An Experimental Investigation on Strength Behavior of Concrete by Replacing N.C.A with R.C.A Using M30 Grade Concrete

Md Wajeed Ali[1] Prof. Syed Arfath[2]
[1]PG Student [2]Associate Professor
[1,2]Department of Civil Engineering
[1,2]Khaja Banda Nawaz College of Engineering, Gulbarga

Abstract— Concrete is one of the most widely used construction material in the world. Destruction of concrete structure due to natural calamities like earthquake, tsunami or by the bombardment, it has became a major problem in finding place for dumping the concrete debris particularly in urban areas. This paper deals with the study of strength of concrete incorporating Recycled Aggregate concrete. The main objectives of this investigation is to find out up to what percentage the Natural Coarse Aggregate (N.C.A) can be replaced by R.C.A in the concrete mix and to find out the extra quantity of cement to be added for each percentage replacement by R.C.A to achieve its target mean strength A series of test were carried out to determine the compressive strength, split tensile strength, flexural strength with and without recycled aggregates. Natural coarse aggregates in concrete were replaced with 0%, 20%, 40%, 60%, 80% and 100% of crushed concrete coarse aggregate. For the strength characteristics, the result showed a gradual decrease in compressive strength, split tensile strength, flexural and modulus of elasticity as the percentage of recycled aggregate is increased.

***Keywords**:* N.C.A-Natural Coarse Aggregate R.C.A-Recycled Coarse Aggregate

I. INTRODUCTION

To accommodate new structures, many structures built in the past centuries are being demolished and destroyed due to their limit of life span, unsuitable position in an ever-growing city, and damaged condition caused by natural disaster. The demolition of structures is generating concrete rubbles and causing environmental problems due to unplanned disposal and scarcity of land fill sites. A large portion of the potentially useful demolition waste is disposed off in landfill sites. The transport and disposal of this waste are economically and environmentally not sustainable. as are large retail spaces or floors with a lot of windows. While the unobstructed space of the soft storey might be aesthetically or commercially desirable, it also means that there are less opportunities to install shear walls, specialized walls which are designed to distribute lateral forces. If a building has a floor which is 70% less stiff than the floor above it, it is considered a soft storey building. This soft storey creates a major weak point in an earthquake, and since soft stories are classically associated with reception lobbies retail spaces and parking garages

To alleviate these problems, nowadays alternative aggregates are drawing more interest in the construction industry [1].In this rapid industrialized world, recycling construction material plays an important role to preserve the natural resources. Rapid industrial development causes serious problems all over the world such as depletion of natural aggregates and creates enormous amount of waste material from construction and demolition activities. One of the ways to reduce this problem, is to utilize recycled concrete aggregate (RCA) in the production of concrete [2].Many significant researches have been carried out to prove that recycled concrete aggregate could be a reliable alternative as aggregate in production of concrete. As widely reported, recycled aggregates are suitable for non-structural concrete applications. Recycled aggregates also can be applied in producing normal structural concrete with the addition of fly ash and condensed silica fume etc.

II. LITERATURE REVIEW

A. A study has been conducted by M C Limbachiya, A Koulouris, J J Roberts and A N Fried [4]

in Kingston University, UK on “Performance of Recycled Aggregate Concrete”. The results of an extensive experimental program aimed at examining the performance of Portland-cement concrete produced with natural and coarse recycled aggregates were reported in their paper. The effects of up to 100% coarse recycled concrete aggregate on a range of fresh, engineering and durability properties have been established and assessed its suitability for use in a series of designated applications.

B. Yong P.C and Teo, D.C.L [2]

Conducted a research on “Utilization of Recycled Aggregate as Coarse Aggregate in Concrete”. Recycled concrete aggregates (RCA) from site-tested concrete specimens were used. These consist of 28-days concrete cubes after compression test obtained from a local construction site. These concrete cubes are crushed to suitable size and reused as recycled coarse aggregate. The main aim of this research project is to utilise recycled concrete as coarse aggregate for the production of concrete. It is essential to know whether the replacement of RCA in concrete is inappropriate or acceptable After testing, a mix design is produced in accordance with the properties obtained from test results. Concrete is then produced with replacement of 0%, 50% and 100% of RCA as well as 100% replacement of saturated surface dry (SSD) RCA with the same mix proportion. For the hardened concrete, the 28-days compressive strength, split tensile strength and flexural strength were determined. From the result, the bulk density of gravel is 1469.8 kg/m^3 and the RCA is 9.8% lower in bulk density than the gravel.

C. The study conducted by Md. Safiuddin et al [1]

presents the effects of recycled concrete aggregate (RCA) on the key fresh and hardened properties of concrete. RCA was used to produce high-workability concrete substituting 0-100% natural coarse aggregate (NCA) by weight. The coarse aggregates are generally oriented with their larger dimension along the length of the prism specimen. It implies that the interfacial bond is more effective along the specimen length. Therefore, a greater restraint to the flexure (bending) occurred, thus compensating the negative impact of the weakness of RCA on the modulus of rupture (flexural strength) of concrete.

III. EXPERIMENTAL INVESTIGATION

The total experimental investigations involved in this dissertation work have been done in details. The details of the work are given below

A. Materials

The materials used in the entire investigations is as follows

1) Cement

Cement used is 53 grade Ordinary Portland Cement (OPC) and the results of various preliminary tests conducted on this cement are as given in table 1 below

Sl. No.	Particulars	Results
1.	Normal consistency	32%
2.	Initial setting time	30 min
3.	Final setting time	2:35min
4.	Specific gravity	2.98
5.	Soundness	4 mm exp
6.	Compressive strength of cement for 28 days of curing	47.06N/mm^2

Table 1: Preliminary Tests Results of Cement

B. Natural Coarse Aggregates

The N.C.A used here are of 20 mm down size. Preliminary test such as water absorption, moisture content, sieve analysis, specific gravity and crushing strength tests have carried out and the results are as given in table 2 below

Sl. No.	Particulars	Results
1.	Water absorption	1.2%
2.	Moisture content	0.9%
3.	Specific gravity	2.7
4.	Crushing strength	17.33%
5.	Flakiness index	19.40%
6.	Elongation index	20.80%

Table 2: Preliminary test results of N.C.A

C. Natural fine aggregates

The source for fine aggregate used is from natural river bed, the details regarding test conducted on it are as given in table 3 below

Sl. No	Particulars	Results
1.	Water absorption	1.3%
2.	Moisture content	1.2%
3.	Specific gravity	2.60
4.	Sieve analysis	Zone II

Table 3: Preliminary test results of N.F.A

D. Recycled aggregate concrete

The Coarse aggregate was taken from the waste concrete cubes, cylinders and beams. The coarse aggregate (C.A) is separated from the concrete by hammering. Mortar adhered to the aggregate is also removed from the aggregate as much as possible. Obtained C.A is sieved under 20mm sieve (passing) and 4.75mmsieve (retained), later these aggregates can be used as R.C.A for further work.

IV. PRELIMINARY TESTS CONDUCTED ON RECYCLED COARSE AGGREGATES

After obtaining the R.C.A from original concrete, preliminary tests such as sieve analysis, water absorption, moisture content, specific gravity and crushing strengths have been carried out. The results of above tests are as given in table .4 below.

Sl. No.	Particulars	Results
1.	Moisture content	1.25%
2.	Water absorption	2.4%
3.	Specific gravity	2.6
4.	Crushing strength	19.64%

Table 4: Preliminary tests results of R.C.A

A. Workability Characteristics

Specimen type M_{30} Grade Concrete	Slump (mm)	Compaction Factor
0%RCA	57	0.95
20%RCA	56	0.89
40%RCA	55	0.86
60%RCA	54	0.85
80%RCA	46	0.84
100%RCA	44	0.81

Table 5: Slump Cone Test and Compaction Factor Test

V. CASTING WORK

In this casting work is carried out based on the co-related quantities of concrete ingredients between N.CA and R.C.A properties in the concrete mix design. Above mentioned work is explained in detail as follows

Casting work based on the Correlated quantities of concrete ingredients between the N.C.A and R.C.A

Quantities of the concrete ingredients which are obtained based on N.C.A and R.C.A have been co-related with each other. Correlation process is given in Appendix-1

Using the material quantities obtained after co-relation cubes, cylinders, prisms and flexural beams are cast. Here, six different mixes are made and in each mix the N.C.A are replaced by R.C.A by 20% i.e., in the 1st mix 100% N.C.A are used in concrete mix where as in 2nd, 3rd, 4th and 5th mix, 20%, 40%, 60% and 80% respectively replacement of N.C.A by R.CA is made. In the final 6th mix N.C.A are completely replaced 100% by R.C.A

Prepared specimens were kept immersed in water and tested for their strength after 7-days and 28-days of curing. .The details regarding their compressive strength, split tensile strength and flexural strength are given in tables.

A. Compressive strength

The cube compressive strength for all the mixes at 7 and 28 days of curing is presented in table-6. The results show that the concrete specimens with more replacement of recycled aggregate have the lowest compressive strength when compared to the concrete specimens with less recycled aggregate for both 7 days and 28 days of curing. 7 days compressive strength is generally 70-85% of the 28 days compressive strength. A graphical representation reduction in compressive strength for different mixes is shown in figure 4.5. Figure 4.1 shows that the compressive strength at 28 days for 20% replacement of N.C.A by R.C.A has dropped around 4.75%. Even up to 60% replacement of recycled aggregate, the compressive strength gets reduced only to a maximum of 10.40% with respect to that of control concrete. There is a drop of 30.61% compressive strength for the 100% recycled aggregate. The compressive strength of the concrete specimens for 60% recycled aggregate is 38.29N/mm^2, which meets the target strength of 38.25N/mm^2. From the obtained results, it is clear that there is a possibility to use 60% recycled aggregate in applications like concrete blocks and pavements. The compressive strength is calculated by using the formula fc = P/A

Where

fc = cube compressive strength in N/mm^2

P = load causing failure in N

A = cross sectional area of cube

Mix No.	%age replacement	Days of curing	Avg. Load (Tested on 3-Cubes) (tones)	Avg. load (N)	Compressive strength (N/mm^2)
1.	0.00	7-days	76.66	752034.6	33.42
		28-days	98.00	961380	42.73
2.	20.00	7-days	73.00	716130.0	31.83
		28-days	93.33	915567.3	40.7
3.	40.00	7-days	70.66	693174.6	30.8
		28-days	90.00	8821900	39.24
4.	60.00	7-days	70.00	686700	30.52
		28-days	87.83	861612.3	38.29
5.	80.00	7-days	64.66	634314.6	28.2
		28-days	76.16	747129.6	33.2
6.	100.00	7-days	58.66	575454.6	25.57
		28-days	68.00	667080	29.65

Table 5.1: Compressive strength using correlated properties in concrete mix design with %age replacement of N.C.A. by R.C.A

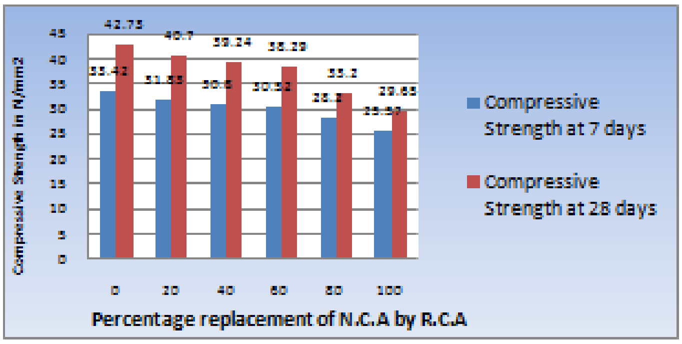


Fig. 5.1: Compressive strength at 7 days and 28 days

B. Split tensile strength

The split tensile test indicates a decreasing trend of split tensile strength at 7 days and 28 days of curing, when the percentage of recycled aggregate is increased. Table 4.2 represents the tensile strength values for mixes at 7days and 28 days of curing. A graphical representation reduction in tensile strength of concrete is shown in figure-4.6. The figure-4.2 shows that the 28 days split tensile strength is significantly greater than 7 days split tensile strength. The concrete specimen with 100% recycled aggregate coarse aggregate at 28 days of curing has the lowest tensile strength, which was only 2.94 N/mm^2. It is around 38.40% drop when compared to control concrete specimen. There is a drop in tensile strength of 8.8%, 16.8%, 24.90% and 35.0% for the concrete specimens with 20%, 40%, 60% and 80% recycled coarse aggregate respectively.

Even up to 60% replacement, the split tensile strength gets reduced only to a maximum of 24.9% with respect to that of control concrete.

Split tensile strength is calculated by using the formula

$$Ft = \frac{2P}{(\pi DL)}$$

Where

Ft = Split tensile strength in N/mm^2

P = Load causing failure in N

D = Diameter of the cylinder in mm

L = Length of the cylinder in mm

Mix No.	%age replacement	Days of curing	Avg. Load (Tested on 3-Cubes) (tones)	Avg. load (N)	Split Tensile strength (N/mm^2)
1.	0.00	7-days	24.3	238383	3.37
		28-days	34.4	337464	4.77
2.	20.00	7-days	21.69	212778.9	3.01

		28-days	31.36	307641.6	4.35
3.	40.00	7-days	19.24	188744.4	2.67
		28-days	28.6	280566	3.97
4.	60.00	7-days	18.1	177561	2.51
		28-days	25.85	253588.5	3.58
5.	80.00	7-days	15.75	154507.5	2.18
		28-days	22.4	219744	3.1
6.	100.00	7-days	14.73	144501.3	2.04
		28-days	21.2	207972	2.94

Table 5.2: Split tensile strength using correlated properties in concrete mix design with %age replacement of N.C.A. by R.C.A

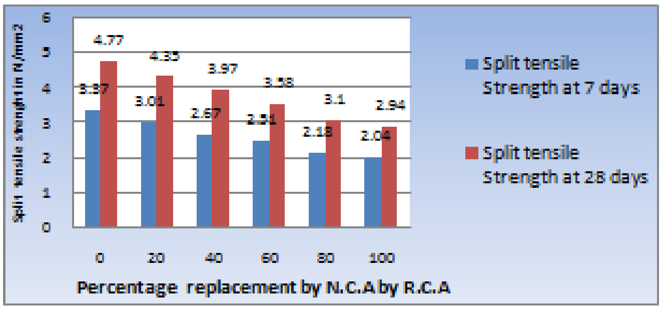


Fig. 5.2: Split tensile strength at 7 days and 28 days

C. Flexural strength

The flexural strength for all the mixes at 7 days and 28 days of curing is presented in table 4.3. The results show that the concrete specimens with more replacement of recycled aggregate have the lowest flexural strength when compared to the concrete specimens with less recycled aggregate. Figure- 4.7 shows a graphical representation for reduction in flexural strength for different mixes. Figure 4.3 shows that there is a drop in flexural strength of 11.3%, 14.9%, 26.8%, 36.90% and 45.10% for the concrete specimens with 20%, 40%, 60%, 80% and 100% coarse aggregates respectively.

Flexural strength is calculated by using the formula.

$$f_f = \frac{PxL}{bxd2}$$

Where

f_f = Flexural strength in N/mm^2
P = load causing failure in N
L = Length of prism in mm
b = Width of prism in mm
d = Depth of prism in mm

Mix No.	%age replacement	Days of curing	Avg. Load (Tested on 3-Cubes) (tones)	Avg. load (N)	Flexural strength (N/mm^2)
1.	0.00	7-days	1.15	11281.5	4.51
		28-days	1.6	15696	6.28
2.	20.00	7-days	1.0	9810	3.92
		28-days	1.42	13930.2	5.57
3.	40.00	7-days	0.75	7357.5	2.94
		28-days	1.36	13341.6	5.34
4.	60.00	7-days	0.71	6965.1	2.78
		28-days	1.17	11477.7	4.6
5.	80.00	7-days	0.62	6082.2	2.43
		28-days	1.01	9908.1	3.96
6.	100.00	7-days	0.55	5395.5	2.15
		28-days	0.88	8632.8	3.45

Table 5.3: Flexural strength using correlated properties in concrete mix design with %age replacement of N.C.A. by R.C.A

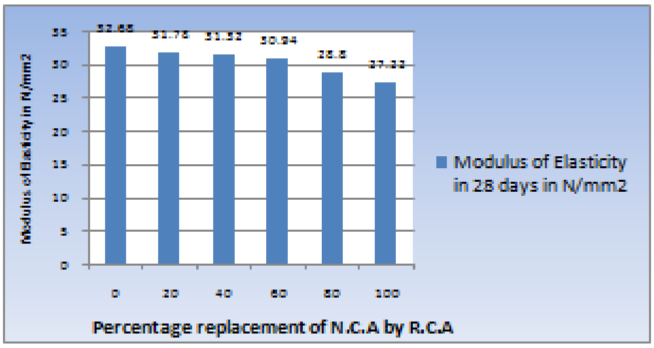


Fig. 5.4: Modulus of elasticity at 28 days strength

VI. Flexural Investigation Using Beams

A. Casting and Curing of Test Specimen

Cast iron mould of internal dimensions 700mm x 150mm x 150mm are used for casting the beams. The internal surface is cleaned and mould oil paste is applied at all corners, then a coat of cutting oil is applied on all internal surfaces. Steel reinforcement cage prepared earlier is kept in the mould. To obtain the required effective depth mortar blocks of 25mm thickness are kept one at each end as covering.

The mould is filled with the concrete in three layers, height of each layer being 1/3rd height of mould and compacted uniformly over the entire cross section area with tamping rod for conventional concrete member and also for RCA member. After compacting the CVC beams and RCA beams the top surface is smoothened and the mould is kept for drying about 24 hours.

After drying, the mould is removed and the surfaces of beams are cleaned and hand curing method is adopted in this investigation. All the specimens were fully wrapped with gunny bags and cured daily for three times. All the beams were treated in this manner. It should be noted that the water which is used for curing should be pure and should be free from impurities

B. Testing and Result of Cvc Beams and Rca Beams

Test specimens are as follows:

Two Beams of grade M_{30} of span 700mm width 150mm, and depth 150mm are tested for conventional beams.

Two Beams of each RCA Mix M2, M3, M4, M5, M6 (20%, 40%, 60% 80%, 100% replacement) span 700mm width 150mm and depth 150mm is tested it act as test specimen.

For all the beams the reinforcement used is 10mmΦ bars and 8mmΦ bars are used as the longitudinal bars and 6mmΦ bars is used as the lateral ties.

	Beam 01		Beam 02
LOAD (KN)	Deflection(mm)	Load(KN)	Deflection(mm)
0	0	0	0
20	0.7	20	0.65
40	0.8	40	0.8
60	1	60	1.05
80	1.3	80	1.3
100	1.5	100	1.45
136*	1.8	135*	1.75
140	2	140	1.95
160	2.6	160	2.6
174**	2.9	173**	2.9

*first crack load **ultimate crack load

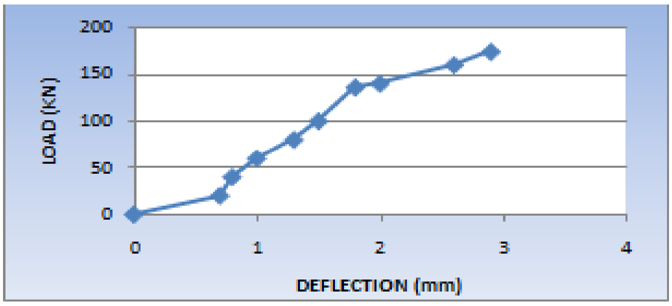


Fig. 6.1: Load V/s deflection curve for CVC RCC beam of Mix M1

	Beam 01		Beam 02
LOAD (KN)	Deflection(mm)	Load(KN)	Deflection(mm)
0	0	0	0
20	0.75	20	0.75
40	0.9	40	0.95
60	1.1	60	1.1
80	1.3	80	1.35
100	1.5	100	1.5
120	1.75	120	1.7
133*	1.9	132*	1.95
140	2.2	140	2.25
160**	2.6	160**	2.55

*first crack load **ultimate crack load

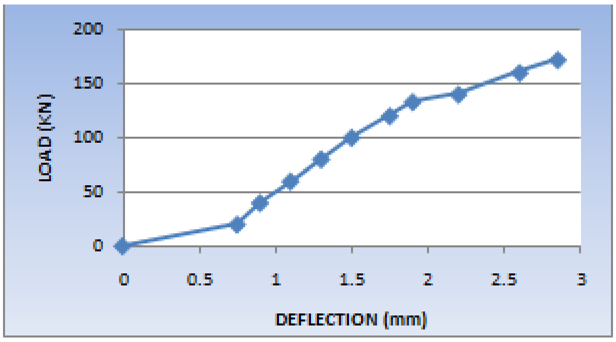


Fig. 6.2: Load V/s deflection curve for CVC RCC beam of Mix M2

	Beam 01		Beam 02
LOAD (KN)	Deflection(mm)	Load(KN)	Deflection(mm)
0	0	0	0
20	0.8	20	0.85
40	0.9	40	0.95
60	1	60	1
80	1.25	80	1.2
100	1.4	100	1.35
120	1.6	120	1.6
130*	1.85	131*	1.9
140	2.2	140	2.25

160**	2.5	160**	2.4

Table 6.3: Load deflection characteristics of RCC beam with Replacing 40% RCA MIX M3 (M_{30} grade)

*first crack load **ultimate crack load

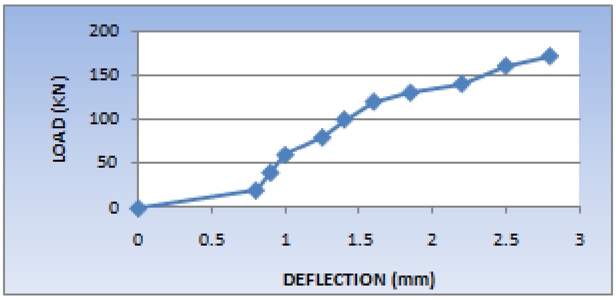


Fig. 6.3. Load V/S Deflection Curve For Rca Rcc Beam Of Mix M3

Beam 01		Beam 02	
LOAD (KN)	Deflection(mm)	Load(KN)	Deflection(mm)
0	0	0	0
20	0.75	20	0.75
40	0.9	40	0.9
60	1.1	60	1.05
80	1.3	80	1.3
100	1.5	100	1.55
128*	1.7	128*	1.7
140	2.1	140	2.1
160	2.5	160	2.55
170**	2.8	169**	2.8

Table 6.4: Load Deflection Characteristics Of Rcc Beam With Replacing 60% Rca Mix M4 (M_{30} Grade)

*first crack load **ultimate crack load

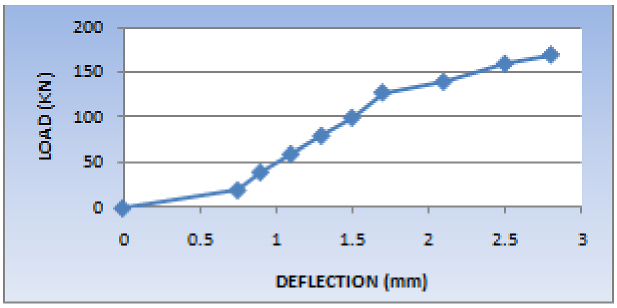


Fig. 6.4: Load V/S Deflection Curve For Rca Rcc Beam Of Mix M4

Beam 01		Beam 02	
LOAD (KN)	Deflection(mm)	Load(KN)	Deflection(mm)
0	0	0	0
20	0.9	20	0.9
40	1.1	40	1.05
60	1.25	60	1.25
80	1.3	80	1.3
100	1.5	100	1.5
125*	1.65	124*	1.65
140	2.1	140	2.1
160	2.5	160	2.55
168**	2.9	167**	2.85

*first crack load **ultimate crack load

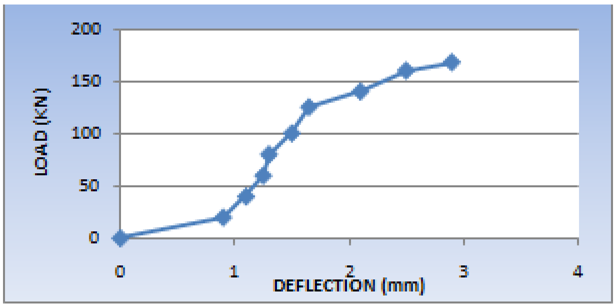


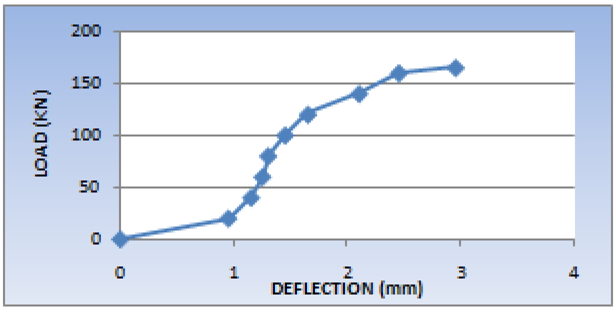
Fig. 6.5: Load V/S Deflection Curve For Rca Rcc Beam Of Mix M5

Beam 01		Beam 02	
LOAD (KN)	Deflection(mm)	Load(KN)	Deflection(mm)
0	0	0	0
20	0.95	20	0.95
40	1.15	40	1.1
60	1.25	60	1.25
80	1.3	80	1.3
100	1.45	100	1.45
120*	1.65	120*	1.65
140	2.1	140	2.15
160	2.45	160	2.5
165**	2.95	165**	2.95

Table 6.6: Load Deflection Characteristics Of Rcc Beam With Replacing 100% Rca Mix M6 (M_{30} Grade)

Beam 01		Beam 02	
LOAD (KN)	Deflection(mm)	Load(KN)	Deflection(mm)
0	0	0	0
20	0.95	20	0.95
40	1.15	40	1.1
60	1.25	60	1.25
80	1.3	80	1.3
100	1.45	100	1.45
120*	1.65	120*	1.65
140	2.1	140	2.15
160	2.45	160	2.5
165**	2.95	165**	2.95

*first crack load **ultimate crack load



Graph 6.6: Load V/S Deflection Curve For Rca Rcc Beam Of Mix M6

VII. CONCLUSION

(1) Little variation in %age passing (Sieve Analysis) is observed between N.C.A and R.C.A. this is mainly because of carrying out proper sieve analysis of R.C.A and by removing the surface dirt present on R.C.A by rubbing with dry cloth.
(2) Water absorption of R.C.A is more than the water absorption of N.C.A due to the older mortar adhered to the surface of aggregate which contribute towards decrease of strengths.
(3) The strength of concrete decreases as the percentage of R.C.A increases. From the concrete mix design the target mean strength of 38.29 N/mm^2 can be achieved for M30 grade concrete by 60% replacement of natural coarse aggregate by recycled coarse aggregates.
(4) Difference in cement quantity based on the properties of N.C.A and R.C.A is 18.32%.For achieving target mean strength for 60% replacement of N.C.A by R.C.A 11.00% of extra quantity of cement is to be added in the concrete mix.
(5) During the initial stage of curing, the rate of development of compressive is fast and gradually reduces up to 28 days of curing.
(6) In case of CVC RCC beam the deflection is less compare to RCA Mix M2, M3, M4, M5 & M6 the load carrying capacity is also more.
(7) As there is considerable reduction in split tensile strength and flexural strength of concrete with recycled aggregates, the loss in strength should be considered while designing members using recycled aggregate concrete.
(8) The concept of R.C.A can be used in concrete structural works of any grade, provided, additional percentage of extra cement is to be added for achieving the desired target strength of the concrete.

VIII. SCOPE FOR FUTURE WORK

The investigation work carried out shows that up to 60% replacement of N.C.A can be made by R.C.A. Some of the works which can still be worked out for future investigations are as listed below.

(1) Replacement of N.F.A by R.F.A can be made in similar fashion as done on N.C.A by R.C.A.
(2) Reuse of concrete debris can also be tested for high grade structural concreting i.e., M40, M60 grades etc.
(3) Concrete mix design with lower W/C ratio of 0.4 can also be made by using suitable admixtures which improves the workability of concrete.
(4) Further research can be carried out to use recycled aggregate in combination with different fibrous materials.
(5) Research can also be carried out using self curing compound on concrete made using recycled aggregate.

REFERENCES

[1] Md. Safiuddin ,Ubagaram Johnson Alengaram et al,' Properties of high-workability concrete with recycled concrete aggregate', Mat. Res. vol.14 no.2 São Carlos 2011 Epub June 03, 2011
[2] Yong, P.C. and Teo,D.C.L 'Utilisation of Recycled Aggregate as Coarse Aggregate in Concrete' UNMAS E-journal of civil engineering, vol 1: issue 1/august 2009
[3] Yasuhiro Dosho, 'Development Of A Sustainable Concrete Waste Recycling System', Journal Of Advanced Concrete Technology Vol.5 No.1, 27-42 February 2007
[4] M C Limbachiya, A Koulouris, J J Roberts and A N Fried in Kingston University, UK 'Performance of Recycled Aggregate Concrete'. RILEM international symposium on Environment-Conscious Materials and System for Sustainable Development 2004 pp 127-136.
[5] IS 10262-1982,'RECOMEMENEDE GUIDELINES FOR CONCRETE MIX DESIGN', March 1998.
[6] IS 383-1970 SPECIFICATION FOR COASE AND FINE AGGREGATE FROM NATURAL SOURCES FOR CONCRETE