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RECENT ADVANCES IN RECYCLE OF CONCRETE

İlker Bekir TOPÇU [1], Tayfun Uygunoğlu [2], Uğur Can ARPALIK [1]

[1] *Eskişehir Osmangazi University, Faculty of Engineering and Architecture, Civil Engineering Department, Eskişehir 26480, Turkey,*
E-mail: ilkerbt@ogu.edu.tr, ugurcanarpalk@gmail.com
[2] *Afyon Kocatepe University, Engineering Faculty, Civil Engineering Department, Afyonkarahisar, 03200, Turkey,*
**E-mail: uygunoglu@aku.edu.tr ; Corresponding Author.*

Abstract

Rapidly increasing concrete production in the world also increases environmental problems as waste concrete and this makes concrete recycling a more important issue. Although there is not much big change in its use as fillers, studies on recycling aggregates have increased in recent years and more efficient results have been started. At the same time, it has become possible to recycle fresh concrete with washing technology. In this study, recent studies were examined on recycling in concrete technology. The studies examined in this paper were mainly focused on the water absorption of the recycling aggregate and to reduce the mixing water. There are some methods on reducing the water absorption of aggregates such as polymer-based treatments, mechanical processes, pre-absorbing and superplasticizer additive methods. In the polymer-based treatment method, the recycling aggregates are immersed in silicon-based additives and surrounded by a thin film layer. As a result, although the water absorption and abrasion resistance positive results on the possibility of negative results in terms of other researches will be deepened. In the mechanical treatment process, recycling aggregates were processed in pan type concrete mixing mixer with stripping blades. It was observed that 10 minutes of treatment yielded the best water absorption rate at different times. The use of superplasticizer additive was observed in the study using 0.10%, 0.15, 0.20, 0.25 and 0.30. As a result, the increase in the amount of water decreases strength of concrete.

Keywords: Waste concrete, recycled concrete aggregate, water absorption.

1. Introduction

The construction sector, which is one of the main sectors of our country, is progressing day by day and there is a significant increase in the number of houses every day. However, when the incident is examined by the other side, the poured concretes and other construction wastes are becoming an increasing waste (Topçu and Şengel, 2004; Durmuş et al., 2009). This subject has started to be examined thoroughly in our country and in 2004, Regulation on Control of Excavation Soil, Construction and Demolition Wastes has entered into force. With the regulation, it has become legal to collect, accumulate, and properly recycle the construction waste. Studies on recycling already existing before the regulation has gained speed with the regulation (Demirel and Şimşek, 2015; Demirel et al., 2015; Sefidehkhan and Şimşek, 2018). Recycling of concrete, generally used as filling material and as a production of concrete from the recycling aggregate. The waste concrete leading to the recycling has been passed through the crushers. It is stated that recycled concrete can be produced with optimum 30% recycled aggregate (Kılınç, 2012).

In general, recycled aggregate concrete has lower strength than plain concrete. It is thought that the reason for the low resistance is due to the physical structure of the recycling aggregate. Cement residues remaining on the recycling aggregate and the rough structure increase the water absorption rate (Demirel and Şimşek, 2015). This problem, which is one of the biggest problems of the recycling aggregate, causes the use of water added to the concrete mixture outside the purpose. Due to the amount of water calculated on the recycle aggregate when the mixture is made, the actual consistency and the amount of water spent for hydration will decrease. Therefore, the

concrete mix water should be used more than the calculated amount. This will increase the water/cement ratio in the mixture and cause a decrease in strength. This problem can be prevented by increasing the amount of cement here but because of the cost of such a method is not very convenient. In this article, three way of the reduction of water absorption in recycling aggregates have been informed about selected studies. These are polymer-based processes, mechanical processes and using of super plasticizer in recycling concrete.

The studies on the improvement of the water absorption rate of the recycling aggregate have been carried out so far and it has been revealed by the researchers that it is one of the main problems of the recycled aggregate concrete. Topçu et al. (2004) stated that it is difficult to use in the production of new concrete due to the high-water absorption rate of the waste concrete aggregates and emphasized the need to know the water absorption capacity and the approximate resistance of the waste concrete aggregate especially when the waste concrete aggregate will be used to produce high strength concrete. Furthermore, it has been determined that the use of waste concrete aggregate increases the workability problem in concrete production, especially if more than 50% waste concrete aggregate is used, the process-ability problem increases. Durmuş et al. (2009) found the average water absorption rate (%) to be 5,486% in recycled aggregate concrete; however, it was about 0.413% in normal crushed aggregate concrete. In the same study, they emphasized that the amount of water absorption is caused by the roughness of the aggregate and the cement residues on the surface. As strength, they stated that the recycle aggregate substitution in the structural concretes was the best 30% and the non-structural concretes 50%. Demirel et al. (2015) examined the size of the recycling aggregates as 0/4 mm and 4/22.4 mm in 2 groups. They found the water absorption rates 13.9% and 7.9% for the material 0/4 and 4/22.4mm, respectively. For crushed stone, these values were 1% and 4.6%. In the same study, the compressive strength test was performed, and the highest compressive strength was obtained by replacing 30% of the recycled aggregates at 36 MPa, while the lowest compressive strength was obtained at 50% of the replaced concretes. Sefidehkhan et al. (2018) indicated that the water absorption rate of the aggregate is much higher than that of the crushed aggregate in the same size. He said that it was thought that the higher water absorption of recycled aggregate is due to the more roughness of the surface of the recycled aggregate than crushed stone. It was also reported that the displacement rate increases because of the higher water absorption rate than the crushed limestone aggregate. The compressive strength test indicated that the strength decreased as the ratio of recycle aggregate increased. The highest compressive strength values were obtained on samples with 40% and 60% recycle aggregates at 90 days. Demirel et al. (2014) stated that the recycling aggregate increased the mixing water in the fresh concrete and the water absorption rate is quite high compared to the literature and the reason for this is caused by cement grains adhering to the aggregate grains. According to TSE and CEB, the elasticity module of the recycled aggregate concrete is very close to the plain concrete results. In the same study, it was stated that the wear loss of the coarse recycling aggregate was higher than the crushed stone aggregate wear loss.

Yehia et al. (2015) observed that the physical and chemical properties of the recycling aggregate contained acceptable variations according to normal but drew attention to the high-water absorption value. They argued that it is possible to produce ideal concrete with different rates of substitution rates, but they also emphasized that it is important to monitor long-term performance and volume change to ensure better evaluation of the concrete produced by the recycling aggregate. Dimiriou et al. (2018) emphasized that the main difference between the recycling aggregate and the normal aggregate is the adherent cement residues on the recycling aggregate and tried to improve this effect by adding mineral admixtures. Because of their studies, they reduced the amount of cement adhering to 24% by 9%. They achieved the appropriate level of concrete production with different substitution rates. They also emphasized that the cost issue.

In this study, the recent developments on recycling aggregate concrete production were investigated. The literature studies were studied for coating of recycled aggregates to preventing the water absorption. Four type methods were used in the studies as i) superplasticizer admixture, ii) Treatment on surface of aggregates, iii) polymer absorbing of aggregates and iv) pre-saturation of aggregates. All these methods were discussed below.

2.1. Super Fluiding Additives in Recycling Waste Concrete

In the reference (Kılıç, 2014) recyclable aggregate, normal aggregate, CEM I 42.5 Portland cement, Sikament FF superplasticizer, high water-reducing additive and natural spring water were used. The recycling aggregate was obtained from 4/8 mm and 8/16 mm crusher and then mixed with normal aggregate. Concrete samples were prepared with these materials and named as follows:

-NRC: Control concrete samples obtained by mixing natural and waste concrete aggregate

-SAC: Super plasticizer (%0.10, 0.15, 0.20, 0.25, 0.30%) added to NRC

In 15 cm cubic shape concretes with cement content of 300 kg/m^3 samples were produced. The water/cement ratio was determined as 0.48 by taking into consideration that the contribution of superplasticizer. The concrete properties are summarized in Table 1. Slump values (SV) of recycled aggregate containing concrete increased by using of superplasticizer (Fig. 1). The SV was increased in ratio of 22% when compared to plain concrete by using superplasticizer in ratio of up to 0.25%. Moreover, the compressive strength of the samples was increased in ratio of 23-36% for 7 days and in ratio of 22-49% for 28 days by enhancement of workability of recycled aggregate concrete.

Table 1. Test results of unit volume weight, slump and compressive strength

Concrete Type	Unit Volume Weight (gr/cm^3)	Slump Value (mm)	Compression Value (MPa)	
			7 Days	28 Days
NRC	2,41	45	31,38	37,36
SAC1	2,41	45	41,62	51,94
SAC2	2,43	50	42,59	55,74
SAC3	2,44	50	40,09	48,02
SAC4	2,45	55	39,78	47,22
SAC5	2,46	55	38,62	45,73

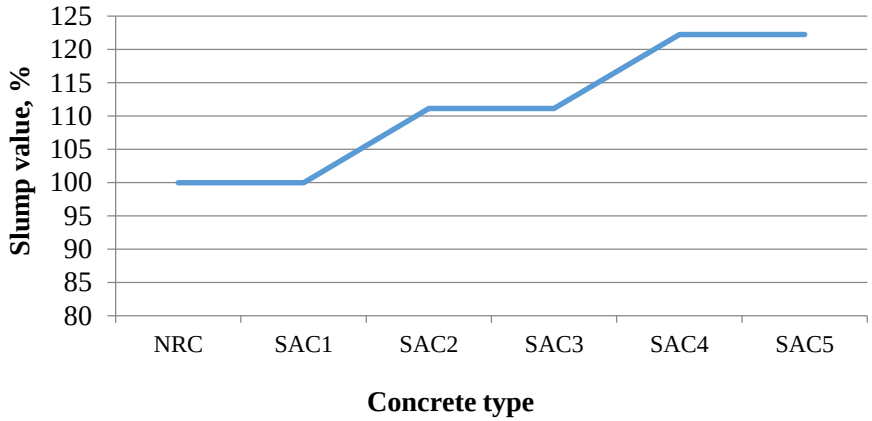


Figure 1. Slump Values (mm)

2.2. Improving Water Absorption of Concrete Recycling Aggregates

In reference (Korkmaz and Karaali, 2017) the recycling aggregate obtained from the debris was subjected to 4 different treatments and their water absorption properties were examined. These processes include powder coating, high temperature firing, acid retention and mechanical treatment. There has been no effect on the water absorption feature in the processes other than mechanical operation, or it has not been fully achieved. Mechanical treatment was performed in pan type concrete mixer with stripping knives at different times to samples of recycling aggregates remaining between 16-32 mm sieves. The water absorption values of the recycling aggregates are as follows.

As can be seen from the table, the best water absorption result was calculated as 3.47% for 10 minutes. To investigate the effect of recycled aggregates on the concrete properties, 3 different mixtures were prepared. The first mixture is for control purposes only with limestone, the second mixture is treated with aggregates for the best water absorption result for 10 minutes and the last mixture is prepared with untreated recycling aggregates.

- In the recycled aggregate mixtures, limestone was used as fine aggregate.
-Water / cement ratio was determined as 0.6 in 3 samples.
-The slump value was kept constant (16 ± 2) cm.

As a result, the compressive strength and water absorption values of the concrete poured by mechanically treated aggregates were better than the poured concrete with untreated recycling aggregates.

Table 2. Water absorption values of mechanically treated aggregates

Mechanical Processing Time (min.)	2	5	10
Water Absorption (%)	5,60	5,30	3,47

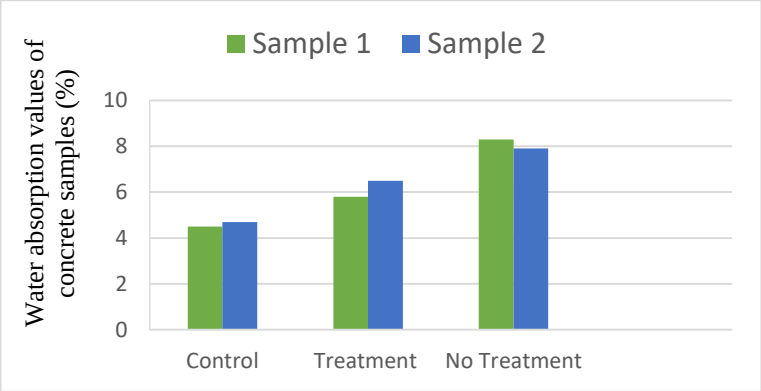


Figure 2. Water absorption values of concrete samples (%)

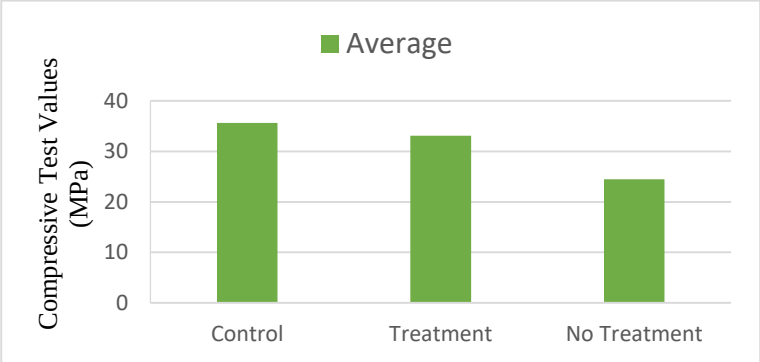


Figure 3. Compressive test values (MPa)

In another study (Katz, 2004), two methods were proposed to improve the quality of the recycled aggregates: i) impregnation with a solution of silica fume that is intended to add a thin layer of silica fume particles over the surface of the recycled aggregate; ii) ultrasonic cleaning of the recycled aggregate in order to remove the loose particles and improve the bond between the new cement paste and the recycled aggregate. The surface texture of aggregates is presented in Fig. 4.

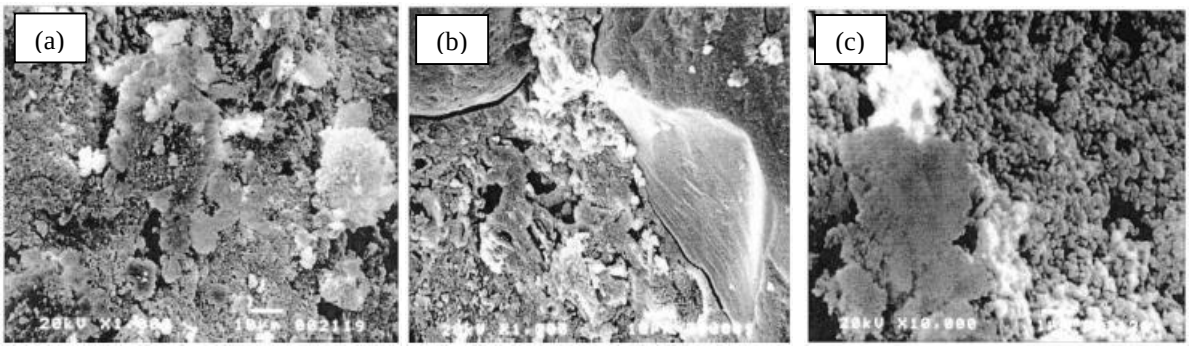


Figure 4. Surface treatment on recycled aggregates (a: non-treated; b: ultrasonic cleaning; c: silica-fume coated)

The silica fume is expected to react with calcium hydroxide from the hydration of the cement to form a dense layer covering the surface of the aggregate, which, in turn, will increase its strength. In ultrasonic cleaning, the aggregate was immersed in the US bath with a large amount of water and was treated for 10 min, after which the water was replaced with clean water and the aggregate was cleaned for an additional 10 min. The SF treatment seems to improve significantly the strength of the new R-aggregate concrete at both 7 and 28 days. The improvement at age 7 days ranged from 23 to 33%, and at 28 days reached a lesser extent of 13–16%.

2.3. Improvement of Recycled Concrete Aggregate Properties by Polymer Treatments

In reference (Spaeth and Djerbi, 2013), the purpose of the recycling aggregates to become close to natural aggregates was investigated by impregnating the recycling aggregates by immersing the polymers in solutions. To get rid of the problem of non-homogeneity in the supply of recycling aggregates, the control concrete was poured and then this concrete was broken, and the recycling aggregate was obtained. In the control concrete mixture, limestone aggregate, CEM I 52.5 was used as binder, and the water to cement ratio was kept as 0.49. The used hydrophobic polymers are silicone-based; alkylalkoxysilanes, poly diorganosiloxanes and polymer solutions at different concentrations. The study examines the effect of this film layer on the water absorption of the aggregate.

Firstly, 6 kinds of polymer mixtures (Table 3) were prepared at maximum and minimum concentrations and water absorption tests were applied to recycling aggregates without reference to any procedure, followed by drying and polymer impregnation processes. Polymer impregnation processes are of 2 types. The first is the combination with simple operation. The aggregate samples were each impregnated by each polymer solution P1 to P6 for 5 min each, and then stored at 20% C at 50% relative humidity at room temperature. Finally, the oven was ventilated at 50 ± 5 ° C for 24 hours until the mass difference was 0.1%.

The other process is called a double combination. In this process, the aggregate samples are absorbed into the first mixture for 3 minutes and then absorbed in another mixture for 5 minutes. And then it is maintained at 50% relative humidity at 20º C room temperature and then ventilated in the oven at 50 ± 5 ° C for 24 hours until the mass difference is 0.1%. The aggregates were soaked in water for 48 hours to measure water absorption values. For each polymer mixture, 3 types of sample samples were impregnated, and water absorption values were measured according to their concentration.

Table 3. Set of polymer-based treatments

Treatment acronyms	Names of product	Compositions	Concentration gradient	
			C_{min} (%)	C_{max} (%)
P1	Sodium silicate solution	Sodium silicate	7	30
P2	BS 2 Wacker siloxane/silane emulsion	Octyl/methyl methoxy co-oligomeric siloxane/silane	5	30
P3	IE 4 Dow Corning silane emulsion	Octyl triethoxy silane	5	40
P4	BS 3 Wacker siloxane/silane emulsion	Siloxane/propyl trimethoxy silane	5	50
P5	BS 4 Wacker siloxane/silane emulsion	Siloxane/propyl triethoxy silane	5	60
P6	BS 5 Wacker siloxane/silane emulsion	Siloxane/alkylalkoxysilane	5	40

All the polymer coated recycled aggregates (RA) have lower water absorption values than reference aggregate (Fig. 5 and Fig. 6). When these polymer solutions were applied on recycled aggregate, the polymeric particles from polymer solution are present enough to spread and diffuse into recycled aggregates pore network. After that, polymerization occurred, polymeric film deposit is developed and transform into hydrophobic resinous which permit to decrease water uptake.

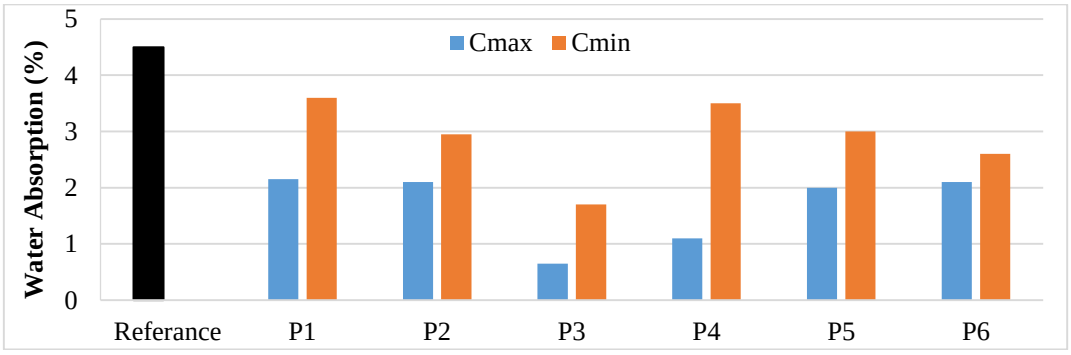


Figure 5. Water absorption values of aggregates soaked in mixtures at maximum and minimum concentrations

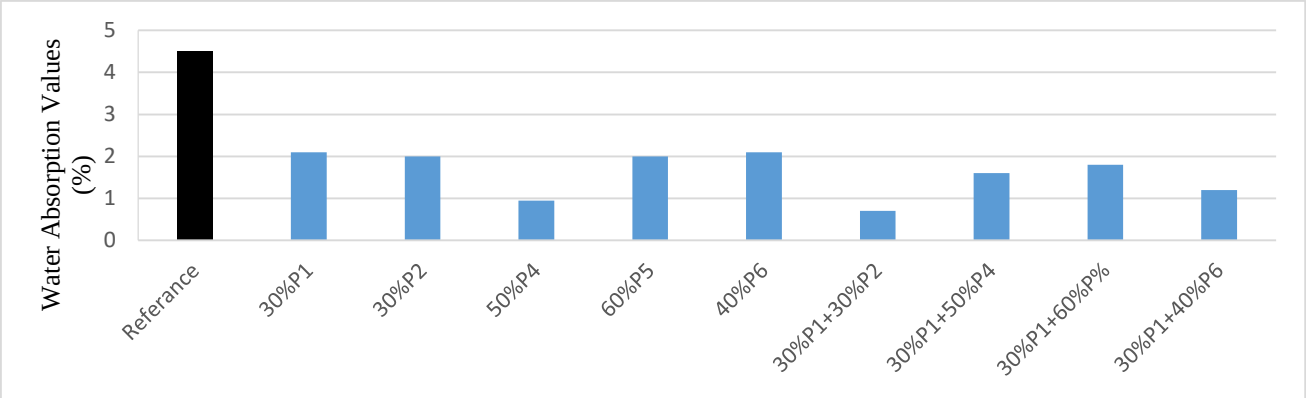


Figure 6. Best water absorption values resulting from different combinations and different combinations

2.4. Improvement of Recycled Concrete Aggregate Properties by Pre-saturation

In reference (González, 2014), authors investigated the solve the water absorption problem of recycled aggregate by technique of pre-saturation can the water absorption of the aggregates was tested to determine the necessary period of soaking to bring the recycled aggregates into a state of suitable humidity for their incorporation into the mixture. Because, recycled aggregates absorb the water during mixing of concrete. For example, a 3 min interval of soaking, in which the recycled aggregate reached up to 47% of complete saturation, and 5 min interval of soaking, with a 50% of complete saturation (Figure 7).

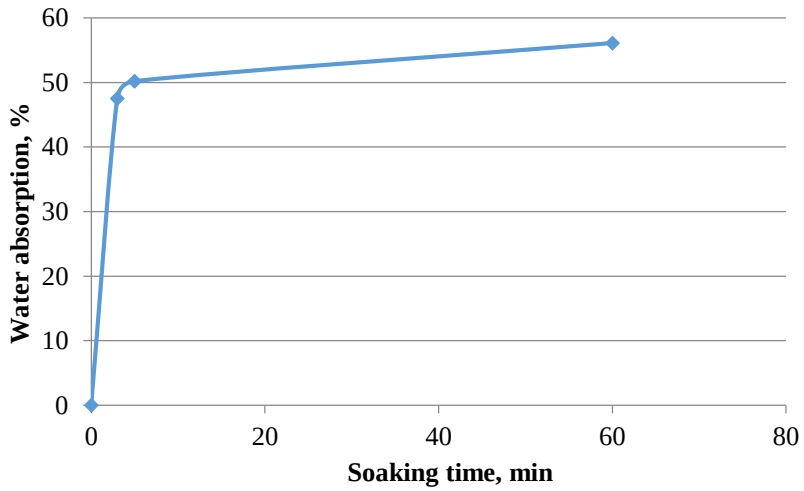


Figure 7. Water absorption of recycled aggregates depending on soaking time

Figure 8 shows that the pre-saturation of the recycled aggregate caused an enhancement in the workability of recycled concrete, with increasing slump values as the soaking interval grew. The improvement of consistency is due to the increase of free water in the concrete mixture when saturated recycled aggregates with dry surface were used, up to 100%-substitution of natural aggregates.

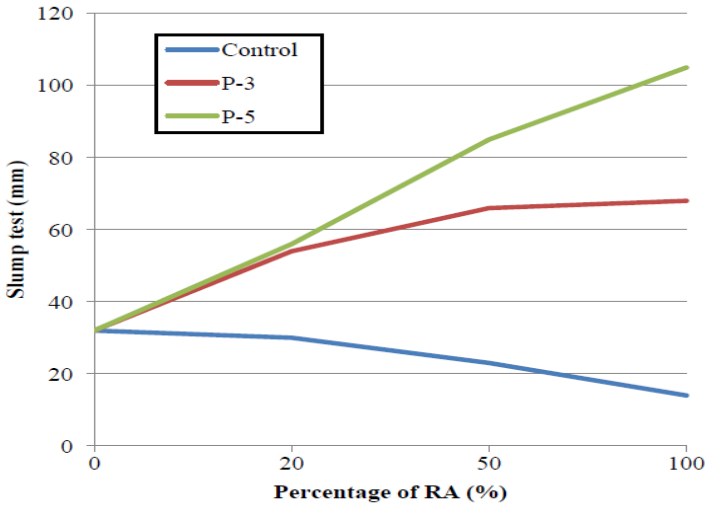


Figure 8. Slump of concrete with pre-saturated recycled aggregate (P-3: 3 min soaking; P-5: 5 min soaking)

3. Conclusion

In this study, recent studies on recycled aggregate concrete are summarized. It is evident in the studies that the water absorption properties of recycling aggregates can be improved by trying different methods. In accordance with the regulations in the studies or close, almost the desired results were taken. The desired pressure values are provided in concrete mixed with aggregates with improved water absorption values. This means that the recycling aggregates can be used for concrete production after being subjected to suitable processes. After these results, we need to work more on concrete recycling to protect our natural resources and to prevent environmental pollution.

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