Punching Behaviour of Flat Slab Using Recycled Aggregate

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Abstract

Recently, researchers have shown an interest in researching recycling aggregates from old concrete and using them in new construction as a means of protecting the environment and natural resources. This thesis includes an experimental investigation into the punching shear behaviour of continuously supported slabs of concrete with natural and recycled coarse aggregate. In the Laboratory at the MS Ramaiah Institute of Technology the tests on punching shear behaviour of inner slab-column connections in flat plates. "Natural and recycled" aggregates were used in six two-way slab models. The slabs were made to only fail while being used as a punching shear. Three specimens of recycled aggregate concrete (RAC) slabs and three specimens of natural aggregate concrete (NAC) slabs were used in the experimental study. Simply supported on four edges, all of the slabs were tested using a central patch load. In order to attain a 25 MPa concrete strength after 28 days, the IS mix design technique was used. For each aggregate size of 12.5mm (Downsize), five concrete mix proportions were used with (0%, 25%, 50%, 75%, and 100%) replacement of natural coarse aggregate with recycled coarse aggregate. Then, casting with a size of 1000 × 1000 × 100 mm was tried with 0% and the highest of the other four (75%). The test findings were then compared with the experimental data and the Codal Provisions for the Accuracy of Ultimate load.

Keywords: RC Flat slab, two-way slab, recycled coarse aggregate, normal coarse aggregate, Punching shear, Regression analysis.

INTRODUCTION

General

Recycled aggregate concrete (RAC) is being marketed for structural uses in an effort to allay worries about sustainability. Mechanical properties of this concrete have been thoroughly studied, and behaviour under actions like bending and one-way shear are documented, the creation of an environment that is conducive to such applications. In multi-storey buildings, particularly in non-seismic locations, column and wall-supported flat slabs are a common structural arrangement. Their performance is governed by punching or two-way shear resistance. If RAC is to be used successfully in flat slabs and other applications that are similar, then its behaviour under two-way shear should be thoroughly understood and logically predictable.

Using scaled slab specimens, a small number of studies on RAC punching shear behaviour have been examined. The experimentally measured punching capacities there have compared to predictions made using equations (mostly empirical) either taken from current design codes or from the literature. Since significant safety factors are almost often included in code-recommended formulae, it is often concluded that these equations yield conservative estimates of RAC punching shear capacity. Simply comparing experimental results to code-recommended equations, in particular, is insufficient to recognise and take into consideration the fundamental principles underlying punched shear resistance. Therefore, it is challenging to understand the influence of RAC on these mechanisms in particular and on punching shear resistance.

Fig 1: Flat slab

Advantages of Flat Slab

- **Rapid construction** - Flat slab construction takes less time since fewer forms are required, which reduces the amount of time spent on construction. The use of tabular formwork may also help to further simplify the job and require less labour overall. Precast welded mesh expedites the setting up of flat slabs, accelerating construction by giving workers more time to install vertical elements.
- **Flexibility for designer** - When working with flat slabs, designers have more freedom to convey their ideas because walls do not impose any limitations. The general floor plan can be changed without affecting the structure of the building. Additionally, better management is more accessible and is thought to be more fire resistant. Additionally, flat slab reinforcement details become simpler, and design work for a certain soffit level is feasible.
- **Flexibility for the proprietor** - Because a flat slab offers so much interior design flexibility, it can be quickly changed if changes are required or the occupant wants room for future expansion. As a result, beams at right angles to square or nearly square crossings are excluded from the grid, which provides greater adjustability for designers and owners.
- **A reduced storey height** - The total thickness of the beam and the slab in the beam-slab system is more than the thickness of the flat slab. Shortening the vertical components of a storey reduces the building's overall height, which in turn lessens the weight of the structure as a whole. The approach works best for high-rise buildings since the total height and weight lost can greatly lower development expenses.
- **Easy electrical and mechanical system installation** - Buildings made of flat slabs don't have beams. Therefore, providing mechanical and electrical services does not need cutting through beams or bending cables. Installing things like electrical ducts, fire suppression ducts, air conditioning ducts, and so on is made simpler by flat slabs.
- **Aesthetics, acoustics, and dispersion of light** - A flat slab might offer an eye-catching sight of the interior of the building. The entire slab is clear and open for any and all uses because there are no obstructions like beams or dividing walls. The lack of adornment on the ceiling makes the light more diffuse and keeps the room lighted evenly. The majority of auditoriums are constructed on flat slabs to maximize the spread of both light and sound.

Disadvantages of Flat slab

- **Thickness** - The thickness of the flat slab is much a greater extent than the slab applied in the beam-slab system. As a result, concrete is used extensively during the construction process.

- **Restrictions on span** - A longer span is associated with a higher bending moment value. To overcome this difficulty, effective slab depth will need to be increased, and drop panels and columns might need to have a larger diameter.
- **Vulnerable to lateral loading** - Brittle (masonry) partitions are not a good option to be supported by a flat slab construction when it comes to resisting lateral loads, such as those brought on by wind, earthquakes, and other seismic activity.
- **Impediment and failure** - The amount that drop panels can obstruct mechanical ducting should be limited. Vertical penetrations, also known as punching shear failure, must not occur near columns.

OBJECTIVES OF STUDY

1. To assess the use of concrete in which its coarse aggregate is replaced by aggregates which are recycled by waste that are generated due to demolition of old constructed buildings.
2. To evaluate and compare the mechanical properties such as compressive strength, tensile strength and flowability of both normal and recycled aggregate concrete.
3. To assess the central load punching shear behaviour on the flat slab condition
4. To assess and compare the load bearing capacities of flat slab with normal aggregate (zero percentage recycled aggregate) concrete and recycled coarse aggregate concrete.
5. To know the variation percentage of strength of flat slab for various specimens of concrete for both normal and recycled aggregate concrete.

LITRATURE REVIEW

➢ **Nuno Reis, Jorge de Brito, (2015)** worked on **"Punching behaviour of concrete slabs incorporating coarse recycled concrete aggregates"**

The paper examines the impact of CRCA on RC slabs' punching techniques by experimental, numerical, and analytical means. Four concrete mixes were created. with this in mind. by CRCA using different substitution ratios biosynthetic coarse aggregates (NCA): 0% (reference mix), 20%, 50%, and 100%. Eight 1100 × 1100 × 90 mm reinforced concrete slabs—two of each concrete type—were then cast and put through punching tests. Less precise and more conservative forecasts for punching strength were generated using Eurocode 2, ACI 318, and MC 2010 with level of approximation I. The several concrete slabs' load vs. displacement profiles were qualitatively comparable. The stiffness of the material in its uncracked state and the cracking load both reduced as the CRCA concentration increased, and These cuts greater than for those the splitting tensile strength and elastic modulus both underwent. Conversely, the stiffness in the cracked state was the same in all mixes, and the the cause of this was the reinforcement's greater influence because it persisted across all slabs. The CRCAC slabs' punching strength was comparable to that of RC slabs; with a 100% substitution of NCA by CRCA, The decrease in power was only 2%. This outcome is consistent with minimal impact CRCA incorporation has on the basis of compression concrete. For considering this paper the main reason was to know how to conduct the punching shear experimentally and the the substitution of coarse aggregate with some percent of recycled coarse aggregate.

➢ **Zaki I. Mahmoud , El tony M. El tony, (2015)** worked on **"Punching shear behaviour of recycled aggregate reinforced concrete slabs"**

In this article, Presented is an experimental examination on concrete's punching shear behaviours slabs made with recycled and naturally existing coarse material. The punching shear behaviours of inner slab-column connections In the laboratory for reinforced concrete at the engineering faculty, flat plates are tested. at Alexandria University. Eight two-way slab samples were moulded and put through two separate sorts of testing until they failed. of aggregate—"natural and recycled"—and two nominal aggregate sizes (12.5 and 25 mm). The slabs had been planned. to only fail whereas being utilised as a punching shear. Six RCAC slab specimens and two slabs of NCAC served as the subject matter for the experimental study. Simply supported on four edges, all of the slabs were tested using a load of a central patch. ACI's A mix design process was employed. to produce concrete with a 35 MPa strength after 28 days. Every aggregate size, recycled coarse aggregate was substituted when it comes to natural coarse aggregate four different percentages: 0%, 30%, 60%, and 100%. The test's Results showed that as more recycled coarse aggregate is substituted for natural coarse aggregate, the first punch crack load, ultimate punch load , stiffness , and energy absorptions decrease. The predicted ultimate failure loads from the codes (ECP 203, ACI 318, JSCE code, Euro code 2, and yield line theory) were compared to the measured ultimate failure loads. The equations for the Euro code – 2 provided outcomes of the trial the best correlation. How much of the coarse aggregates are recycled substitution rises, so do cylinder and cube compressive strengths. Similar to this, the split tensile strength declines

➢ **Saumyaranjan Sahoo , Bhupinder Singh, (2019)** worked on **"Recycled aggregate concrete slab punching shear capacity"**

This study reports the tensile strength of punching balanced slab-column connections built of two grades of recycled Coarse aggregates concrete (RAC), each grade including different volumetric replacement levels (0%, 50%, and 100%) of recycled concrete aggregates generated from laboratory waste concrete. Although measured punching capacities rose with concrete grade, displacement-controlled loading tests revealed that ultimate punching capacities are essentially insensitive to recycled aggregate replacement level. While overly a few current design codes were used to get conservative forecasts., a Strut-and-Tie Model (STM) adapted from the literature for rational estimation of RAC punching capacities gave conservative and reasonably accurate predication of the results of this and other investigations in the literature, as recorded.

➢ **Mahmoud Elsayed, Bassam A. Tayeh, (2021)** worked on **"Punching shear behaviour of RC flat slabs incorporating recycled coarse aggregates and crumb rubber"**

In order to determine the punching shear durability of concrete slabs using a mixture of recycled coarse aggregate (RCA) and crumb rubber (CR), this work includes experimental, analytical, and numerical analyses. In order as a replacement for natural fine and coarse aggregates (FA and NCA, respectively), there were 12 different concrete mixtures. created using varying substitution ratios of RCA and CR. Three substitution ratios of CR (0%, 10%, and 20%) and four substitution ratios of RCA (0%, 25%, 50%, and 100%) by NCA were taken into consideration. Twelve 1000 x 1000 x 100 mm, two-way, simply supported RC slabs had been cast, and put to the test. There were two phases to the experimental programme. The evaluation of the mechanical characteristics and punching shear behaviours of concrete slabs integrating a combination of RCA and CR was done in the first and second stages, respectively. The loss of the concrete strengths was significantly impacted more by the rubber content substitution ratios than by the RCA content. With increased CR and RCA contents, the punching shear strength, stiffness, and toughness of RC slabs containing these materials decreased. Considering the findings of the experiment, the best substitution ratios for the concrete mixture that can be used are 25% RCA and 10% CR since it has no effect on the punching shear strength. The predictions of five approaches, namely ACI 318–2014, ECP 203, Euro − 2, BS8110 and CSA A23.3, were in comparison to experimental results.

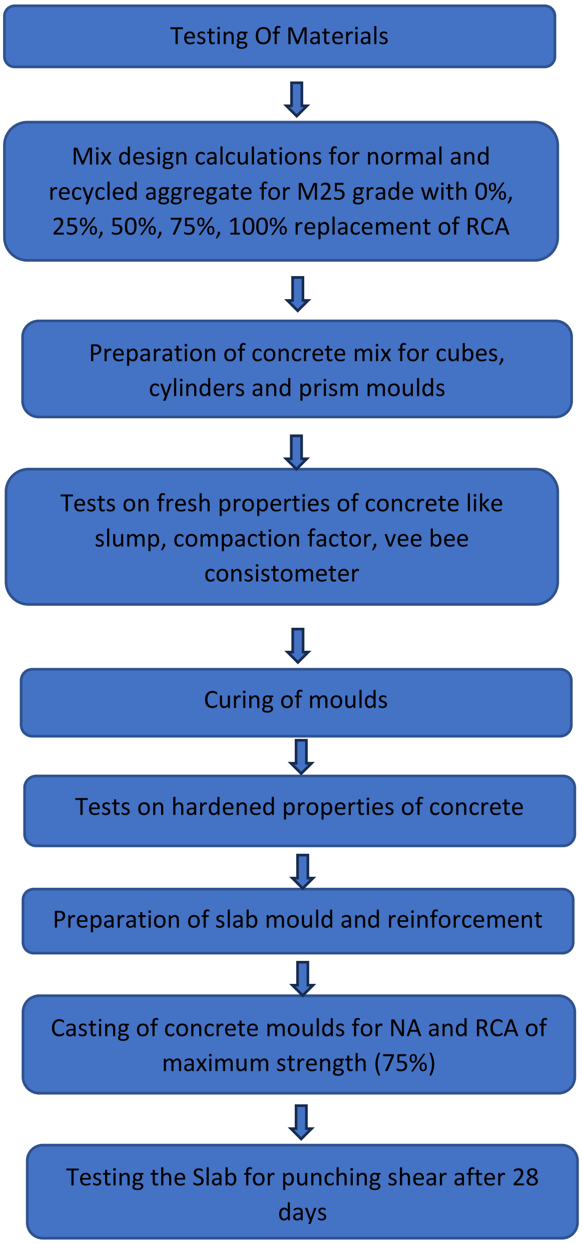
GAP ANALYSIS

➢ The slab-column connection was implemented in my experiment as to know the behaviour of punching shear which was applied on slab will resist at joints or not, since in papers it was not connected by any of the steel reinforcement.

➢ A 10% of cement was replaced by Micro silica to get bond between steel, coarse aggregate, fine aggregate and recycled coarse aggregate, so that the compressive strength RCA was more than NA.

➢ The columns was placed such a way that the slab was divided into column and middle strip and the column was placed in centre of the strips i.e., at 600mm c/c.

METHODOLOGY



Testing Of Materials

Getting the necessary quantity of materials to conduct the experiment is the first step in the work. Cement, fine aggregate (M-sand) meeting zone 2 gradation of IS 383:2016, coarse aggregates (gravel) passing 12.5 mm, recycled coarse aggregate passing 10 mm, micro-silica, a chemical admixture (super-plasticizer), and cement are the materials collected. To learn about a material's properties, such as fineness, specific gravity, gradation, porosity, and water absorption, basic tests are conducted on it. For cement, sand, coarse aggregates, and recycled coarse aggregates, physical tests are performed. These tests that include specific gravity, sieve analysis, and water absorption tests.

Tests on fresh properties of concrete

Concrete that had just been mixed and was still in a plastic, fresh state undergone testing to verify its workability and flowability. To determine if the concrete sample is workable or not before retaining its plasticity and hardening, tests on concrete's fresh qualities, such as the slump cone test and compaction factor test, and vee-bee consistometer test, were carried out. The following steps were taken to test the fresh qualities of concrete:-

SLUMP CONE TEST

The slump test is a laboratory or field test used to determine if concrete is workable. Only the consistency or moisture of concrete mix is evaluated by the slump test. To begin this test, four fresh layers of concrete, each one measuring 1/4 of the height, are poured into the mould and tamped with twenty-five strokes of the rounded end of the tamping rod. The mould is then slowly and carefully raised vertically, with the top layer being rodded to ensure that the mould is completely filled.

Fig 2: Slump Cone

The extra concrete is next levelled off using a trowel or tamping rod. The height of the mould as compared to that of specimen being examined at its highest position

TESTS ON HARDENED PROPERTIES

After the freshness of the concrete that has been determined, it is poured into cube, cylinder, and prism moulds in three layers and tamped with a 16mm dia. blunt-ended tamping rod using 25 blows per layer. It is also compacted using an electrically powered vibrator until There are no more air bubbles. eliminated. The excess concrete is then troweled off of surface to make it flat and smooth, and the concrete is left to set for 24 hours. The moulds are released after 24 hours, and all of the samples are taken out. In the next step, the samples are kept in water bath for curing to control the heat of hydration and tested after time period of 3 days, 7 days and 28 days of curing as given below :-

COMPRESSIVE STRENGTH TEST :-

The Concrete Cube Test will provide concrete's compressive strength, which gives an indication of all of concrete's qualities. Overall, we can learn more strength and the above mentioned parameters with the use of the compressive strength test. This test makes it simple to determine the concrete's psi strength and the level of quality being produced. The sample is put within the apparatus, and the test is run by applying loads to the cube's opposite sides. The load is then given progressively at a rate of 140 kg / cm2 per minute until the samples fail, after which the moveable piece is gently rotated by hand until it meets the top Specimen's specimen surface. The maximum load is then recorded and any unusual features in the type of failure noted

Compressive Strength of the concrete = Maximum compressive load / Cross Sectional area

Materials	Quantities (kg/m^3) for				
	0%	**25%**	**50%**	**75%**	**100%**
Cement	309.38	309.38	309.38	309.38	309.38
Silica fumes	34.375	34.375	34.375	34.375	34.375
Water	165	165	165	165	165
Fine aggregate	844.33	963.33	963.33	963.33	963.33
Coarse aggregate	963.33	633.33	422.16	211.08	_
Recycled aggregate	_	188.38	376.76	564.14	753.52
Chemical admixture	5.15	5.15	5.15	5.15	5.15
Water cement ratio	0.48	0.48	0.48	0.48	0.48

Mix proportions

Experimental Procedure

Preparation of slab mould and reinforcement

After testing of concrete samples of different percentage replacements[0% , 25%, 50%, 75% & 100%] for their respective compressive strengths the replacement percentage which gives maximum strength is noted. Then the slab mould Is prepared of slab size 1000×1000×100 mm with column size 150×150×150 mm (4 numbers per slab), and the reinforcement of 10mm dia @ 150mm c/c at bottom and 10mm dia @ 250mm c/c at top, column reinforcement given was 4-12mmφ with a strriup of 6mm dia respectively. The cover provided for the flat slab was 20mm (effective cover).

Punching tests

Specimens description

A total of six 1000 ×1000× 1000 mm RC slabs were put through punching tests. (Three per concrete mix) and their size that was set in order to simulate the area around a column, in which the radial moments at the contour are approximately null. The total sizes of the slab specimens corresponds to 44% of the span length (Lv) that it intends to model, considering that the moment is 0 at a 0.22 Lv distance from the column axis. The steel reinforcement that was similar in all specimens and was meant to encourage punching failure as opposed to flexural failure. The top flexural reinforcement ratio was 0.93% (#10@250 mm), whereas the bottom reinforcement ratio was 0.25% (#10@150 mm) – both fulfilling the IS recommendations. There was no particular punching reinforcement employed.. The cover was 25 mm, setting the mean reinforcement depth (d) to 50 mm

Fig 4: Wodden mould with reinforcement

After three days, the slab specimens were removed from the mould after being cast using plywood forms. The slabs were subjected to curing (watering): once a day for the first 7 days and every 2 days until the test date (28 days).

Test setup, instrumentation and procedure

Fig 5: Test Setup of Slab

%RCA replacement	Grade of concrete	Water-cement ratio	Slump value	Workability/slump type	Degree of workability
0	M25	0.48	130	Shear	High
25	M25	0.48	110	Shear	High
50	M25	0.48	90	Shear	Medium
75	M25	0.48	65	True	Medium
100	M25	0.48	50	True	Low

Results and Discussion

SLUMP TEST

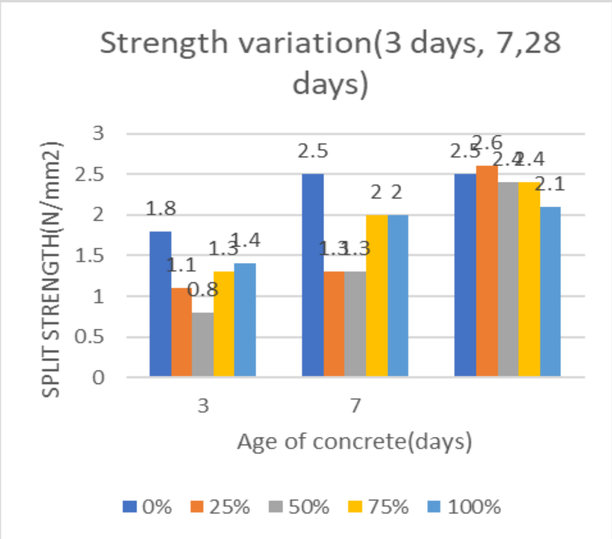
Slump test is the test carried to know the workability or flowability of concrete after the subsidence of concrete when the slump cone was lifted vertically. The table above shows the slump values for various replacement rates of recycled coarse aggregate in M25 concrete. The replacement percentages of 0 and 25 shows high degree of workability and other replacement percentages of 50 and 75 shows medium degree of workability except 0 % which shows low degree of workability. As the replacement rate increases the amount of subsidence / flowability of concrete decreases for water cement ratio of 0.48. Generally 0%, , 25% , 50% & 75% RCA percentages slumps unevenly more on one side. Therefore, the slump obtained is shear slump but for 100% RCA the slump subsidises uniformly on both sides. Hence for 100% the slump obtained is true slump and shows low degree of workability i.e., not good for RCC work.

COMPRESSIVE STRENGTH TEST

The findings of the compressive strength of concrete with normal and recycled coarse aggregates for various concrete ages and replacement % variations are displayed in the previous table. The outcomes demonstrated that as concrete ages, so does its

The items were loaded using 1000 KN hydraulic jacks. The specimens' vertical deflection under various loads was measured using LVDTs. The specimens were simply supported and positioned horizontally between the jack and a square solid steel frame. A steel plate was used to support the slab while it was set atop the concrete blocks. The central patch load was then applied to the slab while maintaining the 150 mm by 150 mm steel plate.

compressive strength for M25 concrete. Comparably, the compressive strength of concrete increases as the replacement percentage of recycled coarse aggregate rises from 0% to 25%; however, as replacement percentage rises further to 50%, the compressive strength of concrete declines more than that of regular concrete.



SL. NO	Age of concrete (days)	Contact area(mm2)	Compressive load(N)	Compressive strength(N/mm2)	% replacement
1	3	(100×100)	135000	13.5	0
2	7	(100×100)	182000	18.2	
3	28	(100×100)	270000	27	
4	3	(100 ×100)	153000	15.3	25
5	7	(100×100)	195000	19.5	
6	28	(100×100)	300000	30	
7	3	(100×100)	103000	10.3	50
8	7	(100×100)	178000	17.8	
9	28	(100×100)	280000	28	
10	3	(100×100)	173000	17.3	75
11	7	(100×100)	230000	23	
12	28	(100×100)	320000	32	
13	3	(100×100)	152000	15.2	100
14	7	(100×100)	195000	19.5	
15	28	(100×100)	300000	30	

Predective Analysis for Punching Shear of Slab

As we have the data of ultimate load for 28 days curing for both normal and recycled aggregate concrete. So everytime it is impossible to do ultimate load calculation for every other concrete samples. So by keeping some parameters into consideration, we need to develop a formula to find out ultimate load for the specimen. So with the data, we need to do a regression analysis to formulate a relationship between independent variables like deflection, grade of concrete, area and thickness.

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-482.2906514	0.557	65535	0.045
X1	13.70318805	0.9654	65535	0.0079
X2	7.565294592	0.44796	65535	0.012
X3	1.65854E-05	0.6575	65535	0.028
X4	2.62751041	0.7658	65535	0.0069

Y	X1	X2	X3	X4
170.9	12.1	27.5	1000000	100
157.5	5.4	36.9	1440000	100
205.19	12.8	29.8	1440000	100
157.7	7.5	37.1	1210000	90
188.5	10.9	32	1000000	100

Formula

$V_u = 13.7\Delta + 7.56\,F_{ck} + 1.66\times10^{-5}\,A_c + 2.62\,T_c - 482.3$

Where,

Δ – Deflection (mm)

Fck – Grade of concrete in (N/mm^2)

Ac – Area of concrete in (mm^2)

Tc – Thickness of slab in (mm)

X1 – Deflection (mm)

X2 – Grade of concrete (N/mm^2)

X3 – Area of Concrete slab (mm^2)

X4 – Thickness of slab (mm)

Stiffness

Before the first fracture load, which was determined at deflection (0.25 mm), the initial stiffness (ki) is regarded as the secant line of the load-deflection curve. The secant line of the load-deflection curve at close to the ultimate load, which was measured at deflection (4 mm), is referred to as the ultimate stiffness (ku). Table 4 displays the stiffness values that were calculated. According to the findings, stiffness improves as aggregate size increases and stiffness falls as recycled replacement ratio increases.

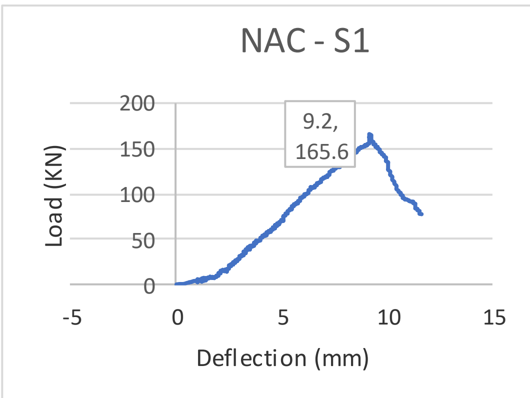
(a) (b) (c)

(d) (e) (f)

(g)

Fig 6: (a) Central patch load applied on slab, (b) Crack pattern of NAC -S1, (c)Crack pattern of NAC- S2, (d) Crack pattern of NAC- S3, (e) Crack pattern of RAC- S1, (f) Crack pattern of RAC- S2, (g) Crack pattern of RAC- S

Figures 8.11 to 8.17 display the final crack patterns of all tested slab specimens. On the bottom face, it is seen that the cracks are radial and primarily run between the loading point and the corners. The patch load was surrounded by a circular punching crack on the top surface, and this was mirrored with an enlarged region on the bottom surface, making it easy to see the truncated cone



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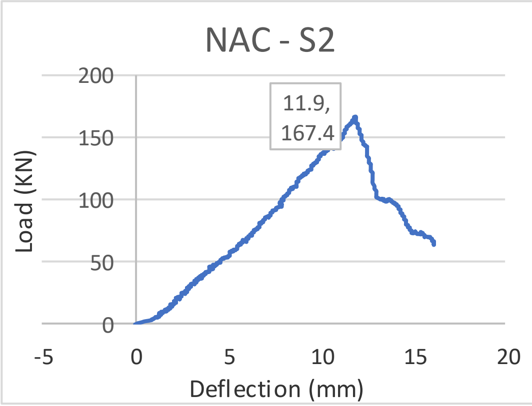
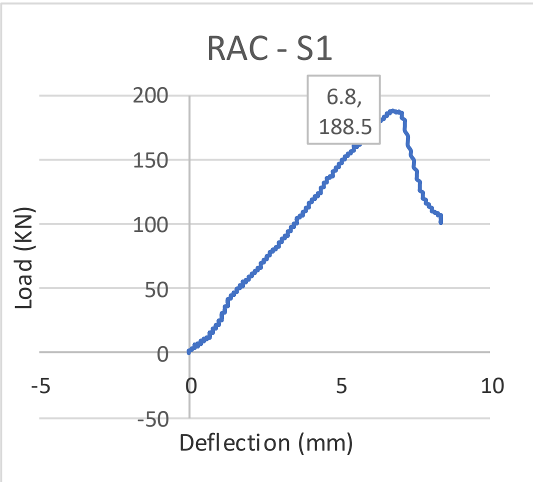
1. The plot of graph shows load vs deflection variation of normal aggregate Flat slab specimen 1 for 28 days of strength of concrete. The plot shows that as the Point load on slab increases, corresponding deflection also increases up to the failure point and then decreases gradually after reaching peak/ultimate load. The ultimate load reaches at a load of 165.6 KN and the corresponding deflection at that maximum failure load reaches up to 9.2 mm and then reduces gradually up to 137.7 KN with corresponding deflection of 10 mm. After reaching this point, the load and corresponding deflection drops suddenly for 78 KN for 11.7 mm deflection.

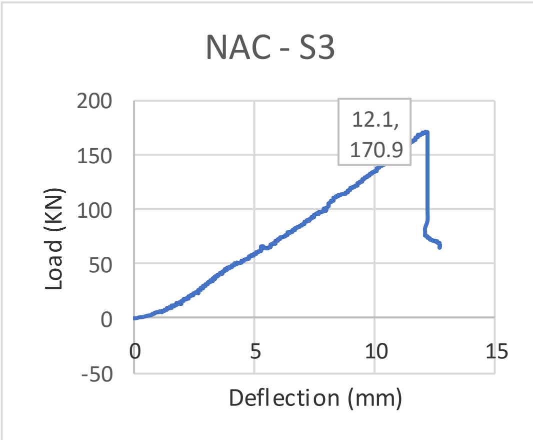


3. The plot of graph shows load versus deflection variation of normal aggregate Flat slab specimen 3 for 28 days of strength of concrete. The plot shows that as the Point load on slab increases, corresponding deflection also increases upto the failure point and then decreases gradually after reaching peak/ultimate load. The ultimate load reaches at a load of 170.9 KN and the corresponding deflection at that maximum failure load reaches upto 12.1 mm and then reduces gradually upto 166.4 KN with corresponding deflection of 12.2 mm. After reaching this point, the load and corresponding deflection drops suddenly for 65 KN for 12.7 mm deflection.

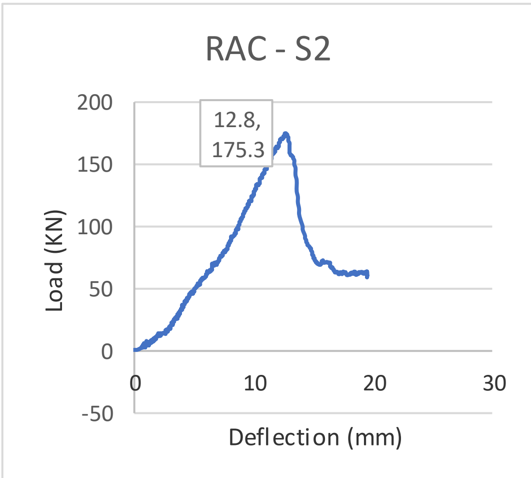


2. The plot of graph shows load versus deflection variation of normal aggregate Flat slab specimen 2 for 28 days of strength of concrete. The plot shows that as the Point load on slab increases, corresponding deflection also increases upto the failure point and then decreases gradually after reaching peak/ultimate load. The ultimate load reaches at a load of 167.4 KN and the corresponding deflection at that maximum failure load reaches upto 11.9 mm and then reduces gradually upto 144.7 KN with corresponding deflection

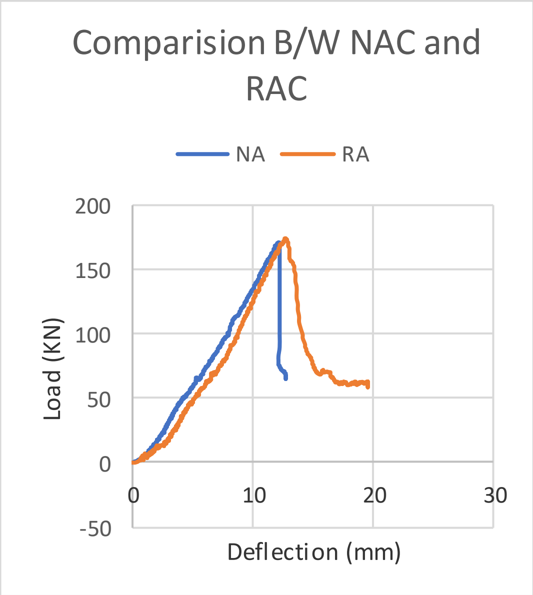
of 12.4 mm. After reaching this point, the load and corresponding deflection drops suddenly for 64.6 KN for 16.1 mm deflection.



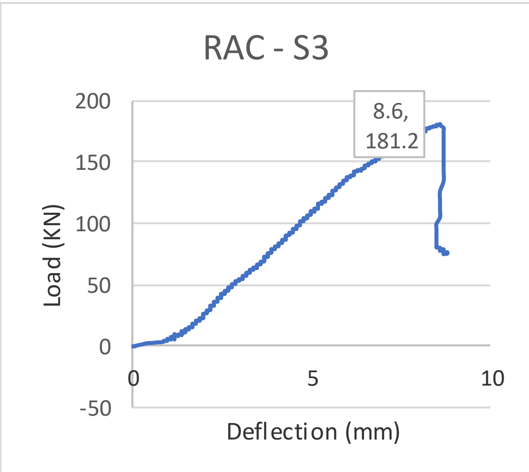
4. The plot of graph shows load versus deflection variation of Recycled aggregate Flat slab specimen 1 for 28 days of strength of concrete. The plot shows that as the Point load on slab increases, corresponding deflection also increases upto the failure point and then decreases gradually after reaching peak/ultimate load. The ultimate load reaches at a load of 188.5 KN and the corresponding deflection at that maximum failure load reaches upto 6.8 mm and then reduces gradually upto 179.2 KN with corresponding deflection of 7.2 mm. After reaching this point, the load and corresponding deflection drops suddenly for 101.9 KN for 8.4 mm deflection.



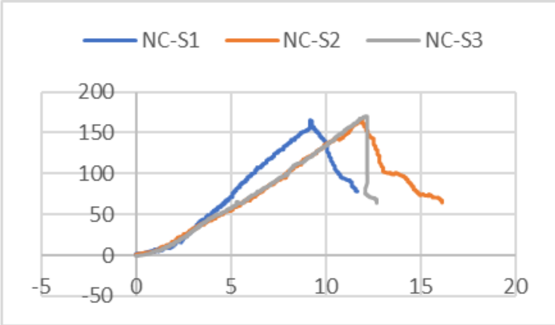
6. The plot of graph shows load versus deflection variation of Recycled aggregate Flat slab specimen 3 for 28 days of strength of concrete. The plot shows that as the Point load on slab increases, corresponding deflection also increases upto the failure point and then decreases gradually after reaching peak/ultimate load. The ultimate load reaches at a load of 181.2 KN and the corresponding deflection at that maximum failure load reaches upto 8.6 mm and then reduces gradually upto 134.7 KN with corresponding deflection of 8.7 mm. After reaching this point, the load and corresponding deflection drops suddenly for 75.5 KN for 8.8 mm deflection.



5. The plot of graph shows load versus deflection variation of Recycled aggregate Flat slab specimen 2 for 28 days of strength of concrete. The plot shows that as the Point load on slab increases, corresponding deflection also increases upto the failure point and then decreases gradually after reaching peak/ultimate load. The ultimate load reaches at a load of 175.3 KN and the corresponding deflection at that maximum failure load reaches upto 12.8 mm and then reduces gradually upto 158.1 KN with corresponding deflection of 13.2 mm. After reaching this point, the load and corresponding deflection drops suddenly for 59 KN for 19.6 mm deflection.



7. The graph shown above represents the comparision made for load versus deflection variation between normal coarse aggregate concrete Flat slab and also recycled coarse aggregate concrete Flat slab for 28 days of strength of concrete. The variation shows that the ultimate load for RCA Flat slab is more when compared to NAC Flat slab and it is increased by a value of 17.4 KN corresponding to deflection change of 1.2 mm variation. Hence, it proves that the Point load carrying capacity of RAC Flat slab is more when compared to that of NAC Flat slab. Therefore, the results reveals that RAC Flat slab has higher compressive strength and fails at higher load than that of NAC Flat slab.



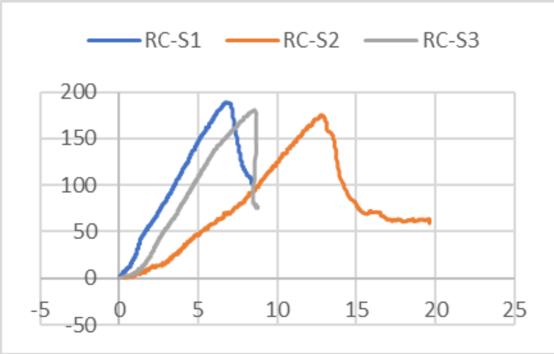
9. The graph above shows that, in the three specimens of Recycled coarse aggregate concrete is RAC-S1 is more effective compare to other two specimens i.e., the load transfer is more and the deflection attained is less so that more cracks are not seen till the ultimate load is attained, whereas in RAC-S2 and RAC-S3 the load attains maximum and also the deflection is also more that intends to more bending

Specimen	Loading in days	Vu (KN) (expt)	Deflection mm	Vu (KN) Numerical		Vu (KN) (expt/num)	
				IS 456	ACI 318	IS 456	ACI 318
NC-S1	28	165.6	9.2	121.12	104.77	1.36	1.58
NC-S2		167.4	11.9	121.12	104.77	1.38	1.59
NC-S3		170.9	12.1	121.12	104.77	1.41	1.63
RC-S1		188.5	10.9	123.22	112	1.52	1.68
RC-S2		175.3	12.8	123.22	112	1.42	1.56
RC-S3		181.2	8.6	123.22	112	1.47	1.61

Conclusion

- As the recycled coarse aggregate replacement percentage rises to a maximum of 75% before falling, the compressive strength of the cube and cylinder increases. The split tensile strength likewise increases in a similar manner.
- As the percentage of recycled aggregate increases, stiffness and energy absorption increases.
- The several concrete slabs' load vs. displacement profiles were qualitatively comparable. The stiffness of the material in its uncracked state and the cracking load both increase with CRCA content, and these decreases were slightly more than those of the elastic modulus and the splitting tensile strength, respectively. On the other hand, the

8. The graph above shows that, in the three specimens of normal aggregate concrete is NAC-S2 is more effective compare to other two specimens i.e., the load transfer and the deflection attained is in slope manner or it is in a form of trend line diagram which gives us intimation before failure of the slab, whereas in NAC-S1 and NAC-S3 the load attains maximum and after that sudden failure of the slab attains.



stiffness in the cracked state was the same in all mixes, and this was attributed to the reinforcement's greater influence because it persisted across all slabs.

SCOPE FOR FUTURE INVESTIGATION

From the present investigation conducted and conclusions obtained, there is still lot of scope for the further research and improvement and modifications over present obtained results. These modifications incorporated may yield better and different results, further improving the knowledge and understanding in this topic, some of them are,

- In this experiment recycled aggregates are obtained from crushing unit directly and used for testing, here we can bring the demolished waste from construction site and crushed, washed and separated the aggregate from other construction wastes manually and make use of these aggregates for testing, results of these two can be compared and conclusion can be drawn.
- In the present investigation concrete for the study considered is M25 grade of concrete. But investigation can be done on other grades of concrete and difference in effect of recycled aggregate on these type of concrete strengths can be compared and conclusion can be drawn.
- In the present study "mineral admixture used is Micro Silica", various other mineral admixtures can be used and results can be compared..
- In the present study normal strength concrete is investigated, investigations on other type of concretes like high strength concrete, high performance concrete, self- compacting concrete, and pumpable concrete can be done conclusions can be drawn.
- In this study flat slab member was considered, but for investigation of other members like beams, columns, normal slabs can be casted using recycled aggregates concrete and study can be done various parameters like stress, strain, flexure, shear, crack width and these can be analysed and compared with natural aggregate concrete.
- Young's modulus can be determined to find out the nature of RCA with different percentage on different grades of concrete.
- Different methods can be used to strengthen the RAC in terms of shear strength properties with partial or full replacement of RCA.
- Cost analysis on recycled aggregates can be done and comparison with natural aggregates can be made.

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