Investigation of Properties of Concrete Produced with Recycled Aggregates

Abdelwahab Z. Amaitik ALTERA¹, Oğuzhan Yavuz BAYRAKTAR², Burak BODUR², Gökhan KAPLAN^{3*}

¹ Department of Engineering Management, Institute of Science, Kastamonu University, Kastamonu/TURKEY

² Department of Civil Engineering, Kastamonu University, Kastamonu/TURKEY

³ Department of Civil Engineering, Atatürk University, Erzurum/TURKEY

Keywords

*Sustainability,
Durability,
Recycling,
Recycled Aggregates,
Ecology.*

Abstract

The greatest frequently applied construction substantial in the construction sector is concrete. Natural resources are mostly used in concrete production. While environmental resources are being consumed, concrete environmental pollution increases during urban transformation or reconstruction. In sustainable life, environmental damage caused by construction demolition wastes necessitates the use of recovered aggregate. Recycled aggregate is a term used to depict squashed solid, mortar, blocks or black-top from development trash that is reused in other structure ventures. Reused total is delivered by pounding annihilated waste to recover the total. For as far back as not many decades the accessibility of Construction and demolition waste has expanded so a lot of that the solid business has started using it thusly decreasing the number of totals. The goal is to examine the physical properties, (grain size distribution, density and water absorption) and mechanical properties, (for example, compressive strength, flexural strength, modulus of elasticity and splitting tensile strength) and durability properties, (for example, sulfate resistance, freezing and thawing resistance, acid resistance, high temperature effect and abrasion resistance) of recycled aggregate. It is seen that the mechanical and durability conduct of recycled aggregate concrete is optional to that of standard concrete yet with the utilizing various admixture and unique blending approach, required properties can be accomplished.

1. Introduction

Due to many reasons such as the rapid increase in the world population and urbanization potential, technological developments in many areas, innovations in industrial areas, and the rapid change in human needs, the interest in the construction sector is increasing day by day. Meeting this interest has brought with it some ecological problems caused by the consumption of natural raw materials and the resulting wastes. Living spaces are shrinking and economic problems are occurring. Recycling comes as an ecological and economic solution method for the solution of these problems.

Recycling as a term, the recycling of waste materials that are left out of use with various recycling methods as a raw material is to re-manufacturing processes.

Recycling, which is a requirement of sustainable development; It is the most important form of waste management that enables the use of depleted natural resources in the most efficient ways and for the future generations.

Concerns about the depletion of world natural resources led to the largest meeting in Rio de Janeiro of heads of state at the Conference of UN Development and Environment, Brazil in 1992. Following this and subsequent summits, the principle of sustainable development was also incorporated into the EU's Amsterdam. The concepts of sustainable development and sustainability have become the most important concepts of our century. The holistic approaches and uses of these two concepts are of great importance in civil engineering which is the oldest known field of engineering which is directly related to the development of societies in human history. In this context, the European Commission has determined that material

manufacturers have important contributions to ensure sustainability in the construction sector. The construction sector is trying to minimize the inputs in the manufacturing processes and to reduce raw material and energy consumption, emissions and space utilization as much as possible [1-3].

On the other hand, the necessary efforts to preserve and improve the ecological wealth as well as the aesthetic appearance will help to provide sufficient resources for future generations and to minimize the harmful effects on the environment. Solid waste management, which is a necessity of creating a good environment, can be described as an important branch of activity that is in a multi-faceted relationship with technical, economic and social disciplines with the necessity of ensuring maximum efficiency in the scarcity and utilization of regular sources like raw materials and energy [4].

Squander the executives; is a type of the board which incorporates the decrease, division, assortment, brief stockpiling, halfway stockpiling, recuperation, transportation, transfer and post-transfer control and comparative procedures of waste at source. With squander the board, it would be an economic and environmental benefit approach to see structural wastes as a resource that should be exploited/evaluated rather than pollution. Waste management has become an increasingly important issue, including the recovery of waste, the limitation of the types of production and consumption that increase the amount of waste, and the creation of employment. Today, there are many studies under the name of demolition and construction waste regulations. In Figure 1, the Waste Management Pyramid proposed by the Ministry of Environment and Forestry is seen. The Pyramid of Management of Waste is assessed from upper to bring down levels. At the end of the day, the initial step is to anticipate the

*Corresponding Author: gkaplan@atauni.edu.tr
(G KAPLAN Orcid: 0000-0001-6067-7337)

Received 18 Dec 2020 Revised 18 Jan 2021 Accepted 18 Jan 2021
Cement Based Composites 2 (2020) 26–34
2717-9303 © 2019 ACA Publishing. All rights reserved.

<https://doi.org/10.36937/cebacom.2020.002.005>

development of waste, if this isn't accomplished, limiting the waste, at the end of the day limiting the waste. In the event that the reuse of the waste is, at that point unrealistic, it is gone for first reusing and afterward vitality recuperation. After these methods, the last treatment to the waste we have or the waste we cannot apply is disposed of [5].

Figure 1. The Waste Management Pyramid [6]

2. Recycling in Concrete Industry

The concrete amount of two billion m^3 was consumed in the world in 2002 and it is expected to be consumed approximately 7.5 billion m^3 in 2050. Construction sector; it supplies fifty percent of its rare material naturally, devours forty percent of the energy total and causes fifty percent of the waste total. Most of wastes causing environmental pollution are caused by structural construction wastes.

Approximately 40% of the structural construction wastes are concrete wastes. However, aggregates constitute about 55-80% of concrete. Natural aggregates, which are the most important raw materials of the construction sector with a wide area, are consumed approximately 8-12 billion tons every year in the world. This has brought about the need for alternative aggregate sources [7].

13-29% by volume and solids of solid wastes; waste of construction formed throughout the demolition and construction of residential, commercial and public buildings, roads, bridges.

This rate increases up to 50% as a result of natural disasters such as earthquakes, storms and floods. This amount of solid waste is 180 million tons per year in European Community countries, 30 million tons in Germany and 136 million tons in the USA. According to 2005 data, the amount of solid waste has been determined that the annual 38 million tons. Accordingly, it is seen that the construction debris wastes corresponding to 25% of the total solid waste amount is approximately 10 million tons.

Between 1990 and 1995, the amount of solid waste produced in Europe increased by 10%. According to the estimates of the Development and Co-operation Economic Organization, in 2020, 45% more waste will be produced than in 1995. 40% of these wastes are concrete, 30% are ceramics, 10% are wood, 5% are metal, 5% are plastic and the remaining 10% are other materials [8,9].

3. Recycling Properties

Solid blends delivered with reused concrete are by and large created by techniques delivered with characteristic total. In any case, more noteworthy water ingestion of the recuperated total ought to be considered when deciding the unit water content. In the blend of reused concrete and distinctive solid classes to be created, standard deviations higher than the proposed objective quality ought to be considered when deciding the trademark compressive quality of the solid. [10]

At the point when normal sand and recycled coarse aggregate total are utilized together, the water/cement proportion required for the necessary compressibility will be in the extents in traditional concrete. For similar droop esteem, the water substance of the recycled aggregate ought to be 5% higher than that of traditional concrete. For the solid to be created with recycled aggregate, the sand-total proportion ought to be a similar proportion as the utilization of normal total. So as to acquire the necessary functionality and the water/cement proportion of the recycled aggregate, it is important to make fitting change and preliminary blends, contingent upon the properties and wellspring of the recycled aggregate [11,12].

Regardless of whether totals from development and destruction squanders can be utilized rather than regular totals or in which zones of the development business can be utilized relies upon whether the material consents to the necessary specialized particulars. In this segment, specialized properties are given and properties of regular total and recouped totals and cements got from them are looked at [13].

3.1. Physical Properties

3.1.1. Particle size distribution

In this research, 14 laboratory specimens in two concrete debris from construction and demolition is generally turned into fine and coarse aggregates after two-stage crushing and sieving. In general, successive series of crushers are used. Concrete wastes, which are made into 50 mm pieces by the first crushing process, are reduced to 15-20 mm by the second crushing process. During the crushing process, brick materials should be crushed considering that they will produce too much thin material compared to normal aggregate and concrete [14].

Some investigators have shown that mortar bar expansion continues as the reactive layer size of reactive silica reconciliations decreases, but the size at which the size drops to 20 μm does not increase in the same way. They stated that expansion was postponed when large aggregate particles were used. They only establish the first stage of expansion of the concrete in reactive fine reconciliation and indicate that it remains constant in the future [15].

On the other hand, in areas where reactive aggregates are made only coarsely, expansion occurs slowly and over a longer period of time. While the aggregate size for aggregate is between 0.15 and 10 mm, it shows that as the aggregate size decreases, expansion increases. As the aggregate size increases, the cement/aggregate ratio giving maximum expansion decreases. It can be said that the use of unidimensional reconciliation gradation in the slow progression of expansions when the aggregate size increases is more advantageous there with expansion [16].

3.1.2. Density

The density value of 2450 kg/m^3 for recycled aggregate, for recycled coarse and fine aggregate values of 2100 kg/m^3 to 2300 kg/m^3 , thin or coarse natural and 2600 kg/m^3 for the aggregate. For the surface dry recycled aggregate 2487 kg/m^3 , for recycled aggregate; 2411 kg/m^3 values for surface dry natural aggregate; 2622 kg/m^3 for oven dry natural aggregate; 2594 kg/m^3 unit weight values were measured. The density of mixed demolition occurring in natural disasters is around 850-1400 kg/m^3 . The types of recycled aggregate classified are divided into 3 types. Accordingly, density values for saturated dry surface aggregates are 1500 kg/m^3 for Type 1 (aggregates from masonry residues), 2000 kg/m^3 for form two (concrete aggregates residues) and Type 3 (regular+recycled aggregate). Aggregates make up about 80% of the concrete mixture [17,18].

The specific gravity of recycled aggregate obtained from different waste sources may be different from each other. However, the density of both recycled aggregates and concretes produced from them is minor than the aggregates of natural and concretes produced with natural aggregates [19].

3.1.3. Water absorption

As per the high pace of water absorption of waste solid totals because of the pertinence of new solid creation is low. Water absorption rate was gotten from 1.63% to 1.65%. The water absorption estimations of coarse and fine recycled totals somewhere in the range of 3.17% and 10.3%. These qualities are somewhere in the range of 0.5% and 1% for normal totals. As needs be, coarse and fine-grained reused concrete has higher water retention limit than common totals [20].

The water absorption limit is most elevated for the reused mortar total, attributable to the profoundly permeable nature of the mortar. Moreover, the nearness of a lot of porosity prompts lower esteems for the particular gravity and the most elevated rate increment in estimation of the obvious explicit gravity over the particular gravity, based on the immersed surface-dry condition [21].

Then again, rock has the most noteworthy incentive for explicit gravity and least incentive for the water absorption limit and the expansion of clear explicit gravity over the particular gravity. Since the reused solid totals for the most part comprise of stone and some fortified old mortar, the qualities for the particular gravity and water absorption limit are between those for rock and reused mortar totals [22].

3.2. Mechanical Properties

3.2.1. Compressive Strength

Compressive quality for concrete made of normal totals; While around 32.5 MPa, the compressive quality of cement made with 100% recycled aggregate was acquired around 18 MPa. Numerous specialists have examined the utilization of recycled aggregate at ideal rate by blending regular total in with recycled aggregate. It has been discovered that the compressive quality declines essentially with the pace of recycled aggregate surpassing half [23,24]

The appropriate ratio of water in the mixture by using the combined recycled and natural aggregate concrete produced by using higher compressive strength values than the original. As high as 0.6-0.75 w/c ratio, the concrete strength value produced by reprocessed concrete reached a value of the reference concrete even when the share of recycled aggregate in the mixture increased to 75%. It has been determined that it may have compressive strength comparable with reference concrete when exceeding 0.55. The parameters considered are the age of the sample, cement, water, sand, aggregate, recovered aggregate, superplasticizer and silica fume [25].

Strength sturdiness, and execution is influenced by the compressive strength of cement, in this way, turning into a first among the best properties of solidifying of cement. Properties relies upon different factors, for example, properties of followed mortar, water bond proportion, different kinds of admixtures, blending approach and various properties [26].

At the point when the w/c ratio proportion is kept to be consistent and sum is expanded it was seen that there was a decline in compressive strength up to 10% lower in contrast with characteristic reference concrete. When there is the substitution of common total by 25% it was seen that compressive strength stays unaffected by this reason [27].

This unconcerned conduct might be because of good control of recycling aggregate concrete evaluating to a bigger substance. It was

seen that when 100% substitution of recycling aggregate concrete is done in concrete there is half increment in standard deviation [28].

3.2.2. Flexural strength

In considers directed to measure bending quality, lower bowing quality estimations of concrete made with recycled aggregate are gotten than those made with common totals. The bending quality of the solid delivered with recycled aggregate was 10% lower than the reference concrete on day 28. Some measure of tile and block cracks recouped concrete delivered by the bending quality of the solid diminished by 9% to 22% discovered that ordinary concrete [29].

One more reason that influences the auxiliary execution of concrete is a flexural strength. It depends upon w/c ratio, recycled total solid substitution proportion, replace of cement and wetness state of total. With the alteration in recycled aggregate substitution extent of reusing total concrete, the flexural strength has been spotted to diminish [30,31].

The ordinary concrete has 6 to 13% more flexural strength at that point recover total framed with 25% and half reusing total. When reusing total was supplanted (100%) to make reusing total 26% less flexural strength was recorded as identified with that of standard cement. This is essentially a direct result of the poor interfacial holding among new and old bond binder covering reusing total [32,33].

3.2.3. Modulus of elasticity

Recycled aggregate elasticity is around 70% of normal concrete and the w/c ratio or impurities in the concrete, stated that a remarkable effect. According to the reference concrete produced elasticity modulus, 7% and 28% on the 28th day were determined to be lower than 17.60% [34].

More experimental data is needed before reaching conclusions in this area since elasticity module is a critical parameter for applications. 90 days waited for the shrinkage value of concrete produced; 0.55 mm/m to 0.80 mm/m measured, whereas the shrinkage value of concrete produced with natural aggregate; 0.30 mm/m. According to this, it can be said that the shrinkage value of the concrete produced will increase [35].

3.2.4. Splitting Tensile Strength

By and large, the circuitous strategy is utilized to acquire the tensile quality of concrete. The splitting tensile test is one of the most well-known backhanded strategies for assessment of tensile quality. w/c ratio, recycled total solid quality, blending material, recycled total solid substitution, test age, kind of bond are different factors on which tensile quality of recycled totals are depends [36].

With the extension recycled aggregate substitution extent splitting tensile quality, is found to diminish. When recycled aggregate was supplanted in concrete at 100%, half and 25% the splitting tensile will in general lessening at 40%, 10% and 6% separately. Getting the above truth, it was watched, when the variety proportion is up to 30% the tensile property of recycled aggregate is the equivalent and some of the time surpasses the tensile quality of new concrete [37,38].

3.3. Durability Properties

3.3.1. Sulfate Resistance

Past investigations concentrated on the mechanical or microstructural qualities of geopolymer and recycled aggregate

concrete. It was discovered that the blend of geopolymer and recycled aggregate concrete not just gives a significant improvement of the inner network of recycled aggregate, yet in addition diminishes natural effect, totally advancing the advancement of recycled development materials. Notwithstanding, it ought to be referenced that exceptionally restricted data is accessible on the toughness parts of geopolymer and recycled aggregate concrete, particularly concerning its sulfate opposition [39].

Table 1. Study on sulfate resistance

Author	Aggregate Type	Aggregate Ratio (%)	Sulfate Conditions - Time
Bulatovic et al. [40]	Course Aggregate (4/8-8/16)	%100	%5 Na ₂ SO ₄ - MgSO ₄ (365 Days)

It is obvious that concretes with recycled concrete aggregate (RCA) are more sensitive to sulfate aggression than concretes with natural aggregate, but the sulfate resistance of concrete with RCA can be achieved if RCA fulfills quality requirements given in EN 206 and if proper cement type is used (i.e. CEM III LH/SR) [40]. Evaluation of sulfate resistance of concrete with recycled and natural aggregates

Table 2. Performance evolution of the interfacial transition zone

Author	Aggregate Type	Aggregate Ratio (%)	Sulfate Conditions - Time
Zhang et al. [41]	Course Aggregate (5-25)	%100	%5 Na ₂ SO ₄ (280 Days)

Under external sulfate attacks coupled with dry-wet cycling, the concentration of sulfate ions at the same erosion depths is higher in recycled aggregate than in natural aggregate; after a 280-day exposure, the concentration ingredient along the erosion depth is slightly sharper in recycled aggregate than in natural aggregate. Basically, the erosion products are the same in recycled aggregate and natural aggregate, including mainly Aft, gypsum, and thenardite [41]. Performance evolution of the interfacial transition zone (ITZ) in recycled aggregate concrete under external sulfate attacks and dry-wet cycling

Truth be told, sulfate attack is one of the primary toughness issues for concrete structures, particularly concrete in situations with sulfate particles. The entrance of sulfate particles adds to the arrangement of ettringite and splits when a basic pressure, created by the extension power of ettringite, is come to. In this manner, sulfate assault could cause spalling, breaking, and diminished quality of concrete structures [42].

The sulfate damage was additionally answered to be more regrettable in recycled aggregate, contrasted with standard concrete, when a high substance of recycled aggregates was utilized. Along these lines, how to counteract or decrease the harm of sulfate assault to concrete structures and improve the sulfate consumption obstruction of recycled concrete has stimulated across the board concern. A couple of studies have demonstrated that geopolymer can give a superior sulfate protection from normal concrete [43].

Xie et al. fly ash based geopolymer in Na₂SO₄ solution for one year and found that the compressive strength quality of the examples expanded constantly. Hardjito et al. likewise announced comparable

trial results. It is noticed that no significant work has been performed on the sulfate effect of geopolymer and recycled aggregate concrete [44,45].

3.3.2. Freezing and Thawing Resistance

Freeze and thaw are regularly utilized as another assessment record of solid solidness. The ice formation of concrete can be reflected by estimating the dynamic elastic modulus, weight reduction rate, and quality loss rate after introduction to solidify thaw cycles. For the most part, this property is principally influenced by porosity, water content, ecological conditions and total sorts [46].

Recycled aggregate concrete with recycled aggregate particles may diminish the ice opposition on the grounds that the retained water can deplete into concrete glue during freezing and thawing cycles. Consequently, recycled aggregate concrete normally has frail ice opposition and isn't suggested for use in an unforgiving domain. In any case, Salem et al. indicated that recycled aggregate concrete with a w/c proportion underneath 0.5 and joining 5% air substance can even now be utilized in unsaturated and moderate virus atmospheres [47].

Table 3. Study on freezing and thawing resistance

Author	Aggregate Type	Aggregate Ratio (%)	Freeze and Thaw Conditions - Cycle
Šeps et al. [48]	Course Aggregate	100	EN 1322- 50

Recycled concrete aggregate resistance to freezing and thawing was performed by several methods. The recycled concrete aggregate was used for making of fiber reinforced concrete and the freeze thaw resistance and resistance to deicing salts were tested. Conclusions are drawn and proposals made for application of the fiber reinforced concrete with recycled aggregate [48]. Resistance of recycled aggregate concrete to freeze-thaw and deicing salts.

Figure 2. Surface of specimen (a) before testing; (b) after 25 cycles; (c) after 50 cycles of freezing and thawing [48]

Like natural aggregate concrete, the compressive strength quality, parting rigidity and flexural quality of recycled aggregate concrete diminishes with an expansion of freezing and thawing cycles, the mass loss expanded and the relative elastic modulus diminished when solid examples are exposed to freezing and thawing cycles. Wu et al. considered the uniaxial compressive pressure strain relationship of coarse recycled aggregate concrete subsequent to solidifying and defrosting cycles [49].

The explanation is that the higher the porosity and water absorption of recycled aggregate concrete, the higher the water absorption capacity. Hence, a higher water absorption and immersion level of water in recycled aggregate prompts the lower ice opposition of recycled aggregate concrete. Notwithstanding, when the water immersion degree is under 91.7%, the solid may not be exposed to

freezing and thawing harm. In this way, the ice damage of recycled aggregate concrete can be improved by reducing the measure of mixing water or decreasing the water immersion of the examples [50].

3.3.3. Acid Resistance

Acids in the water draining into the recycled aggregate concrete cause chemical events that cause the concrete to expand and become damaged. The effect of acids in concrete is called acid attack. Acids form calcium salts, which are soluble or insoluble from cement paste components by ion exchange. In addition, when magnesium salts come into contact with cement paste, magnesium replaces calcium in the gel, which loses its binding value [51].

The effect of acids on recycled aggregate concrete develops as calcium compounds (CH, CSH and CAH) are converted into calcium salts of the attacking acid. Since calcium salts dissolve slowly or quickly in water, the recycled aggregate concrete mortar dissolves over a period of time and the concrete are destroyed. As a result of acid attack, the calcium hydroxide and calcium silica hydrate gels in the hardened concrete have dissolution and form a soft thin layer on the concrete surface and the recycled aggregate concrete becomes more porous and its strength and durability are less [52].

Table 4. Study on acid resistance

Author	Aggregate Type	Aggregate Ratio (%)	Acid Resistance
Rao et al. [53]	Quaternary Blended Cement Concrete (QBCC) of two grades M40 and M60	Fly ash and silica fume are fixed at 20% and 10% respectively with 2% of Nano silica	Two different acids (HCL and H ₂ SO ₄) with different concentrations (3 and 5%)

Acid resistance of QBCC with Recycled Concrete Aggregate is assessed in terms of visual appearance, weight loss, and compressive strength loss by destructive and non-destructive tests at regular intervals for a period of 56 days. The test results showed marginal weight loss and strength loss in both M40 and M60 grades of concretes. The Ultrasonic Pulse Velocity (UPV) results show that the quality of QBCC is good even after being subjected to acid exposure [53]. Acid resistance of quaternary blended recycled aggregate concrete

3.3.4. High Temperature Effect

Recycled aggregate concrete is a material resistant to high temperature and fire effect compared to many building materials. In general, recycled aggregate concrete can withstand certain temperatures (~ 250 °C) at certain times. The parameters that affect the high temperature resistance of the recycled aggregate concrete structural element are the thickness of the rust share layer, the resistance to penetration of the flame and its resistance to heat transfer. Load carrying capacity and loading level of the element are also important factors [54].

When it is considered as concrete alone, it is seen that high temperature causes decomposition and shell pouring on the outer surfaces. The formation of cracks in recycled aggregate concrete elements is mostly seen in joints, well-compacted areas of concrete and areas where reinforcements are present. Especially in cases where the rust allowance is kept low and the reinforcement is exposed, the steel transfers heat very well and increases the degree of damage [55].

Depending on the heat, the hydrated cement loses water and dehydrates. In recycling concrete, hydrated elements lose water in

their structures at certain temperatures. This dehydration causes a significant decrease in the strength of the structure [56].

Table 5. Study on high temperature effect

Author	Aggregate Type	Aggregate Ratio (%)	High Temperature
Zega et al. [57]	recycled concretes (RCs)	75% by volume of recycled coarse aggregate (crushed waste concretes)	500°C

The concretes were evaluated by ultrasound and resonance frequency, and further determination of the static elastic modulus and compressive strength was possible. In all cases the parameters evaluated in concretes exposed to high temperatures are lower than in others with the same characteristics and without any type of processing. For exposure to 500°C for 1 h, the recycled aggregate concrete with a low w/c ratio performs better than the reference concrete [57]. Recycled concrete exposed to high temperatures

3.3.5. Abrasion Resistance

Abrasion resistance is the ability of a surface to withstand abrasion as a result of friction. Abrasive wear is the loss of mass due to the dry friction effect of concrete surfaces (floor, floor concrete, step, road concrete, etc.). Generally, concrete with high compressive strength is also resistant to abrasion. However, recycled aggregate concrete should be preferred according to the friction conditions. Other measures use abrasion resistant recycling aggregates to produce recycling concrete (low w/c ratio ratio) using friction reducing additives or paint, using surface hardening materials on the concrete surface [58].

Erosion is the abrasion of abrasive materials by drawing the surface of concrete, especially at high speeds, with liquids containing suspended particles. This phenomenon is more common in water structures and concrete pipes. The severity of the effect depends on the amount, shape, hardness and flow rate of the solid particles [59].

In addition to abrasion, cavitation insects, which occur in dams, weirs, tunnels and concrete in some water-bearing systems, are also related to abrasion. Cavitation in recycled aggregate concrete is caused by a sudden change in the direction of flow of rapidly flowing water (liquids). Any change in surface geometry of water structures in which water flows rapidly disrupts the continuity of the flow, resulting in low pressure zones. If the static pressure of the flowing water is lower than the vapor pressure in the water, bubbles are formed in this region [60].

Table 6. Study on abrasion resistance

Author	Aggregate Type	Aggregate Ratio (%)	Abrasion
De Brito [61]	recycled concretes	100%	----

It is concluded that there is no loss of abrasion resistance with the incorporation of RAs and that there are reasons to believe that it even improves, even though the quantification of that improvement needs further investigation to be accurate [61]. Abrasion resistance of concrete made with recycled aggregates

Figure 2. Two steps of the abrasion resistance test [61]

3.3.6. Carbonation Resistance

The resistance to carbonization of recycled aggregate concrete can be reduced by highly porous or carbonised particles from recycled aggregates before concrete production. It has an accelerated and normal determination of its resistance to carbonation. In order to ensure good balance between the measured and productive bulk density the effects of water absorption must be taken into consideration on the concrete mixing design. No variations were observed in systemic strength and resistance to carbonation between dry and post-produced concrete aggregates. The low w/c needed for CEM III/B concrete to reach the required carbon-resistance limits results in too high compression strength for buildings and a very high cement content, which raises costs. Accelerated carbonation allows for a fair carbon assessment in sheltered settings, but shows a worse correlation with unsheltered carbonation conditions. The above is primarily due to the relatively low carbonation coefficients of CEM III/B concrete [62-64].

3.3.7. Corrosion Resistance

By soaking it with the determined effective soaking time in nano-silica suspension, the corrosion resistance of recycled aggregate concrete can be reduced. The growing trends in the treated micro hardness of the surrounding area and penetration depths of NS particles have demonstrated the high efficiency of the improval properties of models of recycled aggregate concrete by soaking recycled nano silica for 1 hour. As the nano-silica suspension was changed by 1-h, enhanced mechanical properties were achieved: the compressive strength obviously improved; the interfacial transition zone width between the old mortar was decreased and the interfacial transition region increased micro hardness [65].

3.3.8. Microstructure

It is generally accepted that even with low w/c in concretes made of natural aggregate, the interface transition zone (ITZ) between aggregate and cement paste has a complex structure. In this structure, $\text{Ca}(\text{OH})_2$ crystals are formed perpendicular to the surface of the aggregate grains and this causes the formation of a highly porous structure in the ITZ due to the accumulation of water films close to the aggregate surface [66-68]. Some studies of concretes using recycled aggregate have also shown the weaker ITZ between cement paste and aggregate [69]. In concretes using recycled aggregate, ITZ has a more complex structure. Even if new concrete is designed with lower w / c, ITZ between the recycled aggregate and the paste can lead to a loss of strength. Because $\text{Ca}(\text{OH})_2$ crystals still tend to form in small pores where water is easily absorbed. It has been proven by SEM analysis that ITZ improves with the use of pozzolan in concretes using recycled aggregate [70].

4. Results

In this examination, the properties and the reuse conceivable outcomes of the reused concrete and the solid made with them are analyzed.

By and large; It has been resolved that the solid made with reused totals can be utilized in lower solid applications. The reuse and recuperation of solid squanders from development and destruction squanders can give numerous ecological and financial advantages. These days' development and destruction squanders are substantially more-costly than the expenses of reusing and transfer of landfills because of different assessments.

Coarse and fine-grained recycled aggregate concrete has higher water absorption limit than common totals. Recycled aggregate concrete for the most part decreases the modulus of elastic and quality of concrete. The shrinkage estimation of the solid delivered with reused solid increments. Recycled aggregate concrete diminishes the adherence of cement. The stop defrost obstruction of the solid created with reused solid declines, yet is generally improved by the entraining added substance [50,67].

There are a few constraining obstructions to the utilization of totals recouped from development and destruction squander. These are: (i) Relatively low expenses of landfills and landfills, low duties around there, and reasonable normal totals contrasted with totals recouped from development and destruction squander. (ii) Retaining determinations for structural building. (iii) Lack of approaches that constrain the undertaking proprietors and developers to utilize suitable pieces of the recuperated totals in their tasks. (iv) Lack of data on the exhibition of recouped totals by specialized faculty working in the development business [51].

Issues which are viewed as counteracting the reuse of reused solid squanders ought to be understood. As needs be, can be a coercive measure to build the capacity expenses and duties. Beginning from the common focuses, the foundation of development squander reusing offices can be supported. Some monetary favorable circumstances might be given to manufacturers to support the utilization of these materials. In addition, durability is also a very important issue, except for the use of industrial waste in concrete. Many studies are being carried out to increase the durability of concrete [71,72].

Determinations ought to be set down which figure out which sort of solid waste can be utilized in which development works. Gatherings and meetings about the properties of totals can be composed for the developers. The utilization of a specific measure of reused total might be made necessary in their undertakings [52,66].

According to the results of the experiments in fresh and hardened concrete series produced with natural and recycled aggregate;

The air content of the recycled aggregate concrete series did not differ significantly from that of the normal aggregate concrete series. However, the process losses are higher in recycled aggregate concrete series.

The compressive strength of recycled aggregate concrete series is about 3-7% lower than that of natural aggregate concrete. This decrease increases as the amount of recovered aggregates increases.

Recycled aggregate concrete series has higher splitting tensile strength on day 28 than natural aggregate concrete. As the amount of recycled aggregates increases, splitting tensile strengths improve.

The adherence strength of the concrete produced with recycled aggregate is higher than that of natural aggregate concrete series.

Declaration of Conflict of Interests

The authors declare that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- [1.] Oikonomou, N.D., Recycled concrete aggregates. *Cement and concrete composites* 27(2) (2005) 315-318.
- [2.] Evangelista, L., & de Brito, J., Mechanical behaviour of concrete made with fine recycled concrete aggregates. *Cement and concrete composites*, 29(5)(2007)397-401.
- [3.] Tabsh, S.W., & Abdelfatah, A.S., Influence of recycled concrete aggregates on strength properties of concrete. *Construction and Building Materials* 23(2) (2009) 1163-1167.
- [4.] Evangelista, L., & De Brito, J., Durability performance of concrete made with fine recycled concrete aggregates. *Cement and Concrete Composites* 32(1) (2010) 9-14.
- [5.] De Juan, M. S., & Gutiérrez, P.A., Study on the influence of attached mortar content on the properties of recycled concrete aggregate. *Construction and Building Materials* 23(2)(2009) 872-877.
- [6.] Lukinović, M., Stamenković, B., & Jovanović, L., Green Economy and Waste Management Goals. *zazovi Zelene Ekonomije*, 185.
- [7.] Kou, S. C., & Poon, C.S., Properties of self-compacting concrete prepared with coarse and fine recycled concrete aggregates. *Cement and Concrete composites* 31(9) (2009) 622-627.
- [8.] McNeil, K., & Kang, T.H.K., Recycled concrete aggregates: A review. *International Journal of Concrete Structures and Materials* 7(1) (2013) 61-69.
- [9.] Paranavithana, S., & Mohajerani, A., Effects of recycled concrete aggregates on properties of asphalt concrete. *Resources, Conservation and Recycling*, 48(1) (2006) 1-12.
- [10.] Poon, C.S., & Chan, D., Feasible use of recycled concrete aggregates and crushed clay brick as unbound road sub-base. *Construction and building materials* 20(8) (2006) 578-585.
- [11.] Ferreira, L., De Brito, J., & Barra, M., Influence of the pre-saturation of recycled coarse concrete aggregates on concrete properties. *Magazine of Concrete Research* 63(8) (2011) 617-627.
- [12.] Nagataki, S., Gokce, A., Saeki, T., & Hisada, M., Assessment of recycling process induced damage sensitivity of recycled concrete aggregates. *Cement and concrete research* 34(6) (2004) 965-971.
- [13.] Topcu, İ.B., & Şengel, S., Properties of concretes produced with waste concrete aggregate. *Cement and concrete research* 34(8) (2004) 1307-1312.
- [14.] Yong, P.C., & Teo, D.C.L., Utilisation of recycled aggregate as coarse aggregate in concrete. *Journal of Civil Engineering Science and Technology* 1(1) (2009) 1-6.
- [15.] Lin, Y.H., Tyan, Y.Y., Chang, T.P., & Chang, C.Y., An assessment of optimal mixture for concrete made with recycled concrete aggregates. *Cement and concrete research* 34(8) (2004) 1373-1380.
- [16.] Jo, B.W., Park, S.K., & Park, J.C. Mechanical properties of polymer concrete made with recycled PET and recycled concrete aggregates. *Construction and Building Materials* 22(12) (2008) 2281-2291.
- [17.] Manzi, S., Mazzotti, C., & Bignozzi, M.C., Short and long-term behavior of structural concrete with recycled concrete aggregate. *Cement and Concrete Composites* 37 (2013) 312-318.
- [18.] Kou, S.C., & Poon, C.S., Properties of concrete prepared with PVA-impregnated recycled concrete aggregates. *Cement and Concrete Composites* 32(8) (2010) 649-654.
- [19.] Mills-Beale, J., & You, Z., The mechanical properties of asphalt mixtures with recycled concrete aggregates. *Construction and Building Materials* 24(3) (2010) 230-235.
- [20.] Akbarnezhad, A., Ong, K.C.G., Zhang, M.H., Tam, C.T., & Foo, T.W.J., Microwave-assisted beneficiation of recycled concrete aggregates. *Construction and Building Materials* 25(8) (2011) 3469-3479.
- [21.] Pereira, P., Evangelista, L., & De Brito, J., The effect of superplasticizers on the workability and compressive strength of concrete made with fine recycled concrete aggregates. *Construction and Building Materials* 28(1) (2012). 722-729.
- [22.] Poon, C. S., & Chan, D., Effects of contaminants on the properties of concrete paving blocks prepared with recycled concrete aggregates. *Construction and Building Materials* 21(1) (2007) 164-175.
- [23.] Rakshvir, M., & Barai, S.V. Studies on recycled aggregates-based concrete. *Waste Management & Research*, 24(3) (2006) 225-233.
- [24.] Pedro, D., De Brito, J., & Evangelista, L., Influence of the use of recycled concrete aggregates from different sources on structural concrete. *Construction and Building Materials* 71 (2014) 141-151.
- [25.] Nazarimofrad, E., Shaikh, F.U.A., Nili, M., Effects of steel fibre and silica fume on impact behaviour of recycled aggregate concrete. *Journal of Sustainable Cement-Based Materials* 6 (2017)54-68
- [26.] Courard, L., Michel, F., & Delhez, P., Use of concrete road recycled aggregates for roller compacted concrete. *Construction and building Materials* 24(3) (2010) 390-395.
- [27.] Marie, I., & Quisrawi, H., Closed-loop recycling of recycled concrete aggregates. *Journal of Cleaner Production* 37 (2012) 243-248.
- [28.] Sagoe-Crentsil, K.K., Brown, T., & Taylor, A. H., Performance of concrete made with commercially produced coarse recycled concrete aggregate. *Cement and concrete research* 31(5) (2001) 707-712.
- [29.] Abbas, A., Fathifazl, G., Isgor, O.B., Razaqpur, A.G., Fournier, B., & Foo, S., Proposed method for determining the residual mortar content of recycled concrete aggregates. *Journal of ASTM International* 5(1) (2007) 1-12.
- [30.] Khatib, J. M., Properties of concrete incorporating fine recycled aggregate. *Cement and concrete research* 35(4) (2005) 763-769.
- [31.] Pepe, M., Toledo Filho, R. D., Koenders, E. A., & Martinelli, E., Alternative processing procedures for recycled aggregates in structural concrete. *Construction and Building Materials* 69 (2014) 124-132.
- [32.] Xuan, D., Zhan, B., & Poon, C.S., Assessment of mechanical properties of concrete incorporating carbonated recycled

- concrete aggregates. *Cement and Concrete Composites* 65 (2016) 67-74.
- [33.] Poon, C.S., Shui, Z.H., & Lam, L., Effect of microstructure of ITZ on compressive strength of concrete prepared with recycled aggregates. *Construction and Building Materials* 18(6) (2004) 461-468.
- [34.] Ravindrajah, R.S., Loo, Y.H., & Tam, C.T., Strength evaluation of recycled-aggregate concrete by in-situ tests. *Materials and Structures* 21(4) (1988) 289-295.
- [35.] Etxeberria, M., Vázquez, E., Marí, A., & Barra, M., Influence of amount of recycled coarse aggregates and production process on properties of recycled aggregate concrete. *Cement and concrete research* 37(5) (2007) 735-742.
- [36.] Rao, A., Jha, K.N., & Misra, S., Use of aggregates from recycled construction and demolition waste in concrete. *Resources, conservation and Recycling* 50(1) (2007) 71-81.
- [37.] Hansen, T. C., & Narud, H. (1983). Strength of recycled concrete made from crushed concrete coarse aggregate. *Concrete International*, 5(1), 79-83.
- [38.] Padmini, A. K., Ramamurthy, K., & Mathews, M.S., Relative moisture movement through recycled aggregate concrete. *Magazine of concrete research* 54(5) (2002) 377-384.
- [39.] Elhakam, A.A., Mohamed, A.E., & Awad, E., Influence of self-healing, mixing method and adding silica fume on mechanical properties of recycled aggregates concrete. *Construction and Building Materials* 35 (2012) 421-427.
- [40.] Bulatović, V., Melešev, M., Radeka, M., Radonjanin, V., & Lukić, I., Evaluation of sulfate resistance of concrete with recycled and natural aggregates. *Construction and Building Materials* 152 (2017) 614-631.
- [41.] Zhang, H., Ji, T., & Liu, H., Performance evolution of the interfacial transition zone (ITZ) in recycled aggregate concrete under external sulfate attacks and dry-wet cycling. *Construction and Building Materials* 229 (2019) 116938.
- [42.] Zhao, Z., Remond, S., Damidot, D., & Xu, W., Influence of fine recycled concrete aggregates on the properties of mortars. *Construction and Building Materials* 81 (2015) 179-186.
- [43.] Gómez-Soberón, J.M., Porosity of recycled concrete with substitution of recycled concrete aggregate: An experimental study. *Cement and concrete research* 32(8) (2002) 1301-1311.
- [44.] Xie, J., Zhao, J., Wang, J., Wang, C., Huang, P., & Fang, C., Sulfate Resistance of Recycled Aggregate Concrete with GGBS and Fly Ash-Based Geopolymer. *Materials* 12(8) (2019) 1247.
- [45.] Sumajouw, D.M., Hardjito, D., Wallah, S.E., & Rangan, B.V., Fly ash-based geopolymer concrete: an application for structural members. In *Proceedings of the Geopolymer World Congress: Green Chemistry and Sustainable Development Solutions* (2005) 149-152).
- [46.] Zhang, J., Shi, C., Li, Y., Pan, X., Poon, C. S., & Xie, Z., Performance enhancement of recycled concrete aggregates through carbonation. *Journal of Materials in Civil Engineering* 27(11) (2015) 04015029.
- [47.] Limbachiya, M. C., Leelawat, T., & Dhir, R.K. Use of recycled concrete aggregate in high-strength concrete. *Materials and structures* 33(9) (2000) 574.
- [48.] Šeps, K., Fládr, J., & Broukalová, I., Resistance of recycled aggregate concrete to freeze-thaw and deicing salts. *Procedia Engineering* 151 (2016) 329-336.
- [49.] Wu, J., Jing, X., & Wang, Z., Uniaxial compressive stress-strain relation of recycled coarse aggregate concrete after freezing and thawing cycles. *Construction and Building Materials* 134 (2017) 210-219.
- [50.] Engelsen, C. J., van der Sloot, H. A., Wibetoe, G., Petkovic, G., Stoltenberg-Hansson, E., & Lund, W. Release of major elements from recycled concrete aggregates and geochemical modelling. *Cement and Concrete Research* 39(5) (2009) 446-459.
- [51.] Gonçalves, P., & de Brito, J., Recycled aggregate concrete (RAC)-comparative analysis of existing specifications. *Magazine of Concrete Research* 62(5) (2010) 339-346.
- [52.] De Brito, J., Robles, Recycled aggregate concrete (RAC) methodology for estimating its long-term properties. *Recycled aggregate concrete (RAC) methodology for estimating its long-term properties* 17 (2010) 449-462.
- [53.] Rao, K. J., Keerthi, K., & Vasam, S. Acid resistance of quaternary blended recycled aggregate concrete. *Case studies in construction materials* 8 (2018) 423-433.
- [54.] Hansen, T.C., *Recycling of demolished concrete and masonry* (1992) CRC Press.
- [55.] Montgomery, D.G. Workability and compressive strength properties of concrete containing recycled concrete aggregate. In *Sustainable Construction: Use of Recycled Concrete Aggregate: Proceedings of the International Symposium, London, (1998)* 287-296 Thomas Telford Publishing.
- [56.] Katz, A., Properties of concrete made with recycled aggregate from partially hydrated old concrete. *Cement and concrete research* 33(5) (2003) 703-711.
- [57.] Zega, C.J., & Di Maio, A.A., Recycled concrete exposed to high temperatures. *Magazine of Concrete Research* 58(10) (2006) 675-682.
- [58.] Spaeth, V., & Tegguer, A.D., Improvement of recycled concrete aggregate properties by polymer treatments. *International Journal of Sustainable Built Environment* 2(2) (2013) 143-152.
- [59.] Rahal, K., Mechanical properties of concrete with recycled coarse aggregate. *Building and environment* 42(1) (2007) 407-415.
- [60.] Gokce, A., Nagataki, S., Saeki, T., & Hisada, M. Identification of frost-susceptible recycled concrete aggregates for durability of concrete. *Construction and building materials* 25(5) (2011) 2426-2431.
- [61.] De Brito, J., Abrasion resistance of concrete made with recycled aggregates. *International Journal of Sustainable Engineering* 3(1) (2010) 58-64.
- [62.] Ozturk, A. U., & Kaplan, G., A study of some durability properties of mortars with white cement and Portland cement. *Revista Romana De Materiale-Romanian Journal of Materials* 47(3) (2017) 315-321.
- [63.] Bayraktar, O.Y., Citoglu, G.S., Belgin, C. M., Cetin, S., & Cetin, M., Investigation of effect of brick dust and silica fume on the properties of portland cement mortar. *Fresenius Environmental Bulletin* 28(11) (2019) 7823-7832.
- [64.] Leemann, A., & Loser, R., Carbonation resistance of recycled aggregate concrete. *Construction and Building Materials* 204 (2019) 335-341.

- [65.] Zeng, W., Zhao, Y., Zheng, H., & Poon, C., Improvement in corrosion resistance of recycled aggregate concrete by nano silica suspension modification on recycled aggregates. *Cement and Concrete Composites* 106 (2020) 103476.
- [66.] Bayraktar, O.Y., The possibility of fly ash and blast furnace slag disposal by using these environmental wastes as substitutes in portland cement. *Environmental monitoring and assessment*, 191(9) (2019) 560.
- [67.] Yaprak, H., Memis, S., & Kaplan, G., Effect of Industrial Wastes as Replacement of Fine Aggregate on Properties of Concrete. *Journak of Science and Engineering Research* 4(12) (2017) 228-235.
- [68.] Prokopski, G. & Halbiniak, J., Interfacial transition zone in cementitious materials. *J. Cem Concr Res* 30 (2000) 579-583.
- [69.] Kou, S.C., Poon, C.S., Enhancing the durability properties of concrete prepared with coarse recycled aggregate. *Construction Building Materials* 35 (2012) 69-76.
- [70.] Kong, D., Lei, T., Zheng, J., Ma, C., Jiang, J. & Jiang, J., Effect and mechanism of surface-coating pozzalanics materials around aggregateon properties and ITZ microstructure of recycled aggregate concrete. *Construction Building Materials* 24 (2010) 701-708
- [71.] Aydin, A.C., Kan, A., Candan, F., Aras, UGH, Öz, A., Sulphate Resistance of Boron Active Belite Cement Concrete. *Cement Based Compoasites* 2(2020) 11-15. <https://doi.org/10.36937/cebacom.2020.001.003>
- [72.] Gupta, R.K., Hassan, A., Komar., S., The Investigation of the Corrosive Effects of Sulphates and Salts on the Concrete and the Study of Environmental Changes on it. *Cement Based Composites* 2(2020) 1-5. <https://doi.org/10.36937/cebacom.2020.002.001>.

How to Cite This Article

Altera,A.Z.A, Bayraktar,O.Y., Bodur,B., and Kaplan G., Investigation of Properties of Concrete Produced with Recycled Aggregates, *Cement Based Compoasites*, 2(2020),26-34. <https://doi.org/10.36937/cebacom.2020.002.005>