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Experimental Investigation of Usability of Construction Waste as Aggregate

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Abstract

The aim of this work is to obtain recycled aggregate (RA) from construction debris in order to reduce the rapid consumption of aggregate resources and the environmental impact of these resources. In order to fulfill this aim, the density, porosity, Schmidt hardness test, uniaxial compression resistance, carbonation depth, and ultrasonic p-wave velocity experiments were conducted on different construction debris transported by trucks from 9 different points in Turkey. In addition, the debris samples taken were broken down to the size of the aggregate and subjected to the tests of density, porosity, moisture content, freeze-thaw, and impact resistance. As a result of the conducted experiments, the lowest mass loss as a result of freezing-thawing was in GRA with 9.36%, the highest mass loss was in ORA with 22.58%, the highest ORA average aggregate impact strength index was 21.27%, and the lowest TRA aggregate impact strength index was found to be 18.26%. İt was determined that most of the physical properties of RA obtained from the construction wreckage was within the limit values specified in the literature and that the recycled aggregates could be used instead of natural aggregate. With this work and these results, RA obtained could be used in many areas such as concrete aggregate in the construction sector, underground filling in mining, filling material in gunned concrete, and filling materials on highways.

1. Introduction

Due to the reasons such as the scarcity of natural resources, increased interest in the environmental problems caused by aggregate production and destruction, and insufficient storage area, many countries have to take measures for the reuse and recycling of construction and debris wastes, and many studies have been conducted on these issues [1,2]. Plans are being prepared in order to reduce the wastes in many countries and cities, and the acceptance fees and taxes on the waste storage areas are being increased [3]. According to the 2005 data, 130 million tons of construction debris a year come to exist in the US. For the storage of these emerging wastes, very large areas will be destroyed, and the soil structure will be degenerated. For these reasons, evaluation of the recovery and reuse possibilities of construction wastes is of utmost importance [4].

Natural aggregate production has increased rapidly the in recent years. According to a research work in the USA, 2.7 billion tons of natural aggregates were used in 2004. If it is assumed that the specific gravity of the used aggregate is about 2.7 ton/m^3, it is seen that natural aggregate is produced from the area where it has a volume of 1 billion m^3 per year. This means that the natural environment in a very wide area has been destroyed for natural aggregate production. Also the dust emission, and noise and image pollution caused by the facilities in which these aggregates are produced are the effects to be considered [5,6].

Within the cost of production of one cubic meter of concrete, cement has the biggest share with 40%, coarse aggregate is in the second place with 20% [7,8]. The construction sector, which has grown very rapidly in the recent years, has increased the

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use of aggregate, and accordingly, the production rate. Generally, the increased use of natural aggregate has also brought many problems and complaints.

The construction industry is very old in Turkey. Since the buildings have been built with the old technology and facilities, they are not resistant to earthquakes and the environmental conditions. Besides, Turkey, which became a scene of rapid development years ago, has irregular and unplanned zoning. Due to the unplanned urbanization as well as the risk of damage in the earthquake, many buildings will be destroyed and rebuilt within the scope of the urban transformation project or individually. The construction debris to be generated under this transformation has various negative effects on the environment. In addition, the aggregate used in concrete construction is a work whose production is very difficult, and its energy consumption is too much and costly. The aggregate resources used in concrete are being consumed rapidly. The fact that the aggregate quarries are far away from the city center increases the aggregate prices very much. Noise, dust, explosion-induced noise from the aggregate quarries, and the negative impacts on water resources are very much. In order to reduce the aggregate production on the Earth, recycled aggregate production has been supported, and facilities have been established; many studies have been carried out on this issue [7-13].

The densities of the recycled aggregates (RAs) obtained from different sources are different. The densities of RAs obtained from different sources are different. In the case of the examples given in Table 1, many researchers have obtained different results due to the difference in the components that make up the building (aggregate, water, and cement).

Table 1. Density and water absorption rates of RAs in the literature.

Those who worked	Where the antigens were supplied	Density of RA (g/cm^3)	Water absorption rates of RA (%)
Topçu and Guncan, [14]	Aggregates obtained from concrete residues	2.45	
Poon, [15]	Aggregates obtained from concrete residues	2.1-2.3	
Poon et al., [16]	Aggregates obtained from concrete residues	2.41	3.17 -10.3
Thomas et al., [17]	Aggregates obtained from masonry	0.85-1.4	
Colangelo et al., [18]	Recycled and natural aggregate mixture	2.40	
Rakshvir et al., [19]	Aggregates obtained from concrete residues		1.63 -1.65
Külekçi et al., (this work)	Aggregates obtained from construction rubble	1.6-1.8	8-8.57

It can be seen that the specific weight of concrete wastes obtained from different waste sources is different from each other, and the densities of RAs are lower than those of natural aggregates.

In some studies, it has been argued that the concrete wastes of a certain size, separated from construction and debris wastes, broken and sieved, can be used in concrete production instead of natural aggregates [11,17,20,21]. Some researchers have stated that it may be appropriate to use them in concrete applications that are not a carrier or structural as low standard aggregates since some features do not conform to the standards [7,17,18,22].

RA is widely used in pavements in the United States and Great Britain; furthermore, it has been reported that the use of RAs (coarse and fine-grained) as road base material has a quality that is comparable with the natural road base material in the Netherlands; about 95% of broken concrete waste is used as road base material [23-26].

The concretes made with recycled aggregate should be evaluated in terms of durability. Some durability problems may occur in concretes made with RA. The key reason for the durability failure of RA concrete in a complex environment is the increase of large pore volume fraction. Many researchers have conducted research works on the durability of RA [27,28,29].

In this work, which is carried out and explained in details below, it is aimed to reduce the use of natural aggregate, which is used rapidly in the world, and to reduce the environmental problems that arise during aggregate production, and to ensure the usability of construction wastes as RA. For construction waste to be used instead of or together with natural aggregate, it must provide some mechanical properties. For this purpose, some mechanical properties were determined by conducting experiments on construction wastes taken from 9 different regions in order to reflect the characteristics of the region. Thanks to these features, it will be used in the sectors where natural aggregate is used as an alternative to the storage of construction wastes that are or may be formed in the world. It is aimed to determine the characteristics of the construction wastes in the region in order to recycle the wastes as RA, and to create an alternative to all sectors in which natural aggregate is used and required in the construction sector in the mining sector.

2. Mterials and methods

2.1. Sampling procedure

In this work, the wastes that completed their economic lives or those from the buildings destroyed in the scope of urban transformation were used. For this purpose, the settlements where demolition occurred the most and closest to our work center were selected. The construction wastes used in the work were taken from the NE of Turkey (Figure 1).

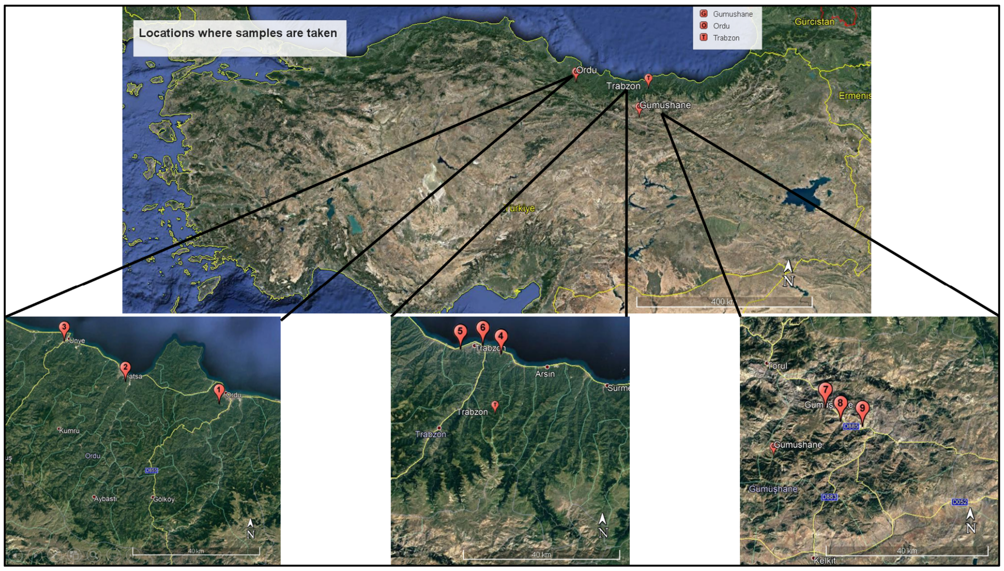

Figure 1. Locations where the samples were taken.

For the construction wastes taken to represent the properties of the region, the samples were taken from 3 different provinces and from 3 different points in each province. The volume of the samples was reduced to a certain size, and they were put into the sacks and brought to the laboratory (Figure 2).

The two-stage crushing and screening processes were performed to downsize the concrete debris, obtained from constructions and wreckages, from blocks to the size of 63-0.063 mm to be able to conduct the aggregate experiments on them. The concrete wastes, turned into 50 mm pieces with the first crushing process, were reduced to the size required for aggregate testing with the second crushing process (Figure 3).

In order to prepare the concrete sample, the CEM I 42.5R Portland cement was used. The chemical, physical, and mechanical properties of the cement are presented in Table 2.

Table 2. Chemical, physical, and mechanical properties of CEM I 42.5 R.

Chemical properties (%)		Physical properties	
SiO_2	18.59	Setting time, Initial (min)	
Al_2O_3	4.69	Setting time, final (min)	
Fe_2O_3	3.04	Volume stability (mm)	
CaO	60.34	Specific surface (blaine), (cm^2/g)	
MgO	1.92	Specific gravity (g/cm^3)	
SO_3	2.89		
Na_2O	0.11	**Mechanical properties**	**Comp. Strenght (MPa)**
K_2O	0.64	2 days	23.9
Loss on ignition	7.19	7 days	51.1
Insoluble residue	0.57	28 days	57.8
S.CaO	0.38		

Figure 2. Sampling from the construction demolitions.

Figure 3. Size reduction and sieve analysis.

2.2. Compressive strength of RC

Concrete classifications were made using the non-destructive and destructive methods on irregularly shaped samples with an average size of 60 x 70 x 40 cm taken from the unreinforced concrete parts of the construction debris. A Schmidt hammer was used as a non-destructive method; the ultrasonic wave velocity determination and uniaxial compression strength method were used as the destructive methods.

2.2.1. Non-Destructive methods

2.2.1.1. Schmidt hardness determination

There are different standards of Schmidt attractive measurements; in our work, the ASTM C805 method was used (ASTM C 805, 2004). In this method, discard readings differing from the average of 10 readings by more than 6 units were used, and the average of the remaining readings was determined. If more than 2 readings differed from the average by 6 units, the entire set of readings was discarded, and the rebound numbers at 10 new locations within the test area were determined.

In the scope of this work, the Schmidt hammer measurements were made on the samples in order to determine the surface hardness of the construction wastes taken from 3 different provinces.

The Schmidt measurements were converted to an uniaxial compressive strength using the formula below:

f_{ck} = 5,5714 x R + 64,857; here, f_{ck} = Characteristic compressive strength (MPa), R = Schmidt rebound hammer value.

2.2.1.2. Ultrasonic pulse velocity (UPV) Test

The UPV test is one of the methods used in many sectors in order to determine the geotechnical properties of the materials because it is damage-free, reliable, cheap, and an easily applicable method.

The UPV measurements were made with a Pundit Lab $^{+}$ model tester, which had a signal time of 0.1 µs accuracy and a signal frequency of 24-500 kHz on the cores taken from the block concrete masses from the land in accordance with the ASTM C 597 standards [31].

The ultrasonic measurements were converted to an uniaxial compressive strength using the following formula:

Cube = 0.0691 x V – 16.364; here, Cube = uniaxial compressive strength (MPa), V = ultrasonic pulse velocity (m/s).

2.2.2. Destructive method

Cylindrical cores were taken from the irregularly shaped samples taken from the construction wreckages and debris; the cores taken were adjusted in a way that their length-to-diameter ratio would be 2, and then their uniaxial compressive strengths were measured (Figure 4).

Figure 4. Cores taken from concrete waste.

2.2.2.1. Uniaxial compressive strength tests

The uniaxial compressive strength tests were applied on the core samples from the debris blocks taken from the land according to the TS EN 12390-3 standard [32]. The cores with a diameter of 52 mm and a length of 110 mm were taken from the block-shaped construction debris taken. The uniaxial compressive strengths of the cores taken were determined after straightening their tips. The tests were applied to a total of 21 core samples as 7 samples for each sample (Figure 5).

In the calculation of the concrete pressure resistance, $f_c = \frac{F}{A_c}$, equality was used. In equality, fc = Compressive strength, MPa, F= Largest load reached at the moment of fracture, N, Ac = Cross-sectional area where pressure was applied on the sample (mm^2) [32].

The pressure resistances obtained are associated with the schmidt hammer and ultrasonic speed.

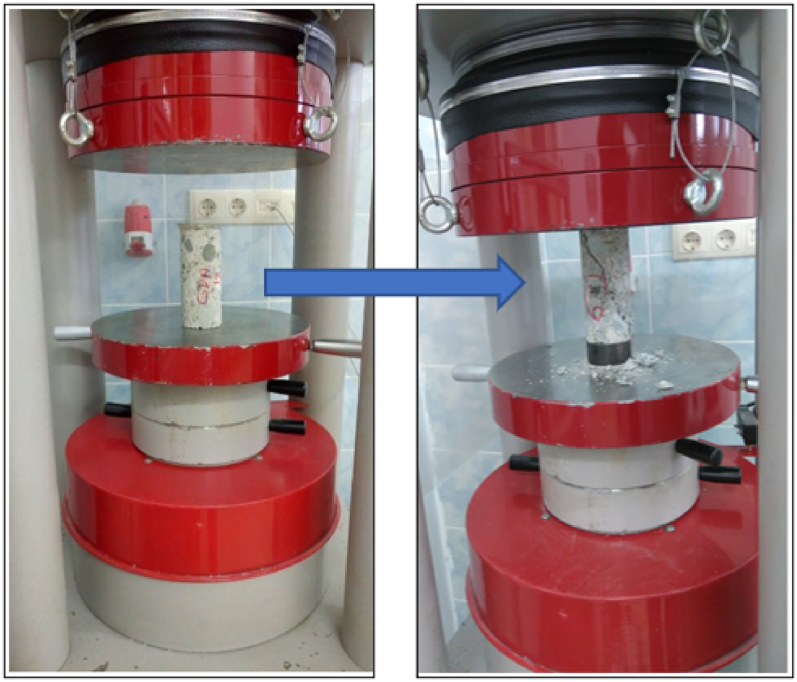

Figure 5. Uniaxial compressive strength test.

2.3. RA Experiments

The construction wastes on which the concrete experiments were conducted were brought down to the appropriate size and density, water absorption, porosity, and impact resistance, and the freeze-thaw experiments were conducted according to the TSE and ASTM standards in order to determine their usability as aggregate. The experiments and the results obtained were compared with the TSE standards, and the extent to which the construction wastes of the region could be used as aggregate was investigated.

2.3.1. Density, porosity, and moisture contents of RAs

The density and water absorption amounts of the aggregates used in this work were determined according to the principles specified in TS EN 1097-6 [33].

In the grain density and water absorption calculation:

Apparent density: $\rho_a = \frac{M_4}{M_4-(M_2-M_3)}$

Oven-dried basis in the particle density: $\rho_{rd} = \frac{M_4}{M_1-(M_2-M_3)}$

Saturated and surface-dried essential grain density: $\rho_{ssd} = \frac{M_1}{M_1-(M_2-M_3)}$

Water absorption rate (WA_{24}), after 24 h of immersion, as a percentage of dry mass, with the aid of the following equation:

$$WA_{24} = \frac{100x(M_1 - M_{4)}}{M_4}$$

% Apparent porosity: $\rho_{rd} \times WA_{24}$

In this formula, M_1: Saturated and air-dried aggregate mass (g), M_2: Mass of the pycnometer containing the sample of the solid aggregate (g), M_3: Only the water-filled pycnometer mass (g), M_4: Mass of the dried sample (g).

2.3.2. Freezing and thawing test

This experiment provided information about the form of behavior the aggregate displayd in case it was exposed to freezing and thawing. The freeze-thaw test was carried out with aggregates of grain size between 4 mm and 63 mm. In this experiment, the aggregate quantities indicated in Table 3 were used according to the TS EN 1367-1 test standard [34].

Table 3. Sample quantities required for freeze-thaw cycle test [34].

Largest aggregate grain size (mm)	Aggregate mass or volume	
	Normal aggregate (g)	Light aggregate (bulk volume) (mL)
4-8	1000	500
8-16	2000	1000
16-32	4000	1500
32-63	6000	-

The samples taken from 8 mm to 16 mm screen opening were subjected to the freeze-thaw cycle for 10 times. Here, cooling at -17,5 °C under water and then dissolving in a water bath at 20 °C were carried out (Figure 6).

After completion of the freeze-thaw cycles, the RA mass loss was calculated in percent after filtered through an 8-mm sieve. This calculation was done using the following equation:

$$F = \frac{(M_1 - M_{2)}}{M_1} x100$$

In this formula, M_1: First dry mass of the test sample (g), M_2: Cumulative oversize (g), F: After completion of the freeze-thaw cycles; the RA mass loss was calculated in percent.

2.3.3. Impact resistance experiment

The impact resistance test was carried out according to the TS EN1097 / 2-D1 standards [35]. By standard, it is to learn about the impact resistance of the aggregate through a certain weight being released from a certain height on the aggregate that is put into a cylindrical container, and is calculated by the following equation:

AIRI (Aggregate Impact Resistance Index) (%) = (B/A) x 100(%)

In this formula, A: Initial amount of material weighed (g), B: Amount of material under a 2.36 mm (g) sieve.

2.3.4. Determination of carbonation depth

A solution was prepared with ethyl alcohol, in which 1% phenolphthalein with pH 8.2-9.8 was used. Immediately after spraying the solution, two areas that did not change color were formed on the surface of the concrete core samples, which did not become carbonated and turned into red-purple. The core samples taken from the building debris were divided into 2 by the splitting method, and the phenolphthalein indicator was sprayed on them; carbonation occurred at heading the core that was in contact with the open cross. At least 10 measurements were taken from the carbonated parts, and the average carbonation depth was determined. The carbonation depth was measured as 1 cm. The concrete sample whose carbonation depth was measured is shown in Figure 7.

Figure 6. Freezing and thawing test.

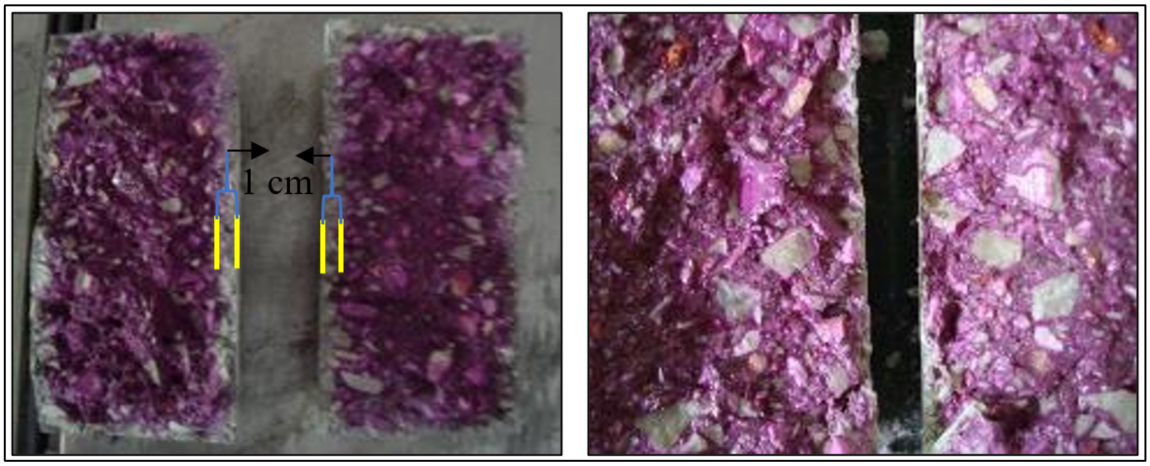

Figure 7. Determination of carbonation depth.

3. Results and discussion

Crushing and elimination were performed on the construction debris taken from different locations in the Black Sea region, and were put through the process. The aggregate groups obtained from 9 different points and aggregates were coded as GRA, TRA, and ORA.

3.1. Compressive strength of recycled concrete

In this work, the Schmidt hardness values were found on 21 core samples from 9 different studied areas according to the ASTM C 805 standards [30]. The surface hardness obtained by the Schmidt hammer is shown in Figure 8.

According to the values found, it was determined that the ORA's Schmidt hammer rebound was the highest; the GRA's samples had the lowest values. The estimated uniaxial compressive strength was found with the help of the formula by taking the average of the Schmidt hardness values. The values found were compared with the uniaxial compressive strength value.

Using the ultrasonic sound velocity method from the non-destructive method, the P-wave velocity was measured, and the compressive resistance was estimated with the help of the formula (Figure 9).

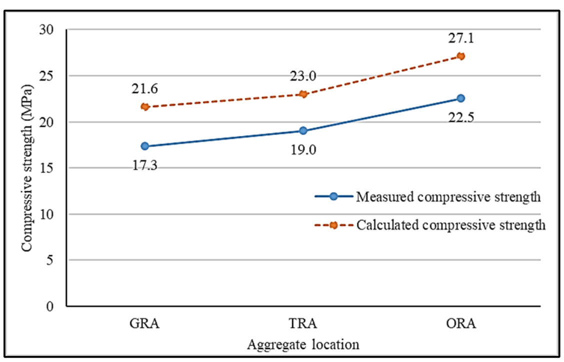

Figure 8. Mean compressive strength values obtained by the Schmidt's attractive and destructive test method.

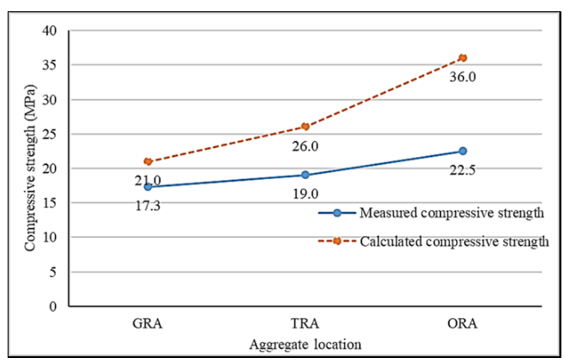

Figure 9. Mean values of compressive strength obtained by the ultrasonic pulse velocity test and destructive test method.

Figure 9. Mean values of compressive strength obtained by the ultrasonic pulse velocity test and destructive test method.

According to the measurements for the samples with 51 mm diameter and an average of 127 mm height, the p-wave velocity of concrete GRA samples were the lowest with an average of 3655.3 m/s, whereas the ORA samples were the highest with an average of 4255.9 m/s.

Between the values obtained by the surface hardness method of construction wastes and uniaxial compression strength values, approximately 16% to 19% difference was found in the compression strength. It is thought that this difference between the compressive strengths is caused by carbonation on the concrete surface during the service life of the concrete samples. Carbonation causes an increase in the surface hardness. It also causes the compressive strengths obtained by Schmidt hammer to be above the expected values.

3.2. Density, porosity, and moisture contents of RAs

As it can be seen in the literature, the densities of aggregates obtained from different sources vary. In this work, the density determination of aggregate samples taken from 3 different samples (GRA, TRA and ORA) was carried out (Figure 10).

When the density results were examined, it was seen that according to the TS EN 1097/6 standards, RAs that were recycled from the construction wastes fell into the class of light aggregate [33].

As a result of the calculations made, it was seen that the porosity of RA obtained from construction debris was also different. The porosity of GRA was found to be 13.67%; the porosity of TRA 14.22%, and the porosity of ORA was 14.21% (Figure 11).

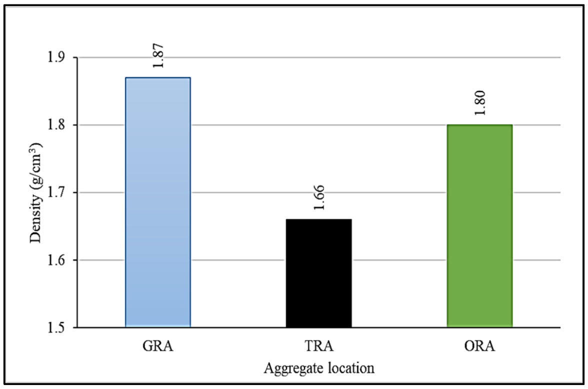

Figure 10. Average density values of recycled aggregates.

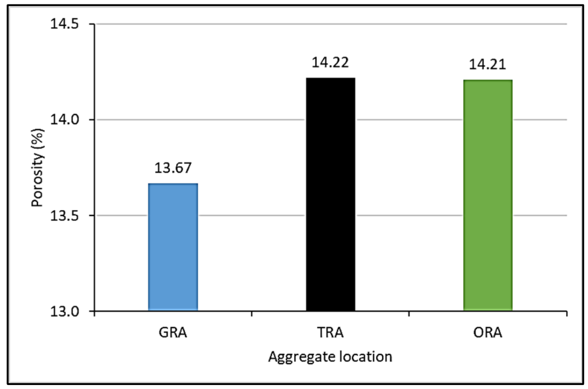

Figure 11. Porosity values of recycled aggregates.

In the conducted study of Tarhan 1989, he also divided the rocks into 6 classes according to their porosity. According to Table 4, RAs comprising the debris we used fell into the class of "multi-cavity" (Table 4).

Table 4. Classification of rocks by porosity.

Classification of rocks	Porosity (%)
Very tight	<1
Less porous	1-2.5
Medium porous	2.5-5
Quite porous	5-10
Very porous	*10-20*
Too much porous	>20

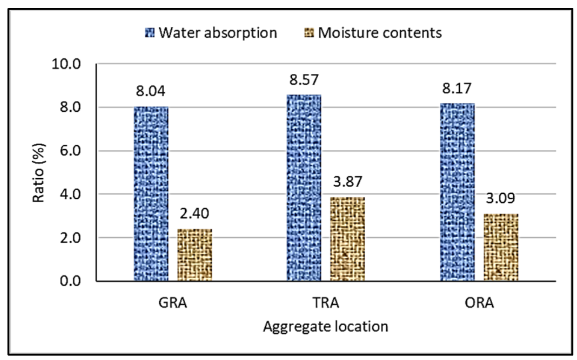

Figure 12. Water absorption and moisture content.

In our work, after the water absorption experiments were carried out in the stated manner, the maximum water absorption rate was found in TRA. (Figure 12).

The moisture and water absorption potentials are important for the construction debris to be used as aggregates. In a study conducted by Topçu *et al.*, they emphasized that the rate of water absorption must be low in order to be able to use the recycled aggregates in concrete production [14]. The lowest water absorption rate in the study was in GRA.

When the porosity, density, and water absorption relations of the recycled aggregates were evaluated, it was seen that the increase in the porosity decreases density values increased the water absorption value. Since the rocks to be used as concrete aggregates are expected to have low porosity and water absorption values, this relationship is important for concrete wastes to be used as recycled aggregates. These physical properties of RAs will directly affect the physical and mechanical properties of the concrete to be made with the aggregates. The porosity, density, and water absorption relationships of the aggregates produced in work are shown in Figure 13.

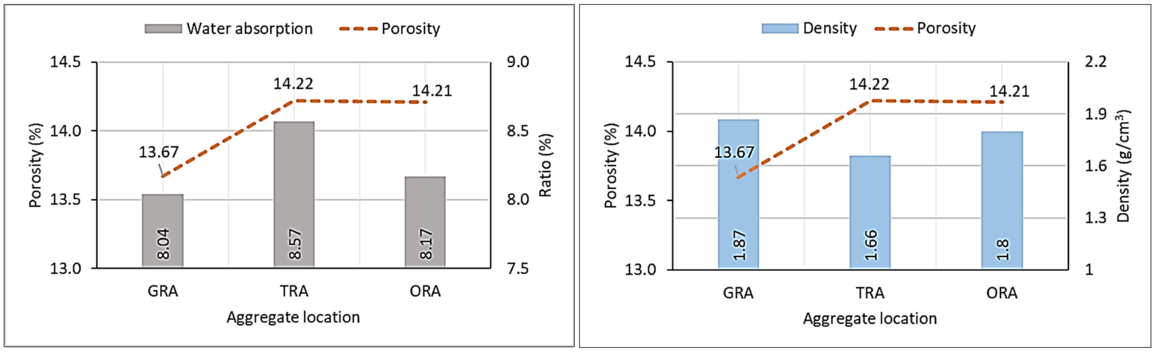

Figure 13. Recycled aggregate porosity, density, and water absorption relationship.

When the recycled aggregate water absorption porosity relationship was evaluated, it was seen that the increase in porosity increased the water absorption values.

Comparing the limit values according to the TS 500 and TS EN 12390-3 standards and the results of this work, it was found that the studied RAs were in the weak aggregate class (Table 5) [32,36].

Table 5. Comparison of density and water absorption rates of RAs with standards.

Agrega properties	GRA	TRA	RA	Standards of TS 500 and TS EN 12390-3			
				Excellent	Good	Medium	Weak
Density (g/cm^3)	1.87	1.66	0.8	>2.9	2.6-2.9	2.5-2.6	<2.5
Water absorption (%)	8.04	8.57	0.17	<0.5	0.5-2.0	2.0-6.0	>6.0

3.3. Freezing and thawing test

The freezing-thawing results of 3 different RAs done according to the TS EN 1367-1 standard are shown in Fig.14 [34].

A freeze-thaw experiment done with water was applied according to TS EN 1367-2. At the end of 10 cycles, the lowest mass loss as a result of freezing-thawing was in GRA with 9.36%, and the highest mass loss was in ORA with 22.58%. According to the TS 706 EN 12620 concrete aggregate standard, if the water absorption rate of the aggregates is less than 0.5% and the compressive strength is greater than 150 MPa, it can be decided that the aggregates will be resistant to the frost. There is no such standard in recycled aggregates. However, frost loss is required to be at most 10% in coarse aggregate. After 10 cycles of the frost dissolution test, it was seen that only GRA was under the value of 10%.

3.4. Impact resistance experiment

After the concrete samples taken from various regions were brought to the aggregate size impact resistance test according to the TS EN 1097-2 / D1 standards, the impact test was repeated for 5 times for each region, and the results obtained were given in Figure 15 [35].

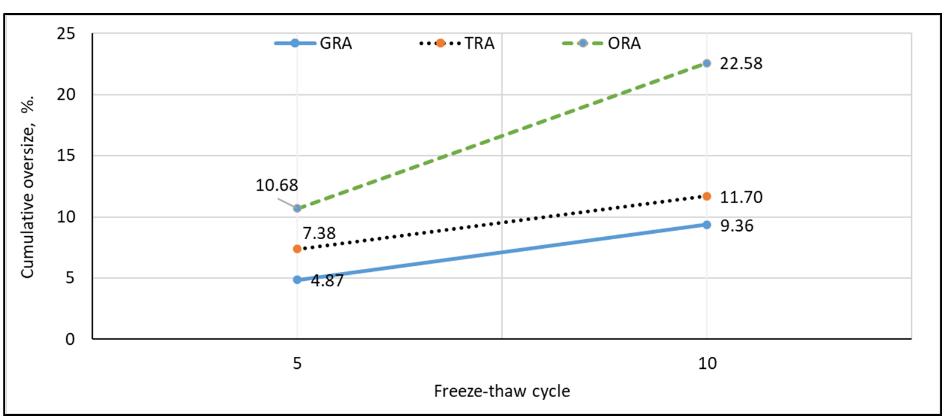

Figure 14. RAs of freeze-thaw test results.

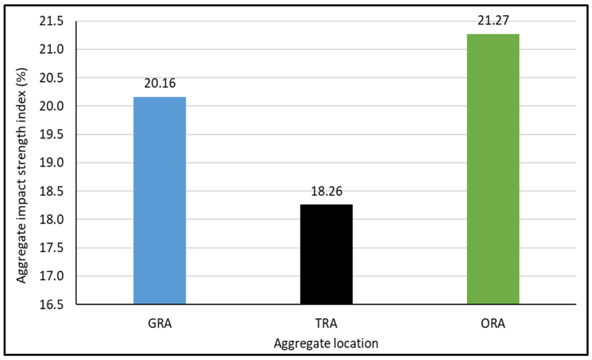

Figure 15. Impact resistance test of recycled aggregates.

As a result of the aggregate impact resistance test on the recycled aggregates, the highest ORA average aggregate impact strength index was 21.27%, and the lowest TRA aggregate impact strength index was found to be 18.26%. When viewed from the perspective of the impact resistance of the areas of use of the recycled aggregates, according to the BS 812: Part 112 standards, the limit values for the areas where the aggregates could be used, a maximum of 25% for concrete slabs was use in the areas with heavy traffic and 50% for other types of concrete [37]. The values found were compatible with both concrete types.

4. Summative assessment

When the values obtained were compared with the general properties of the recycled aggregates in the literature, the porosity, density, and impact resistance values were not determined for the recycled aggregates, while the water absorption value was above the general values for all samples. The comparison of the physical properties obtained with the values stated in the previous studies and standards is shown in Table 6.

Table 6. Comparison of values obtained from this work with the literature.

Type	Experiments	GRA	TRA	ORA	General features*
Recycled Aggregate	Porosity (%)	13.67	14.22	14.21	-
	Density (g/cm^3)	1.87	1.66	1.8	-
	Impact resistance experiment	20.16	18.26	21.27	-
	Water absorption (%)	8.04	8.57	8.17	1.00
	Lowest mass loss as a result of freeze-thaw (%)	9.36	11.70	22.58	10

*[8,9,10,38,39,40].

5. Conclusions

The Schmidt's surface hardness test, ultrasonic P-wave velocity measurement, and uniaxial compressive strength experiments were conducted on the construction wastes taken from 9 different points of 3 different selected provinces in Turkey. In addition, the construction debris was broken down to the size of the aggregate. They were subjected to the density, porosity, moisture content, freeze-thaw, and impact resistance tests.

In conclusion:

- According to the uniaxial compressive strengths done on the cores taken from the construction debris, the highest strength was obtained from the debris samples from ORA with a strength of 22.50 MPa. The core with the lowest strength was measured from GRA with a strength of 17.33 MPa.

- According to the Schmidt surface hardness values, it was determined that ORA had the highest average rebound value, and the GRA samples had the lowest. One of the most important factors affecting the surface hardness of concrete was carbonation. The amount of carbonation increased depending on the amount of CO_2 that concrete was exposed to during its service life. Carbonation in the concrete samples caused an increase in the surface hardness. It also caused the compressive strengths estimated from surface hardness to be above the expected values. For this reason, the determination of only surface hardness and pressure strength of the concretes to be used as a recycled aggregate resulted in erroneous results. There is more air pollution in the ORA and TRA sample area, where the waste concretes were provided in the work compared to the GRA samples area in terms of industrialization, and hence, the amount of CO_2 in the air. Due to the carbonation that occured, the surface hardness of samples taken from ORA and TRA were determined to be higher than those from the GRA area.

- As a result of the porosity measurements, the lowest porosity was observed in GRA. The small porosity of coarse aggregate grains can cause the strength of these grains to be high. For this reason, the porosity of aggregates to be used in concrete production is required to be low.

- As a result of the density determination, the maximum density of GRA was 1.87 g/cm^3. Aggregates with a specific gravity lower than 2.4 are called light aggregates. According to the TS EN 1097/6 standard, therefore, the aggregates obtained from the construction waste in this region can be called light aggregates.

- In evaluating the impact strength of recycled aggregates (RAs), it was seen that the impact strength was the highest in the samples with a low porosity and high density in the samples. In the areas where impact resistance was important, in case RA was used in concrete to be produced, the physical properties such as the density and porosity should not be ignored.

- It is not desirable that the water absorption rates of aggregates formed from construction debris are high. This is because the applicability in the production of new concrete is low with high water absorption rate of concrete aggregates. Rakshvir found that the water absorption ratio was between 1.63% and 1.65% in the experiments done with RA obtained from different sources [19]. Poon determined the water absorption values of coarse and fine recycled aggregates between 3.17% and 10.3% [16]. These values are between 0.5% and 1% for natural aggregates [5]. Accordingly, the coarse and fine-grained RA have a higher water absorption capacity compared to natural aggregates. In this work, the water absorption content of TRA was measured as the highest. Its water absorption value of 8.16 % was above the standards.

- Aggregate is important in the physical properties of the concrete's porosity and compressive strength. Since the physical and mechanical properties of the aggregate affect the concrete properties, the source from which the recycled aggregates are obtained must be known. It would be a correct approach to determine the physical and mechanical properties of the rubble from which the recycled aggregate is obtained before use. In this work, although the places where the aggregate was processed were geographically similar, they showed different physical properties due to the change in the age of the waste concrete and the conditions it was exposed to during its service life.

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بررسی تجربی قابلیت استفاده از پسماندهای ساختمانی به عنوان سنگدانه

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چکیده:

هدف از این کار به دست آوردن سنگدانه‌های بازیافتی از بقایای ساختمانی (RA) (نخاله‌های) به منظور کاهش سریع مصرف منابع کل و تأثیرات زیست محیطی این منابع است. به منظور تحقق این هدف، چگالی، تخلخل، آزمایش سختی اشمیت، مقاومت فشاری تک محوری، عمق کربناسیون و آزمایش سرعت موج اولتراسونیک بر روی بقایای ساختمانی مختلفی که توسط کامیون ها از ۹ نقطه مختلف در ترکیه جمع‌آوری می‌شوند، انجام شد. علاوه بر این، نمونه‌های نخاله‌های ساختمانی گرفته شده به اندازه دانه تقسیم شده و تحت آزمایش‌های چگالی، تخلخل، میزان رطوبت، انجماد ذوب و مقاومت در برابر ضربه قرار گرفتند. در نتیجه آزمایشات انجام شده ، کمترین میزان از دست دادن جرم در نتیجه انجماد-ذوب در GRA با ۹/۳۶٪ ، بیشترین از دست دادن جرم در ORA با ۲۲/۵۸٪ ، بیشترین ORA متوسط شاخص تأثیر ضربه کل ۲۱/۲۷٪ و کمترین شاخص مقاومت در برابر اثر کلTRA، ۱۸/۲۶٪ بود. مشخص شد که بسیاری از خصوصیات فیزیکی RA به دست آمده از نخاله‌های ساختمانی در مقادیر محدوده‌ی مشخص شده در ادبیات تحقیق است و می‌توان از سنگدانه‌های بازیافتی به جای سنگدانه‌های طبیعی استفاده کرد. با این کار و این نتایج، RA به دست آمده می‌تواند در بسیاری از مناطق مانند سنگ دانه در بخش ساخت و ساز، پر کردن زیرزمینی در استخراج، پر کردن مواد در بتن مسلح و پر کردن مواد در بزرگراه‌ها مورد استفاده قرار گیرد.

کلمات کلیدی: سنگدانه‌ها، کربناسیون، مقاومت فشاری، خصوصیات مربوط به دوام، خصوصیات الکتریکی.