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Structural Behavior of Self-Compacting Reinforced Concrete One-Way Slab with Recycled Glass or Plastic as A Fine Aggregate Under Repeated Loads

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Abstract: This paper deals with an experimental study on the structural performance of one-way slabs made of self-consolidation concrete (SCC) with waste plastic and glass as partial substitutes for fine aggregate. A substitution ratio of 33% was employed, and six slab samples measuring 700 mm by 100 mm by 1700 mm, with uniform reinforcement, were categorized into two groups, each including three samples. The initial group underwent static loading, and the subsequent group was subjected to repeated loading. Subsequently, they underwent testing, and the effect of the research factors was examined. The results indicate that the structural behavior of slabs, containing waste as a fine aggregate, is comparable to that performance slab with regular fine aggregates under monotonic and repeated loading. During static loading, the maximum load exhibited a reduction of about 0-3.33% alongside a decline in stiffness. The findings of the specimens submitted to repeated load exhibited variety; the maximum load was reduced by 13.46% with recycled plastic, while the slab with recycled glass increased by 5.77%. All samples exposed to repeated load demonstrated a diminished in ultimate load, stiffness, and ductility. relative to those exposed to monotonic load; slabs using recycled plastic showed a 22.41% decrease in load failure.

Keywords: Self-compacting concrete, Structural behavior, Recycled glass, Recycled plastic, Repeated load.

Introduction

Legislation regarding waste management has markedly enhanced environmental sustainability and the effective management of building and demolition debris in various nations. It has now become a legal requirement and a necessary line of action. The building, infrastructure, and manufacturing sectors are devising strategies to reduce waste production and improve waste management to promote environmental preservation and economic viability. Ali and Al-Tersawy (2012) conducted an experimental study utilizing waste glass instead the regular sand in SCC. The study tested six SCC mixes with recycled glass of (10%, 20%, 30%, 40%, and 50%) from total fine aggregates. The study revealed that raises in recycled glass ratios resulted in a significant decrease in compressive, flexural, and tensile strength.

Safi et al. (2013) conducted investigation focused on the influence of using plastic trash instead sand in self-consolidation mortars on their mechanical and physical qualities. The study tested five replacement ratios (10, 20, 30, 50) percent. The study found that the compressive strength reduction ranged from (15- 33) percent for mortar with (20–50) percent plastic trash. Adaway and Wang (2015) investigated the use of trash glass substitute for natural sand in structural concrete, focusing on its effects on compressive strength. The control mix was created using natural aggregate, whereas five additional mixes incorporated trash glass instead fine aggregates in amounts

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of 15%, 20%, 25%, 30%, and 40%. The study established that the ideal percent of sand replacement with glass aggregate was 30 percent; the compression strength increased with the incorporation of waste glass into the mix until reaching the optimal replacement level; the angular morphology of the glass particles may enhance their bonding with the paste of cement. The study found that waste glass in amounts exceeding 30% adversely affected compressive strength development; the proposal suggested that increasing quantities of angular glass aggregate reduce the available cement paste, leading to microscopic cavities within the concrete matrix.

Khatib et al. (2015) studied the flexural performance of RC beams use waste glass as lightweight aggregates. Four beams of 700mm x 150mm x 100mm were strengthened with the same reinforcement, but the fine aggregate was substituted by 25%, 50%, and 100% expanded glass, respectively (by volume). Substituting fine aggregates with 50 percent glass enhanced the workability. When the expanded glass content surpassed 50%, the ultimate load significantly decreased while the compressive strength diminished progressively with increased expanded glass in the mix. Compressive strength achieved the minimum threshold of 17 MPa for structural concrete uses at a complete replacement of fine particles. Using waste glass developed the ductility of the RC beam, leading to a higher center deflection. Including waste glass marginally reduced the load at which the first crack manifested and diminished the beam's load-bearing capability.

Mohammed (2017) study examined the flexural performance of beams incorporating polyethene terephthalate (PET) waste. The researchers employed three volumes of PET trash as a sand substitute in several concrete mixtures and evaluated eight beams. The findings indicated that the stiffness and failure mode parameters were consistent when PET waste concrete was used as a replacement for conventional concrete. Nevertheless, the maximum load was somewhat reduced, with the most pronounced decrease observed at 15 percent PET content. The deflection at maximum load and load-displacement response exhibited negligible variations. The cross-section of concrete beams exposed to flexure contains a substantial region between the compression zone and tensile steel reinforcement, which can be filled with PET waste concrete. This indicates that PET trash can be utilized to produce flexural concrete components such as slabs and beams.

Choi et al. (2018) examined the flexural properties of reinforced concrete elements containing heavyweight trash glass instead regular sand subjected to cyclic loading, employing three replacement ratios (0%, 50%, and 100%). Reinforced concrete (RC) elements were used to examine the influence of the replacement ratio of trash glass on flexural performance; the dimensions of the RC element test are 15 cm × 20.5 cm × 140 cm. The study revealed that the proportion of heavyweight trash glass replacement affected crack formation patterns; furthermore, substituting all regular sand with heavyweight trash glass in reinforced concrete components significantly increased the likelihood of abrupt failure due to concrete crushing in the rejoin exposed to compression. The complete replacement of regular sand with heavyweight glass trash reduced the compressive strength of the concrete. It caused a drop in the initial crack load and the ultimate load capacity.

Metawei and Arafa (2018) examined the flexural of RC beams utilizing waste glass instead fine and coarse aggregates. Six beams of 100mm×200mm×1200mm with a partially recycled glass of 10 to 30% of the overall aggregates. The result showed that fine aggregates reduced flexural strength more than coarse glass particles due to the decrease of rugged and robust aggregate materials in concrete. Both beams containing coarse and fine glass aggregates exhibited lower bending stiffness, flexural strength, and ductility than the control beam with natural aggregates. The serviceability, bending stiffness, and ductility of beams with fine glass aggregates surpass those with coarse glass aggregates.

Gayatri and Popat (2020) examined trash plastic as a fine aggregate in concrete. The investigation aims to figure out the ideal proportion of waste plastic to substitute fine aggregate in M20 grade concrete by varying its composition from 7.5% to 12.5%, while evaluating the resultant concrete's workability, strength, and durability properties. The research shown that compression strength drops as the ratio of weak reused plastic granules rises.

Adeala and Soyemi (2021) examined the engineering properties of trash glass as a partial substitute for fine aggregate in concrete, evaluating replacement ratios of 5%, 10%, 15%, and 20%. The investigation revealed a reduction in the compression strength of concrete with raises in the content of crushed trash glass. Concrete containing 5%, 10%, and 15% fine waste glass can attain compressive strength adequate for normal-weight concrete at 28 days.

Mohammed et al. (2021) investigated the structural performance of RC slabs, including waste aggregates derived from polyvinyl chloride as a fine aggregate. Six 870 × 870 × 60 mm reinforced concrete slabs were fabricated and then examined under a two-point loading. The investigation established that the ultimate load of the slab utilizing plastic waste as a complete substitution decreased by 22.9 percent. The maximum deflection raised by 14.3

percent, and the slabs exhibited greater ductility at failure. The flexural strength dropped more with higher plastic aggregate content.

Ibrahim et al. (2022) examined reinforced concrete beams' shear and flexural characteristics, including plastic waste as a fine aggregate. This study used replacement ratios 0, 25, 50, 75, and 100 percent and used 14 beams with measurement 1220 mm length, 180 mm wide, and 120 mm thick beams. Results of the study demonstrated that the overall toughness of fine plastic waste aggregate beams decreased by (2 – 18) percent for flexural and (3 – 11) percent for shear in beams. Using plastic waste instead of regular sand reduces toughness, flexural strength, and shear strength.

Al-Darzi (2022) investigated the influence of plastic on the performance of RC slabs. Seven sets of slabs measuring 550x550x110mm, both with and without recycled polyethylene terephthalate, were constructed and subjected to testing. Based on the flexural test results, replacing sand with recycled polyethylene terephthalate raised the initial cracking load by 3.5 percent, 6 percent and 8.9 percent for 5 percent, 10 percent, and 15 percent replacements, respectively, in comparison to the reference slab specimen. Nevertheless, augmenting the amount of recycled polyethylene terephthalate enhanced the resistance to the first fracture; the experimental bending load tests revealed that substituting sand with 5%, 10%, or 15% recycled polyethylene terephthalate reduced the ultimate load by 13.9%, 16%, or 21.6%, respectively.

The performance of concrete beams with crushed glass and plastic waste has been investigated (T. K. Mohammed and Hama (2023). Fifteen beams of 150 mm × 150 mm × 900 mm strengthened by transverse and longitudinal reinforcement were tested to study the effect of waste percentage. The study found that the beams' ultimate load incorporating (0-20%) waste plastic and (0-15%) waste glass powder increased with the longitudinal reinforcement. Also, it was found that glass powder combined with plastic aggregate could be beneficial in terms of ductility and absorbed energy.

Yang et al. (2023) studied the mechanical characteristics and stress strain curves of reused aggregate concrete (RAC) under constant and varying repeated loads. Forty-five samples were used to examine the impact of replacement rate and loading amplitude on the maximum elastic modulus, stress, and strain. Test results indicated that Young's modulus of the RCA decreased as the load amplitude increased due to the decrease of the peak stress and gradual strain increase.

AL-Darzi et al. (2024) investigated the impact load performance of RC slab specimens incorporating trash plastic aggregate. The study employed weight proportions of polyethylene terephthalate ranging from 0% to 4%, 8%, and 16% as substitutes for fine and coarse aggregates and tested eight concrete slabs divided into four groups. The study concluded that A comparable failure mode was observed under impact loads in the four groups. Cracking in standard concrete slabs (Group G1) was more pronounced than in concrete slabs containing polyethylene terephthalate plastic (Groups G2, G3, and G4). The interaction of polyethylene terephthalate plastics diminished the cracks formed in the slab under impact force. The impact of energy is augmented with the rising proportion of shredded plastic incorporated into the concrete.

Adli and Rodji (2024) studied the flexural strength of beams utilizing broken glass bulbs as fine aggregate. This research will examine the impact of trash glass on the flexural capacity of concrete. Three beams utilized two replacement ratios: 5% and 10%. The study found that the incorporation of trash glass enhanced the flexural capacity of concrete. The improvement depends on how much glass is in the concrete mixture. In addition, the flexural capacity raised by 0.5 to 2 kN compared to standard concrete.

The structural performance of several reinforced concrete slabs, columns and beams with fine or coarse waste aggregates has been highly studied. However, the material properties of recycled concrete are complicated, and the optimum replacement ratio of many waste materials is fluctuated. In addition, research deal with concrete members contains waste material under dynamic loads still rare despite the adverse effect of such loading type. This paper will investigate the effect of plastic and glass trash as a partial substitute of fine aggregates in one of the important structural members (one-way slabs) under the effect of repeated loads.

Methodology

Details of Slab

Six slab specimens of 700 mm×100 mm×1700 mm as seen in Figure1 were constructed, two of them are reference slabs have been designed for flexural failure (tension-controlled) in accordance with the ACI 318-19, the first is subjected to static load while the other to repetitive load. The rest are identical in geometry and reinforcement; however, they vary in their reused aggregate composition (waste glass and waste plastic) with a substitution ratio of 33% for the natural sand, as illustrated in Table). The slab nominate includes three abbreviations: SS refers to simply support condition adopted for all specimens, N, RG, and RP refers to natural, recycled glass, and recycled plastic fine aggregates, respectively, the slabs subjected to a monotonic loading denote at the end of specimen designation by M while the capital letter R refers to the repeated loading.

Table 1. Slabs model description

Model designation	Reused materials	(Fine aggregates substitute ratio)	Type of load
SS1. N. M	(reference)	0	monotonic
SS2.RG.M	(waste glass)	33%	monotonic
SS3.RP.M	(waste plastic)	33%	monotonic
SS4. N. R	(reference)	0	Repeated
SS5.RG.R	(waste glass)	33%	Repeated
SS6.RP.R	(waste plastic)	33%	Repeated

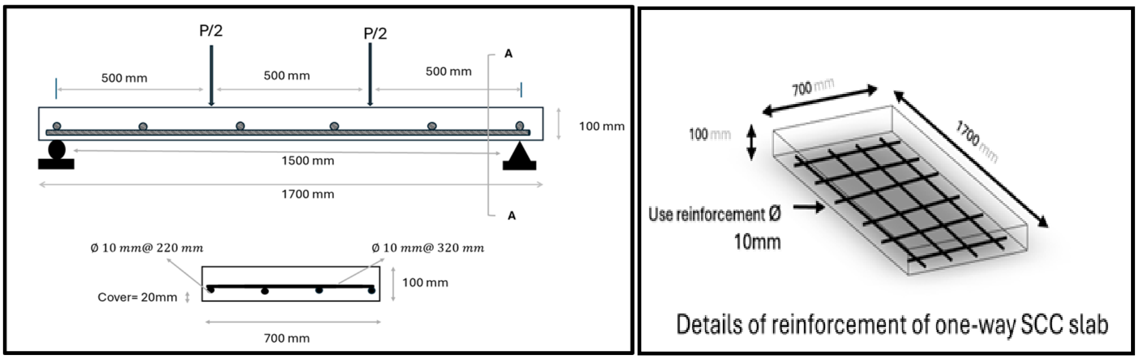


Figure 1. Slab details

Materials

a b

Figure 2. a. Crushed glass, b. Recycled plastic

Ordinary Portland cement conformed to (IQS, NO 5/2019), as shown in (Table 2). fine and coarse aggregates complied with (IQS, NO. 45/1984), and limestone powder with Visco-Crete high-range water reducer superplasticiser are used to produce the concrete. Waste glass and plastic are also used after grinding to the required size as shown in (Figure 2), the classification of recycled glass and recycled plastic adheres to the specified fine aggregate grading outlined in (IQS, NO. 45/1984), (Table 3) illustrated the characteristic of coarse, natural fine , glass, plastic aggregates. The slabs are reinforced in both main and secondary directions with steel bars of 10 mm diameter conformed to (ASTM-A615/A615M, 2020), as shown in Table 4.

Table 2. Cement properties

Chemical Results		
Oxides Composition	Content %	I.Q.S. No.5, 2019
CaO (Free Laminate)		----
SiO2	22.874	----
Al2O3	3.284	----
Fe2O3	3.310	----
Lime Saturation Factor”	0.872	“0.66-1.02
MgO	2.800	<5
C3A	3.102	----
(L.O.I)	2.925	< 4.0
Insoluble Residue	0.811	< 1.50
Physical Results		
Physical Properties	Results	I.Q.S. No.5, 2019
Specific Surface Area (Blaine Method)	310	≥ 280
Initial Setting Time	66	≥ 45 min
Final Setting Time	5.22	< 10 hr
Compressive Strength at two days	19.79	≥ 15 MPa
Compressive Strength at28 days (MPa)	44.7	≥ 25 MPa

Table 3. Coarse, fine, glass, and plastic aggregate properties

Sieve size mm	The grading of coarse aggregate (% Passing by weight)	The grading of natural fine aggregate (% Passing by weight)	The gradation of fine glass aggregate (% Passing by weight)	The gradation of fine plastic aggregate (% Passing by weight)
37.5	100	100	100	100
20	100	100	100	100
14	90.76	100	100	100
10	51.88	100	100	100
4.75	4.24	96.3	93.95	100
2.36	0	79.1	86.32	100
1.18	0	76	36.07	59.8
0.6	0	47.8	18.97	35.6
0.3	0	21.2	5.81	17.8
0.15	0	0.9	1.6	6.6
physical properties	coarse aggregate	natural fine aggregate	glass aggregate	plastic aggregate
S.G	2.65	2.6	2.36	1.2

Table 4. Steel reinforcement properties

Property	Steel reinforcement 10 mm	Specifications of A615/A615M - Grade 60
Yield stress (MPa)	560	420
Ultimate stress (MPa)	643	620
Elongation %	12.5	9

Casting of Self-Consolidating Concrete Slabs

There are three types of SCC mixtures that were used; the first mix made of natural sand and natural gravel (0% RA), whereas the other two mixes containing trash glass aggregate and trash plastic aggregate as partial replacements of sand at a substitution ratio of 33 percent each. A variety of trial mixes were created to attain a compression strength comparable in value for mixes using natural and trash fine aggregates, as demonstrated in (Table 5). (Figure 3) illustrated the casting and testing SCC.

Figure 3. Mixing and testing SCC

Figure 4. Reinforcement, casting and curing SCC slabs

Table 5. Mixes ratios

Mix type	Materials content(kg/m3)							
	cement	limestone	water	fine aggregate	coarse aggregate	waste glass	waste plastic	Super-plasticizer
SCC1	414	135	186	760	820	------	-------	7.65
SCC2-RG	475	125	180	505.85	800	225.3	-------	8
SCC3-RP	500	100	175	509.2	810	------	115.3	9.6

Steel reinforcing grids were constructed and meticulously positioned within the plywood formwork. Concrete elements were amalgamated using a rotary horizontal drum mixer with a 0.4 m³ capacity. Thoroughly mixing concrete for an adequate time is essential for attaining consistency and efficacy. For each concrete mix, six cubes, three prisms, and three cylinders were sampled to evaluate tensile strength, compression strength, , and modulus of rupture. The slabs were covered with damp canvas and plastic sheeting for four weeks. (Table 6) delineate the attributes of fresh and hardened SCC, respectively. To comply with SCC criteria, three categories of testing were conducted on fresh concrete: V-funnel, slump-flow, and L-box tests. The properties of the fresh mixes adhere to the requirements for SCC as specified by (EFNARC, 2005). (Figure 4) alliterated the reinforcing and casting SCC slab.

Table 6. Results of fresh self-consolidation concrete mix

Type of mixes	Slump flow - mm	EFNARC limits	T 500 - sec	EFNARC limits	V-funnel-sec	EFNARC limits	L-Box (h_2/h_1)	EFNARC limits
SCC1	710		2.95		8.96		0.92	
SCC2-RG	720	650-800	2.93	2-5	8.89	8-12	0.93	0.8-1
SCC3-RP	690		3.1		9.4		0.90	

Test Setup and Method

A servo-hydraulic actuator loading frame of 500 kN capacity was used to test al the slabs under four-point loading system as shown in (Figure 5). A load cell is a force transducer that converts applied force into electrical signals for measuring purposes. To measure the vertical displacements of the samples subjected to the applied load used digital dial gauge. The instrument has a capacity of 25.40 mm and an accuracy of 0.01 mm.

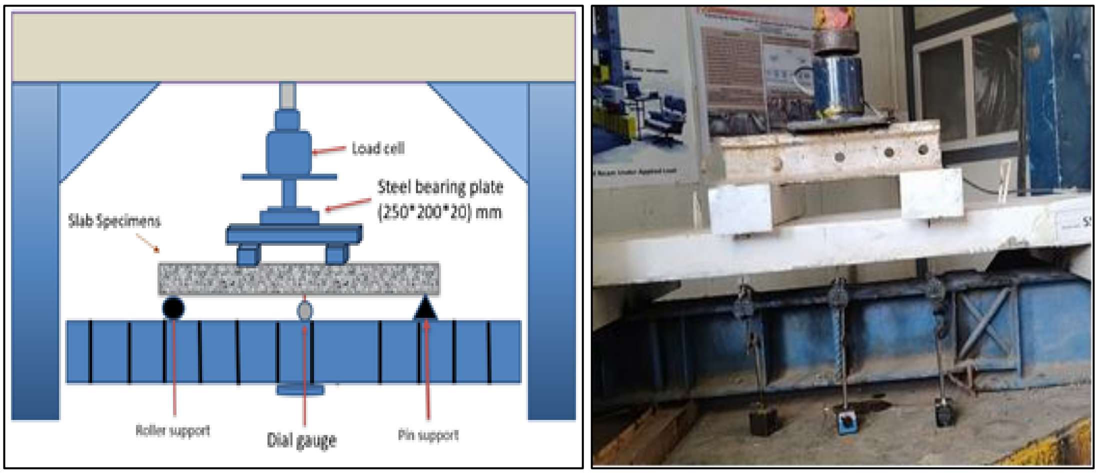


Figure 5. Slabs testing machine

As illustrated in Table 1, the first group includes three specimens tested under static loading with a rate of (2-3) kN till failure, the midspan deflection were recorded at each 5 kN. The other three models which are similar to its counterpart in the previous group in geometric and material properties have been subjected to a repeated loads of ten successive cycles with ascending intensity reaches 70% of the maximum load at which the statically loaded reference failed as shown in Figure 6. Each cycle was implemented at a rate of 2-3 kN until it reached its maximum load, after which it gradually decreased at the same rate till back to zero. After completing all of the loading cycles, the slabs were loaded monotonically up until failure.

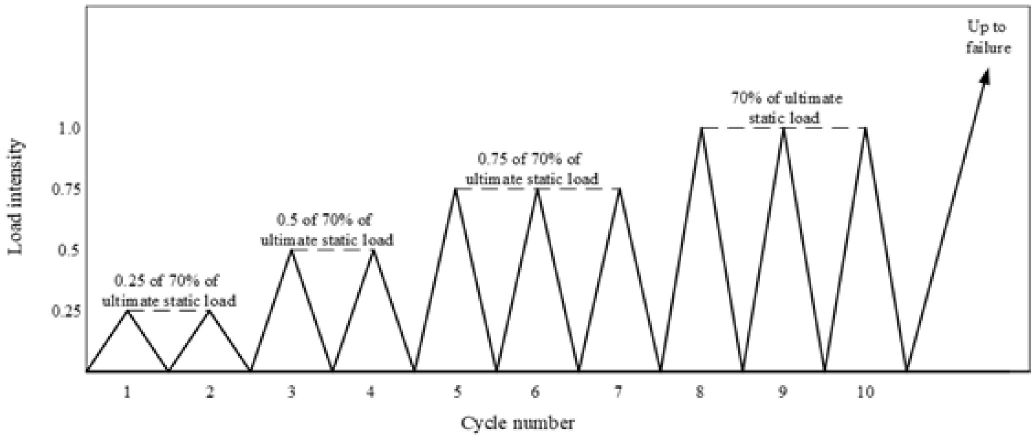


Figure 6. Protocol of repeated load testing (García et al., 2019)

Results and Discussion

Hardened Properties of Concrete Mixes

In order to investigate the effect of trash plastic and glass on the performance of concrete slabs, the concrete mix proportions were selected to produce non-divergent compressive strength values. (Table 7) illustrates the average values of the hardened properties of all mixes.

Table 7. Hardened self-compacting concrete mix properties

Mix type	Compression strength (cube) (MPa)*	Tensile strength (MPa)*	Rupture modulus (MPa)
SCC	37.15	3.81	4.68
SCC-33%-RG	41.03	4.05	5.31
SCC-33%-RP	35.37	3.53	3.9

* Average of three values

It is clear the compression strength and rupture modulus of recycled plastic mix were the lowest due to the high compressibility of plastic trash and the weak bond with the other concrete particles.

General Behavior

Based on the methodology illustrated, the results obtained from the experimental test of one-way slabs are as given in Table 8.

Table 8. First cracking and maximum loads of slabs

Model of slabs	First crack load (kN)	maximum load (KN)	Failure mode
SS1. N. M	20	60	Flexure (tension controlled)
SS2.RG.M	20	60	Flexure (tension controlled)
SS3.RP.M	15	58	Flexure (tension controlled)
SS4. N. R	16 at third cycle	52	Flexure (tension controlled)
SS5.RG. R	20 at fifth cycle	55	Flexure (tension controlled)
SS6.RP.R	15 at third cycle	45	Flexure (tension controlled)

In monotonic loading, the first fracture load and the maximum failure load of specimen SS2.RG.M contains recycled glass are equal to the reference model values, for slab model SS3.RP.M, there was a significant reduction in the first crack load by 25% and a slight reduction in the failure load by 3.33% when compared with the reference slab model SS1. N. M.

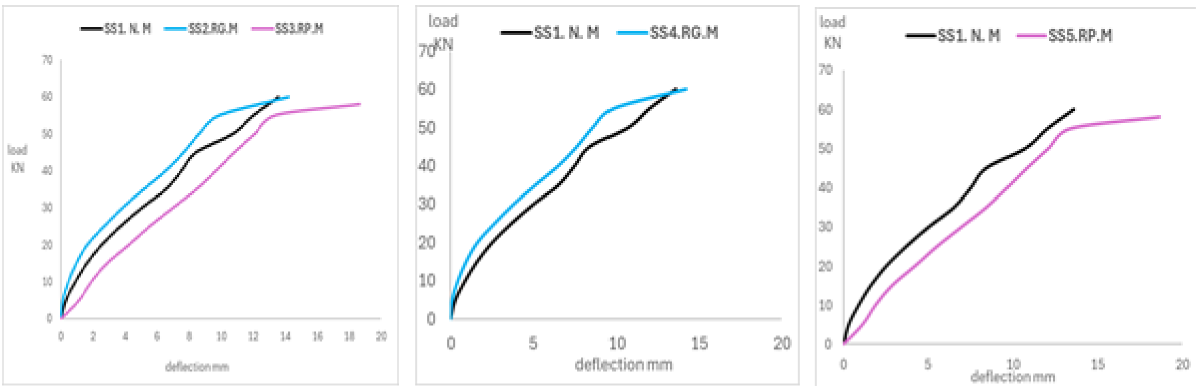
In repeated loading, the results showed that the SS5.RG experienced higher resistance in both first crack and in ultimate load compared to the reference with an increase of 33.33% and 5.77%, respectively that the glass is originally pure sand, adding compressive strength to the mix that contains glass more than the others. On the other hand, specimen SS6.RP.R which incorporates plastic waste yielded the lowest values for the ultimate failure load, a decrease of 13.46%. This decrease is because the compression strength of this model mix is lower than the compression strength of the control model mix. Additionally, the repeated loading cycles weakened the bond between the concrete and the reinforcement due to the presence of plastic particles.

Slab Load–Deflection Curves

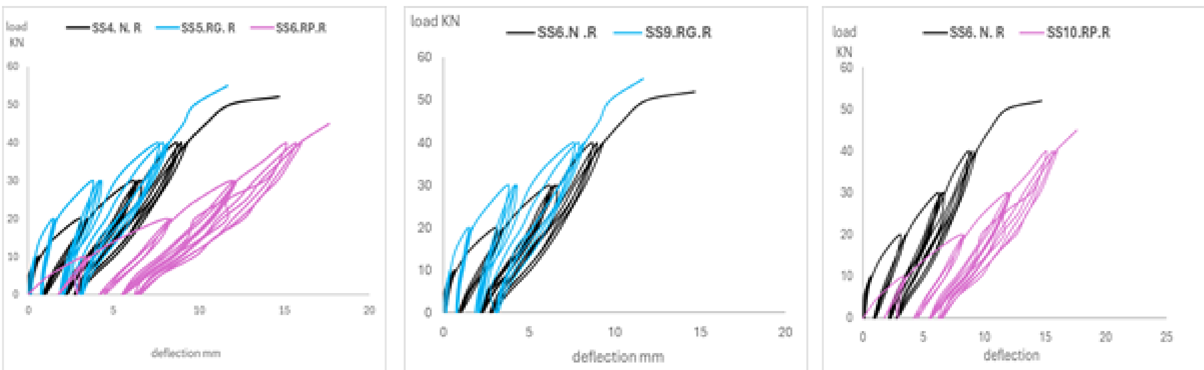
To clarify the structural behavior of the slabs, the load deflection response of each specimen for monotonic and repeated loading conditions are presented. For static specimens, the initial behavior is elastic, exhibiting an approximately linear load-deflection relations. As the first crack appeared and propagated, the curve's tangent decreased as the deflection increased through which additional shear and flexural cracks occurred. The cracks keep appearing while the old cracks extended to the compression zone causing a ductile failure mechanism as in Figure 7.

Deflection values at maximum failure load under static loading for slab specimens incorporating trash materials as a substitute instead of fine aggregate exceed the deflection of the control slab sample SS1. N. M, which exhibited a deflection of 13.59 mm. In sample SS2.RG.M, which contained glass, the deflection measured 14.23 mm, reflecting a 4.7% increase relative to the reference model. In specimen SS3.RP.M, which incorporates plastic, the deflection measured 18.67 mm, reflecting a 37.38% increase relative to specimen SS1.N.M.

In repeated loading and as a result of multiple loading cycles and the fatigue they cause to the slab, the deflection results differed from those in static loading. Specimen SS5.RG. R had a deflection of 11.65 mm, which was 20.69% less than the reference specimen for repeated load SS4. N. R. The reason for this behavior is the effect of repeated loading on the glass grains, which are considered a brittle material, in addition to the effect of the glass grains on the elasticity modulus of the concrete, and, consequently, the effect on deflection as for specimen SS3.RP.M, its deflection was 17.62 mm, which is greater than the deflection of specimen SS. N. R, which was 14.69 mm, by 19.94%.



(a) One way slabs load-deflection response under static loads



(b) One way slabs load-deflection response under repeated loads.

Figure 7. One way slabs Load-deflection curve.

Ductility

The ductility indicates to the capacity of a structural member to undergo significant plastic deformation without fracturing, allowing it to endure inelastic deformations beyond the point of failure while still supporting substantial loads. It is a mechanical property that characterizes a material's ability to deform plastically without rupture. The link between load and deflection, referred to as the ductility index (m), is defined in Equation (1) below and is derived by dividing the ultimate deflection by the yield deflection (Park, 1989). (Figure 8) showed the procedure of determined the ductility index.

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

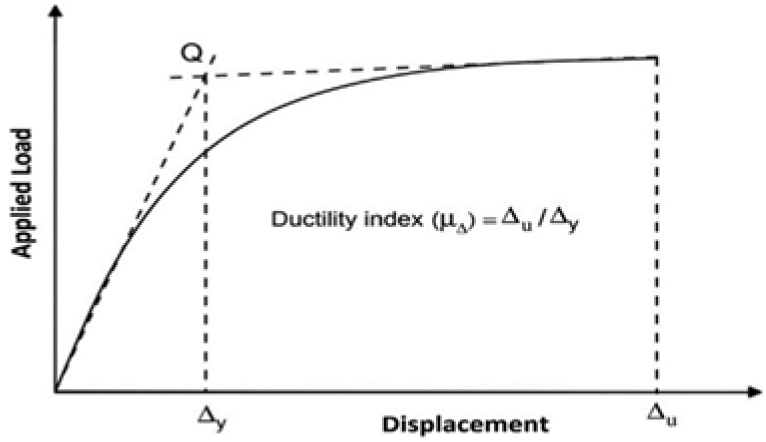


Figure 8. Procedure determination of ductility.

Table 9 presents the ductility calculation for the slab samples. The results indicate that specimens SS2.RG.M and SS3.RP.M, which incorporate recycled materials, exhibit greater ductility than the reference specimen SS1.N.M by 15.52% and 10.56%, respectively, under static loading. This is due to the elevated failure deflection of these two specimens. In instances of repeated loading, all specimens exhibited reduced ductility compared to static loading. Furthermore, after repeated loading, specimens SS5.RG.R and SS6.RP.R exhibited reduced ductility relative to the reference specimen SS4.N.R by 13.83% and 23.9%, respectively, in comparison to static loading.

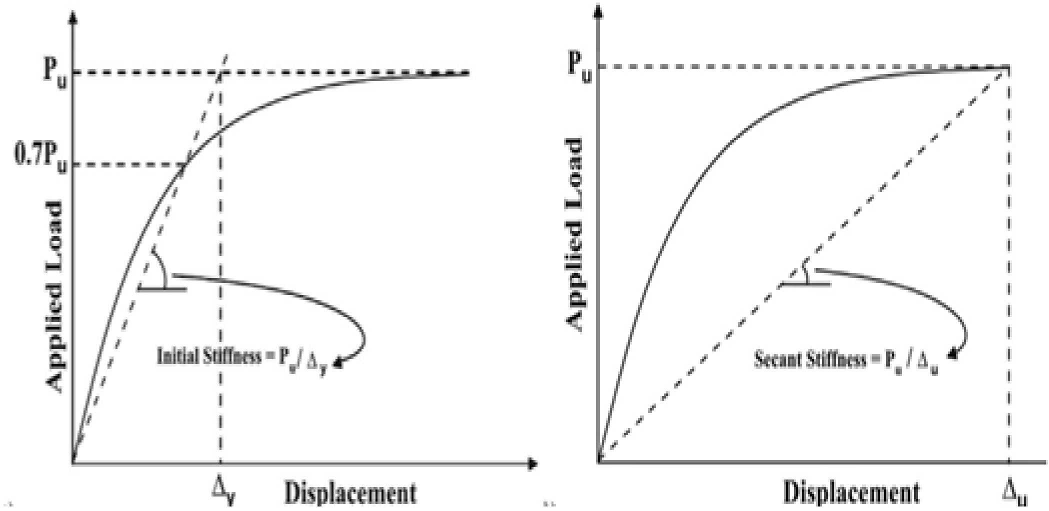
Table 9. Ductility index for evaluated slabs

Model of slab	Displacement at (P=75%Pu) (Δy) mm	Displacement at maximum load (Δu) mm	(Ductility) index (μ = Δ**u**/ Δ**y**)	(($\boldsymbol{\mu r}$- $\boldsymbol{\mu i}$)/ $\boldsymbol{\mu i}$) *100%
MONOTONIC LOAD				
SS1.N.M	8.44	13.59	1.61	…………..
SS2.RG.M	7.67	14.23	1.86	15.52
SS3.RP.M	10.464	18.67	1.78	10.56
REPEATED LOAD				
SS4. N. R	9.218	14.69	1.59	…………
SS5.RG. R	8.485	11.65	1.37	13.83
SS6.RP.R	14.5475	17.62	1.21	23.9

Stiffness

Two approaches for determining stiffness. The methodologies employed were secant stiffness and initial stiffness. We determined the initial and secant stiffness from the load-displacement curve by dividing ultimate load (Pu) by the maximum deflection (Du) for secant stiffness and by the yield deflection (Dy) for initial stiffness. Consequently, a slab exhibiting minimal deflection and maximum load capacity can possess the most excellent stiffness. The following equations illustrate how secant and initial stiffness are correlated with ultimate load, ultimate deflection, and yield deflection (Pam, Kwan, & Islam, 2001). (Figure 9) showed the procedure of determined the initial and secant stiffness.

$$\text{Initial stiffness} = pu/\Delta y \quad (2)$$
$$\text{Secant stiffness} = pu/\Delta u \quad (3)$$



a b

Figure 9. Procedure determination of (a- initial stiffness) and (b- secant stiffness) (Abdulraheem, 2018)

The results in (Table 10) demonstrate that the initial stiffness values of the examined slab specimens differ between specimens based on the materials utilized in their composition. In static loading, specimen SS2.RG.M, incorporating recycled glass, had the highest initial stiffness value. It rose by 12.78% relative to the reference specimen SS1.N.M, whereas specimen SS3.RP.M, which incorporated recycled plastic, had the lowest value, declining by 37.03% in comparison to the reference specimen. The initial stiffness values calculated during repeated loading were lower than those obtained during static loading due to the several loading cycles that induce fatigue in the specimen. The disparities among the several specimens subjected to repeated loading were comparable to those observed under static loading. Specimen SS2.RG. R exhibited an increase of 14.45%, while specimen SS3.RP.R showed a drop of 46.26% in comparison to the reference specimen SS4. N. R.

Conversely, the secant stiffness data demonstrate that specimens SS2.RG.M and SS3.RP.M exhibited lower secant stiffness than the reference specimen SS1.N.M under static loading by 4.75% and 29.86%, respectively. Upon repeated loading, the secant stiffness of specimen SS5.RG.R exceeded that of the reference specimen SS4.N.R by 33.33%, whereas specimen SS6.RP.R exhibited a secant stiffness that was 27.97% lower than that of the reference specimen SS4.N.R.

Table 10. Results of initial and effective stiffness

Slab model	Load at 70 percent of maximum load (Py) (kN)	Displacement at (Py=70 percent Pu) (Δy) mm	Initial Stiffness (py/ Δy)	% diff	Secant Stiffness (pu/ Δu)	% diff
			Monotonic load			
SS1.N.M	42	7.89	5.32	------	4.42	------
SS2.RGM	42	7	6	12.78	4.21	4.75 ↓
SS3.RP.M	40.6	12,12	3.35	37.03 ↓	3.10	29.86 ↓
			Repeated load			
SS4. N. R	36.4	8.77	4.15	------	3.54	------
SS5.RG.R	38.5	8.1	4.75	14.45	4.72	33.33
SS6.RP.R	31.5	14.13	2.23	46.26 ↓	2.55	

Conclusion

1- Incorporating recycled glass and reused plastic as substitutes for sand in SCC diminishes its compression (Fcu), tensile (Ft), and flexural (Fr) strength.

2- In the statically loaded slab samples, the maximum failure load was nearly equivalent, with a reduction in specimens containing plastic waste of merely 3.33% compared to the reference specimen containing natural fine aggregate. In the repeated loading, the ultimate failure load for the specimen containing crushed glass waste was 5.77% greater than that of the control model. Model SS6.RP.R. was 13.46% lower than the control model.
3- The incorporation of recycled glass and recycled plastic as a partial substitute for fine aggregate resulted in heightened deflection under static loading conditions relative to the reference specimen. The increment was 4.7% in specimen SS2.RG.M and 37.38% in specimen SS3.RP.M. During the repeated loading, the deflection of specimen SS5.RG.R was 20.69% lower than that of the reference specimen. In comparison, the deflection of specimen SS6.RP.R rose by 19.95%.
4- Under static loading, the ductility of slabs, including recycled glass and plastic waste as fine aggregates, surpassed that of those using natural sand by 15.52% and 10.56%, respectively. Upon repeated loading, the ductility of specimens containing recycled glass and plastic waste diminished by 13.83% and 23.9%, respectively, in comparison to the reference samples.
5- The inclusion of recycled glass enhanced stiffness under both static and repeated loading, but the use of waste plastic significantly diminished stiffness.
6- Specimens subjected to repeated loading demonstrate reduced in maximum failure load, ductility, and stiffness in comparison to those exposed to static load. The specimen containing recycled plastic SS6.RP.R showed the most considerable decrease in maximum failure load at 22.4%, whereas the specimen with recycled glass SS5.RG.R exhibited the least reduction, around 8.33%. In terms of ductility, the specimen SS6.RP.R had the most pronounced reduction, approximately 33.43%.

Scientific Ethics Declaration

* The authors declares 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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