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Research Article

Shear Strength of Reinforced Recycled Aggregate Concrete Corbels

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This paper is related to a laboratory program for the shear strength of reinforced concrete corbels (RCC) cast with or without recycled aggregate (RA) by investigating the main parameters affecting the corbels behavior including the replacement aggregate recycling ratio, *fcu*, and shear span to effective depth ratio a/d. Eight specimens were cast and tested. The obtained results were compared with ACI and EC2 codes. It is found that the ACI code and E2 code give sensibly conservative results when compared with the findings of the present work for all tested specimens regarding RA, concrete strength, and a/d. Also, the experimental results show that the presence of recycled aggregate decreases slightly both cracking and failure loads. Furthermore, the failure load development due to the effect of compressive strength is more effective with the presence of recycled aggregate, and the 50% ratio of RA was the suitable ratio in elaborate crack and failure loads. Finally, the reduction of the span-depth ratio (from 0.50 to 0.35) increases the crack and failure load by 8.1% and 20.2%, respectively, leading to confirm that the corbel strength is much sensitive to decreasing span-depth ratio compared to the associated deflections.

1. Introduction

Corbels intended in RC structures to carry vertical and horizontal loads to main parts. In corbels, a/d is generally smaller than 1.0 and is subjected to concentrated loads as in support regions. Many studies were conducted to determine the parameters that affect the structural behavior of RCC subjected to vertical and horizontal forces using experimental and analytical programs; these variables were shape and dimensions, the amount of longitudinal and transverse steel reinforcements (A_s and A_{st}), and concrete strength [1, 2].

The processing of materials to make new materials is called recycling. With the advanced development in the infrastructure area, the use of natural aggregate is getting more and more intense. To reduce this significant use, recycled aggregate was used as the substitute materials for the natural aggregate. Recycled aggregate consists of crushed, graded concrete particles treated from the concrete materials that have been used in the structures and destruction wreckage. The recycled aggregate is usually from constructions, roads, and bridges and occasionally even from disasters, like wars and earthquakes [3].

Mattock et al. (1976) [1] discussed the demeanor of RCC under vertical and horizontal loads. The ratio of these loads was the main parameter. Other parameters were the a/d, the amounts of A_s and A_{st}, and the aggregate type. Applying the shear-friction provisions in the ACI 318-71, Section 11.15, the results exhibited that the corbels ultimate load is the lesser of the ultimate load of the corbel-column interface [4].

Foster (1996) [5] investigated the behavior of high-strength RCC. The factors were a/d, f_c, and A_{st}. The experimental results were compared with Rogowsky and MacGregor's plastic truss model and the ACI 318-89 design model. It was noted that the use of the plastic truss model included Warwick and Foster efficiency factor exhibited accurate load results. It was found that the ACI 318-89 design model was not suitable for high-strength concrete corbels.

Bakır and Boduroğlu (2002) [6] proposed a new design formula for estimating the load capacity of corbels. Many parametric types of research are conducted on the laboratory results of RCC. The samples failed by the end and flexural tension failures were ignored in this investigation. A very good description of the corbels' load capacity resulted using the suggested design equation.

Abdel Hafez and Ahmed (2012) [7] studied the structural behavior of steel fibers reinforced high-strength concrete corbels. The studied variables were steel fiber content, a/d, f_c, amount of A_s, and the existence of A_{st}. According to the results, the use of steel fibers or/and horizontal stirrups enhances shear strength and ductility and gives a better ductile behavior till failure. A comparison of the shear strength from tested corbels, ACI 38-08 formulas, and equations prepared by different researchers was conducted and showed that the ultimate load calculated using the G. Campione et al. model [8] was in good agreement with the outcomes of the experiment.

Salman et al. (2014) [9] conducted laboratory work to explore the strength and behavior of RC corbels (self-compacting) with and without steel fibers. The work included 10 specimens with varied compressive strength and equal geometrical dimensions. The concentrated vertical loads only had been subjected to these specimens. The cracking behavior was improved by adding steel fibers resulting in a 31.5% and 25.3% increasing in cracking and ultimate loads, respectively, by increasing steel fibers content from 0% to 0.4%.

Won-Chang and Yun (2017) [10] studied the structural behavior of reinforced recycled aggregate concrete beams that failed in shear without stirrups. The parameters were recycled aggregate replacement ratio (0%, 30%, 60%, and 100%) and a/d (2.0, 2.5, 3.0, 4.0, and 5.0). According to this study, the shear strength can be obtained by using the ACI 318 (2014) code formulas; at the same time, these formulas can be employed to the structural parts made with recycled aggregate.

2. Research Significance

In this investigation, the main goal was the use of RA as coarse aggregate to get rid of waste material resulting from widely demolished concrete structures which appear due to unstable conditions the country is going through. At the same time, there are little data on the corbels behavior made with RA as coarse aggregate. The main investigated variables were recycled aggregate replacement ratio, a/d, and *fcu*.

3. Experimental Program

3.1. Specimens Description. Eight corbels in four groups were put to the test until they failed under vertical loading. Each group consists of two specimens. For the first three groups, the RA replacement ratio (by weight) was 0, 0.5, and 1.0%, with a/d being constant at 0.5, while the 28-day concrete compressive strength was 25, 35, and 45 MPa in the first, second, and third group, respectively. In the last two specimens (the fourth group), the RA replacement ratio and a/d were kept constant at 50% and 0.35, respectively, with *fcu* varying from 25 to 45 MPa. In all groups, the a/d is in the acceptable range suggested by the ACI code (a/d < 1.0). The dimensions of the corbels, in addition to the primary and secondary (stirrups) reinforcement, were maintained constant, as in Figure 1. For all corbels, the width $b = 200$ mm, height $h = 300$ mm, effective depth $d = 275$ mm, and the depth at the outer edge of the bearing area = 150 mm. The dimensions of the supporting column were $200 \times 200 \times 400$ mm and were reinforced with four 12 mm diameter bars at the corners and 10 mm diameter ties spaced longitudinally at 87.5 mm center to center. The primary steel was provided by three 12 mm deformed bars. For primary reinforcement, $f_{y\ \mathrm{ave.}} = 440$ MPa and for the stirrups, $f_{y\ \mathrm{ave.}} = 400$ MPa. The details of corbel specimens are shown in Table 1.

3.2. Materials

3.2.1. Cement. The cement used was ordinary Portland cement that met the standards of Iraqi specification no. 5-1984 [11]. Table 2 depicts the chemical components and physical characteristics of the used cement.

3.2.2. Natural Fine Aggregate (Sand). Natural sand from the Al-Zubair region was used in this study. The fineness modulus of fine aggregate was 2.78. Fine aggregate was tested under the Iraqi standard no. 45-1984 [12]; it can be observed that the grading of sand is within the limits of this specification as shown in Table 3.

3.2.3. Natural Coarse Aggregate (Gravel). The coarse aggregate used in this study was crushed gravel 20–5 mm from the Al-Zubair region. Table 3 shows the aggregate grading that meets the Iraqi specification no. 45-1984 [12].

3.2.4. Recycled Coarse Aggregate. The recycled concrete aggregate obtained from the demolition of concrete cubes which have been brought to the laboratory for testing was used. Its grading satisfied Iraqi standard no. 45-1984 [12] as shown in Table 3. The maximum size of this aggregate was 20 mm. Table 4 shows some properties of fine, coarse, and recycled aggregate. Figure 2 demonstrates the grading curves of the natural coarse aggregate and RA used in the present work.

3.2.5. Water. Ordinary tap water free from injurious substances was added to concrete during mixing and curing.

3.2.6. Steel Reinforcement. A deformed bar of diameter 12 mm was used for main reinforcement and a 10 mm diameter bar was used for ties of the column. Each bar size had three tensile specimens evaluated. The reinforcing bars' characteristics are listed in Table 5.

3.3. Mix Proportions. In this study, three mixes were designed to give three compressive strength levels (C25, C35, and C45). Table 6 presents the details of the mix proportions and the RA replacement ratios of these mixes.

3.4. Specimens Preparation. The cement, sand, gravel, and or RA were mixed thoroughly first. After that, water was added gradually to the materials. The aggregate was added to the

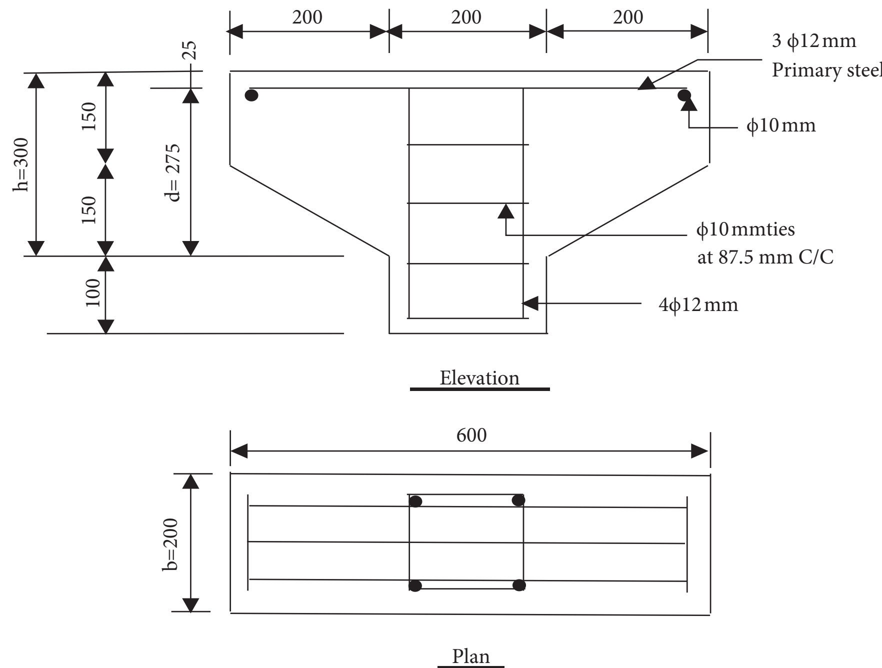

Figure 1: Details of corbels and reinforcement.

Table 1: Details of corbels.

Corbel notation	a/d	*fcu* (MPa)	RA replacement ratio %
C1	0.5	25	0
C2	0.5	25	100
C3	0.5	35	0
C4	0.5	35	50
C5	0.5	45	50
C6	0.5	45	100
C7	0.35	25	50
C8	0.35	45	50

Table 2: Physical properties and chemical composition of the used cement.

Physical properties		Iraqi specification no. 5 [11]
Sitting time (min)		
Initial	130	45 min
Final	240	600 max
Compressive strength (MPa)		
7 days	20.5	15 min
28 days	28.8	23 min
Specific surface, blaine, cm^2/g	3120	2900 min
Chemical analysis (%)		
Lime (CaO)	62.00	
Silica (SiO_2)	21.00	
Alumina (Al_2O_3)	5.26	
Iron oxide (Fe_2O_3)	3.00	
Magnesia (MgO)	2.70	5 max
Sulfate (SO_3)	2.10	
Loss on ignition (LOI)	1.10	4 max
Insoluble residue (IR)	0.49	1.5 max
Lime saturation factor (LSF)	0.92	0.66–1.02
Tricalcium silicate (C_3S)	47.11	
Dicalcium silicate (C_2S)	30.81	
Tricalcium aluminate (C_3A)	8.87	2.5 max
Tetracalcium aluminoferrite (C_4AF)	9.12	

Table 3: Grading of fine and coarse aggregate.

Coarse aggregate				Fine aggregate		
Sieve size (mm)	Passing (%) Gravel	Passing (%) RA	Iraqi standard no. 45-1984 [12]	Sieve size (mm)	Passing (%)	Iraqi standard no. 45-1984 zone 2 [12]
37.5	100	100	100	4.75	99	90–100
20	100	100	95–100	2.36	90	75–100
14	78	85	—	1.18	75	55–90
10	41	35	30–60	0.60	53	35–59
5	2	6	0–10	0.30	17	8–30
2.36	1	2	—	0.15	2	0–10

Table 4: Properties of the used aggregate.

Property	Sand	Gravel	Recycled aggregate
(1) Specific gravity			
(a) Bulk			
(i) Oven dry	2.64	2.65	1.66
(ii) SSD	2.67	2.69	1.73
(b) Apparent	2.68	2.70	1.71
(2) Absorption %	1.29	0.97	3.88
(3) Unit weight (kg/m3)			
(a) Loose	1400	1214	990
(b) Tamped	1480	1271	1077

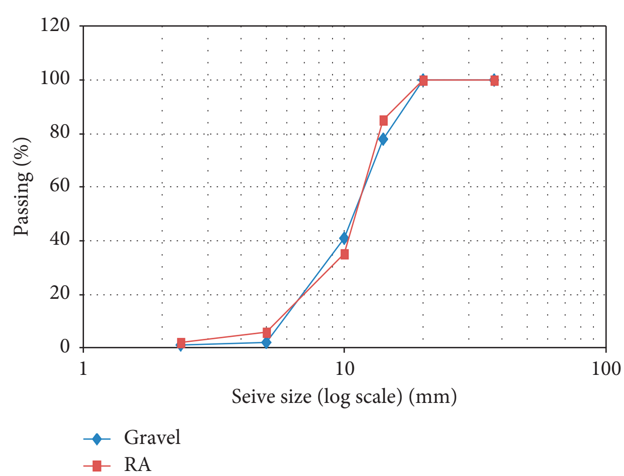

Figure 2: Natural coarse and recycled aggregate grading curves.

Table 5: Characteristics of reinforcing bars.

Bar size (mm)	f_y (N/mm^2)	f_u (N/mm^2)
10	482	595
12	525	674

Table 6: Details of the mixes proportions (kg/m^3).

Mix	RA replacement ratio %	Cement	Water	Sand	Natural coarse aggregate	Recycled coarse aggregate
C25	0	367	185	739	1109	0
C25	100	367	185	739	0	1071
C35	0	420	185	717	1076	0
C35	50	420	185	717	538	519
C45	50	487	195	691	519	501
C45	100	487	195	692	0	1002

mix in SSD condition to avoid any correction due to the higher water absorption of aggregate. Each mix was intended to provide one corbel, three cylinders, and three cubes. Tests on fresh concrete as well as pouring of corbels in prepared steel molds were directly carried out after mixing of concrete. The 150×150 mm cubes and 150×300 mm cylinders (to determine the compressive strength and splitting tensile strength) were cast and cured under the same conditions of corresponded corbels. Molds were opened 24 hrs after pouring and the specimens were covered with polyethylene sheets (moist cured) for seven days followed by air-cured till the date of testing. All corbels, cubes, and cylinders were tested at 28 days of age.

3.5. Concrete Properties. Table 7 presents the fresh and hardened concrete properties of the mixtures. The usual slump test coinciding with ASTM C 143 [13] was accomplished. The splitting tensile strength (f_t) was determined using $300 * 150$ mm cylinders as per ASTM C 496 [14], and the compressive strength (fcu) was determined using 150 mm cubes, as per BS EN 12390-3 [15].

3.6. Test Setup, Loading Procedure, and Instrumentation. A hydraulic testing machine with a loading capacity of 2000 kN was used. The loading scheme adopted is shown in Figure 3. The corbels tested were supported symmetrically by two steel hinges placed at a distance (a) from the face of the column as shown in Figure 3. At each load increment, vertical deflection at the center of the bottom surface of the column was recorded by dial gauge with an accuracy of 0.01 mm per division. Also for all corbels, the first crack and the ultimate loads are recorded while the arrangements of crack propagation were observed.

4. Results and Discussion

4.1. General Behavior under Loading. At the initial steps of loading, all tested corbels behaved elastically; with tiny deflection and no cracks, and as the applied load increases, cracks begin to grow.

Firstly, the cracks appeared as few shear cracks within the region of supports; after that, a long shear crack was formed at either one or both supports and extended toward the point of the application of load. These shear cracks propagate parallel to the line drawn from the midpoint of the load of application to the supports. When applied load increased, the diagonal shear cracks propagate with the formation of new inclined cracks. Near failure, the main diagonal shear crack becomes wider and in some specimens, and this crack tries to separate one of the double corbels from the column as it was propagated between the supports and the column-corbel junction at the sloping face as illustrated in Figure 4. This behavior is consistent with the findings in the literature [16]. All corbels have failed with the same pattern.

4.2. Cracking and Ultimate Loads. Table 8 demonstrates the main characteristics of the current study in terms of cracking and failure state of corbels behavior, while Table 9 shows the ultimate loads calculated according to ACI 318-19 [17] and EC2 (BS EN 1992 codes) [18] and their ratios compared with the findings of the current study. At the same time, Tables 9 and 10 explain 8 comparison cases that are used to depict the parameters that control the corbels' behavior at the crack and ultimate load. It can be seen that the presence of the RA merely decreases both the cracking and ultimate loads. This is because the compressive and tensile strengths of concrete had a simple reduction with the presence of the RA as can be noticed in Table 7. Based on these results, it can be stated that the RA could replace the natural coarse aggregate in corbels. This is in line with the results found by Fattuhi and Hughes [19].

4.3. Deflection. The curves of load-deflection relationships for the tested reinforced recycle aggregate concrete corbels in this study are illustrated in Figures 5–12 . The deflection curves can be divided into two segments that given as follows:

(1) The first segment begins from the initial stage (zero loading and corresponding deflection) to the development of the first crack and this part approximately seems to be a straight line which represents the linear behavior of corbels

(2) The second segment begins from the development of the first crack to the failure stage and this part is usually apparent like curves that represent the nonlinear behavior of corbels

In all cases and with all loading stages, the corbels specimens made with RA exhibited a larger deflection than those without RA. The difference in values of deflection begins very small and increases with the applied load till failure. This is reflecting the reduced mechanical properties of the RA compared to gravel, which reduces the stiffness of RCC made with RA.

4.4. Other Methods. Table 9 shows the ultimate loads of corbels using two models (ACI model and EC2 model) and relative ratio with the results of the current study. This table indicates many points which are given as follows:

(1) For all cases, the ACI and EC2 models underestimate the ultimate loads of RCC, and this can be attributed to the conservative nature of code philosophy.

(2) The outcomes obtained by the ACI and EC2 models are so close. So, no significant difference may be reflected when changing the code of practice in the design.

(3) It can be seen that the two codes are not sensitive to the changes in the type of coarse aggregate (same result when $RA = 0\%$ and $RA \neq 0\%$); this is because that the equations of the codes depend on the compressive strength regardless of the type of material.

(4) The relative ratios of the failure load of the current study to that calculated by the ACI and EC2 codes

Table 7: The properties of fresh and hardened concrete.

Corbel no.	Mix no.	RA replacement ratio, %	Slump (mm)	At 28 days	
				Compressive strength (MPa)	Splitting tensile strength (MPa)
C1	C25	0	150	28.2	1.78
C2	C25	100	120	28.0	1.75
C3	C35	0	147	36.2	1.97
C4	C35	50	130	35.1	1.92
C5	C45	50	138	45.8	2.25
C6	C45	100	118	44.3	2.20
C7	C25	50	130	29.4	1.79
C8	C45	50	135	45.6	2.22

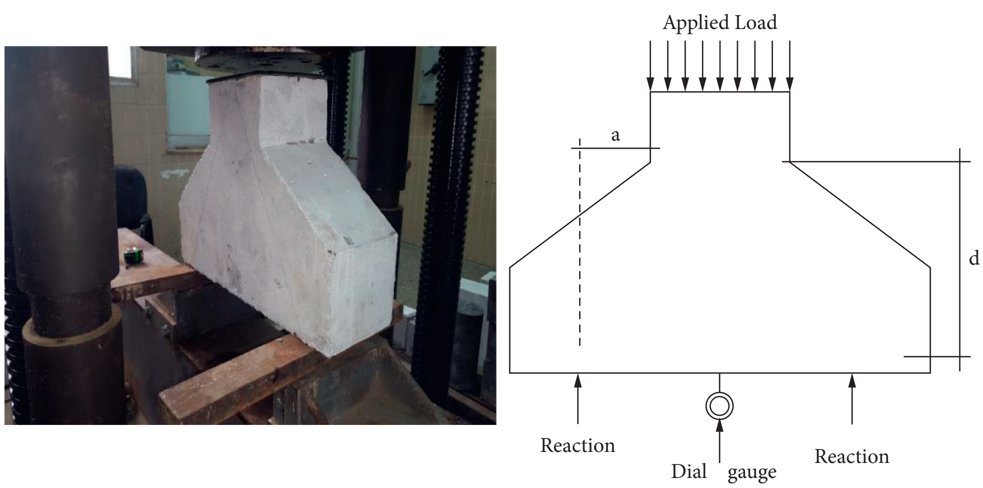

Figure 3: Loading arrangement of corbels.

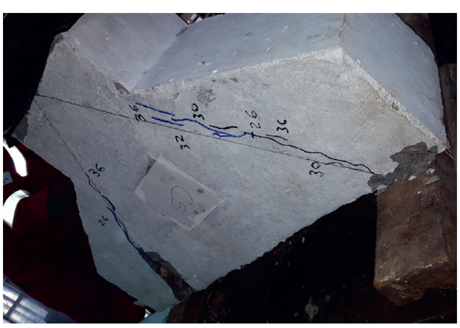

Figure 4: The failure mode for corbel specimens.

ranged approximately from 1.3 to 1.7. This difference can be explained by knowing that the experimental test continues till the failure of the specimen, while the philosophy of the code established on the presumption that the failure occurs slightly after the release of the first crack and sometimes at the yield of the reinforcing steel.

4.5. Replacement Aggregate Ratio. From the results RC corbels, all tested specimens have the same structural behavior till failure which occurred by shear failure (diagonal types). The ratio of the crack load to failure load is recorded in Table 8; it is observed that this ratio increased from 0.52 to 0.58 as the RA increased from 50% to 100%, respectively. Table 10 shows the ratios of crack and failure loads which depicted the effect of aggregate replacement that decrease both cracking loads by 9% and 5% and failure load by 4% and 1% for RA of 50% and 100%, respectively. Also, the impact of RA on crack and failure loads decreases with increasing RA ratio.

Figures 5–7 show the effect of recycled aggregate. The behavior of both specimens (with and without recycled aggregate) is approximately identical as shown in the figures. It can be noticed that the deflection in the RA specimens is larger than that in the specimens without recycled aggregate; this can be related to the reduced modulus of elasticity of recycled aggregate.

4.6. Concrete Strength. The effect of concrete strength can be noticed in Figures 8–11. Figure 8 shows the compressive strength effect for 0% RA replacement ratio in which both specimens have the same trend (i.e., the same structural behavior). For the 0% RA replacement ratio, 8 MPa increasing in compressive strength leads to an increase in the crack and failure load by 3.6% and 13%, respectively.

The effect of the concrete strength in the presence of RA is indicated in Figures 9–11. Similarly, the increase in compressive strength enhanced both cracking and failure loads. For 50% RA replacement ratio, corbels C4 and C5 ($a/d = 0.5$), 10.7 MPa increase in compressive strength

Table 8: Cracking and ultimate loads.

Corbel notation	Crack load (kN)	Ultimate load (kN)	Crack load/ultimate load
C1	206.7	344.6	0.6
C2	197.2	340.0	0.58
C3	214.2	389.4	0.55
C4	194.8	374.5	0.52
C5	216.6	433.1	0.50
C6	197.4	402.8	0.49
C7	203.3	362.9	0.56
C8	234.1	520.4	0.45

Table 9: Experimental and theoretical ultimate loads.

Corbel notation	Exp. (kN)	ACI (kN)	EC2 (kN)	Exp./ACI %	Exp./EC2%
C1	344.6	257.30	255.75	133.9	134.7
C2	340.0	257.30	255.75	132.1	132.9
C3	389.4	263.20	277.50	147.9	140.3
C4	374.5	263.20	277.50	142.3	135.0
C5	433.1	266.1	292.50	162.8	148.1
C6	402.8	266.1	292.50	151.4	137.7
C7	362.9	283.10	277.50	128.2	130.8
C8	520.4	293.30	277.50	177.4	165.2

Table 10: The ratio of 8 comparison cases of corbels.

Case	Crack load state	Ultimate load state	Description of controlled parameters
C2/C1	0.95	0.99	Replacement aggregate 0–100% and $fcu = 25$ MPa
C4/C3	0.91	0.96	Replacement aggregate 0–50% and $fcu = 35$ MPa
C6/C5	0.91	0.93	Replacement aggregate 50–100% and $fcu = 45$ MPa
C8/C7	1.15	1.43	Concrete strength 25–45 MPa with 50% RA
C3/C1	1.14	1.13	Concrete strength 25–35 MPa with 0% RA
C5/C4	1.11	1.16	Concrete strength 35–45 MPa with 50% RA
C6/C2	1.00	1.18	Concrete strength 25–45 MPa with 100% RA
C8/C5	1.08	1.20	a/d 0.5–0.35 with $fcu = 45$ MPa and RA = 50%

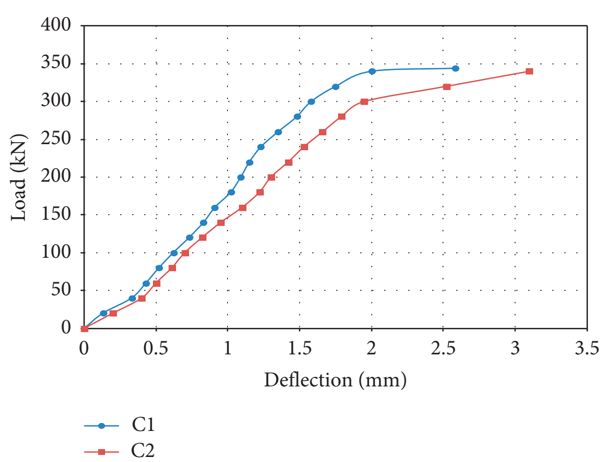

Figure 5: Load-deflection relationship of corbels with 0% and 100% weight fractions of replacement aggregate for concrete strength 28.2 and 28.0 MPa and a/d ratio 0.5.

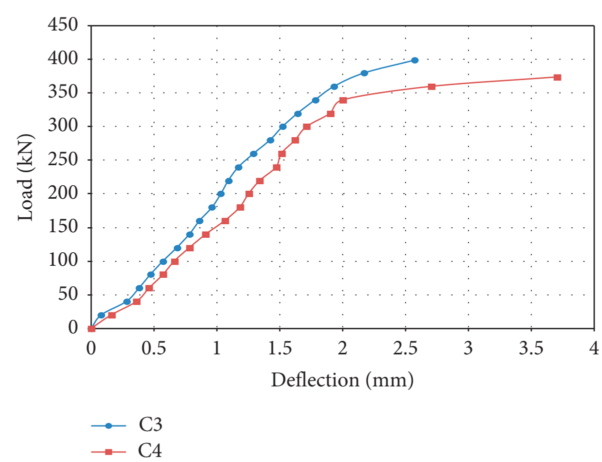

Figure 6: Load-deflection relationship of corbels with 0% and 50% weight fractions of replacement aggregate for concrete strength 36.2 and 35.1 MPa and a/d ratio 0.5.

enhanced both cracking and failure loads by 11.2% and 15.6%, respectively (Figure 9), while for corbels C7 and C8 (a/d = 0.35), 16.2 MPa increase in compressive strength enhanced both cracking and failure loads by 15.2% and 43.4%, respectively (Figure 10). Furthermore, for 100% RA replacement ratio, 16.3 MPa increase in compressive strength of corbels C6 (a/d = 0.5) enhanced the cracking and failure loads by 0.1% and 18.5%, respectively, compared with

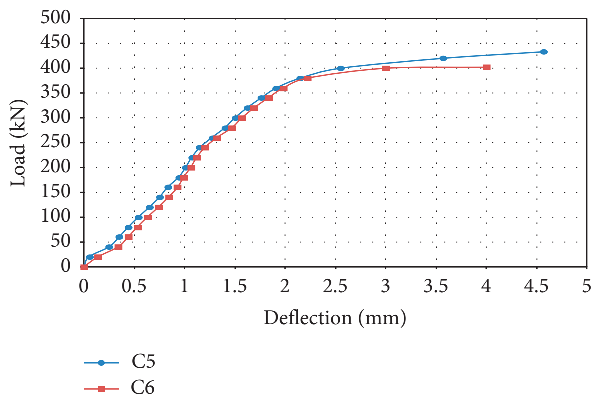

Figure 7: Load-deflection relationship of corbels with 50% and 100% weight fractions of replacement aggregate for concrete strength 45.8 and 44.3 MPa and a/d ratio 0.5.

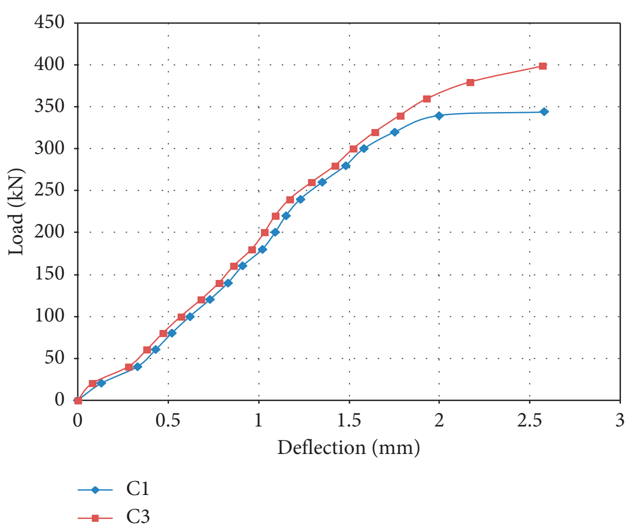

Figure 8: Load-deflection curve of corbels of 0% weight fractions of replacement aggregate for concrete strength 28.2 and 36.2 MPa and a/d ratio 0.5.

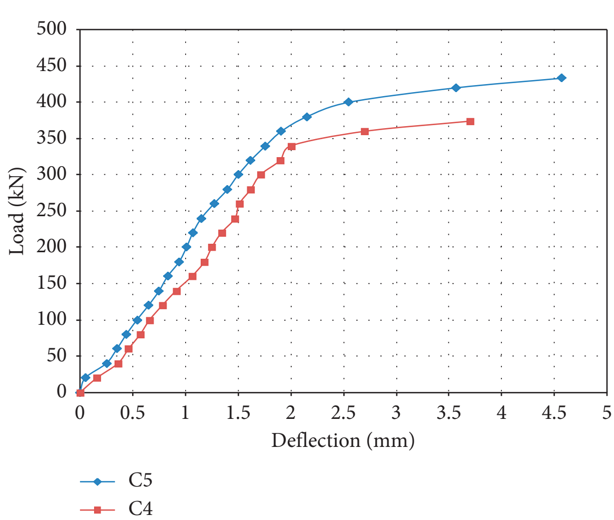

Figure 9: Load-deflection curve of corbels with 50% weight fractions of replacement aggregate for concrete strength 35.1 and 45.8 MPa and a/d ratio 0.5.

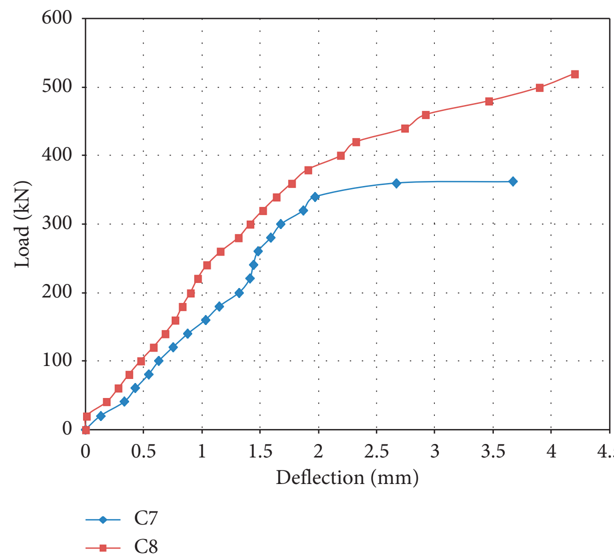

Figure 10: Load-deflection curve of corbels with 50% weight fractions of replacement aggregate for concrete strength 29.4 and 45.6 MPa and a/d ratio 0.35.

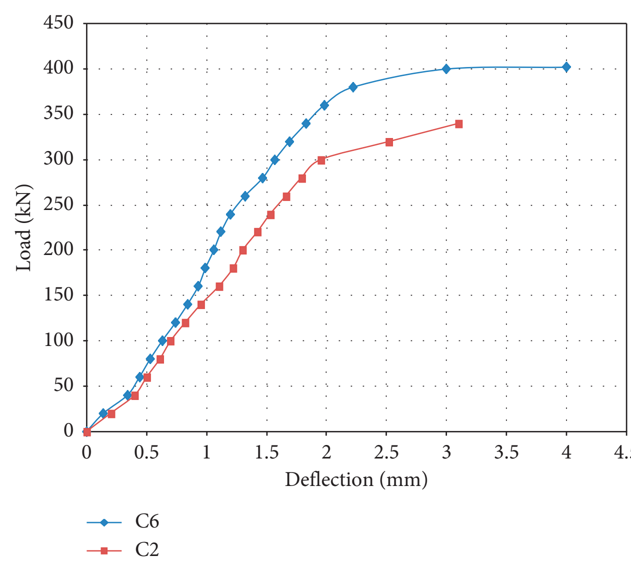

Figure 11: Load-deflection curve of corbels with 100% weight fractions of replacement aggregate for concrete strength 28 and 44.3 MPa and a/d ratio 0.5.

corbel C2 (a/d = 0.5) (Figure 11). The enhancement in failure and cracking loads due to increasing compressive strength is more effective with the presence of recycled aggregate. Also, it can be concluded that the suitable RA replacement ratio attendant to *fcu* increasing was 50%. The effect of this ratio (50%) increases with decreasing a/d.

4.7. Load Span Ratio. The effect of decreasing span-depth ratio is established in Figure 12 in which the reduction in this ratio from 0.50 to 0.35 increases the crack and failure loads by 8% and 20.2%, respectively, as given in Table 8. At the same time, it is clear from Table 8 that the ratio of the crack

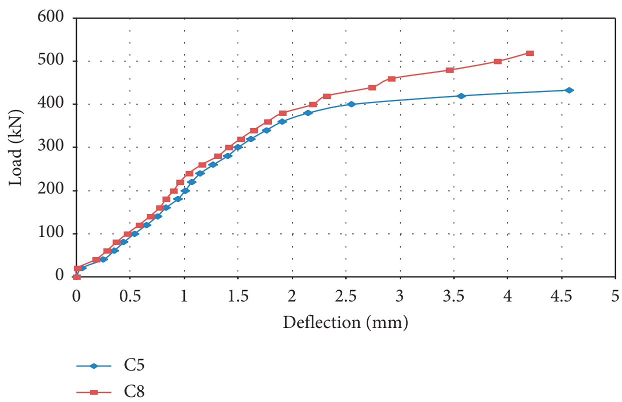

Figure 12: Load-deflection curve of corbels with concrete strength 45.8 and 45.6 MPa and weight fractions of replacement aggregate 50% and a/d ratio 0.5 and 0.35.

load to failure load increases from 0.45 to 0.5 as a/d increases from 0.35 to 0.5, respectively. Table 8 and Figure 12 verify that the corbels' strengths are much sensitive to the reduction in span-depth ratio than the associated deflections. The above-mentioned phenomena were attributed to the failure mechanism of corbels which was arch rib failure and depends on the resistance of the inclined strut. The strength of that strut depends on the compressive strength. The corbels exhibited reserve in shear strength above, causing diagonal tension cracks; this is due to a type of arching action that forms between the top load and bottom supports after the crack pattern was fully developed. This behavior is consistent with the findings obtained by Yassin et al. [20].

5. Conclusions

From the attained present investigation, the following concluding remarks can be summarized as follows:

(1) All corbels showed the same structural behavior and failed in the same manner.

(2) With the presence of the RA, the compressive and tensile strengths of concrete were simply reduced. Thus, a simple reduction in cracking and ultimate loads occurred.

(3) The RA had lower mechanical properties than gravel, which reduces the stiffness of RCC manufactured with RA (i.e., the deflection in the RA specimens is greater than in the specimens without recycled aggregate).

(4) The RA replacement ratio causes decreasing both cracking loads by 9% and 5% and failure load by 4% and 1% for RA of 50% and 100%, respectively, regardless of span-depth ratio. This effect decreases with increasing RA ratio.

(5) Generally, the effect of concrete strength increasing enhanced both cracking and failure load for all specimens, while it was more effective with the presence of RA, and the RA ratio of 50% was the suitable ratio.

(6) The increase in compressive strength enhanced both cracking and ultimate loads. For 10.7 MPa, 16.2 MPa, and 16.3 MPa increase in compressive strength, the cracking and ultimate loads increase by 11.2% and 15.6%, 15.2% and 43.4%, and 0.1% and 18.5%, respectively.

(7) The reduction in a/d (from 0.50 to 0.35) increases the crack and failure load by 8% and 20.2%, respectively, leading to confirm that the corbels strengths are much sensitive to decreasing span-depth ratio compared to the associated deflections.

(8) Because of a type of arching action that arises between the load and bottom supports after the crack pattern has fully developed, the corbels showed a reserve in shear strength above that creating diagonal tension fractures.

(9) The ACI code and E2 code give lower values for failure load than the present results for all tested cases regarding RA, concrete strength, and span-depth ratio.

(10) When the design code of practice is changed, there may be no meaningful difference in the ultimate load of RCC.

(11) Based on the present findings, it is possible to conclude that RA could be used to substitute natural coarse aggregate in corbels.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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