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Structural Behavior of One-Way Reinforced SCC Slabs Made with a Variety of Recycled Aggregates Under Repeated Load

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Abstract: The paper reports an experimental investigation on the structural performance of sustainable one-way self- consolidation concrete (SCC) slabs including concrete or brick waste as partial substitute for coarse aggregate under static and repeated loading conditions. Six reinforced concrete slab specimens were evaluated utilizing self-consolidating concrete and several varieties of recycled material. All specimen slabs of 700 x 100 x 1700 mm with uniform reinforcement and configuration were fabricated. Two variables were examined in the experimental tests: the types of recycled aggregates and the applied load. A replacement ratio of 33% was employed in the specimen mixtures incorporating recycled concrete and bricks. Three specimens were subjected to static load testing, whereas the remaining specimens underwent testing under repeated loads. The deflection response, cracking loads, failure load, ductility index, and stiffness were analyzed. The test results reveal no substantial change in the examined variables between specimens containing recycled materials and those without. The reduction in the ultimate failure load during static loading was 0–3.3%. In the repeated load, the maximum failure load of the sample with recycled concrete diminished by 3.85%, whereas the maximum failure load of the specimen with recycled bricks augmented by 11.54%. The ductility and stiffness of these specimens decreased relative to the reference specimen after repeated loading. The recycled aggregate specimens demonstrate a noticeable reduction in ductility and stiffness after repeated loading compared to similar subjected to static loading.

Keywords: Self- consolidation concrete, Structural behavior, Recycled concrete, Recycled brick, Repeated load.

Introduction

Waste legislation has considerably enhanced environmental sustainability and the effective administration of building and demolition trash in numerous countries. It has now become legal responsibility and a necessary line of action. The building, infrastructure, and manufacturing sectors are devising strategies to reduce waste production and improve waste management, with the objectives of environ-mental preservation and economic viability. Bal and Panda (2013) examined the properties of SCC with concrete trash Instead of gravel. The investigation demonstrates that as the amount of reused concrete aggregate raised, the compressive, tensile, and flexural strength of self-consolidation concrete decreased. Ozbakkaloglu et al. (2018) studied concrete's durability and mechanical properties with reused aggregates of diverse sizes and quantities. Their results indicated that assuming a constant water- cement ratio, recycled aggregate concrete's compressive strength diminishes as the reused aggregate proportion rises. tensile and rupture strengths decrease with the increasing proportion of recycled concrete aggregate.

Ayada and Al-Shafi'i (2022) looked at the characteristics of concrete used brick and reused concrete as coarse aggregates, with 50% and 100% replacement of each material. The research showed that changing the amounts

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of recycled concrete and crushed bricks (0–50%–100%) greatly affected the compressive and tensile splitting strengths but not the flexural strengths. Ahmed et al. (2023) investigated self-consolidation concrete utilizing recycled aggregate in different replacement ratios. Results showed that increased recycled coarse aggregate content led to a decrease in the hardened characteristics of the concrete, indicating potential adverse effects. Bheel et al. (2020) studied the use of brick waste instead of gravel in concrete. The study examined six replacement ratios of crushed brick instead of gravel (0, 20, 40, 60, 80, and 100 per cent) and discovered that the inclusion of recycled brick instead of regular gravel in concrete mixtures reduced both compressive and flexural of concrete.

Alsadey (2019) investigated the properties of concrete when using brick waste as a substitute for natural gravel. The study found that the compressive strength of the concrete decreased after using brick instead natural gravel at 7 and 28 days, and this decrease raised with the rise in the substitution ratio. Zhang and Zong (2014) researched the impact of using reused concrete instead of regular gravel on concrete properties. The study found that the compressive strength of the concrete decreased with an increase in the replacement ratio. When the replacement ratio reached 50%, the compressive strength decreased by 25.37%. Al-Daebal and Khalil (2018). looked at the engineering characteristics of sustainable self-consolidation concrete incorporating recycled brick. They found that the tensile, and rupture, and compressive, strengths capacity, furthermore to the modulus of elasticity, were all lower in mixtures that had 25%, 50%, 75%, and 100% clay brick waste as volumetric replacements for regular gravel in (SCC). The decline in proportion climbs with the rise in the content of brick waste in SCC.

De Brito and Silva (2020) studied the structural design of reinforced concrete slabs with recycled aggregate. Under Eurocode 2, the study used different amounts and qualities of recycled aggregate concrete. The study determined that the substitution of extensively recycled aggregate in concrete replacement causes in significant deformability in the slab, leading to substantial deflection. Mohammed and Najim (2020) examined the mechanical strength and bending performance of SCC including waste concrete aggregate utilizing substitution proportions of (0, 25, 50, 75, and 100) percent in place of regular gravel. Eight reinforced self-consolidation concrete beams, measuring 1200mm x 100mm x 150mm, were employed in the study. The study found that waste concrete aggregate (RCA) beams had lower structural performance than regular self-consolidation concrete beams. The crack and ultimate loads decreased as RCA increased, and deflection increased with initial fracture and maximum loads. However, these reductions can be qualitatively assessed within acceptable limits in structural engineering. RCA is applicable in producing structural (SCC) as its strength and performance meet the necessary criteria for structural application. The study conducted by Hassan and Khudhair (2023) studied the structural performance of reinforced hollow core slabs made from recycled concrete as gravel. It revealed that incorporating recycled material altered internal stresses, maximum load, and ductility of the concrete components. Changes in the replacement ratio of recycled material affected cracking load and ultimate load.

Altaee and Khudair (2020) investigated the structural performance of one-way slabs constructed with (SCC) incorporating reused concrete as gravel. This investigation found that incorporating reused concrete aggregate in concrete mixtures leads to an earlier manifestation of the first fracture. When recycled concrete aggregate is added to mixes, slabs that fail in flexure are less likely to crack or have a lower ultimate moment capacity than slabs made with natural gravel. Slabs containing reused concrete aggregate demonstrate heightened deflection. A higher replacement ratio of recycled concrete aggregate led to more strains at and after the cracking load, referred to as the elastic stage. (AL-Shafi'i et al., 2023) investigated the flexural response of concrete slabs with waste brick as coarse aggregates. Results showed that increasing the proportion of waste bricks from 50% to 100% led to a decline in flexural strength from 20% to 17%. The maximum load of slabs with 50% waste brick as coarse aggregates was 14% to 24% lower than those with natural coarse aggregates.

Abuzaid et al. (2022) examined the structural effects of using recycled concrete or bricks instead of natural gravel in concrete beams. The results show that these materials can replace natural gravel by 50% or 100%, resulting in compressive strength values of 89-97% and 75-86%, respectively. Tensile strength percentages are 70-96% in recycled concrete and 55-80% for recycled bricks. However, replacing natural gravel in half-thickness of beams reduces strength by 3% to 20% and flexural strength by 9% or lower. (Saleh et al., 2018) investigated the flexural behavior of reinforced concrete two-way slabs utilizing crushed bricks as gravel. The study involved casting and testing five square slabs, each measuring 800 mm x 800 mm x 95 mm. The compressive strength of concrete with molten brick aggregate was between 39.2 and 35.2 MPa, while concrete with gravel coarse aggregate had a compressive strength of 40.35 MPa. The flexural strength of concrete using molten brick aggregate diminishes by approximately 12%, 20%, 25%, and 33% as the replacement ratio of waste brick increased from 25% to 100%. The mixtures, including brick aggregate, showed a modulus of elasticity 10-15% lower than natural concrete at 28 days of age. The initial fracture load of the reference slab decreased to 37.8, 34.2, 32.5, and 20.8 kN for slabs incorporating waste brick as gravel at different ratios. The maximum load of slabs composed of waste brick decreased to 95.3, 87.3, 83.3, and 80.0 percent of the maximum load of slabs formed with natural gravel.

Allawi and Jabir (2016) investigated the performance of a reinforced slab concrete model under repeated loading conditions. Results showed that the model had the same cracks and failure pattern as when loaded statically. The ultimate load recorded under repeated loads was lower than that of a similar model exposed to monotonic loads. The maximum deflection and crack count were directly related to the increase in load cycles. Bai and Sun (2010) investigated the flexural performance of reinforced concrete beams made of RCA, comparing different substitution proportions and reinforcing ratios. The results showed that the reused concrete beams had characteristics similar to those of conventional concrete beams, including plasticity, fracturing, yield, and maximum stress properties—the strain of the regular section through stressing of recycled concrete beams often adhered to the cross-section hypothesis. The bending mechanisms of recycled concrete and conventional concrete beams were fundamentally similar, allowing their use in engineering applications. However, the deflection of recycled concrete beams increased with a larger substitution rate, indicating reduced beam rigidity. Crack propagation patterns in recycled and conventional concrete beams were typically analogous. The fracture breadth of recycled concrete beams was marginally more significant than that of traditional concrete beams, but the fracture width diminished as the reinforcement rate increased. The replacement rate of reused coarse aggregate concrete did not affect normal section cracking or maximum bearing moment, and the reinforcing rate had minimal influence on the fracturing moment.

Cheng and Qiao (2016) investigated the bending behavior of reinforced concrete beams using crushed brick aggregate, using three beams with a 35% coarse aggregate replacement ratio. The flexural performance of reused aggregate beams was identical to conventional beams. Using recycled concrete, beams can be divided into phases: elastic, cracking, yielding, and failure. The study found that the fracture load of recycled concrete beams was 40% inferior to conventional beams, with a 13% lesser yield load and 15% more deflection than traditional beams. The study concluded that recycled brick aggregate concrete beams are a viable structural material. Kumar and Premkumar (2017) investigated the study examined the behavior of high-performance concrete with recycled aggregate in beams subjected to static and cyclic loading. Two reinforced concrete beams were tested for conventional concrete (CC) and (RAC). The results showed that RAC's compressive strength decreased by 8% compared to CC after 28 days, split tensile strength decreased by 4.92%, and flexural strength decreased by 2.55%. Under static stress conditions, RAC had the highest deflection of 6.5 mm, and its fracture size was the greatest. CC's maximum load was 164 kN, while RAC's was 140 kN, 8.53% less than CC's. Cracks were observed in all three instances during the third cyclic load, with RAC having an ultimate load of 8.5% inferior to CC. (Al-shaarbaf et al., 2019) examined the performance of self-consolidation concrete void slab strips when repeatedly loaded, finding that specimens failed similarly to those loaded monotonically, with higher fracture rates and lower ultimate load capacity under repeated loading.

This research aims to test one-way sustainable concrete slabs that use concrete and brick waste as a partial replacement for coarse aggregate under static and repeated loads. It will evaluate the structural behavior of these slabs in terms of the first crack load, ultimate failure load, deflection, ductility, and stiffness.

Experimental Program

Geometrical Properties and Reinforcement Details

This research tested six one-way slabs with measurements of 1700 mm length, 700 mm width, and 100 mm thickness. They were divided into two groups according to the load type: three under monotonic loading and three under repeated loading. Each model in the first group had a similar model in the second group. The difference between the three models in each group was using recycled waste as a partial substitution of coarse aggregate with a substitution proportion of 33%. The first model in each group used natural coarse aggregate as a reference model. The second model used recycled concrete to partially replace coarse aggregate, while the third used recycled brick. The reference model was designed to fail under flexural stress ((ACI-318), 2019) code requirements. The reinforcement was similar for all six models. Table 1 shows the model labeling, the type of loading, and the recycled material used, while Figure 1 shows the measurements of the roof model and the reinforcement.

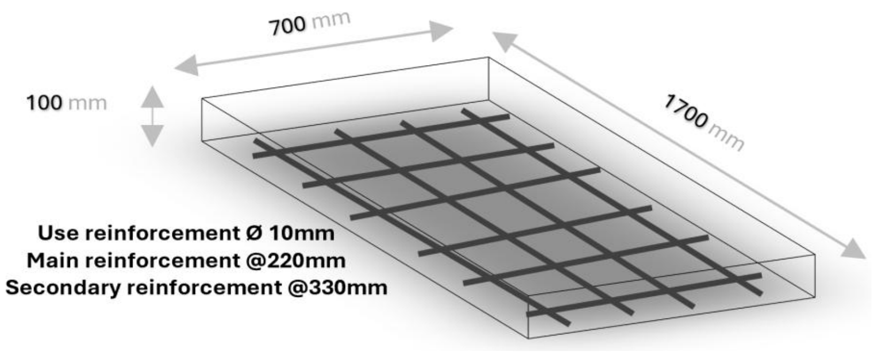


Figure 1. Details of tested reinforced concrete slab.

Table 1. Slabs description

Specimen name	Reused materials	Loading type
S1. N. M	- (reference)	Monotonic loading
S 2.RC. M	33% reused concrete	Monotonic loading
S 3.RB. M	33% reused brick	Monotonic loading
S 4. N. R	- (reference)	Repeated loading
S 5.RC. R	33% reused concrete	Repeated loading
S 6.RB. R	33% reused brick	Repeated loading

Materials

This study employed standard Portland cement (commercially known as Krista), fine and coarse aggregates, limestone powder, reclaimed concrete, and reclaimed bricks. The research utilized a superplasticizer, a high-range water reducer called Visco-Crete, and 10 mm diameter reinforcement steel. The Portland cement adhered to Iraqi requirements (IQS, 2019) whereas the sand and gravel complied with the specifications of Iraqi aggregate standards (IQS, 1984). The classification of reused concrete and bricks complies with the coarse aggregate criteria specified in Iraqi requirements IQS No. 45/1984. The steel conformed to American standards (ASTM-A615/A615M, 2020). Figures 2 (a and b) depict the recycled concrete and recycled bricks.

(a) **(b)**

Figure 2. Recycled aggregate used in this work: (a) recycled concrete and (b) recycled brick.

Mixtures, Molding, and Cured Slabs with the Characteristics of SCC

Three mixes of SCC were designed per to the European specifications to self-consolidation concrete. First mix, SCC1-N, is considered the reference and does not use any waste materials. The second mix contains recycled concrete as a partial replacement of gravel at a replacement rate of 33%, and it was named SCC2-RC. The third mix uses crushed bricks as a partial replacement of gravel at a replacement rate of 33%, and it was named SCC3-RB.

Table 2. Proportion of mixes

Mix type	Materials (kg/m^3)							
	cement	water	Lime ston	Coarse aggregate	fine aggregate	reused concrete	reused brick	superplast icizer
SCC1-N	414	186	135	820	760	....	....	7.65
SCC2-RC	460	175	134	546	760	233.5	....	8.8
SCC3-RB	475	180	125	536	755	....	205	9.5

In the previous paragraphs, the characteristics and specifications of the slabs were mentioned. After preparing the wooden forms according to the required dimensions and coating them with oil to prevent concrete from sticking, 10 mm diameter reinforcing steel was placed according to the design of these slabs. A mechanical mixer with horizontal rotary mixer has a volume of 0.4 cubic meters was used to mix all concrete mixture components. The mixing continued for a period that allowed the mixing and homogenizing of all elements of the mixture. After the mixing process was completed, the concrete was placed in the wooden forms, and the surfaces of these slabs were well-leveled. Then, six cubes with measurements of 150*150*150 mm, six cylinders with measurements of 100*200 mm, and two prisms with measurements of 100*100*500 mm were filled with concrete for each concrete mixture. After filling the wooden forms with concrete, they were enveloped with moist canvas and polythene sheets to inhibit concrete water from evaporating. After opening the molds for cubes, cylinders, and prisms, they were immersed in water for 28 days, while the slabs were treated with water daily for 28 days. After 28 days, the slabs were coated with white water-based paint to facilitate the visualization of cracks that occurred in these slabs during the testing. Figures 4, 5, and 6 illustrate the one-way slabs' casting, curing, and testing.

Tables 3 and 4 outline the characteristics of fresh and hardened SCC, respectively. Three testing methods were conducted on fresh concrete to comply with SCC standards: slump flow, L-box and V-funnel, evaluations. The properties of the mixtures adhere to the SCC requirements established by (EFNARC, 2005). After 28 days, the concrete's compressive, tensile, and flexural strengths were evaluated.

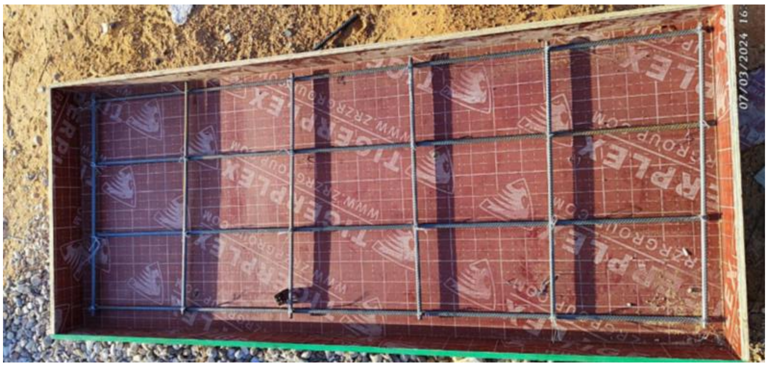


Figure 3. Mold and reinforcement details.

Figure 4. Details of the slab molds

Figure 5. The curing of slabs.

Figure 6. Slab test

Table 3. Fresh self-consolidation concrete mix properties

Tyape of mix	flow mm	T_{500} sec	V.funnel sec	L.Box
1-N	710	2.95	8.96	0.92
SCC2-RC	680	3.1	9.5	0.89
SCC3-RB	700	3.03	9.4	0.91

Table 4. Properties of hardening SCC mixture in (MPa)

Type of mix	f'_{cu}	f'_r	f'_t
SCC1-N	37.15	4.68	3.81
SCC2-RC	35.46	4.41	3.54
SCC3-RB	39. 2	3.42	3.84

The Procedure and Test Setup

As shown in Figure 7, A hydraulic device with a capacity of 500 kN was used to test the one-way slabs. Many components constitute this universal laboratory device: A device for lifting and stabilizing big items is called a hydraulic jack, a force converter that transforms the applied stress into electrical pulses called load cells. A digital gauge was used to determine the vertical displacements of the models when the load was applied, with a capacity of 25.40 mm and an accuracy of 0.010 mm. A four-point loading mechanism was used in the test, as shown in Figure 8.

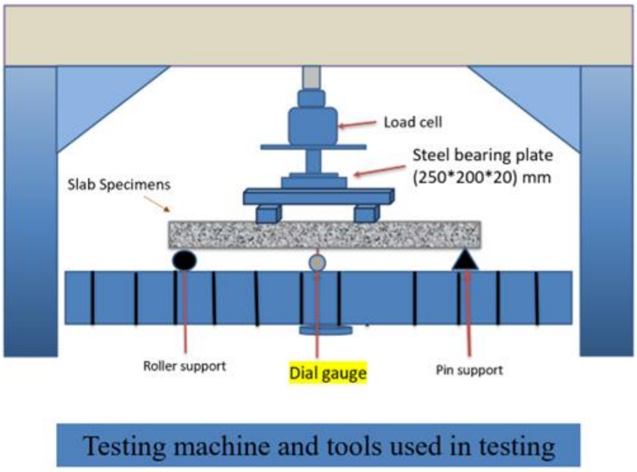


Figure 7. Slabs testing machine.

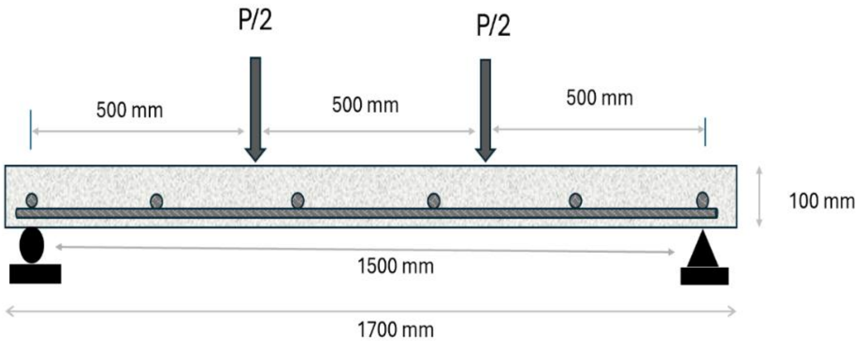


Figure 8. Slab test mechanism.

After dividing the six one-way slab specimens into two groups, each specimen in the first group had a similar specimen in terms of dimensions and materials in the other group. The first group was subjected to monotonic loading, where the load was employed at an incremental velocity of 2 to 3 kN, while the deflection was recorded at the center of the slab every 5 kN. Loading continued in this manner until the specimens failed. The second group was subjected to repeated loading for ten successive cycles, divided into two cycles up to a load of 10 kN, two cycles up to 20 kN, three cycles up to a load of 30 kN, and a final three cycles up to 40 kN. The 40 kilonewton load represents approximately 70 percent of the maximum load value of the corresponding slabs in the first group. After the ten loading cycles were completed, the specimens were loaded until failure. As in the first group, the loading velocity was increased from 2 to 3 kN, and the deflection was recorded at the center of the slab specimens every 5 kN, as shown in Figure 9.

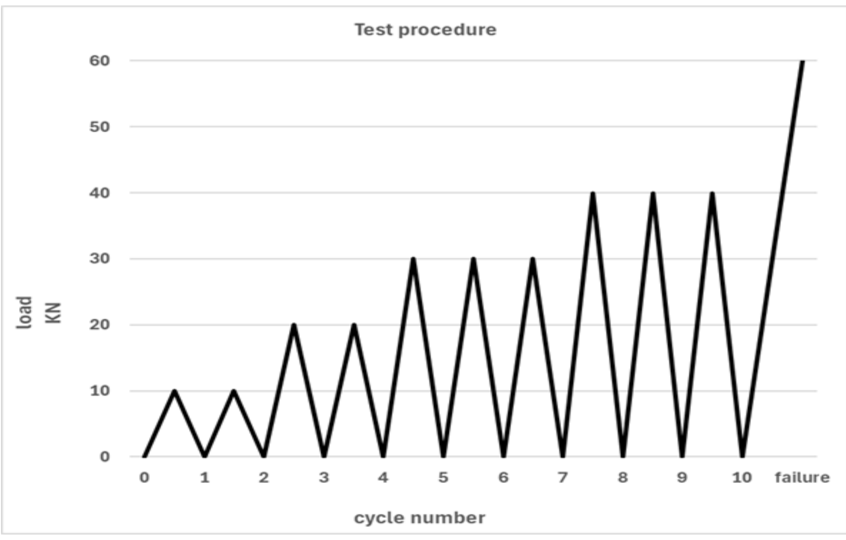


Figure 9. Repeated load procedure (García et al., 2019).

Results and Analysis of the One-Way Slab Tested

General Behavior of One-Way Slabs

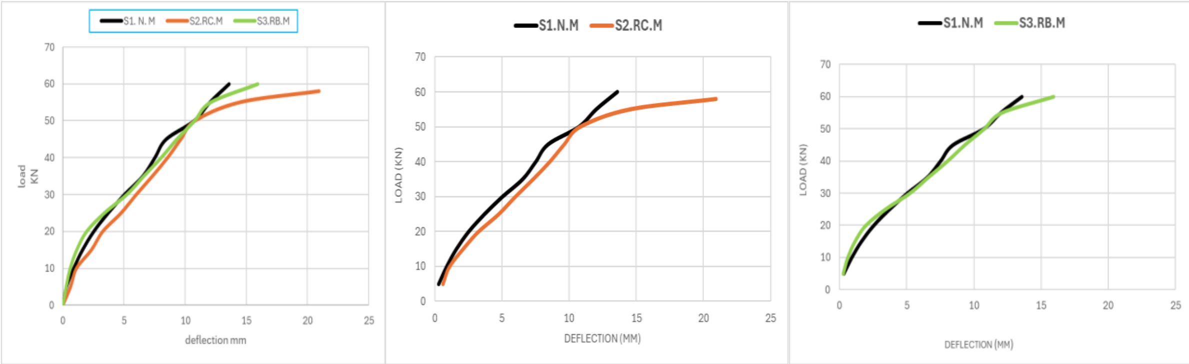
The testing results in Table 5 show that the control sample, S1.N.M., was made from SCC without utilising recycled aggregate and was tested with a monotonically load. For this sample, the initial fracture showed at load of 20 kN and failed at 60 kN. Sample S2.RC.M, which partially replaced the coarse aggregate with reused concrete aggregate, initially cracked at 16 kN and achieved an maximum failure load of 58 kN. The model containing recycled concrete exhibited a 20% reduction in initial rupture load. This decline is twofold: first, the compressive strength of this model's mix is lower than the compressive strength of the reference model's mix; second, the presence of old mortar weakens the bond between the recycled concrete aggregate and the new cement mortar, leading to the appearance of cracks earlier compared to models containing natural aggregate. The decrease in the final load of the model containing recycled concrete was 3.33%. The S3.RB.M slab specimen, which contained brick waste as a partial substitution of the coarse aggregate, had an initial fracture load at 20 kN and an ultimate load of 60 kN. The initial and ultimate failure loads for this sample were identical to those of the control specimen, although the admixture in this specimen had a higher compressive strength. The ultimate failure of all three specimens was flexural. However, the three specimens exposed to repeated loading exhibited lower maximum load values than those tested under monotonic loading. This difference was due to the repeated loading cycles that led to fatigue and deterioration of these slabs. Specimen S4.N.R. exhibited initial failure load values of 16 kN at cycle three and an ultimate load of 52 kN. For Sample S5.RC.R, the first crack appeared at 15 kN at cycle three and failed at a load of 50 kN. The load at which the first crack appeared and the maximum load for this sample, which used recycled concrete instead of some coarse aggregate, decreased by 6.25% and 3.85%, , compared to the control sample when tested with repeated loading. This sample also showed a significant increase in cracks and deflection. The final sample, S6.RB.R, exhibited initial crack and ultimate failure loads at 20 at cycle fifth and 58 kN, respectively. These results indicate a 25% rises in the fracture load and 11.54% rises in the ultimate load, respectively, compared to the repeatedly loaded sample, S4.N.R. The increase in the first crack load and the ultimate failure load of Model S6.RB.R compared to the reference model is due to the increase in the compressive strength of the concrete mix for this model compared to the compressive strength of the concrete mix for the reference model. Additionally, the brick aggregate used is derived from high-strength bricks. Furthermore, the final shape of the brick aggregate particles, which are characterized by surfaces with sharp angles, helps increase the bond between the components of the concrete matrix and enhances the bond between the concrete elements and the reinforcement steel.

Table 5. Ultimate and cracking loads of one-way slabs in (KN).

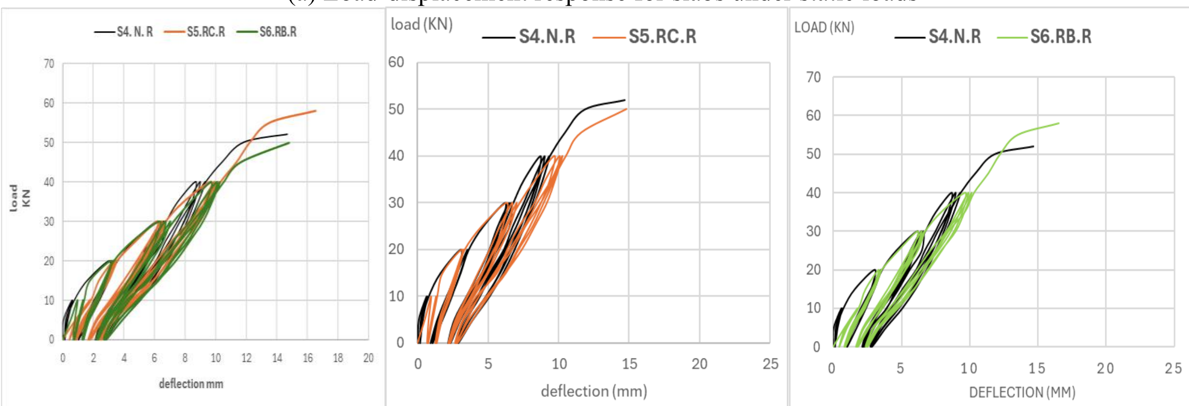
Sample of slab	$P_{ultimate}$	P_{crack}	Mode of failure
S 1. N. M	60	20	Flexure
S 2.RC.M	58	16	Flexure
S 3.RB.M	60	20	Flexure
S 4. N. R	52	16 at cycle3	Flexure
S5.RC. R	50	15 at cycle 3	Flexure
S 6.RB. R	58	20 at cycle 5	Flexure

Slab Load–Displacement Curves

The study of load-displacement curves for one-way slabs, whether they contain recycled coarse aggregate or natural coarse aggregate, is essential to understanding the behavior of these slabs under both static and repeated loading. In the control model S1.N.M under static loading, the deflection at maximum load was 13.59 mm. The deflection in the two models containing recycled concrete and waste brick as partial replacements for coarse aggregate was 20.94 mm and 15.94 mm, with 54% and 17.3% increases, respectively. This is due to the gravel is stiffer compared to waste concrete and crushed brick. Figure 10a shows the load-deflection curves for the samples subjected to static loading. For repeated load, as illustrated in Figure 10b, the deflection for the reference sample S4.N.R was 14.69 mm. In the sample S5.RC.R, the deflection increased slightly by 0.95% to record 14.83 mm. In the last sample, S6.RB.R, the increase in deflection at maximum load was 12.6% compared to the deflection in the reference sample, measuring 16.54 mm. The reason for the high deflection in samples containing concrete and brick waste is the high strain in the concrete containing these wastes compared to the concrete containing natural aggregate.



(a) Load-displacement response for slabs under static loads



(a) Load-displacement response for slabs under repeated loads.

Fig. 10. Load-displacement response for all slabs

Ductility

Ductility denotes a structural element's capacity to maintain strength during significant distortion or deflection. The ductility ratio (μ) may be delineated as the percentage of the highest deflection at maximum load relative to the yield displacement of the identical elastic-plastic process. This study utilizes the same approach by implementing a deflection of 75 percent regarding the maximum load (Δ0.75pu). per (Park, 1989). In tested one-way SCC slabs, regardless of the inclusion of recycled materials, experimental ductility percentages (μ) are calculated by divided the deflection at peak load (Δu) by the deflection at 75% of the load (Δ0.75pu). This methodology was applied to all slabs assessed under both loading conditions: monotonic and repetitive.

$$\text{The ductility index } (\mu\Delta) = \Delta u/\Delta y \qquad (1)$$

Under static load conditions, Table 6 shows that samples made of recycled bricks (S3.RB.M) and recycled concrete (S2.RC.M) have more ductility than the con-trol sample S1.N.M by 6.21% and 39.75%, respectively. This enhancement is attributed to the deflection of these samples exceeding that of the control sample S1. N.M. The ductility in the second group, which was subjected to repeated loading, decreased. This decrease is attributed to the deterioration and fatigue that occur in the models as a result of the successive loading cycles. Also, as indicated in Table 6, there is a decrease in ductility for the models containing recycled concrete aggregates and brick waste by 7.54% and 5.55% respectively, compared to the reference model for repeated loading, which contains natural coarse aggregate.

Table 6. Ductility for one-way slabs

Sample of slab	Ultimate deflection(Δu) mm	Deflection (75%Pu)(Δy) mm	Ductility ratio (μ = **Δu**/ **Δy**)	dif %
S 1. N. M	13.59	8.44	1.61	------------------
S 2.RC.M	20.94	9.33	2.25	39.75
S 3.RB.M	15.94	9.32	1.7	6.2
S 4. N. R	14.69	9.22	1.59	------------------
S 5. RC. R	14.83	10.09	1.47	7.54 ↓
S 6. RB. R	16.54	11.06	1.50	5.55 ↓

Stiffness

Pam et al. (2001). calculate the initial stiffness by determining the secant that inter-sects a load-deflection point corresponding to 70% of Pu and extends to reach Pu, as shown in Figure 11.

$$\text{Initial stiffness} = Pu/\Delta y \quad (2)$$

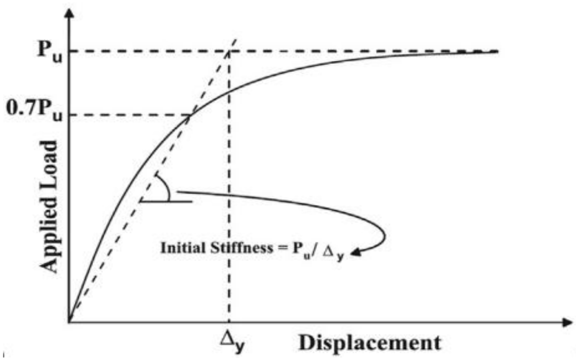


Figure 11. Procedures for determining stiffness (Abdulraheem, 2018)

The calculated values of initial stiffness, as shown in Table 7, indicate a decrease ranging from (7.7%-12.2%) in the initial stiffness values of the two models containing recycled bricks and recycled concrete under static loading. Similarly, under repeated loading, the decrease was between (6.75%-12.5%).

Table 7. Initial stiffness for the one-way slab.

Sample of slab	(Δ)Deflection (mm)	70% pu (kN)	Initial Stiffness	dif %
S 1. N. M	7.89	42	5.32	-----
S 2.RC.M	8.7	40.6	4.67	12.2↓
S 3.RB.M	8.55	42	4.9	7.7↓
S 4. N. R	8.77	36.4	4.15	------
S 5. RC. R	9.64	35	3.63	12.5 ↓
S 6.RB. R	10.5	40.6	3.87	6.75 ↓

Conclusion

1. The partial replacement of natural coarse aggregate with concrete and brick waste leads to a decrease in the properties of hardened self-consolidation concrete, and this decrease increases with the increase in the replacement ratio.
2. The maximum load capacity of the models containing brick and concrete waste in the S.RB3.M and S2.RC.M models decreased by (0-3.33%) compared to the reference model in the static load. While the maximum load capacity value of the sample containing brick waste increased by 11.54% under repeated loading, the ultimate load capacity value of the sample containing concrete waste as coarse aggregate continued to decrease by 3.85% compared to the reference model under repeated loading.
3. The deflection at the maximum load in the models containing brick and concrete waste increased by (17.3%-54%) compared to the reference model for static load. Similarly, the deflection in the models containing concrete and brick waste under repeated load increased by (0.95-12.6%) respectively.
4. Under static loading conditions, the ductility of slabs incorporating concrete and brick waste as coarse aggregates exceeded that of the slab utilizing natural coarse aggregate by 39.75% and 6.21%, respectively. During repeated loading, the ductility of samples incorporating concrete or brick waste was diminished by 7.54% and 5.55%, respectively, compared to the reference specimen.
5. The incorporation of recycled concrete or recycled brick as coarse aggregate in slabs diminished stiffness under both static and repeated load conditions.
6. Repeated loading has resulted in a reduction of failure load, ductility, and stiffness, all of which are inferior to those observed in identical specimens subjected to static loading. The specimen with recycled concrete S5.RC.R exhibited the most significant reduction in maximum failure load, decreasing by 13.8%, whereas

the specimen with recycled bricks S6.RB.R showed the least reduction, at roughly 3.33%. The specimen S5.RC.R exhibited the greatest decrease in ductility, approximately 34.67%.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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References

ACI Committee 318. (2019). *Building code requirements for structural concrete (ACI 318M-19) and commentary (ACI 318R-19).* American Concrete Institute.

Abdulraheem, M. S. (2018). Experimental investigation of fire effects on ductility and stiffness of reinforced reactive powder concrete columns under axial compression. *Journal of Building Engineering, 20*, 750–761.

Abuzaid, E. K. M., Al-Bayati, J. K., & Hashim, M. (2022). Behavior of reinforced concrete beams containing waste crushed concrete and bricks. *Civil and Environmental Engineering Reports, 18*(2), 438–447.

Ahmed, S., El-Zohairy, A., Eisa, A. S., Mohamed, M. A. E.-A. B., & Abdo, A. (2023). Experimental investigation of self-compacting concrete with recycled concrete aggregate. *Buildings, 13*(4), 856.

Al-shaarbaf, I. A., Ali, A. A., & Ahmed, M. A. (2019). Experimental behavior of self compacted concrete voided slab strips under repeated loads. In *2019 12th International Conference on Developments in eSystems Engineering (DeSE)* . IEEE.

Al-Shafi'i, N., Hussein, Z., & Ayada, M. (2023). Flexural behavior of concrete slabs using treated recycled brick aggregate. *AIP Conference Proceedings, 2827*, 020009.

Allawi, A. A., & Jabir, H. A. (2016). Response of laced reinforced concrete one way slab to repeated loading. *Journal of Engineering, 22*(9), 36–54.

Alsadey, S. (2019). Properties of concrete using crushed brick as coarse aggregate. *International Journal of Advances in Mechanical and Civil Engineering, 6*(3), 44–47.

Altaee, M. K. E., & Khudair, J. A. S. (2020). Structural behavior of reinforced concrete one-way slabs cast with self-compacting concrete containing recycled concrete as coarse aggregate. *Basrah Journal for Engineering Sciences, 20*(2), 8–17.

ASTM-A615/A615M. (2020). *Standard specification for deformed and plain carbon-steel bars for concrete reinforcemen*t. West Conshohocken, Pennsylvania, USA: ASTM International

Ayada, M., & Al-Shafi'i, N. T. (2022). Properties of normal strength concrete with treated crushed brick and recycled concrete as coarse aggregate. *Journal of Engineering and Sustainable Development, 26*(2), 30–39.

Bai, W. H., & Sun, B. X. (2010). Experimental study on flexural behavior of recycled coarse aggregate concrete beam. *Applied Mechanics and Materials, 29–32*, 543–548.

Bheel, N., Kumar, K. R., Kumar, A., Bhagam, R., Adesina, A., Meghwar, S., & Memon, N. A. (2020). Innovative use of brick wastes as coarse aggregate in concrete. *IOP Conference Series: Materials Science and Engineering, 981*(3), 032077.

Cheng, Y., & Qiao, G. H. (2016). Experimental study of the flexural behavior of concrete beams with recycled brick aggregate. In *2015 4th International Conference on Sustainable Energy and Environmental Engineering* (pp. 79-82). Atlantis Press.

EFNARC. (2005). *The European guidelines for self-compacting concrete: Specification, production and use.* EFNARC.

García, J. M., Bonett, R. L., Schultz, A. E., Carrillo, J., & Ledezma, C. (2019). Flexural behavior of ungrouted post-tensioned concrete masonry beams with unbonded bars. *Construction and Building Materials, 203*, 210–221.

Hassan, M. R., & Khudhair, J. A. (2023). Structural behavior of reinforced concrete hollow core slabs cast with self-compacting concrete containing recycled concrete as coarse aggregate. *Basrah Journal for Engineering Sciences, 23*(1), 26-32.

IQS. (1984). *Aggregate from natural sources for concrete and construction (no 45).* Baghdad, Iraq:COSQC.

IQS. (2019). *Iraqi standard specifcation for portland cement (no 5).* Baghdad, Iraq: COSQC.

Khalil, W., & Al-Daebal, T. (2018). Engineering properties of sustainable self-compacting concrete with clay bricks waste aggregate. *Kufa Journal of Engineering, 9*(3), 223–237.

Kumar, H., & Premkumar, G. (2017). Behaviour of high performance concrete by using recycled aggregate on beam under static and cyclic loading. *International Journal of Civil Engineering and Technology, 8*(3),210-219.

Mohammed, S. I., & Najim, K. B. (2020). Mechanical strength, flexural behavior and fracture energy of -recycled concrete aggregate self-compacting concrete. *Structures, 23*, 34–43.

Ozbakkaloglu, T., Gholampour, A., & Xie, T. (2018). Mechanical and durability properties of recycled aggregate concrete: Effect of recycled aggregate properties and content. *Journal of Materials in Civil Engineering, 30*(2), 04017275

Pam, H. J., Kwan, A. K. H., & Islam, M. S. (2001). Flexural strength and ductility of reinforced normal- and high-strength concrete beams. *Proceedings of the Institution of Civil Engineers – Structures and Buildings, 146*(4), 381–389.

Panda, K. C., & Bal, P. K. (2013). Properties of self compacting concrete using recycled coarse aggregate. *Procedia Engineering, 51*, 159–164.

Park, R. (1989). Evaluation of ductility of structures and structural assemblages from laboratory testing. *Bulletin of the New Zealand Society for Earthquake Engineering, 22*(3), 155–166.

Saleh, I. S., Faleh, S. K., & Chkheiwer, A. H. (2018). Flexural behavior of RC two way slabs made with crushed melted bricks as coarse aggregate. In *Civil Infrastructures Confronting Severe Weathers and Climate Changes Conference (CISWCC 2018)*.

Silva, R. V., & de Brito, J. (2020). Reinforced recycled aggregate concrete slabs: Structural design based on Eurocode 2. *Engineering Structures, 204*, 110047.

Zhang, S., & Zong, L. (2014). Properties of concrete made with recycled coarse aggregate from waste brick. *Environmental Progress & Sustainable Energy, 33*(4), 1283–1289.

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