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Flexural Behavior of Cement Concrete Beams Containing Recycled Waste Glass as Coarse Aggregate

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Abstract*— Waste glass can be a non-biodegradable substance and at this its drop on a land that becomes a very world organisation property selection. To look out a far higher response to cut back the ecological issues caused by disposable of waste glass is used as concrete manufacturing. Recycled glass as coarse mixture is used to prepare for various grade of concrete mix like M 20, M 40 and M 60 as an alternate for typical crushed stone for creating concrete. The physical and chemical characterize of recycled waste glass coarse mixture is examine and note the similarities with typical crushed stone aggregate. For each mix to hunt out out the mechanical strength of control concrete and RWGCA mixture concrete. Six numbers of cube size 100 × a hundred × 100 metric linear unit are cast. To check flexural behaviour, a hundred twenty five × two hundred × 1100 metric linear unit size of the beams are cast. Beam sections are created as below strengthened sections. For on prime of grade mix, three beams are created with typical crushed stone mixture & alternative 3 beams are created with RWG coarse mixture. All the beams are tested under two point loading. The flexural behaviour of beams are obtained. ANSYS software is used for finite element modeling and the results of experimental values are compared with ANSYS modeling.

***Index Terms*— Control Concrete (CC), Glass Aggregate (RWGCA), Mechanical Strength, Beam Behaviour, Ductility, ANSYS**

I. INTRODUCTION

The growing perception of the use of glass speeds up audits of the use of waste glass in diverse fields of entirely different type. Recent analysis findings have shown that concrete created with recycled glass mixtures is best end of the day strength and higher thermal insulation as a result of its better thermal properties of glass aggregate [1]. One in all the many productive is to the event field wherever the waste glass was reused for value supplemental concrete manufacturing [2]. Literature survey shows that glass is non bio degradable, is one of those materials that can not be applied to land fill. Large quantities of energy are used in the manufacture of concrete cement. To cut back these, researchers have targeting the utiliztion of recycled materials as potential alternatives within the construction industry notably in concrete manufacturing.

The successful use of recycled waste glass aids in reducing the environmental and health problems related to the disposal of waste glass and additionally the inadequacy of area needed for disposal. At present, utilization of waste materials that is. slag, ceramics, ash etc., In concrete manufacturing is one all told the prime analysis interests to reach the goal of achieving property construction.

Waste glass might be a rock bottom material compared with all completely different concrete constituents and is way more cost effective than crushed stone combination [3]. Therefore the thought is to exchange the utmost quantity of the stone mixture as potential to avoid wasting lots of money and to chop back the number of disposable wastes.

Throughout this analysis white colour recycled waste glass stones are effectively used as coarse combination for concrete manufacturing [4]. The properties of recycled waste white colour coarse combination and check results don't appear to be significantly varied from those of management concrete exploitation crushed stone as coarse mixture.

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II. EXPERIMENTAL PROGRAM

A.Cement

Ordinary hydraulic cement (OPC) grade forty three is employed for this concrete production and it's orthodox IS 12269 – 1987. In table one, the properties of cement are tabulated.

Table 1 Properties of Cement

Property	Result
Specific Gravity	3.15
Fineness	2%
Standard Consistency	29%
Initial Setting Time	60 minutes
Final setting Time	600 minutes
Compressive strength	43 MPa

B. Fine Aggregate

In this concrete production regionally obtainable water coarse sand is employed and it's conformist IS 383 -1970 Zone III.

The physical properties of fine mixture are given in Table Two.

C. Recycled Waste Glass Coarse Aggregate

White recycled glass is used as a coarse mixture in th is concrete production. The glass is then smashed, melted and screened for use for the required size. The form of recycled glass is created during this concrete processing, and the width of the glass mixture varies from eight to sixteen mm. The sample of RWGCA mixture is shown in Fig. one.

Figure 1 Glass Aggregate

Table 3 shows the physical properties of the recycled gl ass mixture. Glass mixture scanning (SEM) images are shown inFig.2 and Fig.3. Table gives a pair of the chemical prop erties of the glass mixture.

Table 2 Recycled Waste Glass Coarse Aggregate (RWGCA) Physical Properties

Property	Result
Specific Gravity	2.50
Size of the Aggregate	8mm to 16mm
Shape of the Aggregate	Angular

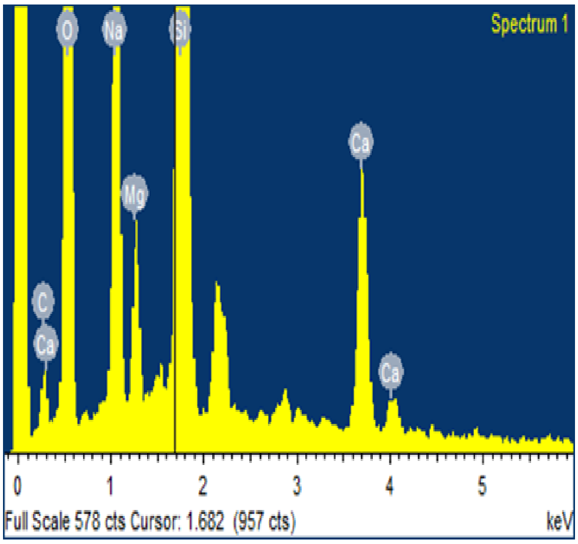

Figure 2 SEM Waste Glass Coarse Aggregate Recycled Images (RWGCA)

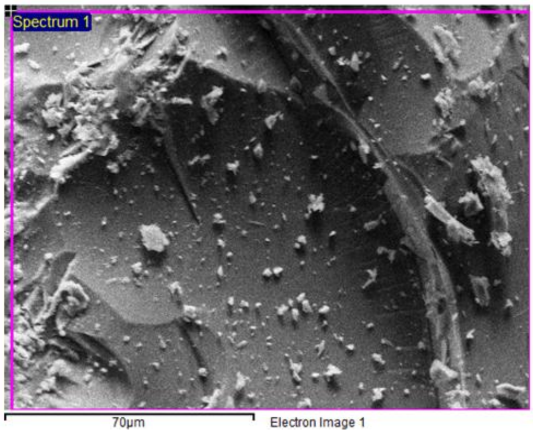

Figure 3 SEM of Waste Glass Coarse Aggregate Recycled (RWGCA) Images

Table 3 Glass Aggregate and Crushed Stone Aggregate Chemical Properties

Constituent	glass aggregate (%)	stone aggregate (%)
SiO_2	78.80	85.97
C_aCO_3	5.44	4.16
Na	8.39	2.68
M_gO	1.84	-
C_a	5.53	-
Al	-	7.20

D. Water

For this concrete development, fresh clean water is used that is free from organic impurities.

E. Chemical Admixtures

In this concrete production, Fosroc SP 430 is employed at the dose of zero.7% to 1.2% weight of the cement. Super pasticizer is to be used for higher workability.

F. Casting, Combining and Curing

The different grades of mixtures M 20, M 40 and M 60 are designed for concrete cubes, beams are made of crushed stone as coarse aggregates and cubes, beams are made of recycled waste glass as coarse aggregates are cast as per IS Code 10262-2009 mix design. For the concrete, admixture is used to reduce the water in concrete making and to obtain concrete workability. For the concrete, admixture is used to reduce the water in concrete making and to obtain concrete workability. It is necessary to maintain a slump of seventy-five metric linear unit to one hundred mm for all concrete work. For conventional concrete mix, crushed stone is used as coarse aggregate and for other mixes, crushed stone is 100% replaced by recycled waste glass. Preparation of Glass aggregate concrete and fresh concrete of RWGCA are shown in Figure 4 and 5. Table 4 shows a table of conventional concrete and glass aggregate concrete mixing ratios of different grades.

Figure 4 Glass Aggregate Preparation (RWGCA) in Concrete

Figure 5 Fresh concrete of Glass Aggregate (RWGCA)

Table 4 Mix Proportions of All Grades

Grade	Mix	Cement	Fine Aggregate	Coarse Aggregate		W/C ratio	Admixture (%)
			Sand	Crushed Stone	RWG		
M 20	CC	1	2.75	3.36	___	0.50	0.7
	RWGCA	1	2.75	___	3.36	0.50	0.7
M 40	CC	1	1.67	2.50	___	0.39	1.0
	RWGCA	1	1.67	___	2.50	0.39	1.0
M 60	CC	1	1.33	2.33	___	0.35	1.2
	RWGCA	1	1.33	___	2.33	0.35	1.2

Thirty six cubes of scale 100 / 100 / 100 mm are casted for compressive strength test to find the compressive strength at 7 and 28 days. The 125 mm / 200 mm / 1100 mm long beam is casted to assess the flexural nature of traditional concrete beams made from stone aggregate and recycled glass concrete beams made from glass as coarse aggregate is casted. With conventional stone aggregate, three beams are casted and the remaining three beams are casted with glass aggregate.

III. TESTING PROCEDURE

A. Compressive Strength

As per IS 516-1959 the different grade concrete mixture of conventional concrete with crushed stone and glass aggregate concrete made with glass mixture are tested at 7days and 28 days. Table 5 shows the mean value.

Table 5 Mechanical Strength of Various Grades

Mix	Code	Mechanical Strength (MPa)	
		7 days	28 days
M 20	CC	18.83	28.00
	RWGCA	19.00	28.30
M 40	CC	35.80	46.60
	RWGCA	36.10	47.00
M 60	CC	51.42	68.50
	RWGCA	51.60	69.12

B. Flexural Behaviour of CC and RWGCA Beams

For flexural purpose, various grade mix of concrete beam size of 125/200/1100 mm are placed. Of the six beams, three beams are made of crushed stone mixture and three alternate beams are made of glass aggregate. The reinforcement bars and blend magnitude relation are tabulated in Table half dozen. Lateral ties of eight metric linear unit diameter bar is employed for shear reinforcement with a hundred and fifty mm spacing. When the natural action amount the beam specimen is mounted in two hundred kN capability of beam testing frame. The beams are supported merely over a span of a thousand metric linear units and subjected to 2 targeted hundreds are applied through a symmetrically placed spreader beam. The load point space is 333.33 mm. The load is applied at 2 points each 166.67 metric linear unit removed from the center of the beam to the support In the middle span and below the load points, 3 dial gauges are used to live the deflections. Load is given at each zero.5 ton interval. Mechanical dial gauge is placed in the center to live the deflection during the final stage. Throghout beam take a look at dimension of the crack, nature of crack and beam deflections are monitored. The first load of crack is obtained through visual inspection. Loading up final word stage is maintained. Look at the below flexure beam specimen in Figure vi. The findings of regular concrete beams and RWGCA beams are shown in Table 7.

Table 6 Detail of Reinforcement and Concrete Ratio

Mix	Beam Code	Ratio	Reinforcement Detail	
			Top	Bottom
M 20	CC	1:2.75:3.36	2 nos. 8	2 nos.10
	RWGCA	1:2.75:3.36	2 nos. 8	2 nos.10
M 40	CC	1:1.67:2.50	2 nos. 8	2 nos.10
	RWGCA	1:1.67:2.50	2 nos. 8	2 nos.10
M 60	CC	1:1.33:2.33	2 nos. 10	2 nos.12
	RWGCA	1:1.33:2.33	2 nos. 10	2 nos.12

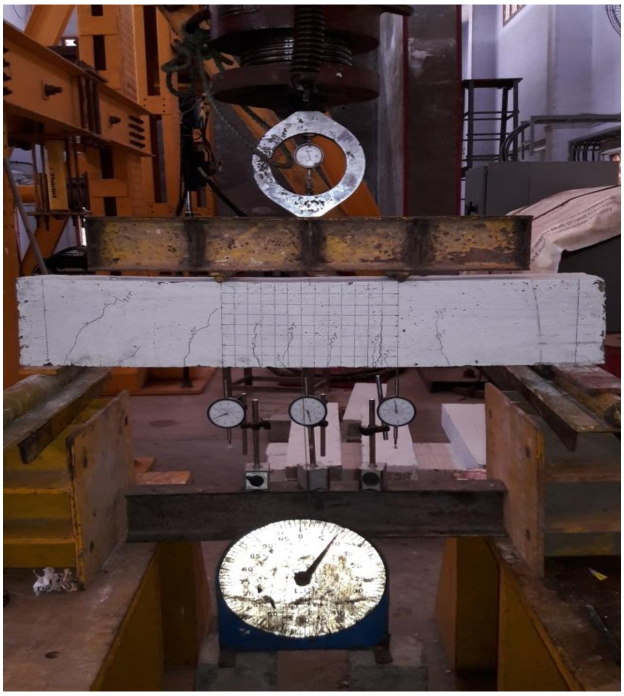

Figure 6 Flexure Test on Beam Specimen

The load deflection behaviour for conventional concrete beams made with conventional aggregate and glass aggregate beams made with waste glass are shown in Figure 7 to 12.

Table 7 Result of CC and Glass Aggregate Beams

Grade	Beam Code	1st Crack Load (kilo Newton)	Service Load (kilo Newton)	Yield Load (kilo Newton)	Ultimate Load (kilo Newton)	Max. Deflection (millimeter)
M 20	CCB	40.0	55.00	80.50	82.50	16.0
	CCGCAB	50.0	60.00	85.00	90.00	17.0
M 40	CCB	37.0	56.68	80.00	85.00	22.0
	CCGCAB	50.0	78.33	115.00	117.50	23.0
M 60	CC	45.0	63.33	92.50	95.00	27.0
	CCGCAB	35.0	85.00	125.00	127.50	22.0

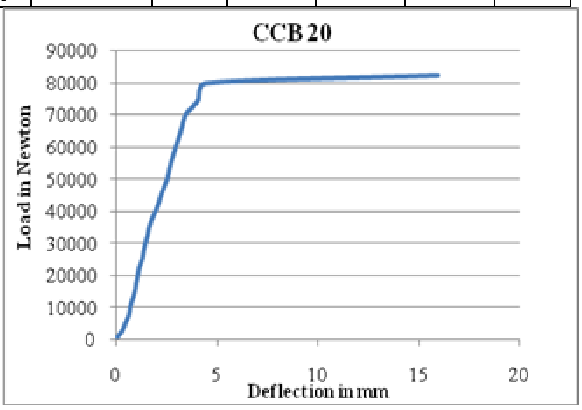

Figure 7 Cement Concrete Beam M 20 (CCB)

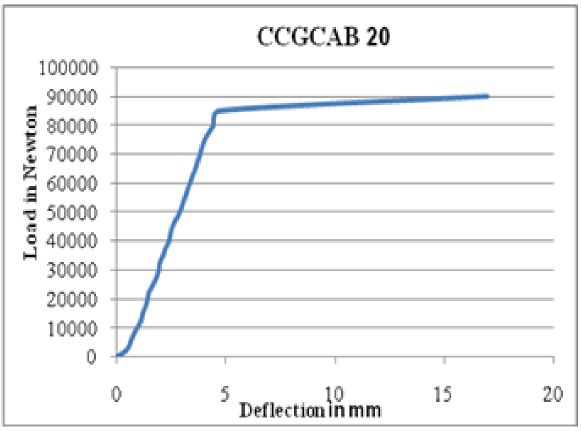

Figure 8 RWGCA Concrete Beam M 20 (CCGCAB)

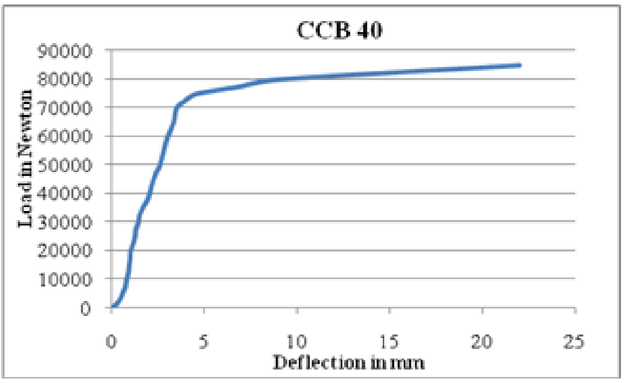

Figure 9 Cement Concrete Beam M 40 (CCB)

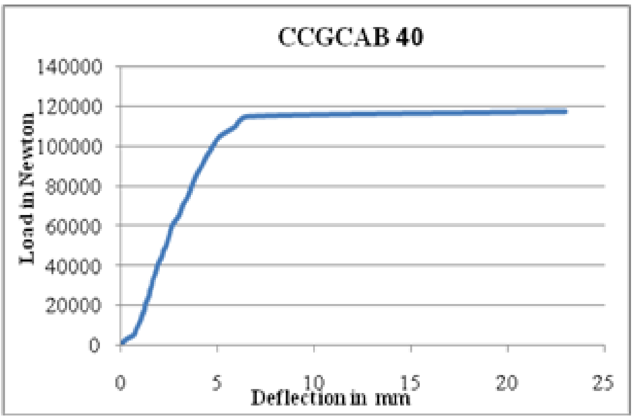

Figure 10 RWGCA Concrete Beam M 40 (CCGCAB)

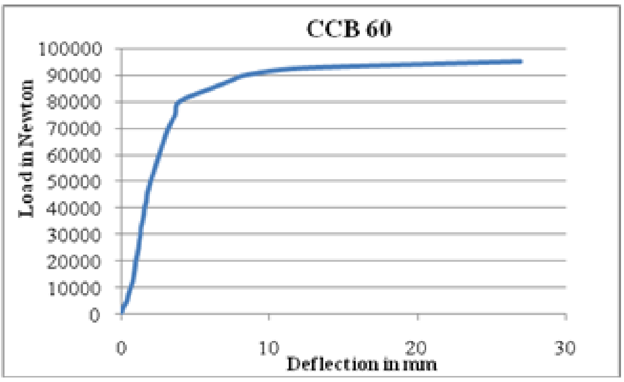

Figure 11 Cement Concrete Beam M 60 (CCB)

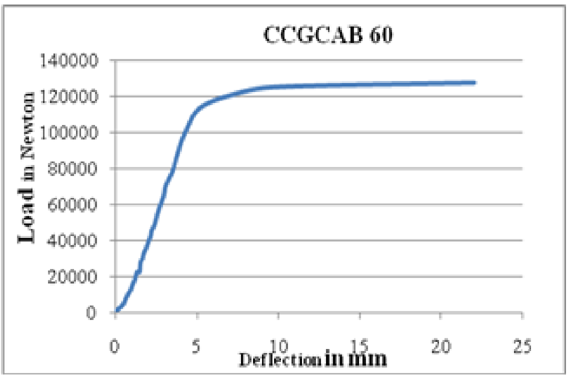

Figure 12 RWGCA Concrete Beam M 60 (CCGCAB)

C. Crack Patterns of CC and RWGCA Beams

The cracks form within the flexure area when the load is applied. The maximum bending moment is carried by the reinforcement of the strain steel and the rotation of beams inflates the steel stress. All the cracks are formed in flexure zone and also the variety of cracks are in between ten or twenty five. The last word load for the quantitative load relationship (pu/py) ranges from one.02 to 1.06. Once the compression zone has been crushed, the beam's ultimate failure occurred in the middle of steel bar buckling. During regular intervals, the crack dimension is marked. The crack measurements are generally enlarged in the pressure area and the cracks are often perpendicular to the direction of the beam. In standard concrete beams made of mixed stone and RWGCA concrete beams made of glass aggregate crack patterns a lot of or less same and also the typical crack patterns are shown in Figure twelve to seventeen.

Figure 12 Failure Pattern of Concrete Beam M 20 (CCB)

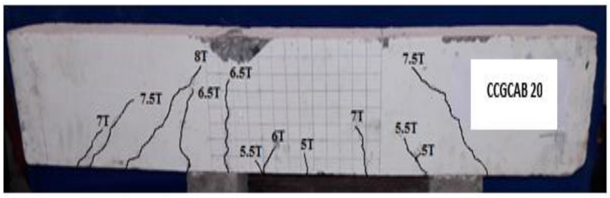

Figure 13 Failure Pattern of RWGCA Concrete Beam M 20 (CCGCAB)

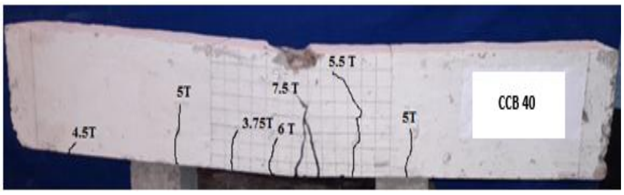

Figure 14 Failure Pattern of Concrete Beam M 40 (CCB)

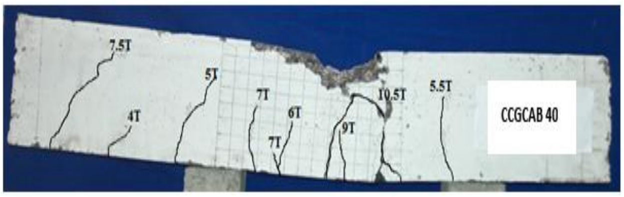

Figure 15 Failure Pattern of RWGCA Concrete Beam M 40 (CCGCAB)

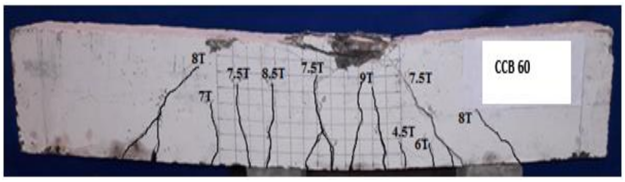

Figure 16 Failure Pattern of Concrete Beam M 60 (CCB)

Figure 17 Failure Pattern of RWGCA Concrete Beam M 60 (CCGCAB)

D. CC and RWGCA Ductility Beams

Table 8 tabulates the ductility displacement of cement concrete made from crushed stone aggregate and RWGCA concrete made of glass aggregate.

Table 8 Ductility CC and RWGCA Beam Displacement

Mix	Beam Code	Minimum Deflection (milli metre)	Maximum Deflection (milli metre)	Ductility Ratio
M 20	CC	4.46	16.00	3.59
	CCGCAB	4.71	17.00	3.61
M 40	CC	8.93	22.00	2.46
	CCGCAB	6.52	23.00	3.53
M 60	CC	12.18	27.00	2.22
	CCGCAB	9.62	22.00	2.29

D. Ansys Modeling of CC and RWGCA Beams

ANSYS software version 16 is used for finitie element modeling. The mesh was set up to provide square or rectangular elements and nodes in the concrete portion of the model for solid 65 element. 4666 nodes and 3380 elements are needed for total mesh model beam generation. These nodes and elements follow a concrete mapped mesh modeling procedure in which meshes are produced in even order. Free mesh simulation is the one that randomly creates the meshes.

Figures 18 and 19 demonstrate the meshing of concrete reinforcement and meshing. The results of ANSYS are compared with the experimental results and the values are shown in Table 9. The deflected form of traditional concrete beams made of crushed stone aggregate and RWGCA beams made of glass aggregate was shown in Figure 20 to 25.

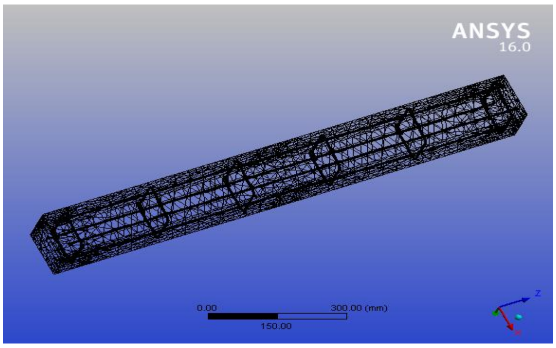

Figure 18 Meshing Reinforcement

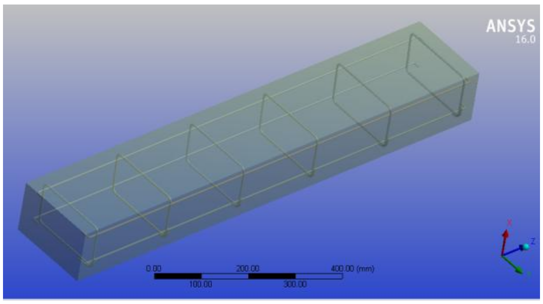

Figure 19 Meshing Concrete

Table 8 of CC and RWGCA Beams

GRADE	Beam Code	Yield Load (kilo Newton)		Maximum Load (kilo Newton)		Ultimate Deflection (millimeter)	
		Experimental	ANSYS	Experimental	ANSYS	Experimental	ANSYS
M 20	CCB	80.50	70.20	82.50	74.30	16.00	15.6
	CCGCB	85.00	78.30	90.00	82.80	17.00	16.4
M 40	CC	80.00	72.00	85.00	76.80	22.00	20.1
	CCGCB	115.0	106.0	117.5	108.8	23.00	21.9
M 60	CC	92.50	82.40	95.00	80.20	27.00	25.2
	CCGCB	125.0	115.0	127.5	117.6	22.00	20.9

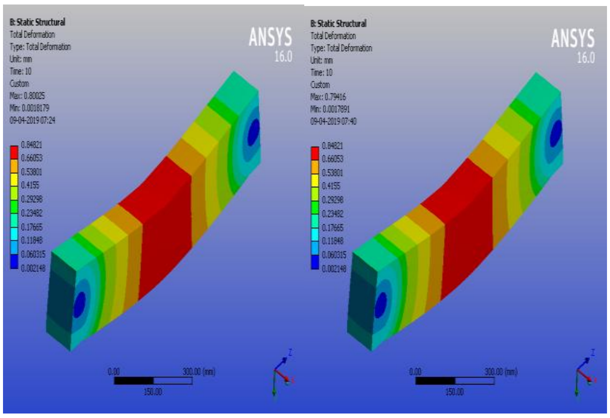

Figure 20 & 21 Beam Deflected Shape of M 20 CC and M 20 (CCGCA)

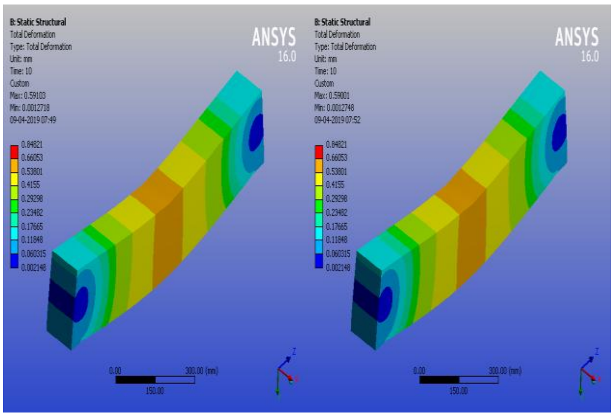

Figure 22 & 23 Beam Deflected Shape of M 40 CC and M 40 (CCGCA)

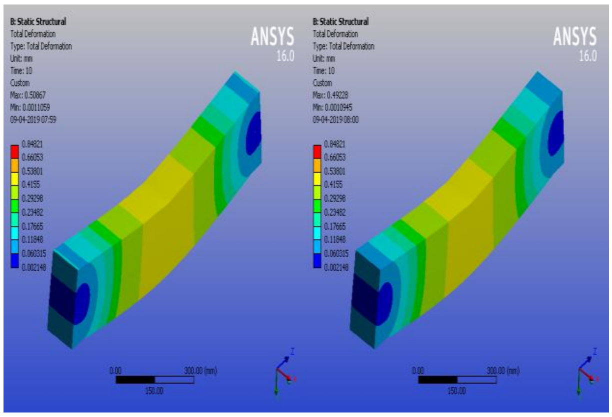

Figure 24 & 25 Beam Deflected Shape of M 60 CC and M 60 (CCGCA)

IV. RESULTS AND DISCUSSIONS

Compressive strength is derived from traditional concrete of different grades made from crushed stone aggregate and recycled glass concrete made from glass aggregate tests. Recycled waste glass coarse aggregate's chemical properties are identical to the properties of crushed stone aggregate and alumina is not shown in glass aggregate. The mechanical properties of RWGCA concrete cubes are marginally higher than CC concrete cubes due to non-absorption water in the glass aggregate.

The mechanical strength of cubes of seven days and twenty eight days are compared and shown in diagram twenty six to twenty eight. Different grade levels of traditional concrete beams made of crushed stone aggregate and recycled waste glass concrete beams made of glass aggregate were previously tabulated. RWGCA concrete beams crack patterns are similar to control concrete beams. Figure 29 compares and shows the comparison of load deflection curve for RWGCA beams and load deflection behavior CC beams.

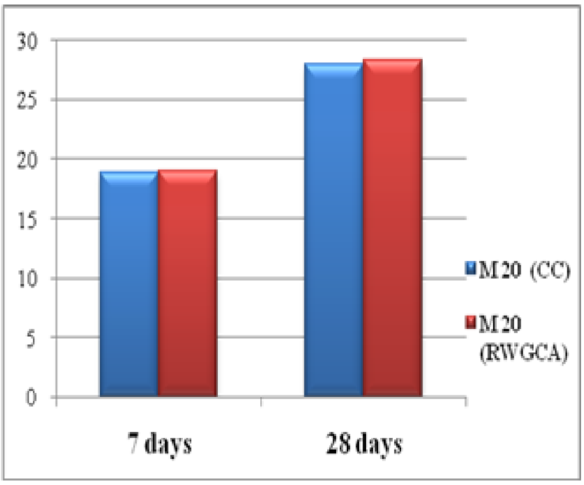

Figure 26 M 20 CC and RWGCA Cube Comparison

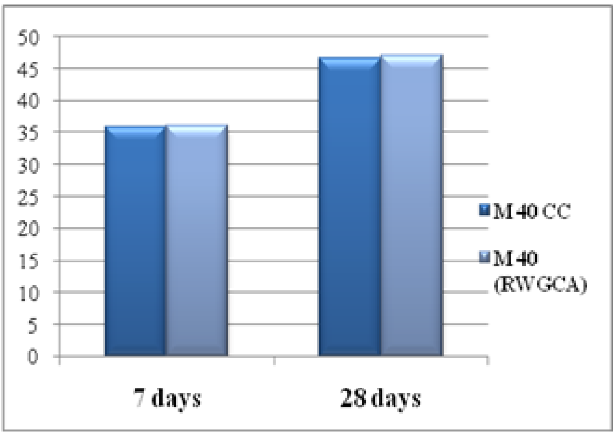

Figure 27 M 40 CC and RWGCA Cubes Comparison

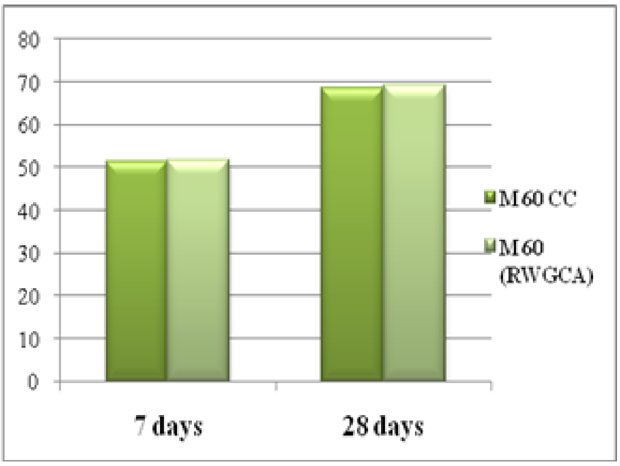

Figure 28 M 60 CC and RWGCA Cubes Comparison

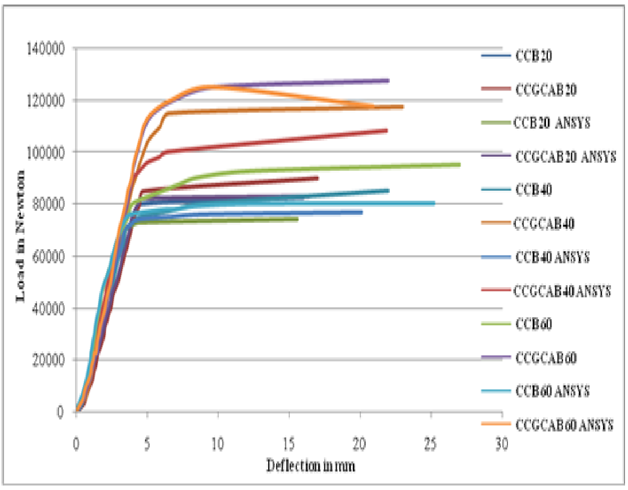

Figure 29 CC and RWGCA Concrete Beams Load Deflection Curve Comparison

V. CONCLUSION

Based on results the conclusions are drawn.

1. The use of glass aggregate in concrete increases the mechanical strength of all different grade mix when compared to control concrete using crushed stone aggregate.
2. The reason of non absorption water in glass aggregate leads to strength increase.
3. The maximun load carrying capability of M 20 grade glass aggregate beam is 7% higher than control concrete beam.
4. The maximum load carrying capacity value of M forty and M sixty RWGCA concrete beams are 38% and 34% higher than the control concrete beams respectively.
5. Crack pattern and crack width of RWGCA beams are not much difference with control concrete beams.
6. When compare with ANSYS modeling the load carrying capacity is 7% to 8% is lower than the experimental load carrying capacity.

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