Journal of Civil, Construction and Environmental Engineering
2021; 6(6): 202-207
http://www.sciencepublishinggroup.com/j/jccee
doi: 10.11648/j.jccee.20210606.15
ISSN: 2637-3882 (Print); ISSN: 2637-3890 (Online)

Proper Mix Proportion and Construction Method of Waste Concrete Using Recycled Coarse Aggregate in Site Considering Environment

Nam Wook Kim*, Min Hwan Kim

Department of Civil and Environmental Engineering, Honam University, Gwangju, Republic of Korea

Email address:
kimnw@honam.ac.kr (N. W. Kim)
*Corresponding author

To cite this article:
Nam Wook Kim, Min Hwan Kim. Proper Mix Proportion and Construction Method of Waste Concrete Using Recycled Coarse Aggregate in Site Considering Environment. *Journal of Civil, Construction and Environmental Engineering.* Vol. 6, No. 6, 2021, pp. 202-207.
doi: 10.11648/j.jccee.20210606.15

Received: November 20, 2021; **Accepted**: December 14, 2021; **Published**: December 24, 2021

Abstract: When the concrete waste is recycled as the aggregate, the concrete waste is generally carried to the plant and the recycled aggregate is manufactured. However, in this method it needs significantly much energy and causes much CO_2 when the concrete waste is carried to the plant. Therefore, it is need to consider about environment to study on recycling of concrete waste in site. In this study, it is investigated, appropriate mix proportions used recycled coarse aggregate, properties of fresh concrete, pumpability, and properties of hardened concrete in case recycling of concrete waste in site, and when the mortar is brought to the site and the recycled coarse aggregate in the dry state is used, the recycled coarse aggregate is put into the mortar in which the amount of water corresponding to the water absorption rate of the recycled coarse aggregate in the dry state is corrected, it is discussed the freshness and curability of the concrete produced in the above, as well as the aging and pumping properties of the slump. From the scope of this study, when the mortar is brought into the site and the recycled coarse aggregate in an air-dried state is put in the site, if the amount of water corresponding to the effective water absorption rate of the regenerated coarse aggregate is corrected at the mortar manufacturing stage, the compressive strength and tensile strength, the static elastic modulus and the chloride ion penetration depth were about the same as when the recycled coarse aggregate in the surface dry state was used. In addition, it is considered that the same degree of fluidity as when the recycled coarse aggregate in the surface dry state is used even after pumping.

Keywords: Mix Proportion, Construction Method, Waste Concrete, Recycled Aggregate, Pumpability

1. Introduction

When waste concrete is used as an aggregate for concrete, it is common to transport the waste concrete to an intermediate treatment plant, manufactured recycled aggregate, and use it as recycled aggregate concrete at a new site. However, this method requires the transportation of waste concrete material many times, which consumes transportation cost and energy. On the other hand, when the waste concrete material is reused on-site, a large-scale concrete manufacturing plant may be constructed and recycled aggregate concrete may be manufactured on-site. However, the use is limited because it costs a lot to construct a concrete manufacturing plant on site and it is assumed that the plant cannot be constructed in mountainous areas. Therefore, it is conceivable that only recycled aggregate is manufactured from the dismantled concrete, mortar is brought in from the ready-mixed concrete factory, and then the recycled aggregate is mixed on site. In that case, it is desirable to sufficiently absorb water from the recycled aggregate in consideration of workability such as pumping property of the recycled aggregate concrete. However, due to environmental issues, heavy metals may elute if a large amount of water is used to treat the recycled aggregate, In addition, 40 environmentally friendly researches on compounding and construction methods for on-site recycling of waste concrete requires a large amount of cost for water treatment, in some cases, the recycled aggregate must be used in an air-dried state. [1, 2] In previous studies on-site recycling of waste concrete (a method that does not construct a plant on-site), there is an example of examining by the aggregate replacement method in which recycled aggregate is mixed with ordinary aggregate, few studies have been conducted on the purpose of using the entire amount of recycled aggregate. In addition, the current situation is that little research has been conducted on the clear formulation of recycled aggregate when it is used in an air-dried state. As for the manufacturing method of recycled concrete, a method has been proposed in which concrete mixed with each material excluding recycled aggregate is brought to the site and recycled aggregate is put into the site, but only mortar. As far as the author knows, no research has been conducted on how to manufacture recycled concrete by manufacturing it in a plant and bringing it to the site to manufacture recycled concrete. [3, 4]

In this study, when the mortar is brought to the site and the recycled coarse aggregate in the dry state is used, the recycled coarse aggregate is put into the mortar in which the amount of water corresponding to the water absorption rate of the recycled coarse aggregate in the dry state is corrected, it is discussed the freshness and curability of the concrete produced in the above, as well as the aging and pumping properties of the slump.

2. Experimental Outlines

The flow of on-site recycling assumed in this study is as shown in Figure 1. The materials used are as shown in Table 1. And stone and recycled coarse aggregate were used as the coarse aggregate. The concrete was manufactured by first manufacturing mortar (shaded part in Table 3) from which coarse aggregate was removed from each formulation, and then adding coarse aggregate and mixing. [5]

2.1. Discussion of Concrete Mixing (W / C=45%, 55%, 65%)

The types of coarse aggregate and the composition of concrete are shown in Tables 2 and 3, respectively. The water-cement ratio was set to 3 levels of 45%, 55% and 65%, and the coarse aggregate was set to 4 levels depending on the type and condition. CS-SSC used surface dry stone for coarse aggregate, RA-SSC used surface dry recycled coarse aggregate, and RA-ADC used dry recycled coarse aggregate. RA-ADW used dry recycled coarse aggregate as the coarse aggregate, but the amount of water equivalent to the water absorption rate (3.5% in this case) of the recycled coarse aggregate was corrected in advance at the mortar manufacturing stage. Then, we mainly compared RA-SSC and RA-ADCW and discussed them. Since RA-ADCW corrects the amount of water corresponding to the water absorption rate, the apparent amount of water increased as shown in Table 3.

2.2. Fresh and Hardened Concrete Mixing (W / C=45%, 65%)

As a test item, first, mortar from which coarse aggregate is removed from each formulation is manufactured, a mortar flow (0 stroke flow) test is performed, then coarse aggregate is added and mixed, and according to KS F 2402, slump test was conducted. Then, standard curing is performed in water until the 28th day of the age, and then the shrinkage test according to KS F 2424, the split tensile strength test according to KS F 2423. In the salt water immersion test, the test was first immersed in water having a NaCl concentration of 10% for a predetermined day. After that, the permeation depth was measured by splitting and spraying silver nitrate.

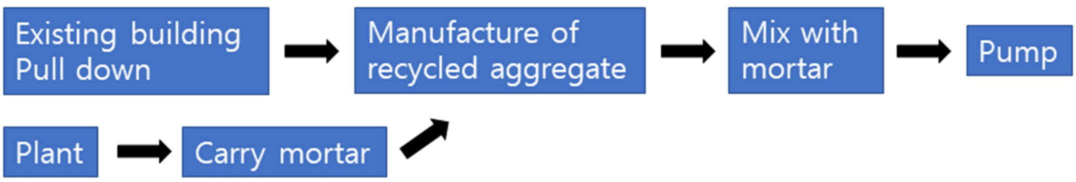

Figure 1. *Assumed schematic diagram of recycling of waste concrete in site.*

Table 1. *Physical properties of used materials.*

Kinds	Properties
Cement	Ordinary port land cement (Density: 3.15g/cm^3)
Fine aggregate	River sand (Density: 2.63g/cm^3, Absorption: 2.11%, F. M: 2.85)
Coarse aggregate	Crushed stone (Density: 2.65g/cm^3, Absorption: 1.35%, F. M: 6.81) Recycled aggregate (Density: 2.35g/cm^3, Absorption: 6.78%)
Chemical admixture	Water reducing AE admixture High range water reducing admixture

Table 2. *Kinds of coarse aggregate to mix.*

Kinds	Condition
CS-SSC	Crushed stone under saturated surface-dry condition
RA-SSC	Recycled aggregate under saturated surface-dry condition
RA-ADC	Recycled aggregate under air-dry condition
RA-ADCW	Recycled aggregate under air-dry condition added to water content

2.3. Discussion of Aging and Pumping (W / C=55%)

When dry recycled coarse aggregate is used, water absorption by the aggregate may cause slump loss due to aging. Therefore, after mixing the concrete, a slump test was conducted every 30 minutes to measure the aging. Considering the decrease in slump due to pumping during construction, we used a slump test to discuss pumping performance. The slump test is a simple evaluation method of pumping performance that focuses on the amount of water when concrete is sent, but it is an indirect evaluation method because it measures the amount of water, and it is an indirect evaluation method after direct feeding. It cannot be converted to slump, therefore, in this study, a breeding test for the maximum size of coarse aggregate of 40 mm or less, which is generally used as shown in Figure 2, was used, and a force of 3.5 MPa was applied with the water cock closed. The acting load was applied for 2 minutes, and then the concrete sample was taken out and examined as a slump after pumping. At that time, since the capacity of the commonly used slump test is as small as about 2 liters, as shown in Figure 3. The mini slump capacitor whose straightness and height are reduced to 2/3 of the slump cone is used, and we made a new one and decided to measure the relationship between the slump and the mini slump.

Table 3. *Used mix proportion.*

W/C (%)	Kinds of coarse aggregate	Air content (%)	Unit content (kg/m^3)				
			W	C	S	G	Ad**
45	CS-SSC	4.5	175	389	747	979	1.0
	RA-SSC					897	
	RA-ADC					871	
	RA-ADCW		175+27*				
55	CS-SSC		175	318	805	979	1.0
	RA-SSC					897	
	RA-ADC					871	
	RA-ADCW		175+27*				
65	CS-SSC		180	271	826	979	0.5
	RA-SSC					897	
	RA-ADC					871	
	RA-ADCW		175+27*				

*amount of additional water absorption is added to water content.
**W/C=45%: High range water reducing and AE admixture
**W/C=55%, 65%: Water reducing and AE admixture

Figure 2. *Concrete pumping tester.*

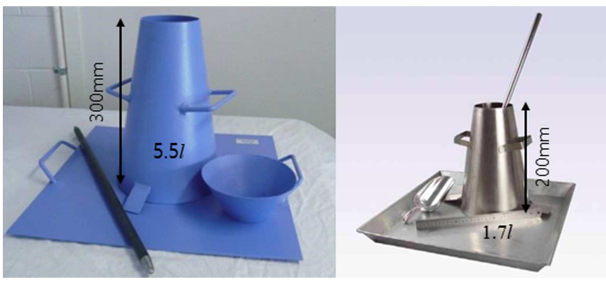

Figure 3. *Used mold for slump test and mini slump test.*

3. Experimental Results and Discussions

3.1. Properties of Fresh Concrete

As shown in Figure 4, in the case of RA-ACDW, the amount of water corresponding to the water absorption rate was corrected, so the mortar flow (0 stroke flow) was larger than the other formulations. Even if it is made into a slump, it will be slightly larger than other formulations, and in most cases, the recycled coarse aggregate does not seem to absorb the amount of water corresponding to the water absorption rate. On the other hand, in the case of RA-ADC, the mortar flow was about the same as RA-SSC, but as shown in Figure 5, the slump was about 100mm lower than that of RA-SSC. It is considered that this is because the dry recycled coarse aggregate absorbed the mixed water. [6, 7]

3.2. Properties of Hardened Concrete

As shown in Figure 6 and Figure 7, the compressive strength and tensile strength of RA-SSC were slightly lower than those of CS-SSC using crushed stone. This is thought to be because the strength of the recycled coarse aggregate itself is smaller than that of crushed stone. [8, 9]

On the other hand, in the case of RA-ADCW, the same strength as RA-SSC can be obtained, and even if the amount of water corresponding to the effective water absorption rate is corrected, the strength is not affected, and this correction method is considered to be effective. As shown in Figure 8, the static elastic modulus was slightly lower in the case of RA-SSC, RA-ADC, and RA-ADCW than in the case of CS-SSC using crushed stone. This is thought to be because mortar with a small static elastic modulus is attached to the recycled coarse aggregate. As shown in Figure 9, the chloride ion penetration depth is about the same for CS-SSC, RA-SSC, and RA-ADCW, and RA-ADC seems to be difficult to penetrate. It is considered that this is because, in the case of RA-ADC, the recycled coarse aggregate in the air-dried state absorbed water and the apparent water-cement ratio became smaller, as in the case of strength. From the viewpoint of durability, the chloride ion penetration depths of CS-SSC, RA-SSC, and RA-ADCW are about the same, and it is considered that the correction method of this formulation is effective. [10-12]

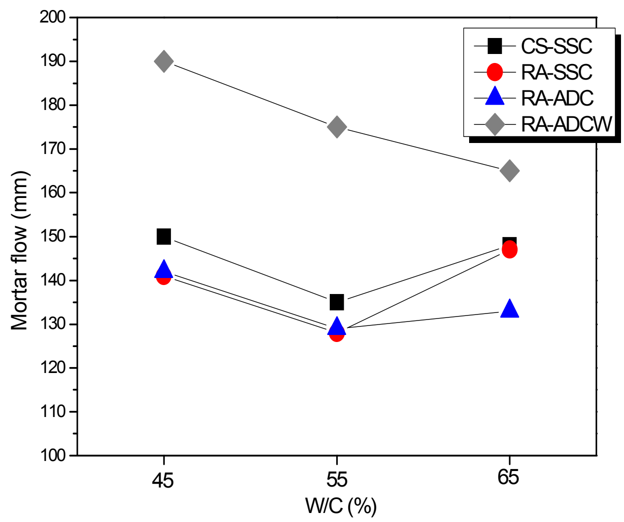

Figure 4. *Results of mortar flow test.*

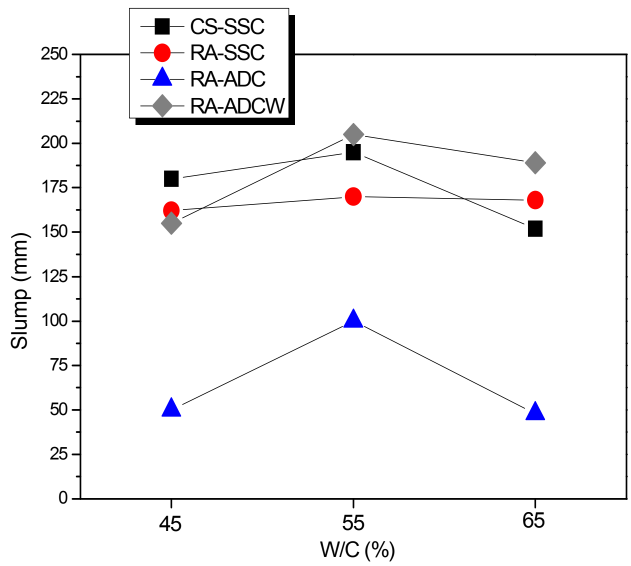

Figure 5. *Results of concrete slump test.*

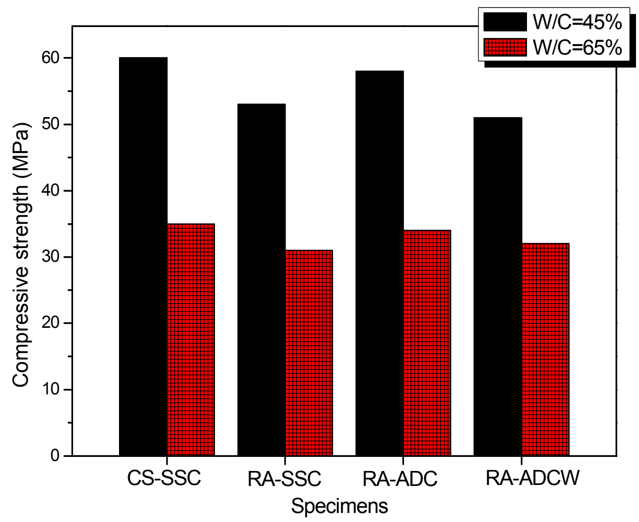

Figure 6. *Results of compressive strength test.*

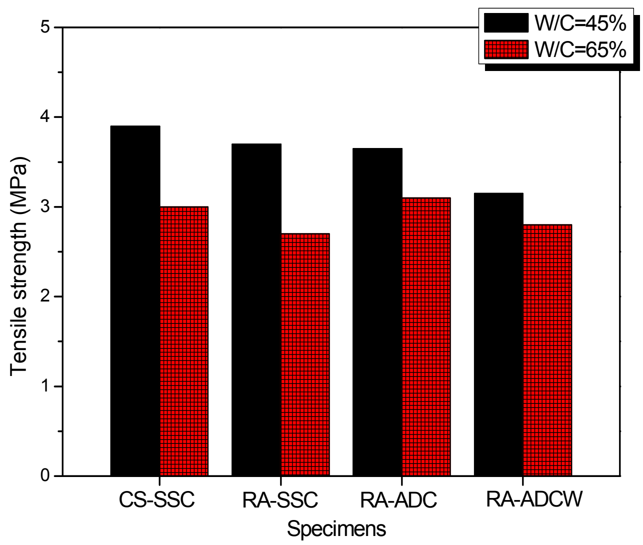

Figure 7. *Results of tensile strength test.*

3.3. Discussion of Changes over Time and Pumping Performance

As shown in Figure 10, in the case of RA-ADCW, the slump becomes large because it seems that the amount of water corresponding to the effective water absorption rate is not immediately absorbed during mixing, however, the slump loss tended to be larger than that of RA-SSC. As shown in Figure 11, the same tendency was seen in the mini slump, the estimation of the slump reduction due to pumping was 70mm as shown in Figure 11 for the concrete mini slump that was pressurized with the drain cock of the pressure bleeding tester closed, so the relational expression shown in Figure 12 was shown, from (the relationship between Figure 10 and Figure 11, the slump after pumping is estimated to be 140mm.

Considering that the elapsed time of RA-ADCW is 30 minutes, pumping causes a slump reduction of 40mm, but it is almost the same as that of RA-SSC, and it seems that there is no problem in construction. Since RA-SSC uses recycled coarse aggregate in a dry state, it can be estimated that there is almost no slump reduction due to pumping. [13-16]

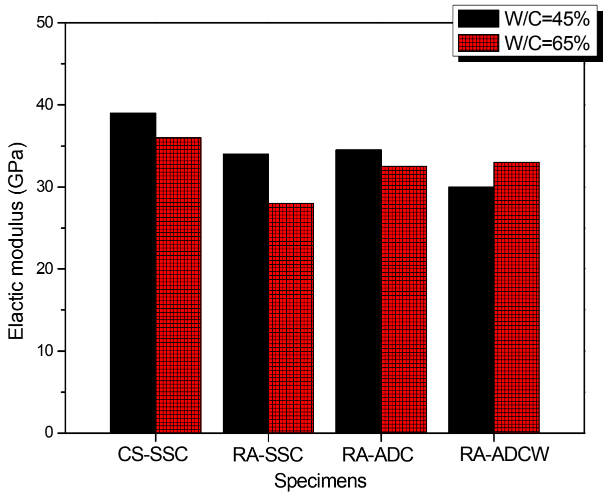

Figure 8. *Results of elastic modulus test.*

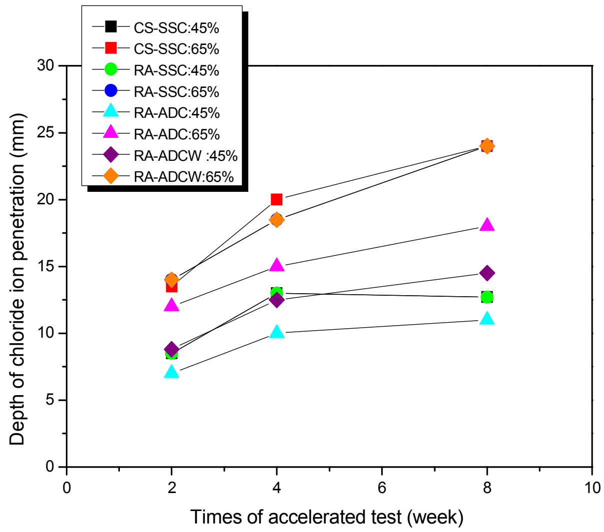

Figure 9. *Depth of chloride ion penetration.*

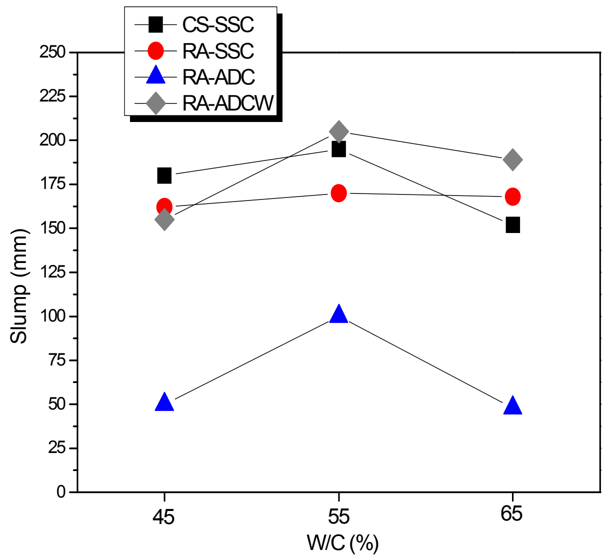

Figure 10. *Relationship between elapsed time and slump.*

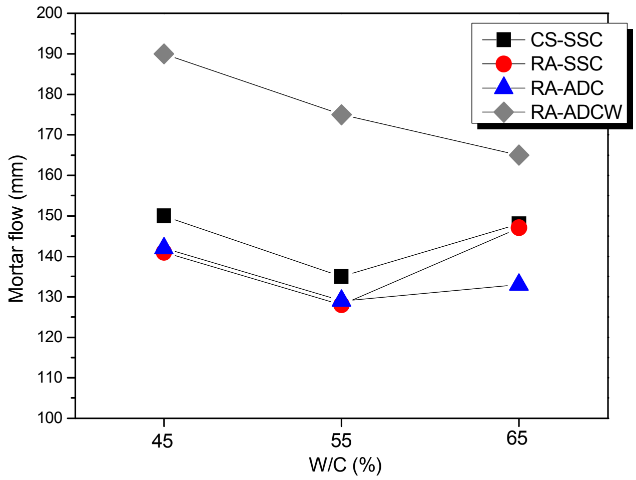

Figure 11. *Relationship between elapsed time and mini slump.*

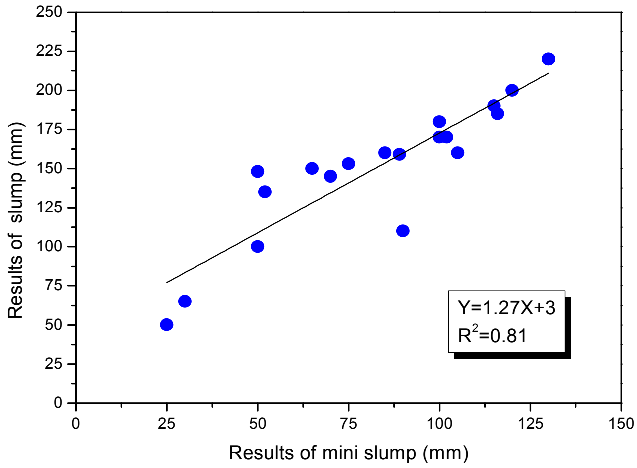

Figure 12. *Relationship between mini slump and slump.*

4. Conclusions

When the mortar is brought into the site and the recycled coarse aggregate in an air-dried state is put in the site, if the amount of water corresponding to the effective water absorption rate of the regenerated coarse aggregate is corrected at the mortar manufacturing stage, the compressive strength and tensile strength, the static elastic modulus and the chloride ion penetration depth were about the same as when the recycled coarse aggregate in the surface dry state was used. In addition, it is considered that the same degree of fluidity as when the recycled coarse aggregate in the surface dry state is used even after pumping.

References

[1] Sawamoto, T., et al. (2009), "A Study on the Use of Concrete Aggregates in Environmentally Friendly Waste Materials", *Annual Report of Japan Construction Association*, 40 (1), 23~30.

[2] Yoda, K., et al. (2001), "A Study on the Practicality of Recycled Concrete Manufactured by Stage Mixing", *J. of the Japanese Society of Architecture,* 54 (1), 1~7.

[3] Kim, N. W., et al. (2008), “A Study on the Property Estimation of Recycled Coarse Aggregate and Characteristic of Recycled Aggregate Concrete Using the Surface Coated Treatment Method”, *J. of Korea Society of Civil Engineers*, 28 (4A), 603~609.

[4] Park, R. S., and Bae, J. S., (2007), “An Experimental Research on the Quality Improvement of Recycled Aggregates Using Surface Treatment Method”, *J. of Korea Society of Civil Engineers*, 27 (3A), 421~426.

[5] Rashwan, M. S., and Abourizk, S., (1997), “The Properties of Recycled Concrete”, *Concrete International, ACI*, 19 (7), 58-60.

[6] Yang, I. H., and Jeong, J. Y., (2016), “Effect of Recycled coarse Aggregate on compressive strength and mechanical properties of concrete”, *J. of Korea Concrete Institute*, 28 (1), 105~113.

[7] Lee, M. K., et al. (2005), “Strength of recycled concrete with furnace slag cement under steam curing condition”, *J. of Korea Concrete Institute*, 17 (4), 613~620.

[8] Sim, J. S., et al. (2006), “Characterization of Compressive Strength and Elastic Modulus of Recycled Aggregate Concrete with Respect to Replacement Ratios”, *J. of Korea Society of Civil Engineers*, 26 (1A), 213~218.

[9] Salem, R. M., et al. (2003), “Resistance to Freezing and Thawing of Recycled Aggregate Concrete”, *ACI Materials Journal*, 100 (3), 216-221.

[10] Sim, J. S., et al. (2005), “Fundamental performance evaluation of recycled aggregate concrete with varying amount of fly ash and recycled fine aggregate”, *J. of Korea Concrete Institute*, 17 (5), 793~801

[11] Sriravindrarajah, R., et al. (2012), “Mix Design for Previous Recycled Aggregate Concrete”, *International J. of Concrete Structures and Materials*, 6 (4), 239~246.

[12] Mas, B., et al. (2012), “Influence of the Amount of Mixed Recycled Aggregates on Properties Concrete for Non-Structural Use”, *Construction and Building Materials*, 27 (1), 612~622.

[13] Padmini, A. K., et al. (2009), “Influence of Parent Concrete on the Properties of Recycled Aggregate Concrete”, *Construction and Building Materials*, 23 (2), 829~836.

[14] Kou, S., et al. (2011), “Comparisons of Natural and Recycled Aggregate Concretes prepared with the Addition of Different Mineral Admixtures”, *Cement and Concrete Composites*, 33 (8), 788~795.

[15] Corinaldesi, V., et al. (2009), “Influence of Mineral Additions on the Performance of 100% Recycled Aggregate Concrete”, *Construction and Building Materials*, 23 (8), 2869~2879.

[16] Cartuxo, F., et al. (2015), “Rheological Behavior of Concrete made with Fine Recycled Concrete Aggregate – Influence of the Superplasticizer”, *Construction and Building Materials*, 89 (1), 36~47.