3,466cm2/g	river sand FM:2.56 large size:5mm	average size:13㎛ activation-temperature:800℃ activation-time:1hour	FA: density:2.13 fineness:2,926cm2/g	SBR Latex(1.01) Epoxy(1.12)
Property	compressive strength 16.279MPa absorption 5.7%	specific gravity :3.15 fineness:3,466cm2/g	river sand FM:2.56 large size:5mm	average size:13㎛ activation-temperature:800℃ activation-time:1hour	BFS: density:2.93 fineness:4,204cm2/g	SBR Latex(1.01) Epoxy(1.12)

Table 2. Chemical composition of Hwangtoh

chemical composition	ratio(%)	chemical composition	ratio(%)
SiO_2	42.5	CaO	0.57
Al_2O_3	36.6	K_2O	0.41
MgO	0.69	Na_2O	0.18

Table 3. Physical properties of cement

density	fineness (㎠/g)	stability (%)	setting time[gilmore(min)]		compressive strength(Mpa)		
			first	end	3day	7day	28day
3.15	3,466	0.10	303	460	21.9	26.8	35.2

Table 4. Physical properties of fine-aggregate

Type	(F.M)	density (g/㎤)		absorption ratio (%)	size classification level
		overdry condition	surface drying condition		
River sand	2.56	2.51	2.55	1.86	4

Table 5. Physical properties of SBR Latex

Type	Solid (%)	Viscosity (25℃, cP)	Surface Tension (dyne/㎝)	pH value	Density (g/㎤)
Liquid	50±2	70	35	10.3	1.01

Table 6. Physical properties of Epoxy resin

Epoxy Equivalent	Molecular Weight	Hue (Gardner)	Density (g/㎤)	Viscosity (mPas, 20℃)
170	340	< 1	1.19	3500

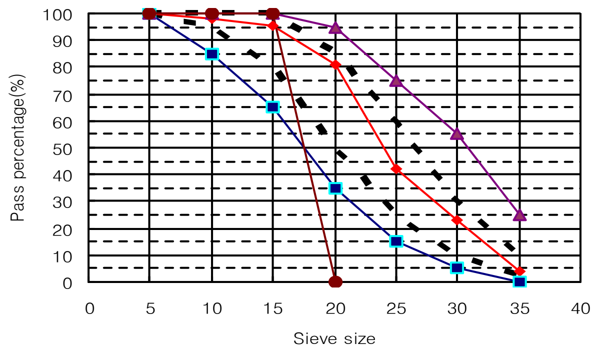


Figure 1. Fine aggregate grading classification

3.2 Test plan and method

To conduct the test, the absorption rate of Hwangtoh brick and the property influencing factors of the activated Hwangtoh mortar were first set as parameters. The OPC mortar and existing dry Hwangtoh mortar were also tested as controls. In terms of absorption rate, dampening time was set to be 15 and 30 minutes, and the water to cement ratio (W/C) was set to 60% based on a fundamental experiment. For the sake of comparison, two different levels of W/C were also set, at 55% and 65%. In addition, natural Hwangtoh and activated Hwangtoh were used as substitute for cement to compare the properties of activated Hwangtoh mortar with those of the others. The activated Hwangtoh sintered for one hour at 800℃ was used, as it showed the best performance in previous studies. The replacement ratio of activated

Hwangtoh was set at five different levels: 5%, 10%, 15%, 20%, and 25%, to analyze appropriate replacement condition, reduce the volume of cement used and improve the performance as a result. FA and BFS were used as admixture. The two polymers of epoxy resin and SBR latex were selected and used with admixture. The overall experiment factors and level are indicated in Table 7.

Table 7. Experiment factors and level

Experimental factor	Level	Type
W/C	3	55%, 60%, 65%
Hwangtoh	2	Normal(H), Activated(AH)
Aggregate size	4	standard curve(in:1, out :2),singular(1)
Brick absorption	2	15min, 30min
Hwangtoh substitution	5	5%, 10%, 15%, 20%, 25%
Admixture	2	Fly ash, Blast furnace slag
Hwangtoh Ready Mixed Dry mortar	1	Flow15cm, 18cm
Polymer	2	Epoxy, SBR-latex

The mix and test specimen are shown in Table 8. The specimen was manufactured at a different proportion of experiment factors by group. A total of 26 specimens were made in 9 groups.

The mortar was mixed using a machine mixing method, using different proportions of experiment factors according to the experiment schedule. The flowability of the mortar was measured first, and then specimens were made for compressive strength and bond strength tests. The specimen for compressive strength test was molded in a cubic form of 5cm x 5cm x 5cm, and cured in a wet condition. The specimen for bond strength test of the masonry unit was manufactured, as shown in Figure 2, by placing the upper and lower bricks crossed in the middle using a plate. More specifically, the lower bricks were placed first, and the plastic glue mold for bricks was separately manufactured to a size of 9cm×9cm×1cm, on which the upper bricks were crossed with the lower bricks. The specimens were cured for 28 days at room temperature, and tested. The specimen were placed to be crossed in a test machine and tested by putting the load until the masonry unit fell to analyze the characteristics of bond strength of the mortar as calculated using Equation (1).

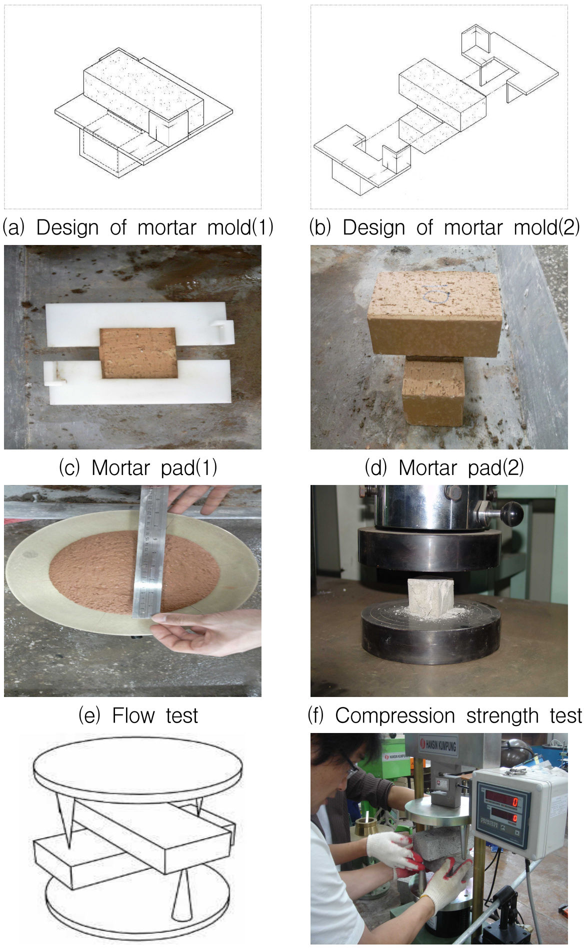
Bond strength = load/bonded area(MPa) — Equation (1)

Table 8. Mix and test specimen

Series	No.	Specimen	W/C (%)	Weight(kg/m3) Cement	Water	Sand	Hwangtoh	Admixture (kg)	Polymer (kg)
Ⅰ. Plain mortar (W/C)	1	S-55	55	159	275	566	0	-	-
	2	S-60	60	155	293	552	0	-	-
	3	S-65	65	151	310	539	0	-	-
Ⅱ. Natural Hwangtoh Mortar	4	H-55	55	118	273	562	47	-	-
	5	H-60	60	118	273	562	47	-	-
	6	H-65	65	113	307	535	45	-	-
Ⅲ. Activated Hwangtoh mortar	7	AH-55	55	118	273	562	47	-	-
	8	AH-60	60	115	291	548	46	-	-
	9	AH-65	65	113	307	535	45	-	-
Ⅳ. Substitution ratio of activated Hwangtoh	10	AH-5	60	147	292	552	9	-	-
	11	AH-10	60	139	292	551	18	-	-
	12	AH-15	60	131	291	550	27	-	-
	13	AH-20	60	123	291	549	37	-	-
	14	AH-30	60	107	290	548	55	-	-
Ⅴ. Aggregate	15	In 1	60	115	291	548	46	-	-
	16	out 1	60	115	291	548	46	-	-
	17	out 2	60	115	291	548	46	-	-
	18	singular 1	60	115	291	548	46	-	-
Ⅵ.Brick absorption	19	15min	60	115	291	548	46	-	-
	20	30min	60	115	291	548	46	-	-
Ⅶ.Ready mixed dry mortar	21	flow15	-	0	946	54	0	-	-
	22	flow18	-	0	936	64	0	-	-
Ⅷ. Mortar mixing admixture	23	FA-10	60	115	291	548	32	14	-
	24	BFS-10	60	115	291	548	32	14	-
Ⅸ. Mortar mixing polymer	25	EPO-5	60	117	276	555	46	-	7
	26	SBR-5	60	117	276	555	46	-	7

※ Material condition
- Cement(Ordinary portland):fine aggregate(river sand)=1:3
- Cement brick(190×90×57mm), Bond volume(90×90×10mm)
- Natural Hwangtoh(temperature:20℃, size:13micron)
- Activated Hwangtoh(temperature:800℃, activation time:1 hour, cooling: fast)
- superplasticizer 2%

SD: standard deviation, V: variation



(a) Design of mortar mold(1) (b) Design of mortar mold(2)
(c) Mortar pad(1) (d) Mortar pad(2)
(e) Flow test (f) Compression strength test
(g) Bond strength test(1) (h) Bond strength test(2)

Figure 2. Method of testing

4. Test results and considerations

A comparative analysis was performed to evaluate compressive strength and bond strength according to property influencing factors to present appropriate conditions of activated Hwangtoh mortar for strength improvement and utilization in Hwangtoh masonry brick.

4.1 Test results

Activated Hwangtoh mortar was tested at different levels of factors influencing the bond strength property. The compressive and bond strength test results are indicated in Tables 9 and 10, respectively. Compressive strength, brick bond strength and strength correlation coefficient were measured at 28 days, and the test results were drawn based on the data. It was found that as the W/C increased, the compressive strength decreased by 25% from 24.47MPa to 18.21MPa, or in the ratio of 1.021~0.760 compared to at 60% W/C, while the bond strength increased by 35% from 0.5MPa to 0.69MPa, or in the ratio of 0.8024~1.149 compared to at 60% W/C.

Table 9. Result of compressive strength test

	W/C (%)	Compressive strength(28days)					
		Strength (MPa)	SD	V	Coefficient	H/S AH/S	AH/H
S55	55	24.47	1.02	1.05	1.021		
S60	60	23.96	0.36	0.13	1.000		
S65	65	18.21	0.95	0.91	0.760		
H55	55	20.68	0.08	0.01	1.104	0.845	
H60	60	18.74	0.24	0.06	1.000	0.782	
H65	65	16.85	0.29	0.08	0.899	0.925	
AH55	55	29.00	0.23	0.05	1.140	1.185	1.402
AH60	60	25.45	1.13	1.28	1.000	1.062	1.358
AH65	65	21.35	0.75	0.56	0.839	1.172	1.267
AH0	60	23.96	0.36	0.13	0.981		
AH5	60	22.86	0.22	0.05	0.936		
AH10	60	23.14	1.10	1.21	0.947		
AH15	60	24.43	0.86	0.74	1.000		
AH20	60	26.00	0.83	0.69	1.064		
AH25	60	26.09	0.30	0.09	1.068		
AH30	60	25.68	0.21	0.05	1.051		
AG I1	60	20.98	1.87	3.48	1.000		
AG O1	60	22.34	0.11	0.01	1.064		
AG O2	60	20.60	3.11	9.68	0.981		
AG S1	60	19.75	0.77	0.59	0.941		
FA10	60	23.52	0.13	0.02	1.000		
BFS10	60	26.83	0.80	0.64	1.141		
EPO5	60	24.79	0.01	0.00	1.000		
SBR5	60	24.92	0.70	0.49	1.005		

Table 10. Result of brick bond strength test

	Brick bond strength(28days)					
	Strength (MPa)	SD	V	Coefficient	H/S AH/S	AH/H
S55	0.50	0.04	0.00	0.824		
S60	0.60	0.01	0.00	1.000		
S65	0.69	0.02	0.00	1.149		
H55	0.40	0.00	0.00	0.910	0.800	
H60	0.44	0.00	0.00	1.000	0.725	
H65	0.52	0.00	0.00	1.192	0.752	
AH55	0.39	0.03	0.00	0.931	0.780	0.985
AH60	0.42	0.02	0.00	1.000	0.700	0.963
AH65	0.54	0.02	0.00	1.280	0.782	1.035
AH0	0.60	0.01	0.00	0.828		
AH5	0.91	0.04	0.00	1.246		
AH10	0.74	0.03	0.00	1.020		
AH15	0.73	0.11	0.01	1.000		
AH20	0.60	0.01	0.00	0.821		
AH25	0.42	0.02	0.00	0.579		
AH30	0.48	0.07	0.00	0.658		
AG I1	0.77	0.00	0.00	1.000		
AG O1	0.66	0.02	0.00	0.857		
AG O2	0.62	0.08	0.00	0.805		
AG S1	0.05	0.01	0.00	0.065		
15min	0.51	0.00	0.01	1.000		
30min	0.77	0.11	0.00	1.509		
flow15	0.42	0.02	0.00	1.00		
flow18	0.70	0.02	0.00	1.666		
FA10	0.47	0.02	0.00	1.000		
BFS10	0.58	0.04	0.00	1.235		
EPO5	0.48	0.16	0.03	1.000		
SBR5	0.30	0.03	0.00	0.629		

※F(bond strength N/cm2)=,P:maximum load(N/),A:area of brick(cm2)

4.2 Test results and analysis

In this section, a comparative analysis of compressive and bond strength was implemented by mix proportion with different levels of W/C, activated Hwangtoh, grading of fine aggregate, absorption rate, admixture and polymer.

4.2.1 Analysis of strength with W/C

When ordinary Hwangtoh was mixed, the overall strength was shown to be lower than that of Plain. More specifically, the compressive strength was shown to be 85~93% that of Plain, while the bond strength was 75~80%. It was found in the ordinary Hwangtoh mortar with replacement ratio of 25% that as the W/C increased, the compressive strength decreased, from 20.68MPa to 16.85MPa, while bond strength increased from 0.40MPa to 0.52MPa. In addition, when activated Hwangtoh was mixed, the compressive strength was shown to rise by 27~40% while the bond strength was shown to be similarto ordinary Hwangtoh mortar, at 96~103% (Figures 3 and 4). That is, when activated Hwangtoh was mixed, the bond strength was maintained at a similar level, while the compressive strength was greatly improved in comparison with ordinary Hwangtoh mortar.

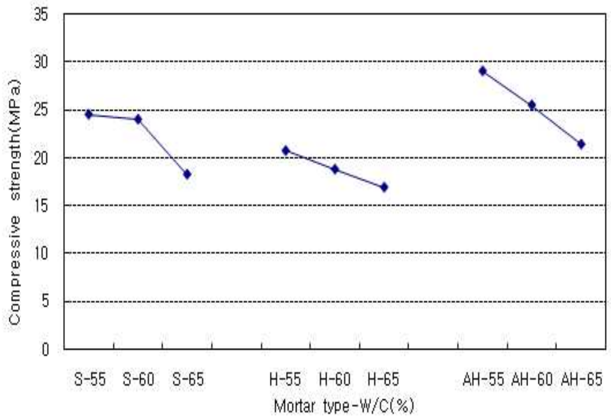


Figure 3. Analysis of the compressive strength test results

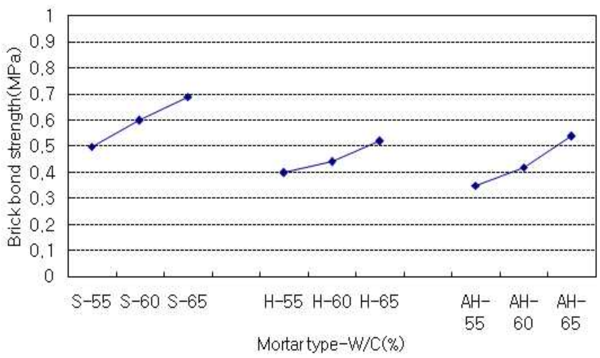


Figure 4. Analysis of the bond strength test results

4.2.2 Analysis of strength with replacement ratio of activated Hwangtoh

The highest compressive strength was shown at 26.09Mpa in the activated Hwangtoh mortar with a replacement ratio of 25%. As the replacement ratio increased, a gradual improvement of strength was found. On the other hand, the highest bond strength was shown at 0.91MPa in the activated Hwangtoh mortar with a replacement ratio of 5%. As the replacement ratio increased, a gradual decrease in strength was shown. At the replacement ratio of 15%, asharp decline in strength was shown. Taking this fact into account, an appropriate replacement ratio of Hwangtoh for masonry mortar should be set at less than 15% (see Figures 5–6)

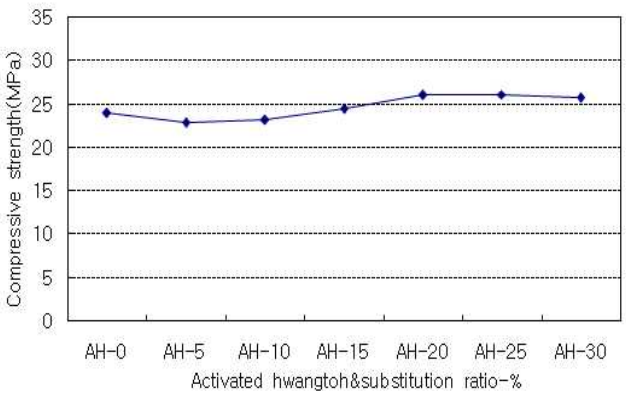


Figure 5. Analysis of the compressive strength test results

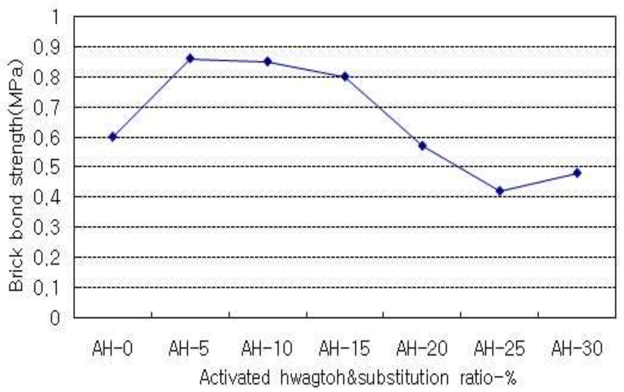


Figure 6. Analysis of the bond strength test results

4.2.3 Analysis of strength with grading of fine aggregate

Thehighest compressive strength was found at 22.34MPa in AGO1 (out of the standard grading of aggregate), and was not greatly affected by grading of fine aggregate (affected by less than 7%). However, the bond strength was greatly affected by grading. The highest bond strength was found at 0.77MPa in AGI1 (within the range of the standard grading of aggregate). Segregation of materials and a sharp decline in strength were observed in AGS1 (with single grain size) (Figures 7 and 8). Therefore, when mixing aggregate in mortar, the aggregate with single grain size should be avoided, and it is appropriate to use aggregate within the range of the standard grading of aggregate).

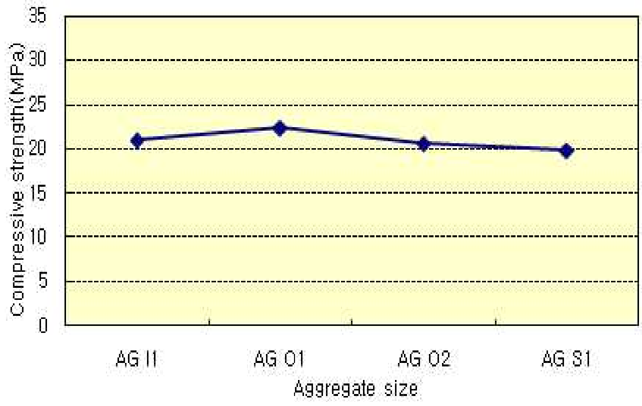


Figure 7. Analysis of the compressive strength test results

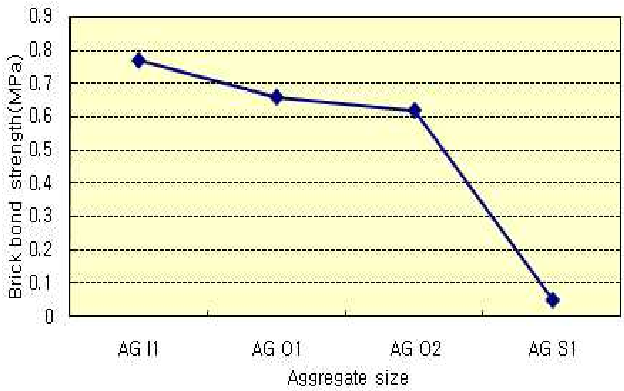


Figure 8. Analysis of the bond strength test results

4.2.4 Analysis of strength with absorption rate

Through the analysis of bond strength of brickwith absorption rate of Hwangtoh brick, in the

30-minute dampening condition, the bond strength of the brick with absorption rate of 20% was measured at 0.77, while in the 15-minute dampening condition, the bond strength of the brick with absorption rate of 18% was measured at 0.51MPa, which means the bond strength was improved by about 50% at 20% absorption rate in the 30-minute dampening condition compared to in the 15-minute dampening condition at 18% absorption rate. In addition, when compared with the existing dry Hwangtoh mortar, the bond strength of the activated Hwangtoh mortar was improved by 10~20% (see Figure 9). Therefore, to secure the integrity of the structure in brick masonry structural construction, it is believed to be advantageous to set the absorption rate as high considering the absorption rate of the brick itself. It was found that the activated Hwangtoh mortar for masonry had higher bond strength than the existing dry Hwangtoh mortar.

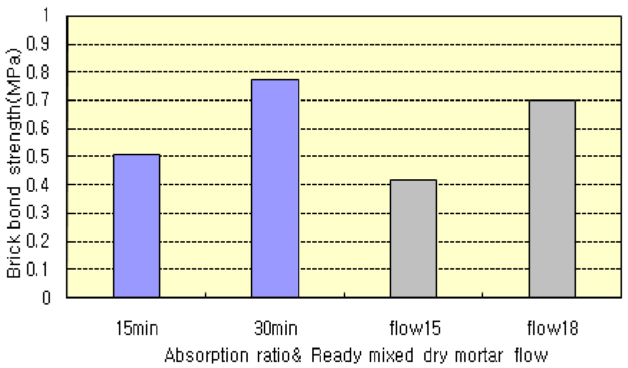


Figure 9. Analysis of the bond strength test results

4.2.5 Analysis of strength with admixture and polymer

The compressive strength of the mortar with BSF was 14% higher than that of the mortar with FA. The compressive strength of the mortar with BFS was measured at 26.83MPa, compared to 23.42MPa for the mortar with FA. There was almost no difference in the compressive strength between the mortar with epoxy resin and the mortar with SBR latex as polymer. However, when using SBR latex, the bond strength dropped by 37% compared with when epoxy resin was used (see Figures 10 and 11). Therefore, to improve the compressive strength of activated Hwangtoh mortar it is more appropriate to use BFS than FA as admixture, and epoxy resin than SBR latex as polymer.

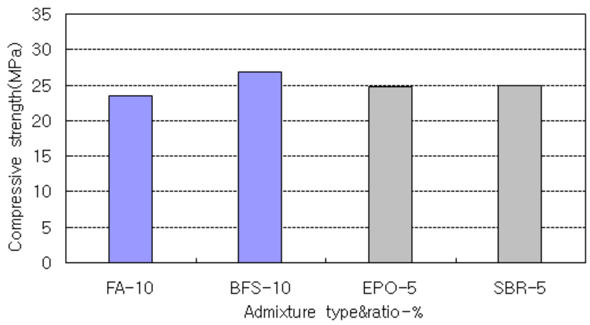


Figure 10. Analysis of the compressive strength test results

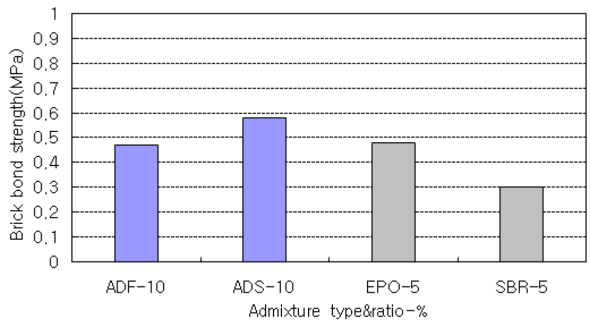


Figure 11. Brick bond strength Ⅴ

5. Conclusion

This study aims to present appropriate conditions of activated Hwangtoh mortar for utilization in Hwangtoh brick masonry units by implementing a comparative analysis of compressive strength and bond strength considering each parameter that might have an impact on strength properties. For the analysis, the Hwangtoh was mixed in as a replacement for cement to apply the characteristics and the pozzolanic reaction to the mortar as non-structural material for masonry and plastering.

The research findings are as follows:

1) The ordinary Hwangtoh mortar was compared with Plain mortar. Compressive strength and bond strength of ordinary Hwangtoh mortar were shown to be 85~93% and75~80%, respectively, compared with those of Plain mortar. When replacing 5~10% of cement with Hwangtoh, the bond strength greatly increased by 23~50% at a similar compressive strength level. Hwangtoh is believed to have great utility for bond strength improvement.
2) In selecting a grading of aggregate to improve the strength of mortar, if a single grading of aggregate was used, the bond strength sharply dropped by 90% compared to when using standard grading. The aggregate around the standard grading is believed to be appropriate, and improved water content through dampening is effective to improve brick bond strength.
3) When manufacturing mortar with improved compressive strength, it is most appropriate to set the mix proportion of W/C at 60%, replacement ratio of activated Hwangtoh at 20~25%, and BFS at 10%.
4) When manufacturing mortar with improved bond strength, it is most appropriate to set the mix proportion of W/C at 65%, and replacement ratio of activated Hwangtoh at 10%.
5) There were no differences in compressive strength found when using between epoxy resin and SBR latex. When using SBR latex, the bond strength greatly decreased by 60% compared with when epoxy resin was used. To improve bond strength, it is more appropriate to use epoxy resin.

As presented in these research findings, the bond strength was shown to be low. It should also be noted that the bond strength of a brick masonry unit is greatly affected by factors other than mortar properties, such as the characteristics of the brick and the workmanship of the worker, particularly for masonry work. These should also be studied in the future to improve bond strength based on a material property analysis taking the influencing factors into account.

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