A Study on Latent Hydraulic Property for the Strength Developing of the High Flow Concrete with Stainless Steel Slag

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1. Introduction

Latent hydraulic property refers to a property that does not cause curing by merely mixing water but hardens in an alkaline environment and turns into a hardly soluble hydrate. Generally, blast furnace slag is said to have latent hydraulic property. Based on its characteristics, the initial strength shows a downward trend with the amount of slag increases, but long-term strength tends to increase conversely if curing is sufficiently carried out[1]. Therefore, when compered concrete without latent hydraulic property and concrete having latent hydraulic property with the growth rate from initial strength to long-term strength, concrete with latent hydraulic properties seems to exhibit greater growth rate.

Recent research has confirmed that the concrete with N stainless slag fine aggregate (hereinafter: NSS) and powder (hereinafter: NSSP) have the same performance as ordinary concrete. Meanwhile, hydrate formation was confirmed in the stainless steel slag[2].

In this study, it aims to verify latent hydraulic property of mortar with stainless steel slag, by comparing the initial strength and long-term strength of mortar with stainless steel slag and some other mortars with different materials, such as the ordinary mortar, calcium carbonate mortar and blast furnace slag mortar.

2. Experimental condition

2.1 Materials

Details of the materials used in this study are shown in Table 1.

Table 1: Materials

Material	Kinds	Quality
Powder	Ordinary portland cement	Density：3.16g/cm³, Specific surface area：3170cm²/g
	Stainless slag (NSSP)	Density：3.05g/cm³, Specific surface area：5868cm²/g
	Limestone (LS)	Density：2.71g/cm³, Specific surface area：5189cm²/g
	Blast furnace slag fine powder (BS)	Density：2.90g/cm³, Specific surface area：4280cm²/g Bascity：1.89　Gypsum addition
Fine aggregate	Crushed sand	Density：2.59g/cm³, Water absorption：0.87% Fineness modulus：2.78 Solid volume percentage for shape determination：56.0%
	Stainless slag (NSS)	Density：3.08g/cm³, Water absorption：1.53% Fineness modulus：2.96 Solid volume percentage for shape determination：55.9%
Admixture	High-range water reducing agent (SP)	Base：Polycarboxylic acid-based compound
	AE water reducing agent (SV10)	Base：Oxycarboxylic acid salt

2.2 Experimental method

The mix design of mortar is shown in Table 2. The composition of mortar was cement 1, sand 3 and the water cement ratio was 0.50 in mass ratio. The substitution ratios of the amount with NSS to crushed sand in fine aggregate are 0% and 30%, respectively. Nine rectangular specimens with a cross section of 40 mm^2 and a length of 160 mm were prepared for each compound, and the compressive strength test and the bending strength test were carried out on 14 days, 28 days and 105 days of age. Bending tests were carried out on three specimens at each age, and the compressive strength tests were carried out for 6 pieces of specimens that were cut in the bending strength test.

Table 2: Mix Design

No	Propotion name	NSS Substitutability(%)	Water(g)	Cement(g)	Powder(g)			Fine aggregate(g)		Admixture(g)	Admixture name
					NSSP	LS	BS	Crushed sand	NSS		
No.1	NSS 0%(Normal)	0	1000	2000	0	0	0	6000	0	25.0	SV10
No.2	NSS 30%(Normal)	30	1000	2000	0	0	0	4200	1800	25.0	SV10
No.3	NSS 0%(NSSP)	0	1000	2000	1030	0	0	6000	0	27.3	VP700
No.4	NSS 30%(NSSP)	30	1000	2000	1030	0	0	4200	1800	27.3	VP700
No.5	NSS 0%(LS)	0	1000	2000	0	1030	0	6000	0	27.3	VP700
No.6	NSS 30%(LS)	30	1000	2000	0	1030	0	4200	1800	27.3	VP700
No.7	NSS 0%(BS)	0	1000	2000	0	0	1030	6000	0	27.3	VP700
No.8	NSS 30%(BS)	30	1000	2000	0	0	1030	4200	1800	27.3	VP700

3. Result

3.1 Compressive strength test result

Fig.1 shows the results of the compressive strength test, Table 3 shows the growth rate (%) from 14 days to 28 days of age, from 28 days to 105 days of age, and from 14 days to 105 days of age.

When compared the compressive strength of mortar with NSSP and mortar with LS, at the age of 14 days, the data of the mortar with NSSP less than the mortar with LS (both NSS 0% substitution and NSS 30% substitution). However, at the age of 105 days, the data of the mortar with NSSP better than the mortar with LS (NSS 0% substitution) and it approximately equal to LS (NSS 30% substitution). In the growth rate of compressive strength with high flow mortar, in the age range of 28 days to 105 days, except for mortar with LS, the compressive strength of the NSS 30% substitution was the largest.

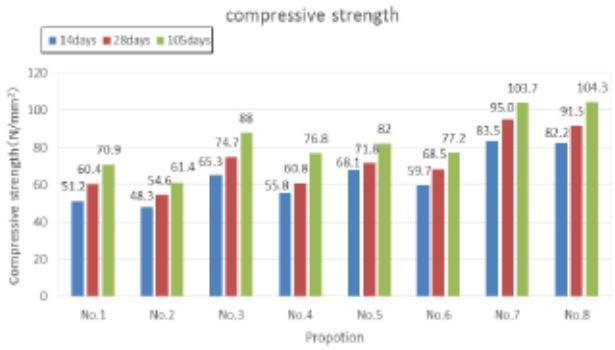

Fig.1: Compressive strength test result

Growth rate	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
14−28days	18.0	13.0	14.4	9.0	5.4	14.7	13.8	11.3
28−105days	17.4	12.5	17.8	26.3	14.2	12.7	9.2	14.0
14−105days	38.5	27.1	34.8	37.6	20.4	29.3	24.2	26.9

Table 3: Growth rate of compressive strength (%)

3.2 Bending strength test result

Fig.2 shows the results of bending strength tests. Table 4 shows the growth rate (%) from 14 days to 28 days of age, 28 days to 105 days of age, and from 14 days to 105 days of age.

When compared the bending strength of mortar with NSSP and mortar with LS, at the age of 14 days, the data of the mortar with NSSP less than the mortar with LS (both NSS 0% substitution and NSS 30% substitution). However, at the age of 105 days, the data of the mortar with NSSP better than the mortar with LS (NSS 0% substitution) and it approximately equal to LS (NSS 30% substitution).

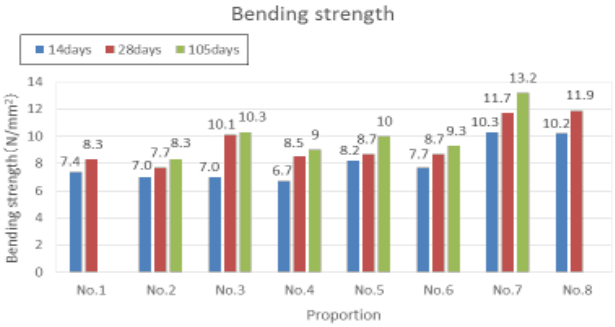

Fig.2: Bending strength test

Growth rate	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
14−28days	12.2	10.0	44.3	26.9	6.1	13.0	13.6	16.7
28−105days		7.8	2.0	5.9	14.9	6.9	12.8	
14−105days		18.6	47.1	34.3	22.0	20.8	28.2	

Table 4: Growth rate of bending strength (%)

4. Conclusions

The results from this study are summarized as follows.

(1) Both compressive strength and bending strength, when compared the strength of mortar with NSSP and mortar with LS, at the age of 14 days, the data of the mortar with NSSP less than the mortar with LS (both NSS 0% substitution and NSS 30% substitution). However, at the age of 105 days, the data of the mortar with NSSP better than the mortar with LS (NSS 0% substitution) and it approximately equal to LS (NSS 30% substitution).

(2) In the growth rate of compressive strength, in the age range of 28 days to 105 days, except for mortar with LS, the compressive strength of the NSS 30% substitution was the largest.

From the above, it is considered that there is a possibility that the stainless steel slag has latent hydraulic property.

References

1) Michio F. and Toshiaki T., 1991. Durability of concrete and foundation of chemistry. : Cement newspaper publisher.

2) Yutaro O., 2016. Studies on the effective use of stainless steel slag for self-compacting concrete. Master thesis of Yamaguchi University.