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Properties of Recycled Aggregates and Their Effects on Concrete

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Abstract- The increase in the cost of extracting natural aggregates, the destruction of nature through the consumption of natural resources, and the increase in construction waste have led to an increase in studies being conducted today on the use of "recycled concrete aggregates" for concrete production. Concrete with recycled aggregates is an alternative to the use of natural aggregates in concrete. In this study, a database of 27 items was created to study the parameters that affect concrete produced using recycled concrete aggregates in different proportions. Firstly, physical properties of recycled concrete aggregates such as abrasion value, density, water absorption capacity were investigated in the database. In the second stage, the factors affecting the slump, unit volume weight and strength of concretes produced with RCA were evaluated. As a result, it was found that the increase in the density of the recycled aggregate resulted in a decrease in abrasion values, while the unit volume weight and strength of the concrete increased. It was also found that the recycled aggregates had no effect on the slump of the concrete, and that the unit volume weight and strength of the concrete decreased as the amount of aggregate used increased.

Keywords Concrete Waste, Recycled Concrete Aggregates, Compressive Strength

1. Introduction

Concrete is the most widely used construction material worldwide, consisting of 60–80% by volume of natural aggregates. The increasing demand for concrete structures and the development of infrastructure are putting a strain on the limited available non-renewable resources, so it is crucial to reduce environmental impact and conserve non-renewable resources by developing sustainable sources such as recycled aggregates in the construction industry. Replacing natural aggregates with recycled aggregates in concrete products not only offers a sustainable solution to these problems but can also reduce construction costs [1].

Recycled aggregates are produced in recycling plants in the same way as natural aggregates. The process usually involves two stages: Crushing (primarily with jaw crushers and secondarily with impact crushers), removal of impurities, and sieving. After the first crushing stage, large pieces of steel are separated by electromagnets. Impurities such as dirt, gypsum, plaster and other construction waste must be carefully removed by water cleaning or air screening. Recycled aggregates can also be processed in mobile recycling plants. These are typically used on demolition sites with large quantities of homogeneous waste to be reused on site (e.g., reconstruction of roads and highways, large industrial facilities). Processing in mobile recycling plants is limited to single stage crushing, magnetic separation and sieving [2].

Concrete with recycled aggregate is an alternative to using natural aggregate in concrete. Recycled aggregate is an aggregate obtained by recycling clean concrete waste and must contain a very low percentage of other construction waste. For example, the British Standard defines recycled concrete aggregate as recycled aggregate with a maximum brick/fine material content of 5%, a maximum lightweight material/asphalt content of 0.5%, and a maximum other contaminant content of 1%. Replacement of natural aggregates with recycled concrete aggregates can be complete (100%) or partial [3]. However, due to the high-water demand of fine materials smaller than 150 µm, the use of fine recycled concrete aggregates below 2 mm is rare. The high water absorption and high cohesion of the fine recycled concrete aggregates also make the quality control of the concrete very difficult. Therefore, some standards and specifications prohibit the use of fine recycled concrete aggregates for structural purposes [4].

With the rapid economic development and urbanization of society, the construction industry worldwide has entered a golden age, and as a result, the generation of construction and demolition waste has increased tremendously [5]. This increase has forced practitioners to look for alternatives that can minimize waste transportation and disposal costs. On the other hand, the scarcity of natural resources for fill material needed for geotechnical structures such as railroad and highway embankments, conventional soil retaining walls, and reinforced soil retaining walls has become a serious environmental problem in many places. Therefore, especially in densely populated areas, the reuse of concrete demolition as a construction material is considered important both economically and environmentally [6]. The reuse rates of concrete demolition reach 5% in China, 17% in the United Kingdom, 4.5% in Brazil, 90% in Japan, 75% in the Netherlands, and 80% in many European countries [7, 8]. Since 2012, at least 10 million tons of construction waste have been generated annually as a result of the urban transformation program. In Turkey, the average annual amount of construction and demolition waste collected only by IBB has been 57.4 million tons since 2010 (see Fig. 1). These wastes have been dumped in landfills, causing many landfills to be 100% full, damaging the environment and opening new landfills, so recycling them is the most logical and practical way to eliminate this problem [9].

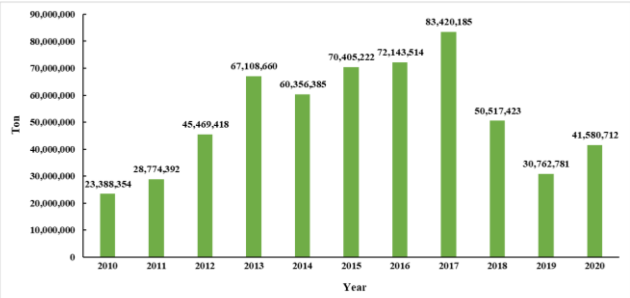

Fig. 1. Annual Amount of Excavation Waste Collected by IBB

According to the data presented in Fig. 1, it is seen that our country has a great potential for the supply of recycled aggregates from construction and demolition waste. It is known that aggregates obtained from recycling are environmentally friendly and have many different uses such as ready-mixed concrete production, hot asphalt production, filter material, filling material, foundations and sub-foundations of highways and railways. The most important problem in the use of recycling materials is that construction and demolition wastes have different mechanical and chemical properties due to their age and the materials they are made of. Therefore, these wastes should be characterized physically, mechanically, hydraulically and chemically.

In this study, a database of recycled aggregates with various properties was created to investigate recycled aggregates and the parameters affecting them. Various factors in the database were correlated with the strength and concrete properties obtained.

2. Material and Metod

In this study, the physical properties of Recycled Concrete Aggregates (RCA) were first evaluated. For this purpose, the density, abrasion, and water absorption values of RCAs were analyzed using data obtained from 27 articles. Later in the study, the fresh slump values of concretes produced with RCA and the effects of RCA percentage and binder dosage on the strength values were analyzed. The strength values are for 28-day specimens. A summary of the data set used is given in Table 1.

3. Findings and Discussion

3.1. Physical Properties of RCAs

3.1.1. Density

The density values of coarse and fine aggregates obtained from the articles in the database are presented in Fig.s 2 and 3, respectively. For coarse aggregates, these values are between 2.2 and 2.5 g/cm^3, with an average value of 2.41 g/cm^3. For fine aggregates, these values are between 2.13 and 2.69 g/cm^3, with an average value of 2.48 g/cm^3. In general, the density for both aggregates is above 2.4 g/cm^3. Depending on the density, natural aggregates are divided into three as seen in Table 2. Accordingly, recycled materials can be called "aggregates".

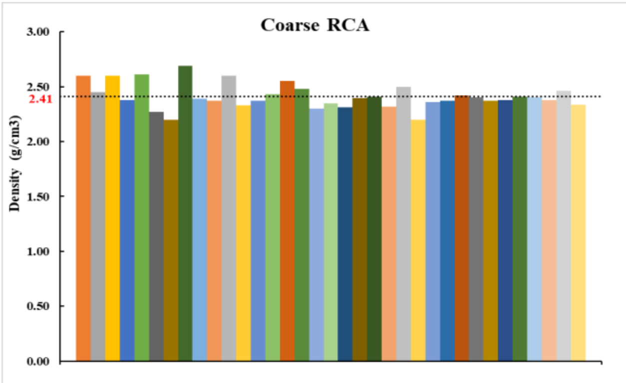

Fig. 2. Coarse RCA Density Values for All Database

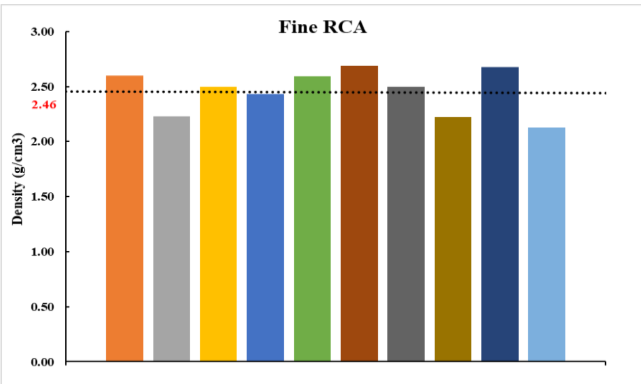

Fig. 3. Fine RCA Density Values for All Database

Table 1. Studies that constitute the database

No	References	Waste Resource	RCA (%)	Abrasion Value for RCA (%)	Water Absorption for RCA(%)	Cement Dosage (kg/m^3)	Slump Value (cm)
1	Domingo et al. (2009) [10]	Recycled Aggregates Coming from Construction Waste and Concrete Work Demolitions.	0-100	40.22	5.19	380	5-19
2	Köken et al. (2008) [11]	IMO Konya Branch Test Specimens	0-100	31.72	4.62	320	7.5-9
3	Demirel et al. (2017) [12]	Class C30 7-Day Waste Concrete	0-100	28.4	6.7	320	8-10
4	Polat et al. (2014) [13]	Bingöl Province 7 (Turkey) Waste Curb Stones	0-50	-	0.85-2.1	400	6.2-8.2
5	Demirel et al. (2014) [14]	C30 Class 28 Day Waste Concrete	0-100	38.4	6.2-13.7	320-400	-
6	Sefidehkhan et al. (2018) [15]	C20 Class Waste Concrete	0-100	40.56	4.6-4.8	314	5.2-8.1
7	Goksu et al. (2018) [16]	ITU Structural and Earthquake Engineering Laboratory Structural Test Specimens	0-27	36	3.5-2.7	300	-
8	Kılıç et al. (2007) [17]	Urban Transformation in Isparta Province	32.23	-	6.26	258-300	4.5-6.5
9	Durmuş et al. (2009) [18]	Waste Concrete Produced in Different Grades	100	35.63	5.48	101-138	-
10	Dilbas et al. (2015) [19]	Istanbul Province Sütlüce Neighborhood Urban Transformation	0-100	-	3.5	350	17-19
11	Demirel et al. (2015) [20]	Class C35 28-Day Waste Concrete	0-100	35.7	13.9-7.9	368-460	8-10
12	Tosun (2014) [21]	ISTAC Demolition Waste	0-60	38.04	10.4-6.02-7.8	297.5	17-23
13	Gaurav et al. (2020) [22]	Laboratory Test Samples	0-100	21.2	5.7	360-450	8-9.5
14	Sargam et al. (2019) [23]	Concrete Sidewalk, Minnesota	60	-	6.17-8.13	349	3.81-5.08
15	Chowdhury et al. (2020) [24]	Demolition waste from a 45-year-old building in Taiyuan city	0-56	14.28	4.7	283-379	17-20
16	Assaad et al. (2019) [25]	RCA Obtained from High Strength (62 MPa) Concrete	54	34.6-42.4	5.63-6.13	320-440	16-18.5
17	Poongodi et al. (2019) [26]	Local debris source unknown, Warangal/India	0-50	-	3.12	400	3-16
18	Mohammed et al. (2020) [27]	Lab. waste (25-30 MPa) Anbar University, Iraq	0-72.38	-	6.53	450	-
19	Sagoe et al. (2001) [28]	Commercially graded unwashed Coarse RCA	100	23.1	5.6	238-254	7.5-9
20	Kamaruddin et al. (2019) [29]	Source unknown , Malaysia	0-100	-	4.38	400	62-65.5
21	Limbachiya et al. (2000) [30]	Source unknown , UK	0-100	-	4.9	370	-
22	Rao et al. (2010) [31]	15 Years of Unspecified Culvert Ruin, India	0-100	37.1	3.1	401	4.9-5.75
23	González et al. (2008) [32]	Unknown origin, Spain	0-50	39.65	5	325-345	7.3-7.6
24	Li et al. (2009) [33]	Source unknown,China	66	20	4.6	400-500	4-11.5
25	Tangchirapat et al. (2008) [34]	Lab waste cylinder sample 25-40 MPa	0-100	33.08	11.91-2.31	190-380	5-10
26	Gonzalez et al. (2007) [35]	Landfill, Spain	0-50	34	4.59	325-345	-
27	Eguchi et al. (2007) [36]	Lab. waste, Japan	0-100	22.2-28.4	5.69-7.92	300	-

Table 2. Classification of Aggregates According to Density [37]

Class	Limit Value
Light Aggregate	≤ 2.4 g/cm^3
Aggregate	2.4~2.8 g/cm^3
Heavy Aggregate	≥2.8 g/cm^3

3.1.2. Water Absorption

Water absorption capacity is a parameter that shows how much water the aggregates used in concrete remove from the environment at the time of mixing. If this value is large, water correction is required in concrete mix designs; otherwise, serious problems occur in the slump and strength values of concrete. For natural aggregates, this value is in the range of 0.5%–2% [38]. In the analyzed database, water absorption values for coarse and fine aggregates are presented separately in Fig. 4 and Fig. 5. When the data are analyzed, it is seen that the values for coarse aggregates are 0.85%–9.11% with an average value of 5.73%, and the values for fine aggregates are 2.10%–13.90% with an average value of 8.70%. As a result, the water absorption capacity of RCAs is on average 2.86 times higher for coarse aggregates and 4.35 times higher for fine aggregates compared to the upper limit of the water absorption capacity of natural aggregates.

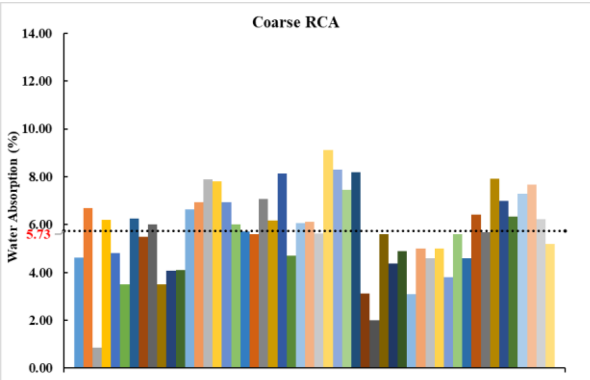

Fig. 4. Coarse Aggregate Water Absorption Capacity for All Database

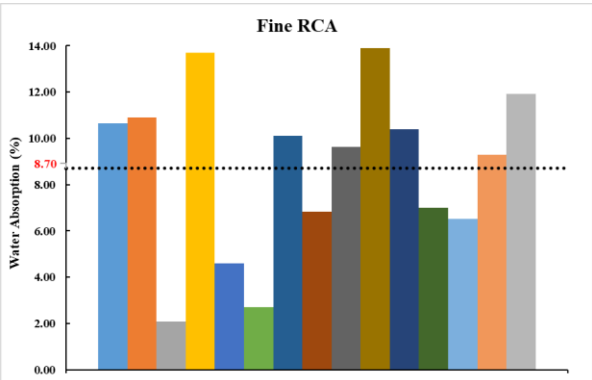

Fig. 5. Fine Aggregate Water Absorption Capacity for All Database

3.1.3. Abrasion

The resistance to abrasion caused by impact and friction in concrete is provided by aggregates, which are the skeleton of the concrete structure. When we look at the literature, it is seen that "Los Angeles Abrasion Test" is performed to measure the abrasion resistance of aggregates. Fig. 6 shows the results of LA tests available in the database. According to these data, the abrasion values of recycled concrete aggregates obtained from various sources range between 20% and 42.4% and average 32.3%.

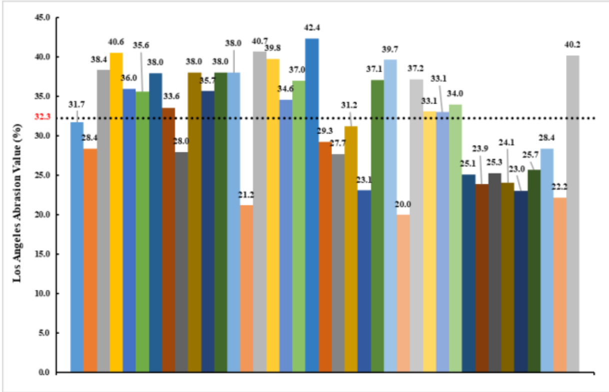

Fig. 7. Los angeles abrasion values of RCAs

The aggregate properties that affect abrasion resistance are density and water absorption capacity. The higher the density value, the higher the abrasion resistance, i.e. the lower the LA value. Fig. 7 shows an increasing trend in LA value with decreasing specific gravity. Fig. 8 shows the relationship between the water absorption capacity of coarse aggregates and LA values; the decrease in water absorption capacity caused an increase in LA values.

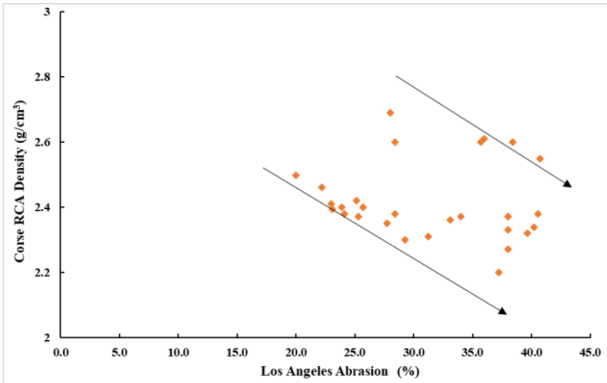

Fig. 7. Relationship between LA Values and Coarse Aggregate Density values

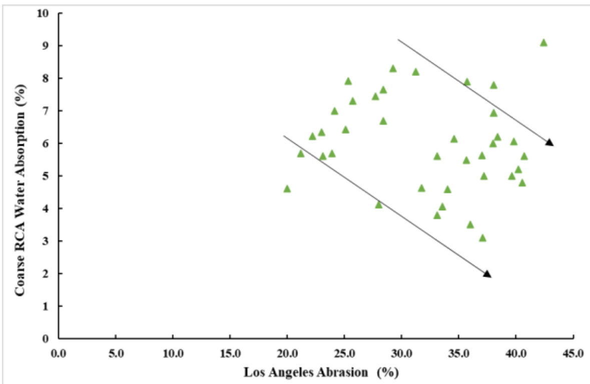

Fig. 8. Relationship between LA Values and Coarse Aggregate Water Absorption Capacity

3.2. Effects of RCAs on the concrete

3.2.1. Slump values

In the design phase, the slump value is determined taking into account the properties of the aggregate depending on the type of application and the place of placement of the concrete, and the increase of this value leads to an increase in the workability of the concrete. The slump value is divided into five classes according to the regulation TS EN 206 [37]. The details of this classification system are presented in Table 3. Fig. 9 shows the slump values obtained from the analyzed articles.

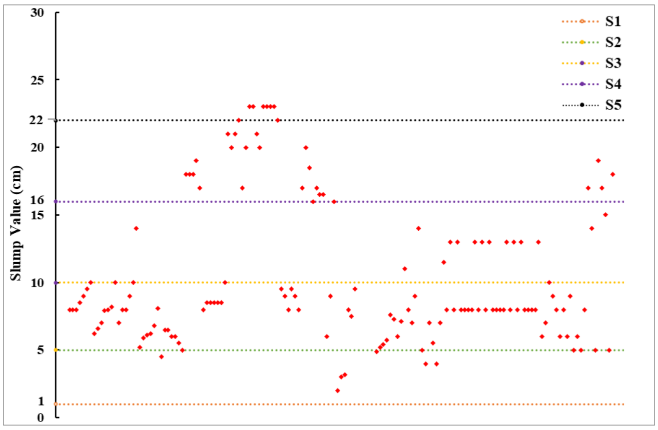

Fig. 9. Slump Values for the Entire Database

Table 3. Slump with Consistency Class [39]

Consistency Class	Slump (cm)
S1	1-4
S2	5-9
S3	10-15
S4	16-21
S5	≥22

The effects of the abrasion value, the water absorption capacity of coarse RCA, the percentage of RCA used, the cement dosage used and the water absorption capacity of fine RCA on the slump value are analyzed in the diagrams A, B, C, D and E in Fig. 10.

When the abrasion values of the RCAs were analyzed, although there was no general trend, the increase in the abrasion value led to an increase in the maximum values reached by the slump values. The increase in the water absorption capacity of coarse RCAs led to an increase in slump values. RCA in different proportions has no effect on slump value, and with different proportions of RCA, the desired slump value can be achieved depending on the design properties of the concrete. The maximum amount of the slump value of each dosage decreased with increasing dosage of cement used in the concrete produced with RCA.

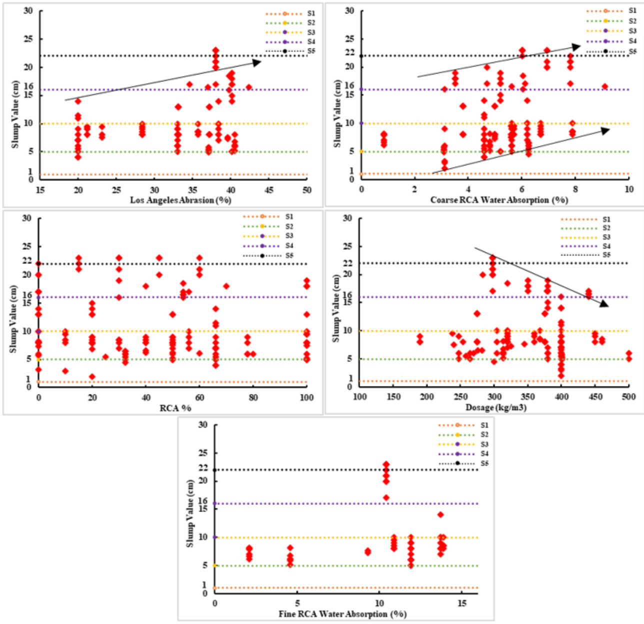

Fig. 10. Factors Affecting the Slump Value

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3.2.2. Unit Volume Weight

The unit volume weight of concrete gives information about the properties of the materials that make up the concrete and the amount of void space in the concrete. If the unit volume weights of the aggregates forming the concrete are high, the unit volume weight of the concrete is also high. On the other hand, the high amount of air in the concrete causes the unit weight to be low. The classification of concrete based on unit volume weight is presented in Table 3. Fig. 11 shows the data unit weight values of concretes produced with RCA. According to Fig. 11, the average unit volume weight of concrete produced with RCA is 2283 kg/m3. According to Table 4, it is within the limit values valid for normal concrete classes.

Table 4. Class of concrete for unit volume weight limit value [39]

Class	Limit Value (kg/m^3)
Heavy	> 2600
Normal	800 <-<2600
Lightweight	<800

The factors that positively and negatively affect the unit volume weight of concrete are analyzed in eight different graphs from A to H in Fig. 12. The increase in the abrasion value of RCAs caused a decrease in the unit weight of concrete up to 40%, but in general, the increase in the abrasion value led to an increase in the upper limits of this value. As expected, the increase in the unit volume weight of fine and coarse RCAs caused an increase in the unit volume weight of concrete. The increase in the water absorption capacity of fine and coarse RCAs led to a decrease in the unit volume weight. The proportional increase in the use of RCA in the concrete mix resulted in a decrease in the unit volume weight of the concrete. The unit volume weight of concrete increased with the increase in cement dosage in concretes produced with RCA. The increase in slump values of fresh concrete led to a decrease in the unit volume weight.

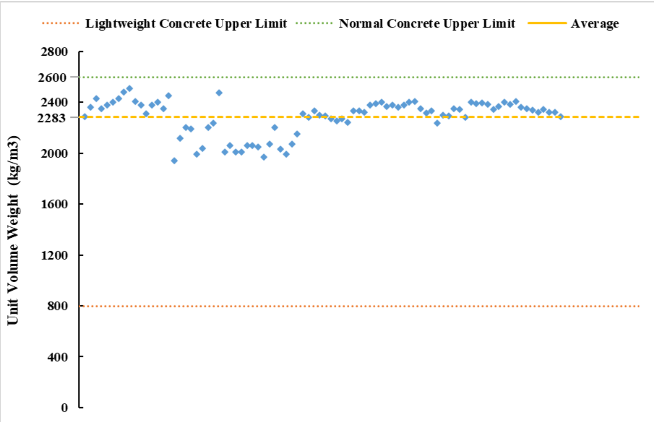

Fig. 11. Unit Volume Weight Values for All Database

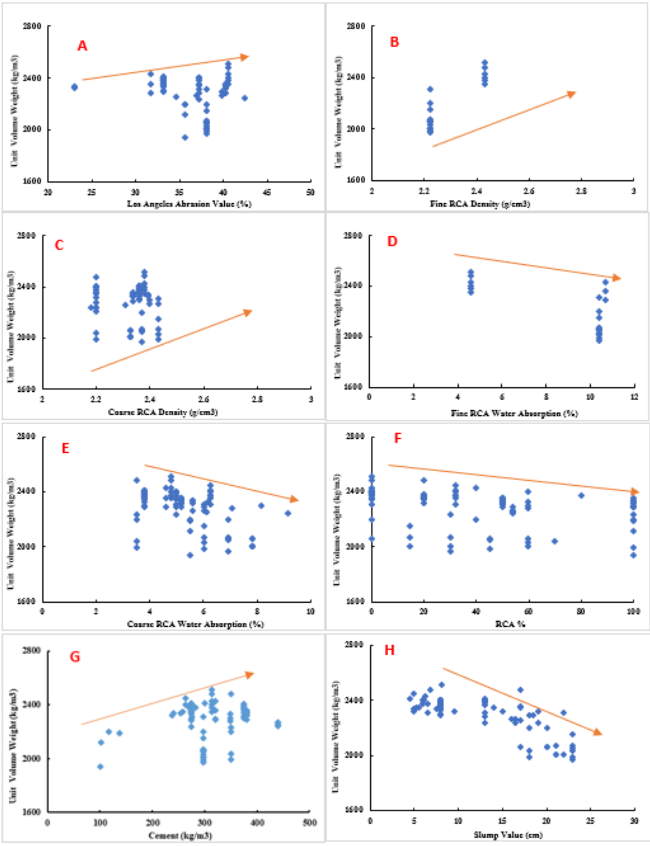

Fig. 12. Factors Affecting the Unit Volume Weight of Concrete

3.2.3. *Compressive Strength*

The factors affecting the 28-day compressive strength values of the RCA-produced concretes in the database are illustrated in Fig. 13 and Fig. 14.

When the strength values are between 20 and 40 MPa, the increase in the abrasion value does not affect the strength value, but the increase in the abrasion value in the lower and upper parts of these values caused an increase in the strength values. The increase in the unit volume weights of fine and coarse RCAs caused an increase in compressive strength values. The increase in the water absorption capacity of fine and coarse RCAs led to a decrease in compressive strength values. As the percentage of RCA increased, strength values decreased. Although there is an increase in compressive strength values in general as the amount of cement used in concretes produced with RCA increases, this increase is not significant in the range of compressive strength values between 20 and 40 MPa. As the unit volume weight of the concrete produced with RCA increased, the compressive strength values increased due to the decrease in the voids in the concrete. The decrease in slump values caused a decrease in strength values.

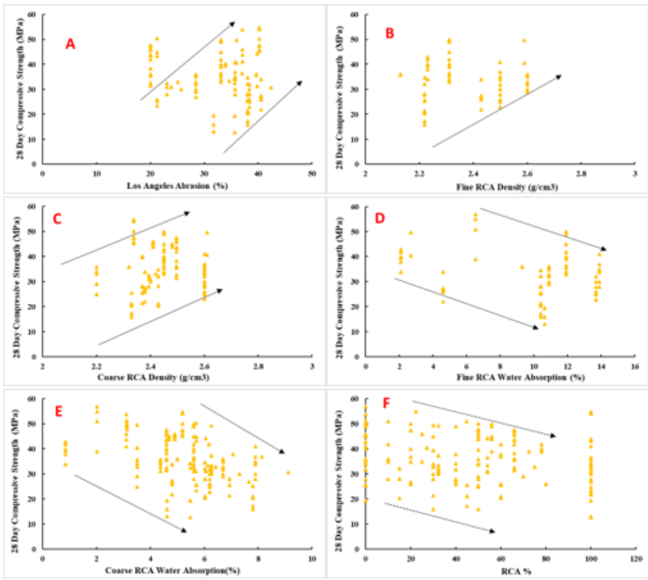

Fig. 13. Effect of RCA Properties on Concrete Strength

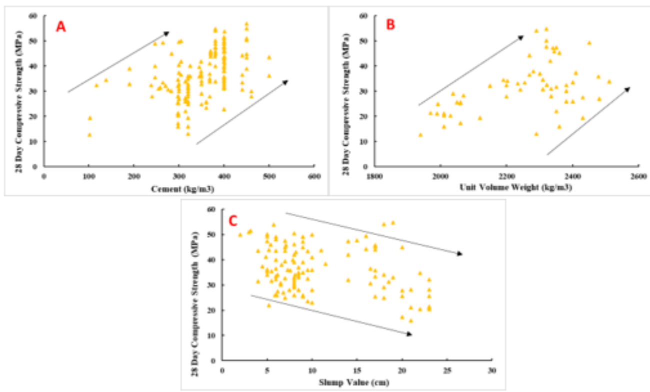

Fig. 14. Factors affecting the properties of concrete produced with RCA

4. Conclusion

The following conclusions were reached within the scope of this study.

1. The average unit volume weights of coarse RCAs are 2.41 g/cm3 and fine RCAs are 2.48 g/cm3. The density for both aggregates is above 2.4 g/cm3.

2. The average water absorption capacities of coarse RCAs and fine RCAs are 5.73% and 8.70%, respectively. As a result, these values are 2.86 and 4.35 times the water absorption capacity of coarse and fine natural aggregates, respectively. The higher water absorption capacity of RCAs is attributed to the binding agents surrounding the recycled aggregates.

3. The abrasion values of RCAs are 32.3% on average, which is very high compared to natural aggregate. The abrasion values of coarse RCAs decreased with the increase in unit volume weight and increased with the decrease in water absorption capacity.

4. According to the regulation TS EN 206, the region where the slump values of concretes produced with RCA are concentrated is class S2 with a rate of 60.67%. It was found that the amount of aggregate and binder used has a direct influence on the slump value of the concrete.

5. The unit volume weight values of the concretes produced with the RCA forming the database are 2283 kg/m^3. This value is in the normal concrete class according to the TS EN 206 regulation. As the RCA ratio used in the concrete mix increased, the unit volume weight decreased.

6. It was observed that compressive strength values decreased as the percentage of RCA usage increased. On the other hand, as the unit volume weights of fine and coarse RCAs increased, compressive strength values increased, while compressive strength values decreased with the increase in water absorption capacity.

7. Recycled concrete aggregate has been shown to be a partial or complete substitute for natural aggregate but tends to lead to an overall reduction in concrete strength compared to natural aggregate.

References

[1] W. Tang, P. Ryan, H. Cui, and W. Liao, "Properties of self-compacting concrete with recycled coarse aggregate," Adv. Mater. Sci. Eng, vol. 11, 2016.

[2] S. Marinković, V. Carević, "Comparative studies of the life cycle analysis between conventional and recycled aggregate concrete," in New Trends in Eco-efficient and Recycled Concrete, pp. 257-291, 2019.

[3] B. 8500, 2019 Concrete - Complementary British Standard to BS EN 206 Part 2: Specification for Constituent Materials and Concrete. BSI, London.

[4] DIN EN 206, Concrete Specification, performance, production and conformity, European Standard, 2001

[5] L.P.F.Abreu, J.R.M.Oliveira, H.M.R.D.Silva,, P.V. Fonseca,"Recycled asphalt mixtures produced with high percentage of different waste materials," Constr. Build. Mater, vol. 84, pp. 230-238, 2015.

[6] U.Aqil, F.Tatsuoka and T.Uchimura, "Strength and deformation characteristics of recycled concrete aggregate as a backfill material", Soils Found, vol. 45, pp. 53-72, 2002.

[7] H.Liu, J.Zhang, B.Li, N.Zhou, X.Xiao, M.Li, and C.Zhu, "Environmental behavior of construction and demolition waste as recycled aggregates for backfilling in mines: Leaching toxicity and surface subsidence studies", Journal of Hazardous Materials, 2019.

[8] H.Evin, and A.Özdemir, "Büyükşehirlerin Kati Atik Yönetimi Etkinliğinin Veri Zarflama Analizi Kullanilarak Ölçülmesi", Adıyaman Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, vol. 42, pp. 422-454, 2022.

[9] İ. A.Ş., "İbb Açik Veri Portali," 04 04 2022. [Online]. Available:https://data.ibb.gov.tr/dataset/istanbul-yillik-hafriyat-atik-tonajlari-ve-arac-sayilari.[Accessed 27 06 2023].

[10] A.Domingo-Cabo, C.Lázaro, F.López-Gayarre, M. A.Serrano-López, P.Serna, and J. O.Castaño-Tabares, "Creep and shrinkage of recycled aggregate concrete", Constr Build Mater, vol. 23, p. 2545–2553, 2009.

[11] A.Köken, M. A.Köroğlu, and F.Yonar, "Atik Betonlarin Beton Agregasi Olarak Kullanılabilirliği", Journal of Selcuk-Technic, vol. 7, 2008.

[12] C.Demirel, and O.Şimşek, "Atık Betonların Geri Dönüşüm Agregası Olarak Beton Üretiminde Kullanılmasının Basınç Dayanımı Üzerine Etkisinin Araştırılması", International Academic Research Congress , 2017.

[13] H.Polat, U. E.Yurtcan, and M. N.Kolak, "Atık Bordür Taşlarının Beton Agregası Olarak Kullanılabilirliğinin Araştırılması", Tr. J. Nature Sci, Vol. 3, No. 2, 2014.

[14] C.Demirel, and O.Şimşek, "C30 sınıfı atık betonun geridönüşüm agregası olarak beton üretiminde kullanılabilirliği", Selcuk Univ. J. Eng. Sci. Tech, vol. 2, no. 2, 2014.

[15] H. P.Sefıdehkhan, and O.Şimşek, "Farklı oranlarda geri dönüşüm agregası kullanılarak üretilen betonun bazı mühendislik özelliklerinin araştırılması", Politeknik Dergisi, vol. 21, no. 1, pp. 83-91, 2018.

[16] C.Goksu, Y.A.Ilyassaribas, A.Ilki, "Geri Dönüştürülmüş Agrega İle Elde Edilen Betonun Mekanik Özellikleri", In Actual Problems In Manufacturing Building Materials And Ways of Their Solution, Baku, 2018.

[17] İ.Kiliç, and A.Kadayifçi, "Geri Dönüştürülmüş Atik Betonlarda Silis Dumaninin Etkileri", Trakya Üniversitesi Fen Bilimleri Dergisi, Vol. 8, No. 2, Pp. 115-121, 2007.

[18] G.Durmuş, Ö.Cana and O.Şimşek, "Geri Dönüşüm Agregalardan Üretilen Farkli Siniflardaki Betonun Mühendislik Özelliklerinin Belirlenmesi", 5. Uluslararası İleri Teknolojiler Sempozyumu, Karabük, 2009.

[19] H.Dilbas, Ö.Çakır, and M.Şimşek, "Kentsel Dönüşüm Sonucu Oluşan Molozların Geri Dönüşümle Betonda Kullanımı–Silis Dumanı Katkılı Geri Kazanılmış Agregalı Betonlar", 9.Ulusal Beton Kongresi, Turkey, 2015.

[20] C.Demirel, A. G. K.Toklu, O.Şimşek, , P.M.Y.Okulu, Y.D.B.Kirklareli, "Geri Dönüşüm Agregasinin Beton Üretiminde Kullanilabilirliği ve Sürdürülebilirlik Açisindan Değerlenirilmesi", 2nd International Sustainable Buildings Symposium, Ankara - Turkiye, 2015.

[21] T. Y., "Geri Kazanilmiş Agregali Betonlarin Cdf Yöntemi İle Donma-Çözülme (Yüzeysel Kabuk Atma) Dirençlerinin Belirlenmesi", Erzurum: Atatürk Üniversitesi Fen Bilimleri Enstitüsü İnşaat Mühendisliği Ana Bilim Dalı Yapı Bilim Dalı, 2014.

[22] G.Gaurav, and B.Singh, "Analytical investigation in bond of deformed steel bars in recycled aggregate concrete", Journal of Sustainable Cement-Based Materials, 2020.

[23] Y.Sargam, B.Melugiri Shankaramurthy, and K.Wang, "Characterization of RCAs and their concrete using simple test methods", Journal of Sustainable Cement-Based Materials, 2019.

[24] M.T.U.Chowdhury, Y.Liu, J.Zhang, M.Ronaldo, W.Zhaoxu, and G.Yaodong, "Comparative Assessment of Aggregates on Mechanical Properties of Concrete", Journal of Ceramics and Concrete Sciences, vol. 5, no. 1, 2019.

[25] J. J.Assaad, P.Matar, and A.Gergess, "Effect of quality of recycled aggregates on bond strength between concrete and embedded steel reinforcement", Journal of Sustainable Cement-Based Materials, 2019.

[26] K.Poongodi, P.Murthi, R.Gobinath, A.Srinivas, and G.Sangeetha, "Mechanical Properties of Pavement Quality Concrete Using Recycled Aggregate", International Journal of Innovative Technology and Exploring Engineering (IJITEE), vol. 9, no. 1, 2019.

[27] S.I.Mohammed, and K.B.Najim, "Mechanical strength, flexural behavior and fracture energy of Recycled Concrete Aggregate self-compacting concrete", Structures, vol. 23, pp. 34-43, 2020.

[28] K.K.Sagoe-Crentsil, T.Brown, and A.H.Taylor, "Performance of concrete made with commercially produced coarse recycled concrete aggregate", Cement and concrete research, vol. 31, no. 5, pp. 707-712, 2001.

[29] S.Kamarudin, "Self-Compacting Concrete with incorporation of Recycled Concrete Aggregates", International Journal of Integrated Engineering, vol. 11, no. 9, pp. 164-173, 2019.

[30] M.C.Limbachiya, T.Leelawat, and R. K.Dhir, "Use of recycled concrete aggregate in high-strength concrete", Materials and structures, vol. 33, pp. 574-580, 2000.

[31] M.C.Rao, S.K.Bhattacharyya, and S.V.Barai, "Behaviour of recycled aggregate concrete under drop weight impact load", Construction and Building Materials, vol. 25, no. 1, pp. 69-80, 2010.

[32] B.González-Fonteboa, and F.Martínez-Abella, "Concretes with aggregates from demolition waste and silica fume. Materials and mechanical properties", Building and Environment, vol. 43, p. 429–437, 2008.

[33] J.Li, H.Xiao, and Y.Zhou, "Influence of coating recycled aggregate surface with pozzolanic powder on properties of recycled aggregate concrete", Construction and Building Materials, vol. 23, no. 3, p. 1287–1291, 2009.

[34] W.Tangchirapat, R.Buranasing, x C.Jaturapitakkul, and P.Chindaprasirt, "Influence of rice husk–bark ash on mechanical properties of concrete containing high amount of recycled aggregates", Construction and Building Materials, vol. 22, p. 1812–1819, 2008.

[35] B.Gonzalez-Fonteboa, and F.Martinez-Abella, "Shear strength of recycled concrete beams", Construction and Building Materials, vol. 21, no. 4, p. 887–893, 2007.

[36] K.Eguchi, Teranishi, "Application of recycled coarse aggregate by mixture to concrete construction", Construction and Building Materials, vol. 21, p. 1542–1551, 2007.

[37] TS 706 EN 12620, "Beton Agregalari" Türk Standartları Enistitüsü, Ankara, 2003.

[38] BS EN 1097, "Tests for mechanical and physical properties of aggregates Determination of particle density and water absorption", Britain, 2022.

[39] T.E.206-1, "Beton: Özellik, Performans, İmalat ve Uygunluk," Türk Standartları Enistitüsü, Ankara, 2002.