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Durability Evaluation of Concrete Using Fine Sand of Nakdong-River

Soon-Oh Kwon[1] · Su-Ho Bae[1]* · Hyun-Jin Lee[1]

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It is strongly needed to investigate the fine sand as an alternative fine aggregate of well-graded river sand because the fine sand which is being enormously distributed in the midstream and downstream of Nakdong-River in Korea has a poor grading but good quality as a fine aggregate for concrete. Thus, the purpose of this experimental research is to evaluate the durability of concrete using the fine sand to utilize it actively as a fine aggregate. For this purpose, the concrete specimens using different fine sand were made for the specified concrete strength of 35MPa, and then their durability such as the resistance to freezing and thawing and carbonation, and drying shrinkage were evaluated. It was observed from the test results that the resistance to freezing and thawing and carbonation of concrete using the fine sand was similar to that of concrete using reference sand, but the drying shrinkage of concrete using the fine sand with small fineness was comparatively lager than that of concrete using reference sand.

Keywords : Fine sand, Durability, Freezing and Thawing, Carbonation, Drying shrinkage

1. INTRODUCTION

Due to the recent shortage of well-graded river sand resulting from a rapid growth of the domestic concrete construction, sea sand, crushed sand, and etc. are increasingly used instead. It is, however, well noted that non-washed sea sand used in reinforced concrete structures leads to corrosion of the reinforcing steel, and thus eventually results in damage to concrete. Also, it is well known that crushed sand is difficult to maintain the allowable amount of passing 0.08mm sieve and to adjust grading(Donza et al., 2002; Oh et al., 2007; Chung et al., 1996). Thus, it is strongly needed to develop an alternative fine aggregate instead of sea sand and crushed sand(Park et al., 2004; Kou and Poon, 2009; Al-Harthy et al., 2007).

On the other hand, it is required to utilize the fine sand of Nakdong-River as a part of that, because the fine sand is being enormously distributed in the midstream and downstream of Nakdong-River and has a poor grading but good quality as a fine aggregate for concrete.

Thus, the purpose of this experimental research is to evaluate the durability of concrete using the fine sand to utilize it actively as a fine aggregate. For this purpose, the concrete specimens using different fine sand were made for the specified concrete strength of 35MPa, and then their durability such as the resistance to freezing and thawing and carbonation, and drying shrinkage were evaluated.

2. EXPERIMENTAL WORK

2.1 Concrete mix design with types of fine aggregate

2.1.1 Materials and mix proportion

To collect the fine sand samples, field survey was performed through Nakdong-River mainstream of 334 km. As a result, the sand samples were collected from upstream(Andong), midstream(Dalseong), and downstream(Changnyeong) of

* Corresponding author E-mail: shbae@andong.ac.kr

[1]Department of Civil Engineering, Andong National University, Andong, 760-749, Korea

Nakdong-River mainstream and upstream sample was well-graded reference sand to compare with fine sand samples. Their physical properties are given in Table 1. Fig. 1 shows the grading curve for three types of sand samples.

To manufacture concrete specimens using reference and fine sand, respectively, ordinary portland cement(KS L 5201, Type 1) with a specific gravity of 3.15 was used as shown in Table 2. Coarse aggregate was crushed stone with maximum size of 25mm and density of 0.00265g/mm^3. To control fluidity of concrete mixture, air entraining(AE) and high-range water reducing agent of polycarbonic acid were used as a kind of superplasticizer. The properties are shown in Table 3.

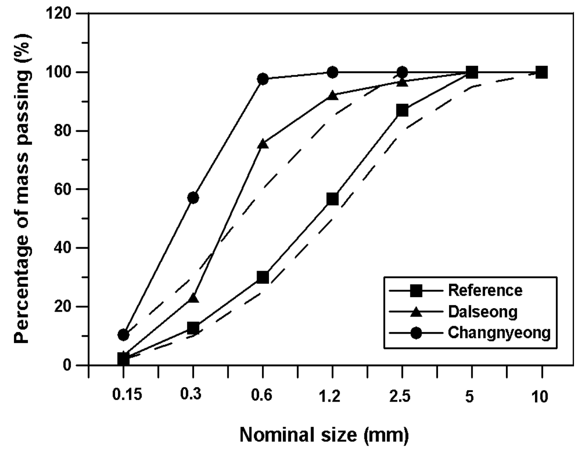


Fig. 1. Grading curve for three types of sand samples

Table 1. Physical properties of fine aggregates

Sample types		Density (g/mm^3)	Absorption (%)	Bulk density (kg/m^3)	Amount of passing 0.08mm sieve (%)	Fineness modulus
Up stream	Reference	0.00254	2.15	1,660	4.25	2.72
Mid stream	Dalseong	0.00252	2.19	1,540	2.24	2.09
Down stream	Changnyeong	0.00251	2.40	1,430	0.79	1.35

Table 2. Physical properties of cement

Specific gravity	Setting time (min)		Fineness (m^2/kg)	Compressive strength (MPa)		
	Initial	Final		3 Days	7 Days	28 Days
3.15	225	340	341	25.1	40.8	57.4

Table 3. Properties of Chemical Admixtures

Type	Specific gravity	pH	Solid content (%)	Quantity (%) (by mass of cement)	Main component
Superplasticizer	1.05	3～4	18	0.5~2.5	Polycarbonin acid admixture
Air entraining agent	1.08	12	28	0.002~0.004	Surfactant

Table 4. Mix proportions of concrete

Specimens	Strength level	Target slump (mm)	Target air content (%)	W/C (%)	S/a (%)	Unit mass (kg/m^3)				SP (C×%)	AE (C×%)
						W	C	S	G		
Reference	High strength	210 ± 30	5.0 ± 1.0	34.0	43	160.7	470	625	972	1.6	0.002
Dalseong				30.0	38	153.3	510	622	1,043		
Changnyeong				34.0	38	173.3	510	600	1,010		
Reference	Moderate strength	150 ± 25	5.0 ± 1.0	47.0	45	177.3	380	677	950	1.3	0.002
Dalseong				41.0	40	166.7	410	674	1,038		
Changnyeong				44.0	40	180.0	410	658	1,017		
Reference	Low strength	120 ± 25	5.0 ± 1.0	61.0	48	182.7	300	733	926	0.9	0.002
Dalseong				53.5	42	173.3	325	730	1,035		
Changnyeong				63.5	42	206.0	325	692	985		

Table 4 shows the mix proportions of concrete with strength level such as high, moderate, and low strength for reference sand and two types of fine sand, respectively. The target slump is 120±25mm to 210±30mm according to the strength level and air content is 5.0±1.0% irrespective of that. As shown in Table 4, it was observed that W/C ratio of concrete was slightly different according to the sand sample type even though the strength level is equal. That is because unit water content required to obtain the target slump was different with its characteristics, as admixture dosage with strength level is same.

2.1.2 Test specimens

Concrete cylinders (∅ 100×200mm) were made to measure the compressive strength. After casting, concrete cylinders were demolded after 24 hours and were cured in the water of 20±2℃ for 7 and 28 days, respectively.

According to the KS F 2405(Standard test method for compressive strength of concrete, 2010), compressive strength tests of concrete cylinders were carried out at 7 and 28 days, respectively.

2.2 Durability experiment of concrete using fine sands

2.2.1 Materials and mix proportion

Materials used for durability experiment of concrete using fine sand is equal to that used for "2.1 Concrete mix design with types of fine aggregate". Table 5 shows the mix proportions of concrete with sand sample type. W/C ratio of concrete with fine sand type was obtained for the specified concrete strength of 35MPa by using "3.2 correlation between compressive strength and C/W ratio".

2.2.2 Test specimens

Concrete cylinders(Ø 100×200mm) were made to measure the carbonation depth, concrete prisms were made to estimate drying shrinkage(100×100×400mm) and freezing and thawing (76×101×412mm). After casting, concrete cylinders and prisms were demolded after 24 hours and were cured in the water of 20±2℃ until test began.

2.2.3 Test for resistance to freezing and thawing

According to the KS F 2456(Standard test method for resistance of concrete to rapid freezing and thawing, 2008), concrete prism was cured in the water for 14 days and then freezing and thawing test of that was carried out. During the test, relative dynamic modulus of elasticity was measured until 300 cycles of freezing and thawing, each 30 cycles. The durability factor are calculated as follows.

$$DF = \frac{PN}{M} \tag{1}$$

where, DF: durability factor of the test specimen, P: relative dynamic modulus of elasticity at N cycles(%), N: number of cycles at which the relative dynamic modulus of elasticity reachs 60% or number of cycles at which the exposure is to be terminated, M: number of cycles at which the exposure is to be terminated.

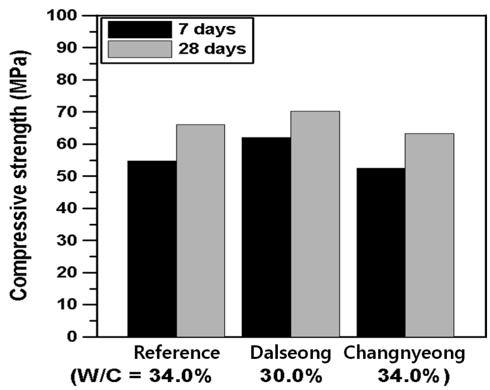
2.2.4 Accelerated carbonation test

According to the KS F 2584(Standard test method for accelerated carbonation of concrete, 2010), concrete cylinder was fixed in the constant temperature and moisture room(20±2℃, 60±5% RH) for 4 weeks, after wet curing for 4 weeks. Before the test, concrete cylinder was cut in half and the rest

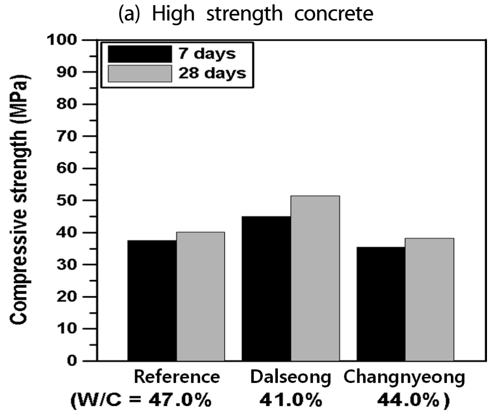
Table 5. Mix proportions of concrete

Specimens	Specified concrete strength (MPa)	Target slump (mm)	Target air content (%)	W/C (%)	S/a (%)	Unit mass (kg/m^3)				SP (C×%)	AE (C×%)
						W	C	S	G		
Reference	35	150 ± 20	5.0 ± 1.0	45	43	174	386	728	987	0.9	0.003
Dalseong				44	42	172	390	709	709		
Changnyeong				43.5	39	180	414	640	1,032		

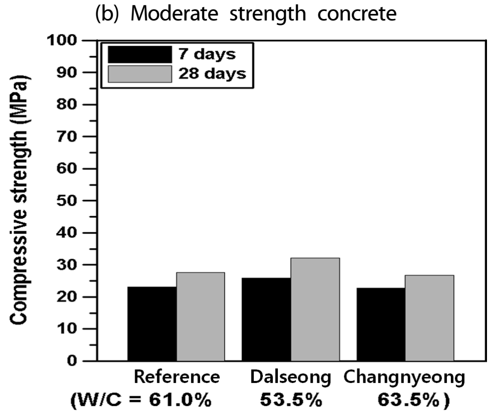
surfaces except the exposed surface were covered with epoxy resin to prevent penetration of carbon dioxide. The proceed test specimens were kept in the accelerated carbonation testing apparatus and their carbonation depths were measured by using 1% phenolphthalein solution according to the accelerating ages(7, 28, 56, and 91 days).



(a) High strength concrete



(b) Moderate strength concrete



(c) Low strength concrete

Fig. 2. Compressive strength of concrete

2.2.5 Length change test

According to the KS F 2424(Standard test method for length change of mortar and concrete, 2010), the initial value of length change for concrete prism was estimated right after demolding and concrete prism was cured in the water. After 7 days, length change for that was evaluated and then was estimated according to the ages(28, 56, 91, and 182 days) for concrete prism fixed in the constant temperature and moisture room(20±1℃, 60±5% RH).

3. RESULTS AND DISCUSSION

3.1 Compressive strength of concrete

Fig. 2 shows the compressive strength of concrete using reference and fine sands with strength level. Since W/C ratio of concrete with fine sand sample differs under equal strength level, it is required to make correlation formula between compressive strength and C/W ratio to obtain W/C ratio with fine sand sample for the specified concrete strength.

3.2 Correlation between compressive strength and C/W ratio

Fig. 3 and Table 6 show the correlation between compressive strength at 28 days and C/W ratio of concrete using reference and fine sands, respectively. It was revealed that when the

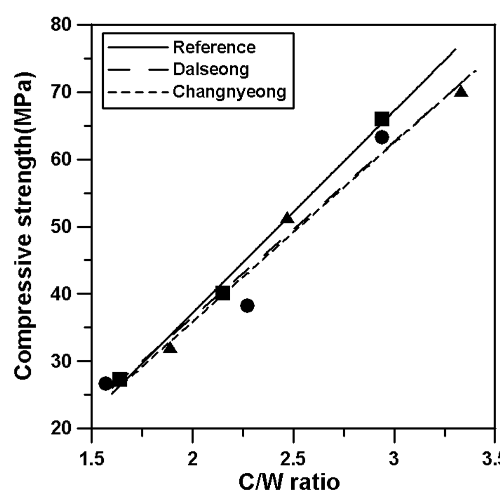


Fig. 3. Correlation between compressive strength and C/W ratio

Table 6. Correlation formula between compressive strength and C/W ratio

Specimens	Correlation between compressive strength and C/W ratio
Reference	$f_c = 30.42(C/W) - 23.59$
Dalseong	$f_c = 25.94(C/W) - 15.02$
Changnyeong	$f_c = 26.77(C/W) - 17.90$

physical properties of aggregate differed, the correlation between compressive strength and C/W ratio also was different. W/C ratio of concrete with fine sand sample is the same as Table 5 for the specified concrete strength of 35MPa.

3.3 Durability of concrete using fine sands

3.3.1 Resistance to freezing and thawing

Generally, durability factor shows a index of resistance to freezing and thawing. For instance, a durability factor smaller than 40 means that the concrete is probably unsatisfactory with respect to resistance to freezing and thawing; 40 to 60 is the range for concretes with doubtful performance; above 60, the concrete is probably satisfactory; and around 100 it can be expected to be satisfactory(Neville, 1997).

Fig. 4 shows the durability factor of concretes using reference, Dalseong, and Changnyeong specimens, respectively. It was found that the resistance to freezing and thawing was excellent for all the concrete specimens, because the durability factor of those were above 90. Thus, it could be concluded that the fine sand type had no effect on the resistance to freezing and thawing, when air content of concrete was entrained to 4-6%.

3.3.2 Resistance to carbonation

Fig. 5 shows the carbonation depth of concrete using reference, Dalseong, and Changnyeong specimens, respectively until accelerating age of 91 days. It was observed that the carbonation depth for all the concrete specimens were not occurred until accelerating age of 28 days but are progressed after that time and were almost similar until accelerating age of 91 days. Thus, it could be concluded that the fine sand type had no effect on the resistance to carbonation until accelerating age of 91 days.

3.3.3 Length change

Fig. 6 shows the length change of concrete using reference, Dalseong, and Changnyeong specimens, respectively until 182 days. It was observed that the length change of concrete was reduced with decreasing unit water content and that of Changnyeong fine sand was largest, as unit water content of Changnyeong fine sand was most. Thus it was thought that the length change of concrete was more dependent on unit water content than W/C ratio.

It was revealed that the length change of Changnyeong fine sand was relatively larger than that of reference sand, because the unit water content of Changnyeong fine sand with a small

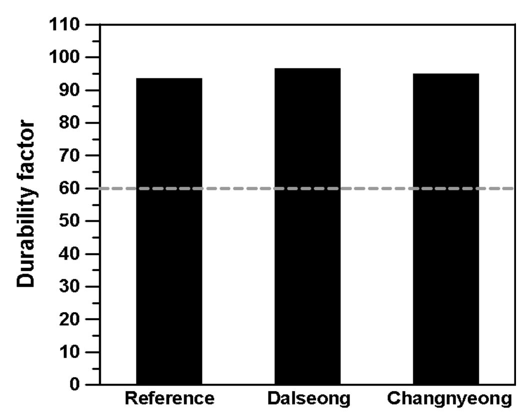


Fig. 4. Durability factor of concrete

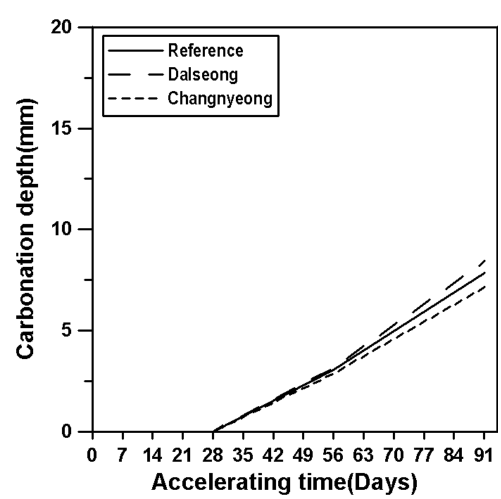


Fig. 5. Carbonation depth of concrete

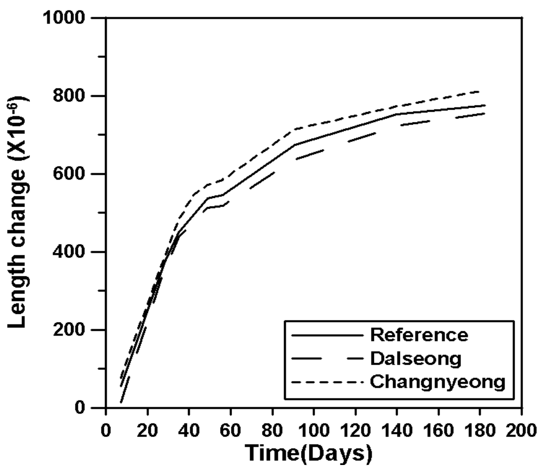


Fig. 6. Length change of concrete

fineness modulus of 1.35 was more required than that of reference sand to obtain the target slump. Thus, it was thought that the fine sand with fineness modulus above 1.5 should be used to utilize the fine sand as a fine aggregate for concrete.

4. CONCLUSIONS

The following conclusions were drawn from the experimental study on the durability of concretes using fine sands of Nakdong-River.

1. It was revealed that the durability factor of all the concretes using reference and fine sands, respectively were above 90 when air content of concrete was entrained to 4-6%. Thus, it could be concluded that the fine sand type had no effect on the resistance to freezing and thawing.
2. It was observed that the carbonation depth of concrete using fine sands were almost similar to that of concrete using reference sand until accelerating ages of 91 days. Thus, it could be concluded that the fine sand type had no effect on the resistance to carbonation.
3. It was found that the length change of Changnyeong fine sand which was most in unit water content was largest. Thus, it was thought that the length change of concrete was more dependent on unit water content than W/C ratio.
4. It was observed from the test results that the resistance to freezing and thawing and carbonation of concrete using fine sand were almost similar to that of concrete using reference sand but the length change of Changnyeong fine sand was relatively larger than that of reference sand, because the unit water content of Changnyeong fine sand with a small fineness modulus of 1.35 was more required than that of reference sand to obtain the target slump. Thus, it was thought that the fine sand with fineness modulus above 1.5 should be used to utilize the fine sand as a fine aggregate for concrete.

Acknowledgements

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