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Evaluation of shear behavior of prepared recycled concrete aggregate concrete deep beam

Abeer Hassan Wanas[1], Jasim Jarallah Fahad AL- Kaabi[1], Haider Amer Mushatat[1]
[1] Civil Engineering Department, Mustansiriayah University

ABSTRACT

In this article, the shear behavior of a deep beam made of Recycled Aggregate Concrete (RAC) was analyzed. Rapid urbanization has presented a massive new activity that is necessary to meet the needs of the influx of people. Developments of all types, from housing to infrastructure, necessitate considerable input from both natural and monetary resources. The purpose of this study is to compare the strength and loading capacity of RAC to that of Naturally Aggregate Concrete (NAC). The samples were evaluated at a controlled deformation rate of 2mm/minute in the "Material Testing Laboratory of the Department of Civil Engineering," where this investigation was conducted. The researcher has chosen two different sizes of coarse totals to use throughout this study: those measuring 5mm to 15mm (60.2%) and those measuring 15mm to 25mm (40.3%). In support of her claims, the researcher presents a variety of charts and datasets in the following research. There is an overall drop in strength in the recycled aggregate concrete samples. The load-deflection curves and the techniques are depicted by which the specimens failed. Shear required beams' experimental data and predicted values. This study reveals that compared to natural aggregate concrete, recycled aggregate concrete has weaker compressive, flexural, and breaking tensile strengths. The maximum load-bearing strength of longitudinally supported beams built of "recycled and natural aggregate concrete" is also not significantly different.

Keywords: Shear behaviour, infrastructural, natural aggregate concrete

Corresponding Author:

Abeer Hassan Wanas
Civil Engineering Department
Mustansiriayah University
Baghdad, Iraq
Email: abeer_al_rubay@uomustansiriyah.edu.iq

1. Introduction

Rapid urbanization has required massive new construction to keep up with the influx of people. Construction of everything from individual homes to massive infrastructure overhauls uses up a lot of time, money, and raw materials. Since concrete is frequently used in these endeavors, its manufacturing value increases significantly. More than 1.6 billion metric tons of cement and 10 billion metric tons of fine and coarse aggregates are consumed annually in the construction industry around the world. (PK, 2001). This leads to widespread forest loss and soil degradation [1]. Construction and demolition debris, including concrete, brick, and asphalt pavement, account for 30 percent of all garbage in the globe. As a result, there has been a rapid rise in awareness of the importance of recycling to lessen the effects of garbage on the environment generally and global warming specifically. A significant practice that seeks to eliminate waste and protect the environment is the use of "recycled asphalt pavement" (RAP) procured from old pavements and "recycled aggregate concrete" (RAC) procured from old buildings and constructions. There are many different types of materials used in the construction industry [2]. The need for new construction projects must be met, despite the fact that material consumption is a major environmental concern due to the strain it places on natural resources. However, another problem connected to this is the destruction of existing buildings. It may be essential to demolish an old building in order to create a way for a new one, or because its useful life has come to an end. The amount of trash created by these two reasons alone during this deconstruction will be substantial. The garbage known as "construction and demolition waste" is another worldwide issue. (CDW). CDW is widely regarded as Europe's most wasteful corporation. In 2014, the construction industry was responsible for producing 871 million metric tons of garbage [3]. This CDW can be recycled in an effective manner by being used as aggregate in new concrete. Crushing the debris into small enough pieces results in these "recycled aggregates." (RA). The concrete produced with these "recycled aggregates" is known as "recycled aggregate concrete." (RAC). To reap the benefits of this RAC, which include effective waste management and the protection of quarrying sites, it is necessary to evaluate its features and behavior on material and structural levels [4, 5]. Most studies concluded that the mechanical properties were diminished when RCA and RAP were used in place of natural aggregate. Bairagi et al. found that using 50.2% RAC can reduce the robotic aspects of large blends by up to 15.5%, while using 100% RAC can increase that reduction to 40.3%. Hassan et al. found that using RAP aggregates reduces the "tensile" and "compressive strength" of concrete, with the amount of RAP present directly relating to the strength loss. They found that "RAP concrete" combinations, in comparison to the control concrete mixture, exhibited greater adaptability and high-stress power [6-8]. Katkhuda et al. began comparing the tensile resistance of recycled concrete aggregate, natural concrete aggregate, and treated recycled aggregate in 10 full-size reinforced concrete columns. Shear stirrups were not used in the production of RC beams, and either half or all of the aggregate was recycled. Both a 2.0 and 3.0 "shear span-to-depth ratio" (a/d) were used to test the beams. No matter what the "shear span-to-depth ratio" is, the results reveal that beams produced of untreated RCA will have a lower shear capacity than beams made of genuine aggregates. Using treated RCA makes the material stronger when compacted because the acid dissolves the mortar holding the recycled aggregate together. When comparing treated concrete mixtures aggregate to organic or untreated "recycled concrete aggregate," they discovered a marginal improvement in beam shear capacity [9]. Most of the 900 million tonnes of waste produced annually by the construction industry are composed of concrete and other inert materials. The European Union's target of recycling 70.5% of all garbage produced in Europe by 2020 makes recycling an absolute necessity. Once the concrete has been broken, sifted, and any metals removed, it is distributed as gravel or fines. It provides options for using road undercoats in place of "natural aggregates" (NA) as per the standards [10]. A total of nine beams, each with a shear span-to-depth ratio of 4.2%, were tested in two-point bending using a variety of replacement ratios and shear support ratios. There was a noticeable difference in the fracture patterns and failure modes of the "NAC and RAC beams" that lacked shear reinforcement. The NAC beam cracked in a pure diagonal pattern, whereas the RAC beam cracked in an "S" pattern. This "S"-the shaped crack was 45 degrees, whereas the diagonal crack in the "NAC beam" was 30 degrees. For a given quantity of reinforcement, service load deflections did not vary by more than 10% of overall replacement tiers. Normalized shear strength was not significantly different across beams with and without shear reinforcing [8, 11]. Shear and flexure critical specimens were also tested and analyzed. Natural coarse aggregates were crushed limestone, whereas "recycled coarse aggregates" were made from waste residues from a 1920s-era foundation. Although "recycled aggregate" incorporation affected initial stiffness and maximum deflections for flexure critical samples were found to be huge [2, 5], differences in final load capacity for both shear and "flexure critical specimens" were found to be modest.

1.1. Aims and objectives

1. To estimate the tensile strength for recycled aggregate concrete.
2. To determine the “load-carrying capacity” of longitudinally placed RAC beams.
3. To determine the accuracy of strength prediction

1.2. Significance of the study

The large-scale new development has been necessitated by rapid urbanization in order to fulfill the needs of the inflow of people. Since concrete is a common material utilized in these projects, it becomes significant from a production perspective. The study brought forward important findings regarding the RAC which will eventually be used in the construction sector and the efficacy of building materials will increase significantly in terms of strength and loading capacity. This would also help in preventing damage in harsh environments and also an earthquake as shown in Figure 1.

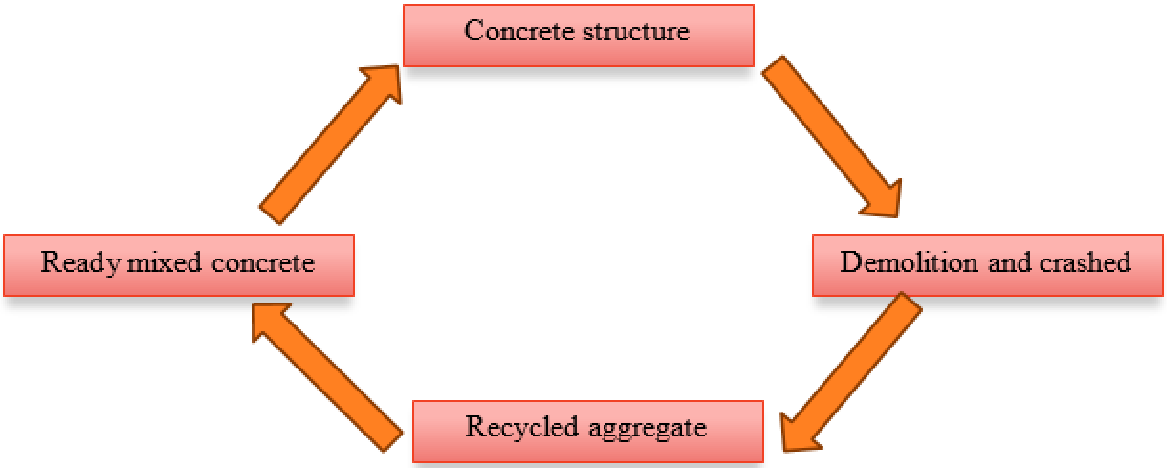

Figure 1. RAC diagram

1.3. Literature review

Several nations have established standards or recommendations in support of the usage of RA and RA concrete as a result of the decades-long study of these materials characteristics. In every instance, it has been demonstrated that replacing NA entirely or in part with recycled alternatives is a practical choice. But there haven't been many studies done in the area of structural behaviour. Early studies on the structural effectiveness of RA were published in Japan [12]. The automated properties of RA concrete were studied by E. Ghorbel et al., who drew on a large database of previously published empirical advances in the literature. According to their observations, adding RA reduces the elastic modulus for a given amount of compressive power since RA has a smaller elastic modulus than NA and needs a larger "volume of RA concrete" paste to maintain the same precise hang. With RA present, "tensile strength" decreases for a certain "compressive strength" [13]. Etxeberria et al. used commercially generated RA to blend sizable batches with "RA replacement ratios" of 25%, 50%, and 100% by volume. Coarse aggregates allowed this to be achieved. We created three "longitudinally reinforced beams," each with a unique "transverse steel shear reinforcement ratio" for each type of concrete. The beams were constructed to break due to shear forces acting at a 45-degree angle. Beams with higher alternate percentages of "NA with RA" had poorer shear load carrying capacity [14, 15], even though the concrete constrictive strength of each beam was precise. Despite the fact that the "concrete compressive strength" of each beam was identical, this was the result. Supported "RC beams" manufactured from RA were compared to beams made from NA concrete to determine the effect of different factors on the structural behavior, and the results were presented by Salah A. Aly et al. According to their results, the shear strength of the tested specimen improves as the "RA ratio" increases to 50%. However, the ultimate load was lowest for the specimen with a 75% RA replacement ratio, demonstrating that replacement ratios greater than 50% resulted in a decrease in the beam's shear capability. It was also found that as the "shear span-to-depth ratio" grew, the shear strength of a beam made of "coarse aggregate" declined. Using a control mix and 50.3% RA, Gonzalez-Fonteboa and Martinez-Abella fashioned concrete beams. Both the NA and RA concretes had similar compressive strengths. (40 MPa). Different "shear reinforcement ratios" were used to generate "longitudinally reinforced concrete beams" from each type of concrete. The beams broke apart due to shear. Their research showed that neither the deflection nor the ultimate shear strength of the "NA and RA concrete beams" were significantly different from one another [16]. Using "coarse recycled aggregate" (RCA) and steel fibers, Chaboki et al. investigated the shear characteristics of reinforced concrete beams. Different "transverse reinforcing" distances were used to cast 27 beams. (TR). The concrete mixes used 0 percent, 50 percent, and 100 percent recycled aggregate, which was gathered from demolished buildings. Beams contained "steel fibres" (SF) at volumetric rates of 0%, 1%, and 2%. Results showed that the maximum strain and shear behavior of RA concrete beam specimens were improved by SF when compared to control test samples. The effect of the SF was mitigated by reducing the interval between the TR. The RA beams get more deformed when SF is operated at 2%. Ultimate shear strength was also improved when RA was applied to materials with varying transverse spacings. González-Fonteboa et al. showed that different types of concrete have only a modest effect on both deflection and ultimate load. Unfortunately, the repurposed concrete beams that were being used all broke too soon. Erdem et al. [17] state that structural applications should be avoided while using concrete made with RAP aggregate. Concrete's shear behavior was studied by Yang et al. at temperatures of 200 C, 300 C, and 400 C with varying quantities of "recycled coarse aggregate," from 0% to 100%. Peak strain should have grown linearly with temperature while residual shear strength and shear modulus declined sharply. After being heated at 400 °C, the specimen's mean shear strength at 100 RCA replacement dropped by 66.4% compared to its unheated counterpart. Both natural aggregate and "recycled aggregate concrete" RC beams lose load-bearing capacity in high temperatures, as shown by Maruta et al. [18]. Beams with "reinforcing bars ratios" of 1.3%, 2.0%, and 2.7% were evaluated alongside beams with "RA replacement ratios" of 0%, 50%, and 100% by Mahdi Arezoumandi and colleagues. There was a "concrete compressive strength" of 35 MPa. The shear strength of the "RA100 beams" tested and evaluated for this study was found to be lower than that of the "RA50 and NA concrete beams," according to quantitative data analysis. The shear capacities of "NA and RA50 concrete beams" [19] did not significantly vary. Twenty "reinforced concrete beams" with different span-depth percentages (1.63, 2.63, and 3.31), "longitudinal reinforcement ratios" (0.54, 0.84, and 1.63%), and "RA replacement ratios" (0% to 100%) were tested for their shear strength. Their research showed that a higher "RA replacement ratio" resulted in lower "shear strength." [20]. Columns made from natural aggregates (NA), recycled asphalt pavement (RAP), recycled coarse aggregate (RCA), and recycled asphalt pavement (RAP) were tested for their "axial compressive behaviour of RC." The results demonstrated that increasing levels of RAP-RCA and RAP content resulted in a decrease in axial power in the column. Axial capacity was barely increased by 2.40 percent for the RAP20-RCA80 column in the RAP-RCA column specimens. As the amount of RAP in the columns increases, the compressive capacity of the load may also decrease. There was a 31.2 percent decrease in axial load when comparing the RAP100 column specimen to the control column specimen NA. As RCA quantities in the columns increase, the capacity for the axial compressive load will decrease. The experimental axial capacity increased to 5.88% for the RCA20 column alone and decreased to 28.31% for the RCA100 column [21] compared to the control column specimen. Abedalqader et al. conducted an experiment to see how exposing substances to temperatures of 20, 200, 400, and 500 degrees Celsius altered the results of a computerized analysis of their mixtures. Three different amounts of RAP aggregates (10.2%, 20.2%, and 30.2%) were used to replace the NCA, whereas four different amounts of RCA were utilized to replace the NCA (20.2%, 40.2%, 60.2%, and 100%). There have also been mixtures of RCA and RAP at the percentages of 90.3% RCA and 10.2% RAP, 70.2% RCA and 30.2% RAP, and 80.2% RCA and 20.2% RAP. With decreasing percentages of RCA and RAP, the results showed that the automatic and biological properties dropped to a more comfortable level at the same temperature. Mechanical characteristics deteriorated with increasing temperature when utilizing the same percentage of recycled aggregates as a substitute. When temperatures rise, the automatic properties of "RAP-RCA" combinations can drop to the same extent as those of NCA, RAP, and RCA alone mixtures. Recycled mixtures of 80.2% NCA and 20.2% RCA, 90.2% RCA and 10.2% RAP, and 90.2% RCA and 10.2% RAP for RAP-RCA blends are best for usage in high temperatures [22].

2. Materials and methods

2.1. Material properties

Regular portland cement from a nearby supplier was utilized in the concrete recipes. The coarse aggregates used ranged in size from 5 mm to 15 mm (60.2% of the total weight) and 15 mm to 25 mm (40.3% of the total weight). River sand with a passing size of 5 millimeters was used as aggregate in all recipes. Reinforcing bars ranged in size from 10mm to 12mm. The recycled aggregates were created by crushing the analyzed beam samples. Primary crushing was performed with handheld jackhammers and secondary crushing was performed at crushing plants. The same size distributions were discovered for "recycled aggregates." Soaking the "recycled aggregates" for 24 hours accounted for their prolonged absorption time. The superplasticizer "Rheobuild 834" was used to get the material to the right consistency for shaping.

2.2. Specimen details

The fabric's automated properties were calculated after it was tested for strength of concrete, split tensile, and flexural tensile strength. In accordance with "ASTM C39" and "ASTM," "compressive and splitting tensile strengths" were measured using 100 mm in diameter by 200 mm in length cylinders.Prisms of 100 mm in width, 100 mm in depth, and 500 mm in length were used to determine the "flexural tensile strength" in accordance with ASTM C78.

2.3. Material protocol

A regulated deformation rate of 2mm/minute was used to collect samples in the "Material Testing Laboratory of the Department of Civil Engineering". Deflections at the span's midpoint were measured with an LVDT. (Linear variable differential transformer). Beam specimens were marked with a grid of 25mm × 25mm dots to indicate the area of constant moment. Next, a focused camera on a tripod was used to take pictures of the mid-span, and the load values were recorded as the pictures were taken. It would therefore be possible to picture the fracture propagation process in response to load levels.

3. Results and discussion

All of the strengths are shown to be diminished in Table 1 for the recycled aggregate concrete samples. All RAC strengths were compromised to some degree by NAC, but the extent of the compromise was almost the same across the board as shown Figures 2-4.

Table 1. Mechanical properties of RAC beam specimens

	Strength (MPa)		
	Compressive	**Splitting tensile**	**Flexural tensile**
RAC00	31.09	6.12	7.07
RAC30	27.89	5.89	6.02

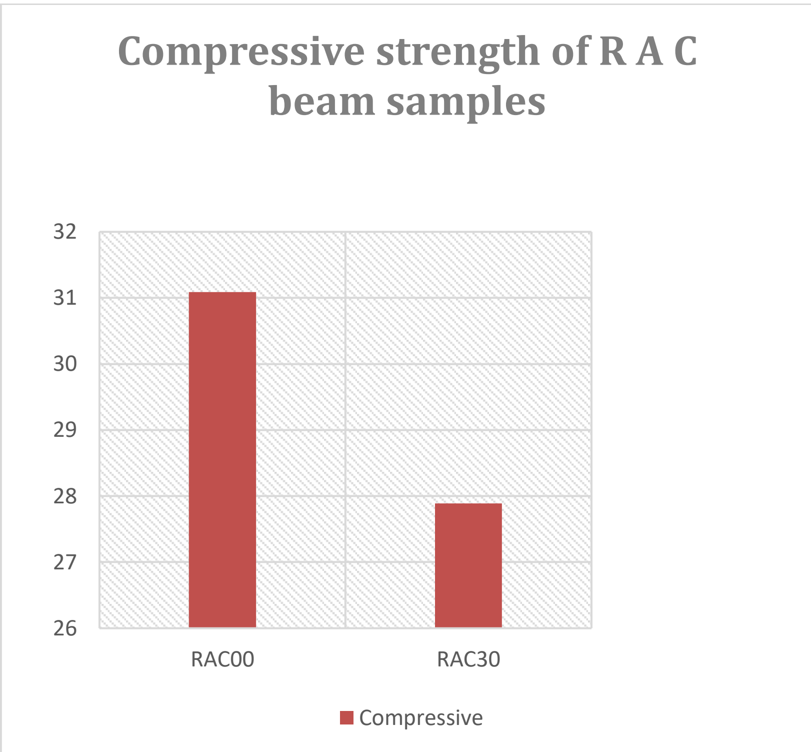

Figure 2. Compressive strength of RAC beam samples

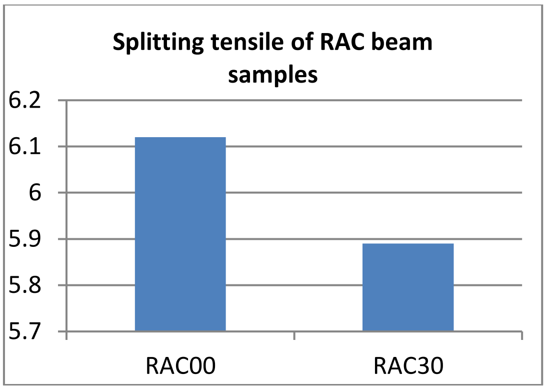

Figure 3. Splitting tensile of RAC beam

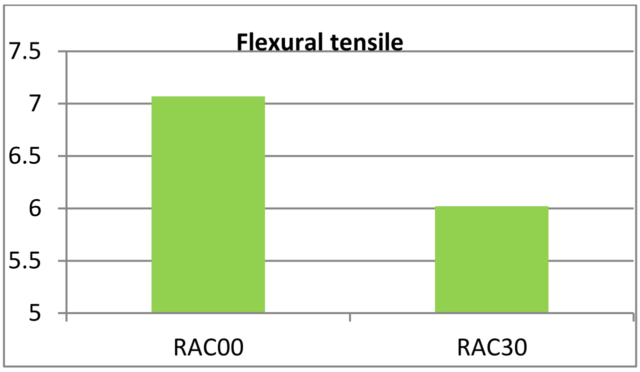

Figure 4. Flexural tensile of RAC beam

Variation in the maximum load bearing capacity is extremely small. In contrast to "natural aggregate concrete specimens," "recycled aggregate concrete specimens" were found to have a lower initial rigidity. These results were also shared, and they demonstrated a correlation between the increased down immobility of RAC occurrences and their lower elastic modulus. The load-deflection curves and the failure modes of the specimens are shown in Table 2 and Figure 5.

Table 2. Load-Deflection Curves of Tested RAC Beam Specimens

	Load	**Displacement**
RAC100	5	1.5
	51	4.9
	65	6.3
	62	6.5
	64	6.8
	63	7.4
	51	8.5
RAC30	3	1.3
	12	1.5
	32	4.6

	56	8.7
	54	9.3
	62	12.1
	39	14.8

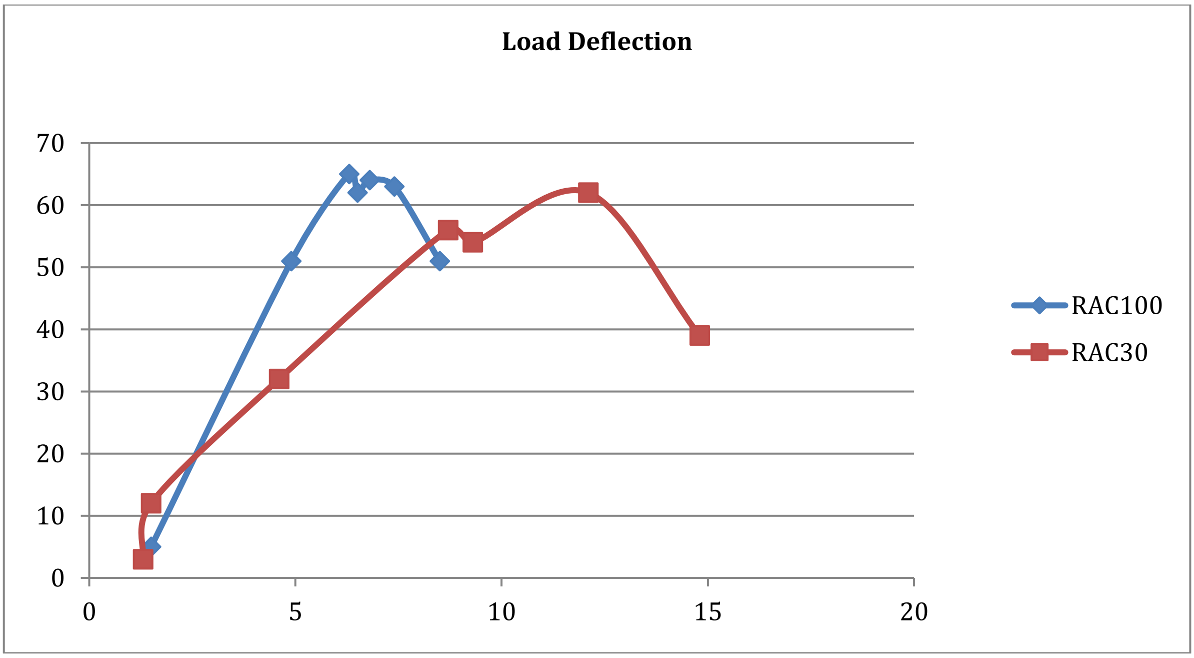

Figure 5. Load-Deflection curves of tested RAC beam specimens

The experimental results and predicted values for shear critical beams are shown in Table 3. The ratio of the experimental value to the predicted value is greater than 1 for all of the predicting equations. It is important to note, however, that there is not a great deal of variation in the ratios. Therefore, it is shown that the same formulae used for recycled concrete samples also apply to natural aggregate concrete samples.

Table 3. Forecasts for shear strength of beam specimens

		Predicted load (kN)					**Pexp/Pred**				
					MC-2010					**MC-2010**	
	Exp. (kN)	EC2	BS-8110	ACI-318	LoA I	LoA II	EC2	BS-8110	ACI-318	LoA I	LoA II
RAC00	70.1	59.8	53.7	46.6	38.9	43.6	1.3	1.4	1.61	1.9	1.7
RAC30	66.9	57.6	51.1	44.8	35.4	42.6	1.3	1.4	1.6	2.0	1.7

Predicted values consistently underperform experimental weights; projected precision and accuracy are almost identical over a wide range of concrete-related comparisons as in Table 4.

Table 4. Comparison of shear strength predictions of NAC and RAC

Capacity	Exp	EC2	BS8110	ACT318	LoA I	LoA II
NAC	63	59	52	44	36	40
RAC	60	57	49	46	39	42

Slabs produced of RA (coarse aggregates) concrete would be constructed using the exact same structure equations as slabs constructed with NA concrete [23], as shown by research by Schubert et al. on the behavior of fourteen RA (coarse aggregates) concrete slabs. Belen Gonzalez-Fonteboa and Fernando Martinez-Abella tested eight beams to shearing failure. Each had a rectangular portion throughout its length. They manufactured recycled concrete that was 6.3% more cement intensive than conventional concrete and contained 50% coarse particles. According to the results, the structural performance of the concrete beams in terms of deflections and maximum load hardly changed at all. Only by examining the cracking were differences found [24]. The "Equivalent Mortar Volume" (EMV) method, developed by Fathifazl et al., is a novel mix design for constructing RA beams. The results showed that the shear capacity of "RA concrete beams" was comparable to that of "NA concrete beams." [25]. Arezoumandi et al. found that the stability importance of concrete batches made with NA and RA at 100% replacement ranged from 36 MPa to 32 MPa. In a four-point bending arrangement, they created three sets of beams using each concrete type and then failed them under shear, resulting in diagonal cracking. Beam testing revealed that RA concrete beams possessed worse shear capacity when compared to control beams [26]. Beams with longitudinal support rates between 2.6% and 4.4% were studied by Maruyama et al. Both the NA and RA 3 cement beams demonstrated the same fracture patterns and failure mechanisms; however, for shafts containing between 50 and 100% RA alternate in place of "virgin aggregate," the "RA concrete beams" displayed 10 to 20% meagerer shear stability than the "NA concrete beams" [27]. The 32 "shear push-off specimens" investigated by Xiao et al. had varying RA replacement ratios. There was no discernible shift in shear stress slip curvature, fracture route, or shear transmission, as reported by the researchers [27]. According to research conducted by Corinaldesi et al., the elastic modulus of concrete beam joints constructed with "recycled aggregates" has decreased, necessitating adjustments to the defeat tools. Changing the mix design, as by adding fly ash, can improve the characteristics of these joints and achieve the desired behavior of natural concrete [28]. Altering the parameters has made the study of deep beams an interesting field of research. However, recent studies have documented the operation of deep beams in shear. According to ACI 318, deep beams are those that are loaded on one face and shielded on the other, with a shearing span-to-depth percentage of less than or equal to two. Deep beams fail in shear because of their geometrical size. Internal stresses are disrupted by shear action, which consists of compression in one plane and tension in the other. This results in a rapid shear failure of the beam as the beam depth increases. The crack pattern forms and the beam collapses significantly more rapidly than in small-size deep beams [29]. Raghu et al. conducted a thorough experimental and technical analysis of the concrete element of shear resistance in beams made of high-strength concrete. (HSC). Twenty-four beams, some with and some without shear reinforcement, will be evaluated as part of the experimental program to determine the extent to which concrete contributes to shear strength. Evidence from the literature and experiments was compared to the rigid rules outlined in the codes of practice. Extrapolating the current HSC shear resistance criteria reduces the design margins [30]. Angelakos et al. presented the findings of shear testing on 21 large RC beams. It has been found that shear stress at failure is influenced more by concrete strength than by longitudinal reinforcing. The shear stress at failure decreases noticeably with increasing member size and decreasing longitudinal reinforcement ratio. Using criteria including concrete strength, beam depth, and shear span-to-depth ratio, Yang et al. strained 21 beam samples to analyze their shear properties. Brittle failures characterized by wide diagonal cracks and an accelerated fuel release rate due to the length effect have been observed in studies with a smaller shear span-to-depth ratio and a deeper beam at the exact shear span-to-depth percentage [28].

4. Conclusion

In comparison to natural aggregate concrete, recycled aggregate concrete was shown to have weaker compressive, flexural, and tensile breaking strengths. Recycled and organic material concrete produced comparable final load-carrying capacities for longitudinal shear support. The recycled aggregate concrete beam specimen, on the other hand, was not as rigid and failed at a larger angle of deflection. One possible explanation is that the elastic modulus of "recycled aggregate concrete" is lower. It is shown that both specimens may be accurately predicted using any strength prediction approach. When comparing different types of concrete, all projected values are lower than the experimental values, and there is little variation in accuracy and precision.

5. Recommendations

More research with varying conditions and standards is recommended to identify the most successful RAC, and if necessary, improvements can be made by creating several types of RAC that would be useful in different geographic locations. More information useful for improving RAC production could be gleaned from trials using multiple RAC kinds.

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Conflict of interest

The authors declare that they have no conflict of interest, and all the authors agree to publish this paper under academic ethics.

Author contributions

All the authors contributed equally to the manuscript.

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References

[1] M. Arezoumandi, A. Smith, J. S. Volz, and K. H. Khayat, "An experimental study on flexural strength of reinforced concrete beams with 100% recycled concrete aggregate," *Engineering Structures*, vol. 88, pp. 154-162, 2015.

[2] B. S. Hamad and A. H. Dawi, "Sustainable normal and high strength recycled aggregate concretes using crushed tested cylinders as coarse aggregates," *Case Studies in Construction Materials*, vol. 7, pp. 228-239, 2017.

[3] B. S. I. C. E. 2, "Structural use of concrete. Part 1: Code of practice for design and construction, London:," 2004.

[4] W. G. L. C. S. P. CEN. J. Z. Xiao, "Design of concrete structures, Part 1-1: General rules and rules for buildings, Brussels," 2012.

[5] J. Xiao, W. Li, and C. Poon, "Recent studies on mechanical properties of recycled aggregate concrete in China—A review," *Science China Technological Sciences*, vol. 55, pp. 1463-1480, 2012.

[6] A. M. Knaack and Y. C. Kurama, "Behavior of reinforced concrete beams with recycled concrete coarse aggregates," *Journal of Structural Engineering*, vol. 141, no. 3, p. B4014009, 2015.

[7] M. Code, "First Draft Volume 1 and 2," *Fib Bulletins*, vol. 55, p. 56, 2010.

[8] H. H. Hussein, I. Khoury, W. K. Hamid, and A. Abdulmohsin Khamees, "Structural Performance of Concrete Corners Reinforced with Different Steel Reinforced Detail under Static Loading," in *Forensic Engineering 2022*, pp. 1109-1120.

[9] O. A. Harry and I. E. Ekop, "A comparative analysis of codes prediction of shear resistance in beams without shear reinforcement," *Am J Civil Eng Archit*, vol. 4, no. 1, pp. 39-43, 2016.

[10] K. P. Mehta, "Reducing the environmental impact of concrete," *Concrete international*, vol. 23, no. 10, pp. 61-66, 2001.

[11] S. Arora and S. Singh, "Analysis of flexural fatigue failure of concrete made with 100% coarse recycled concrete aggregates," *Construction and building materials*, vol. 102, pp. 782-791, 2016.

[12] G. Aguilar, A. B. Matamoros, G. Parra-Montesinos, J. A. Ramírez, and J. K. Wight, "Experimental evaluation of design procedures for shear strength of deep reinfoced concrete beams," 2002: American Concrete Institute.

[13] A. Committee, "Building code requirements for structural concrete (ACI 318-08) and commentary," 2008: American Concrete Institute.

[14] P. Bakir and H. Boduroğlu, "Mechanical behaviour and non-linear analysis of short beams using softened truss and direct strut & tie models," *Engineering Structures*, vol. 27, no. 4, pp. 639-651, 2005.

[15] M. A. a. Roa'a, I. A. Aljazaery, and S. K. Al_Dulaimi, "Generation of High Dynamic Range for Enhancing the Panorama Environment," *Bulletin of Electrical Engineering and* Informatics, vol. 10, no. 1, 2021.

[16] K.-H. Yang, H.-S. Chung, E.-T. Lee, and H.-C. Eun, "Shear characteristics of high-strength concrete deep beams without shear reinforcements," *Engineering structures*, vol. 25, no. 10, pp. 1343-1352, 2003.

[17] A. B. Ajdukiewicz and A. T. Kliszczewicz, "Comparative tests of beams and columns made of recycled aggregate concrete and natural aggregate concrete," *Journal of Advanced Concrete Technology*, vol. 5, no. 2, pp. 259-273, 2007.

[18] *Changes to the Concrete Design Standard in the 2019 Edition of the ACI Building Code (ACI 318-19)*

[19] K. N. Rahal and K. S. Al-Shaleh, "Minimum transverse reinforcement in 65 MPa concrete beams," *Structural Journal*, vol. 101, no. 6, pp. 872-878, 2004.

[20] R. S. Pendyala and P. Mendis, "Experimental study on shear strength of high-strength concrete beams," *Structural Journal*, vol. 97, no. 4, pp. 564-571, 2000.

[21] D. Angelakos, E. C. Bentz, and M. P. Collins, "Effect of concrete strength and minimum stirrups on shear strength of large members," *Structural Journal*, vol. 98, no. 3, pp. 291-300, 2001.

[22] M. Kotsovos, "trength and behaviour of deep beams, in 'Reinforced Concrete Deep Beams," *F. K. Kong, Van Nostrand Reinhold Publications, New York.* , 2003.

[23] G. Russo, R. Venir, and M. Pauletta, "Reinforced concrete deep beams-shear strength model and design formula," *ACI Structural Journal*, vol. 102, no. 3, p. 429, 2005.

[24] C. Tang and K. Tan, "Interactive mechanical model for shear strength of deep beams," *Journal of Structural Engineering*, vol. 130, no. 10, pp. 1534-1544, 2004.

[25] H. Egyptian Code of Practice for Design and Construction of Reinforced Concrete Structure, Giza, Egypt, ECP203- 2018. .

[26] M. Ibrahim, A. El Thakeb, A. Mostfa, and H. Kottb, "Proposed formula for design of deep beams with shear openings," *HBRC Journal*, vol. 14, no. 3, pp. 450-465, 2018.

[27] A. M. J. Taha K Mohammedali, Khattab Saleem,and Abbas H Mohammed "STM ExperimentalVerivication for Reinforced Concrete Continuous Beams " *International Journal of Civil Engineering and Technology (IJCIET)* vol. 10, pp. 2227-2239, 2019.

[28] E. Alrajfi, A. M. Ashteyat, and Y. Z. Murad, "Shear behaviour of RC beams made with natural, recycled aggregate concrete and reclaimed asphalt aggregates under normal and elevated temperature," *Journal of Building Engineering*, vol. 40, p. 102681, 2021.

[29] F. Al Mahmoud, R. Boissiere, C. Mercier, and A. Khelil, "Shear behavior of reinforced concrete beams made from recycled coarse and fine aggregates," in *Structures*, 2020, vol. 25: Elsevier, pp. 660-669.

[30] P. Mendis, "Design of high-strength concrete members: state-of-the-art," *Progress in Structural Engineering and Materials*, vol. 5, no. 1, pp. 1-15, 2003.