Experimental Study on Strength and Durability of High Strength Recycled Aggregate Concrete

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ABSTRACT

The use of recycled aggregates in concrete is a whole range of possibilities in the reuse of materials in the construction industry. The utilization of recycled aggregates is a good solution to the problem of excess of waste material. The object of this project is to determine the impact value, crushing strength, and specific gravity of RAC. The laboratory trails were conducted to determine the possibility of 100 percent of recycled aggregate. The volume of construction waste material has been increasing yearly. Many researchers state that recycled aggregate concrete (RAC) are only suitable for non-structural concrete. The crucial issue required in using devasted concrete as aggregate is related to finishing awesome workability. Recycled aggregates generally have densities slightly less than the original materials used. And also recycled aggregates is the higher water absorption due to presence of old cement mortar adhered to the RA particles.RCA tests were made in the single size diversion (20-5mm) using business plant for the era of beat rock all out including vital jaw and assistant cone crushers and screens. That RCA had 3 to 10%lowert thickness and 3 to 5 times higher ingestion. RA was done at 0,20,30,50 and 100%. Compressive quality at 28 days for 30% substitution by RA has no huge variety with that of NA yet past that there is a continuous lessening in quality.

Keywords: Aggregate, concrete, Recycled Aggregates, Workability.

1. INTRODUCTION

Cement is a standout amongst the most generally utilized development material bringing on an appeal for it. As a consequence of this, there is an expansion in the interest for its constituents like the coarse totals, sand, concrete and water. This increment sought after is creating broad quarrying of normal totals as it is required as coarse totals in solid generation furthermore it frames the significant constituent by mass in cement. Keeping in mind the end goal to possess property in development there has been store of substitution for various constituents of cement by optional building materials. as an option, counterfeit totals like manufacturing plant made sand chamber scoria, fly powder, stretched earth, broken blocks and steel might be utilized wherever fittingly. it's few advantages like low value, general accommodation of material, capacity, low vitality interest and usage underneath very surprising ecological conditions.
Reusing cement is the best decision to lessen the enthusiasm on incredible customary resources and to oblige the measure of waste that is masterminded in landfills. Reused concrete has been generally used as an unbound material as a piece of dams, bases, and sub-bases. RAC has in like manner been used as a part of the improvement of pavements and squanders yet in less cases as the investigation in this field is almost no the most extreme limit of RAC has not yet been explored. The usage of reused concrete in weight bearing structures has not expanded wide affirmation likely in perspective of the nonattendance of accessible information on the subject, for instance, expected fresh and cemented material properties. Concrete is by all record by all account not the only reused material that has been used as a part of past advancement applications. Reused dark top, fly searing remains, and slag have been used as a part of past exercises. Reused materials add to material practicality, diminish environmental impact of demolished materials, and end up being saving. The cost of an endeavor could reduce if concrete does not should be pulled and dumped, and rather be used to supplant a touch of virgin aggregate in the new strong structure. Henceforth this study is completed principally to investigate the conceivable outcomes of utilization of RAC in auxiliary development which prompts maintainable monetary development with the best use of crushed squanders produced.

2. REVIEW OF LIETARATURE

2.1 General

The vast majority of the waste materials created by crushing structures are arranged by dumping them as area fill or for recovering area. In any case, with the interest in area expanding step by step, the areas, limit and width of the area that can get waste materials are getting to be restricted. Including the expense of transportation, that makes the transfer a noteworthy issue. Thus, reuse of decimation waste gives off an impression of being a powerful arrangement and the most fitting and huge scale use would be to utilize it as totals to deliver concrete for new development.

2.2 Findings from the Literature Survey

- Many creators reason that for up to 30% substitution, no diminishment in compressive quality
- RCA have more prominent water assimilation, lesser thickness and particular gravity than NA
- The estimations of effect and scraped area qualities are more for RCA
- There is decrease in pressure quality, split rigidity and modulus of versatility of RAC with expanded % of substitution
- Workability decreases with expansion in trade for steady w/c proportion
- Recycled total cement is less solid than normal total cement and imperviousness to corrosive, sulfate and chloride assault lessens with expansion in rate substitution of characteristic totals by reused totals.
- Study of microstructure of reused total demonstrates that the RAC has more porosity and less security improvement creating lower quality advancement in RAC when contrasted with NAC.
- Type and wellspring of guardian total impacts its quality properties
- Age at annihilation and beginning quality of guardian cement additionally impact the RCA quality and properties.
- Various rules and gauges have been built up by different nations for RCA
- They successfully help in picking the right quality RCA for developments

3. MATERIALS

The relevant codes of practice have been mentioned for all tests in the reference and all the tests have been performed as per the relevant codal procedure and guidelines.

3.1 TESTS ON COARSE AGGREGATES

The decimated waste cement required for the present study was acquired from the building annihilation exercises which were experiencing close to our area. The devastated cement was smashed physically to acquire the totals with joined mortar in them. These totals were washed altogether to expel the stuck mortar to most extreme conceivable degree. At that point these reused totals were dried and utilized as coarse totals as a part of new concrete

1 SIEVE ANALYSIS

Strainer examination is utilized to discover the measure of various sizes of totals utilized as a part of a solid blend. In this anticipate, sifter examination was completed on coarse total and fine total. The sifter sizes were from 20mm to 2.36mm. From the strainer examination the molecule size circulation in an example of total is found. Fineness modulus can be found. The bigger the estimation of fineness modulus, the coarser is the material.

2 CRUSHING TEST

Test on natural aggregate:
Empty weight of measuring jar: 1.95kg
Weight of sample + jar: 4.722kg
Weight of sample (W_1): 2.772kg
Weight of portion of sample passing 2.36mm sieve (W_2): 0.764kg
Aggregate crushing value: =27.56%

Test on recycled aggregate:
Empty weight of measuring jar: 1.95kg
Weight of sample + jar: 4.752kg
Weight of sample (W_1): 2.558kg
Weight of portion of sample passing 2.36mm sieve (W_2): 0.715kg
Aggregate crushing value: =28.1%

3 IMPACT TEST

Test on natural aggregate:
Empty weight of measuring jar: 0.922 kg
Weight of sample + jar: 1.262kg
Weight of sample (W_1): 0.34kg
Weight of portion of sample passing 2.36mm sieve (W_2): 0.072kg
Aggregate crushing value: =21.176%

Test on recycled aggregate:
Empty weight of measuring jar: 0.914kg
Weight of sample + jar: 1.202kg
Weight of sample (W_1): 0.288kg
Weight of portion of sample passing 2.36mm sieve (W_2): 0.086kg
Aggregate crushing value: =29.86%

4 BULK DENSITY

Test on natural aggregates:
Weight of cylinder: W_1: 1.332kg
Weight of cylinder + water: 4.420kg
Weight of water: 3.088kg
Volume of container: 3.088kg

For compact state:
Weight of cylinder + aggregates in compact state: 6.134kg
Weight of aggregates W_c: 4.802kg
Bulk density: W_c/V= 1.555kg/l

For loose state:
Weight of cylinder + aggregates in loose state: 5.668kg
Weight of aggregates W_c: 4.336kg
Bulk density: W_c/V= 1.404kg/l

Test on recycled aggregates:
Weight of cylinder: W_1: 2.824kg
Weight of cylinder + water: 5.83kg
Weight of water: 3.006kg
Volume of container: 3.006l

For compact state:
Weight of cylinder + aggregates in compact state: 7.162kg
Weight of aggregates W_c: 4.338kg
Bulk density: W_c/V= 1.44kg/l

For loose state:
Weight of cylinder + aggregates in loose state: 6.786kg
Weight of aggregates W_c: 3.962kg
Bulk density: W_c/V= 1.31kg/l

5 WATER ABSORPTION AND SPECIFIC GRAVITY

Test on natural aggregate:
Weight of saturated aggregate suspended in water with the wire basket: W_1: 2.168kg
Weight of basket suspended in water: W_2: 0.968kg
Weight of saturated aggregate in water: Ws: 1.2kg
Weight of saturated surface dry aggregate in air: W_3: 1.934kg
Weight of water equal to volume of the aggregate: W_3-W_s: 0.734kg
Weight of oven dried aggregate: W_4: 1.928kg

- Specific gravity: dry weight of aggregate/ weight of equal volume of water :W_4/ (W_3-Ws):2.627
- Apparent specific gravity: dry weight of aggregate/ weight of equal volume of water :W_4/ (W_4-W_s): 2.648
- Water absorption: % by weight of water absorbed in oven dried weight of aggregate: [(W_3-W_4)/ W4]×100: 0.311%

Test on recycled aggregate:
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Table 1: **Test on fine aggregates**

PROPERTIES	NA	RA
FINENESS MODULUS	6.25	5.45
SPECIFIC GRAVITY	2.657	2.469
BULK DENSITY	COMPACT STATE-1.55kg/l LOOSE STATE-1.404kg/l	COMPACT STATE- 1.44kg/l LOOSE STATE- 1.31 kg/l
CRUSHING VALUE	27.56%	28.1%
IMPACT VALUE	21.176%	29.66%
WATER ABSORPTION	0.311%	2.24%

3.2 TESTS ON FINE AGGREGATES

Table 2: **Test on fine aggregates**

PROPERTY	RESULTS
FINENESS MODULUS	2.35
SPECIFIC GRAVITY	2.492
BULK DENSITY, % voids	Compact state- 32.2% Loose state- 36.482%
MOISTURE CONTENT	0.604%

3.3 TESTS ON CEMENT:

Table 3: **Tests on cement**

PROPERTY	RESULT
FINENESS	0.04
SPECIFIC GRAVITY	3.279
STANDARD CONSISTANCY	30.5%
SETTING TIME	INITIAL- 80min FINAL-6hr 30 min

3.4 MATERIALS USED IN MIX DESIGN

The commonly used materials for concrete production are cement, sand and coarse aggregate. In this work it is tried to partially replace cement by fly ash and part of coarse aggregate by recycled concrete aggregate.

Cement: The grade of cement used in this work is ordinary Portland cement, 43 grade manufactured as per IS 8112.

Fine aggregate: Locally available sand free from silt, organic matter and passing through 4.75mm sieve confirming to zone 2 as per IS 383 is used as fine aggregate. The specific gravity of sand used is 2.492.

Coarse aggregate: Natural aggregate: the natural coarse aggregate of maximum size 12.5mm passing and retained on 4.75mm sieve is used and the specific gravity used is 2.657.

Recycled aggregate: the recycled aggregate size of maximum size 12.5mm passing and retained on 4.75mm sieve is used and the specific gravity is 2.469..

Silica fume: Silica fume for 10% replacement of cement with specific gravity 2.22

3.4.1 PERUMAL'S METHOD OF MIX DESIGN FOR HIGH STRENGTH CONCRETE:

Target mean strength: Target mean strength $\overline{f_{ck}}$ is calculated as follows:

$\overline{f_{ck}}$ = f_{ck} + (t x s) with usual IS notations. When adequate data are not available to establish, the f_{ck} value can be determined from the following table 3.8 given by ACI report 318.

Selection of maximum size of coarse aggregate: The maximum size of the coarse aggregate is selected from the following table 4 as given by ACI Report 211.4R.93.

Table 4: **Maximum size of coarse aggregate**

Characteristic Compressive Strength, f_{ck} (MPa)	Maximum aggregate size (mm)
Less than 62	20 – 25
Greater than or equal to 62	10 - 12.5

Estimation of free water content: The water content to obtain the desired workability depends upon the amount of water and amount of super plasticizer and its characteristics. However, the saturation point of the super plasticizer is known, and then the water dosage is obtained from the following table 3.10. If the saturation point is not known, it is suggested that a water content of 150 liters/m3 shall be taken to start with.

Table 5 : **Determination of minimum water dosage**

Saturation Point (%)	0.6	0.8	1.0	1.2	1.4
Water (l/m^3)	120-125	125-135	135-145	145-155	155-165

Super plasticizer dosage: The super plasticizer dosage is obtained from the dosage at the saturation point. If the saturation point is not known, it is suggested that a trial dosage of 1.0% shall be taken to start with.

Estimation of air content: The air content (approximate amount of entrapped air) to be expected in HPC is obtained from the following table 3.11 as given ACI Report 311.4R.93 for the maximum size of CA used. However, it is suggested that an initial estimate of entrapped air content shall be taken as 1.5% or less since it is HPC, and then adjusting it on the basis of the result obtained with the trial mix.

Selection of coarse aggregate (CA) content: The coarse aggregate content is obtained from the following table 3.12 as a function of the typical particle shape. If there is any doubt about the shape of the CA or if its shape is not known, it is suggested that a CA content 1050 kg/m3 of concrete shall be taken to start with. The CA so selected should satisfy the requirements of grading and other requirements of IS: 383 – 1970.

Selection of water-binder (w/b) ratio: The water-binder ratio for the target mean compressive strength is chosen from figure 3.7, the proposed w/b ratio Vs. compressive strength relationship. The w/b ratio so chosen is checked against the limiting w/c ratio for the requirements of durability as per table 3.5 of IS: 456-2000, and the lower of the two values is adopted.

Estimation of fine aggregate (FA) content

The absolute volume of FA is obtained from the following equation:

$$V_{fa} = 1000 - [V_w + (M_c/ S_c) + (M_{sf}/ S_{sf}) + (M_{ca}/ S_{ca}) + V_{sol} + V_{ea}]$$

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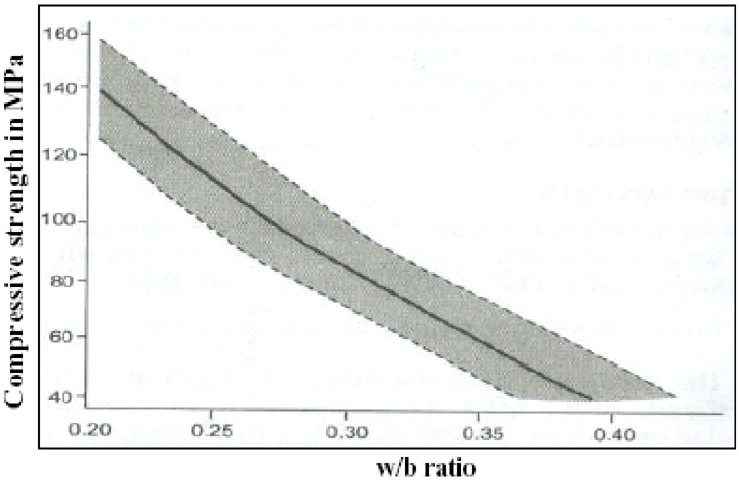

Figure 1: W/b ratio v/s compressive strength relationship

Estimation of fine aggregate (FA) content

The absolute volume of FA is obtained from the following equation:

$V_{fa} = 1000 - [V_w + (M_c / S_c) + (M_{sf} / S_{sf}) + (M_{ca} / S_{ca}) + V_{sol} + V_{ea}]$

3.4.3 FOR NATURAL AGGREGATE CONRETE: M60

Perumal's method:

- Size of CA = 12.5 mm
- Water content = 160 kg/m^3
- SP dosage, d =3%
- Entrapped air content, V_{EA} = 2 %
- CA content = 1000 kg/m^3
- Water binder ratio = 0.4
- Calculation of binder content, b would then be done as follows: 400kg/m^3
- Considering 10 % replacement of cement by silica fume,
- Cement content = 360kg/m^3
- Silica fume content = 40kg/m^3
- Total solid content of SP was 33% (S) and its specific gravity was 1.1 (S_S) and computation of super plasticizer is (3%)-9.392kg/m^3
- Considering the specific gravity of CA as 2.657, FA as 2.492, silica fume as 2.22 and cement as 3.279, fine aggregate content is calculated as
- FA content = 726.244kg/m^3

Summary of the designed mix is shown below:

- CA = 1000 kg/m^3
- Silica fume = 40kg/m^3
- FA = 726.244 kg/m^3
- Water = 160 kg/m^3
- Cement 360kg/m^3
- SP (3%) = 9.392kg/m^3

3.4.2 DESIGN MIX PROPORTIONS:

Thus, the mix proportions for different percentage replacement by RCA are calculated by using Perumal's method whose calculations are given in the appendix and the values are given in the below table

Table 5: **Mix proportions for M60 concrete grade**

Mix no	RCA%	w/c	cement (kg/m3)	Fine aggregate (kg/m^3)	Silica fume (kg/m^3)	NCA (kg/m^3)	RCA (kg/m^3)	Water (kg/m^3)	S.P in %
1	0	0.4	360	762.244	40	1000	0	160	3
2	10	0.4	360	758.236	40	900	100	160	3

3	20	0.4	360	751.095	40	800	200	160	3
4	30	0.4	360	743.953	40	700	300	160	3
5	40	0.4	360	736.812	40	600	400	160	3

4. STRENGTH TESTS ON CONCRETE

4.1 COMPRESSION TEST:

4.1.1 Compression Strength Tests on Concrete:
The compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications concrete is employed to resist the compressive strength or to carry loads where compressive strength is important. It is also used as qualitative measure for other mechanical properties like flexural strength, modulus of elasticity and split tensile strength of hardened concrete.

4.1.2 Preparation of Test Specimen:
The ingredients of concrete were mixed using the mixer. Cast iron moulds of 150mm X 150mm X 150mm were used the cube specimens. Once the concrete was poured in moulds, they were compacted thoroughly by placing on table vibrator. Demoulding was done 24 hours after casting and then the specimens were kept for curing in the curing tank.

4.1.3 Test Procedure:
At the time of testing the cured cubes are surface dried. It is then placed centrally over the lower plate of the universal testing machine (UTM). The top plate is lowered till it touches the top surface of the cube. The cube is compressed by operating the UTM at a constant rate of 14N/mm^2 and the dial gauge reading is noted when the cube yields. The compressive strength is computed using the following expression.

Compressive strength: (ultimate load / contact area of cube)Contact area of cube: 150mm X 150mm

Figure 2: Test setup for compression

4.2 SPLIT TENSILE TEST ON CONCRETE
Normally concrete is very strong in compression but weak in tension. Indirect tensile test is used to indicate the brittle nature of the concrete specimens that contained natural aggregates and different percentages of recycled aggregate replacement.

4.2.1 Preparation of Test Specimen:
The ingredients of concrete were mixed using the mixer. Cast iron cylindricalmoulds of 100 mm diameter and 200 mm length were used as the cylinder specimens. Once the concrete was poured in moulds, they were compacted thoroughly by placing on table vibrator. De-moulding was done 24 hours after casting and then the specimens were kept for curing in the curing tank.

4.2.2 Test Procedure:
At the time of testing the cured cylindrical specimens are surface dried. It is then placed along its length over the lower plate of the universal testing machine (UTM). The top plate is lowered till it touches the top surface of the specimen. The specimen is subjected to load by operating the UTM at a constant rate of 14N/mm^2 and the dial gauge reading is noted when the specimen yields. The split tensile strength is computed using the following expression.

Split tensile strength: (ultimate load / contact area of cube)
Contact area of cube: 200mm X 100mm.

4.3 FLEXURE TEST:

4.3.1 Flexure Test on Concrete:

Flexure in general is nothing but bending. In reinforced concrete members, little dependence is on the tensile strength of concrete since steel bars are provided to resist all the tensile force. However, tensile stresses are likely to develop in concrete due to shrinkage, temperature variation and many other reasons.

4.3.2. Test Procedure:

At the time of testing the cured cylindrical specimens are surface dried. It is then placed along its length over the lower plate of the universal testing machine (UTM) for flexure. The top plate is lowered till it touches the top surface of the specimen. The specimen is subjected to a 2 point load by the specimen yields. From the number of divisions obtained from the dial gauge reading, we see the chart provided by the manufacturer to get the force applied in kgf. –'P'

Flexure strength: $(P \times l/bd^2)$

4.4 DURABLE PROPERTIES

SORPITIVITY

*The sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material.
*Water was used of the test fluid. The cylinders after casting were immersed in water for 28,56, and 90 days curing.
* The specimen size 100mm dia x 50 mm height after drying in oven at temperature of 100 + 10 °C were drowned with water level not more than 5 mm above.
*The specimen should be oven dried for 3 days and weight is measured.
*After 3days of oven dried specimen should be placed in a one side opened cover for `15 days

Fig 3 Specimen placed in cover

* After `15days the base of specimen and the flow from the peripheral surface is prevented by sealing it properly with non-absorbent coating. (layer will be on three sides only bottom should be opened)

Fig 4. Specimen with sealant

*The quantity of water absorbed in time period of 30 minutes was measured by weighting the specimen on a top pan balance weighting upto 0.1 mg.
*surface water on the specimen was wiped off with a dampened tissue and each weighting operation was completed within 30 seconds.
*Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity.
*The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t)

Fig 5: Specimen placed in water

Fig 6: Weighing of specimen

The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t) $I=S.t^{½}$

4.5. Water absorption test

*The 100mm dia x 50 mm height cylinder after casting were immersed in water for 90 days curing.
*These specimens were then oven dried for 24 hours at the temperature110°C until the mass became constant and again weighed.
*This weightwas noted as the dry weight (W1) of the cylinder.After that the specimen was kept in hot water at 85°c for 3.5 hours.
*Then this weight was noted as the wet weight (W2) of the cylinder.
% water absorption = [(W2– W1) / W1] x 100

4.6. Rapid Chloride Permeability Test

Rapid chloride permeability test According to ASTM C1202 test, water-saturated, 50 mm thick, 100 mm thick diameter concrete specimen is subjected to applied DC voltage of 60 V for 6 hours.In one container 3.0% NaC1 solution and in the other container 0.3 M NaOH solution.

Fig 7: **Compression test results of concrete**

TEST RESULTS AND DISCUSSION

The durability of fiber reinforced concrete that is resistance to chloride penetration is studied. Rapid chloride ion penetrability tests were for copper slag specimens, an electrical current recorded at 1 minute intervals over the 6 hour time, resulting in the total charge passed in coulombs is shown in Table and Table shows chloride permeability as per ASTM C 1202. The testing of specimen were done at 7 days, 14days, 28days and 56 days.. RCPT values for mix proportion.

5. RESULTS AND DISCUSSION

5.1 COMPRESSION TEST RESULTS:

Table 6 : Compression test results of concrete

% replacement	3 daysN/mm^2	7 daysN/mm^2	14daysN/mm^2	28 daysN/mm^2
0%	40.52	49.99	51.88	69.3
10%	40.08	49.95	50.32	68.9
20%	40.45	49.93	52.32	68.3
30%	38.23	48.35	50.0	67.02
40%	36.78	47.10	47.22	59.21

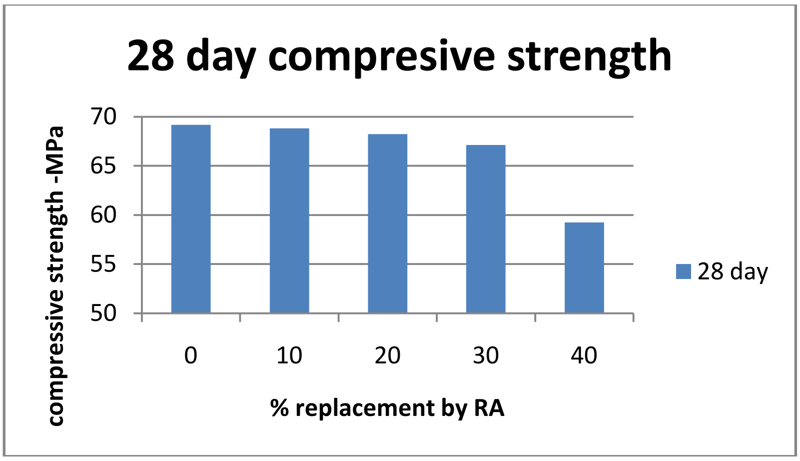

Fig 8: 28 days Compressive strength of concrete

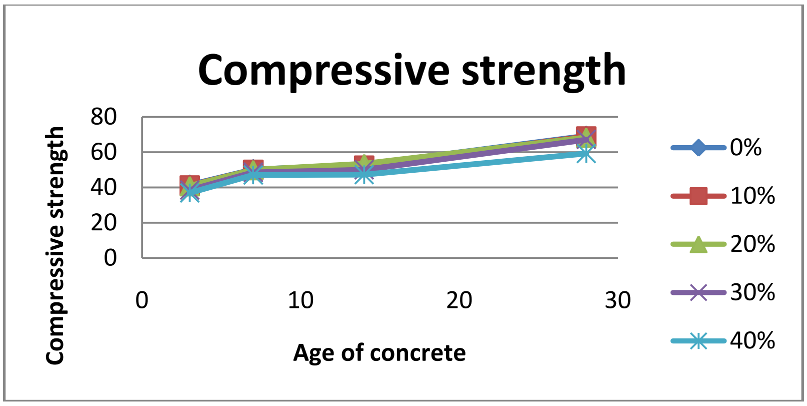

Fig 9: Compression test results of concrete

The above figure 6.8 gives a comparison of compressive strength developed with age for different replacement ratios of recycled aggregate concrete. It can be concluded from the graph that for both natural aggregate concrete and recycled aggregate concrete the compressive strength progressively increases with age of concrete as seen in the graph.

Also it can be seen that the strength development in recycled aggregate concrete is less than that of natural aggregate concrete at all age and the reduction in strength increases with increase in the replacement of natural aggregate by recycled aggregate.

From the graphs and test results it can also be concluded that though with increase in replacement of natural aggregates there is a decrease in the strength development, replacement up to 30% by recycled aggregates is found to be usable as it crosses the target strength of 67MPa at 28 days.

5.2 FLEXURE TEST RESULTS:

Table 6 : Flexural test results of concrete

Sl no	% replacement	No of divisions	Flexure strength (N/mm^2)
1	0	348	4.83
2	10	336	4.69
3	20	330	4.59
4	30	280	3.90
5	40	252	3.49

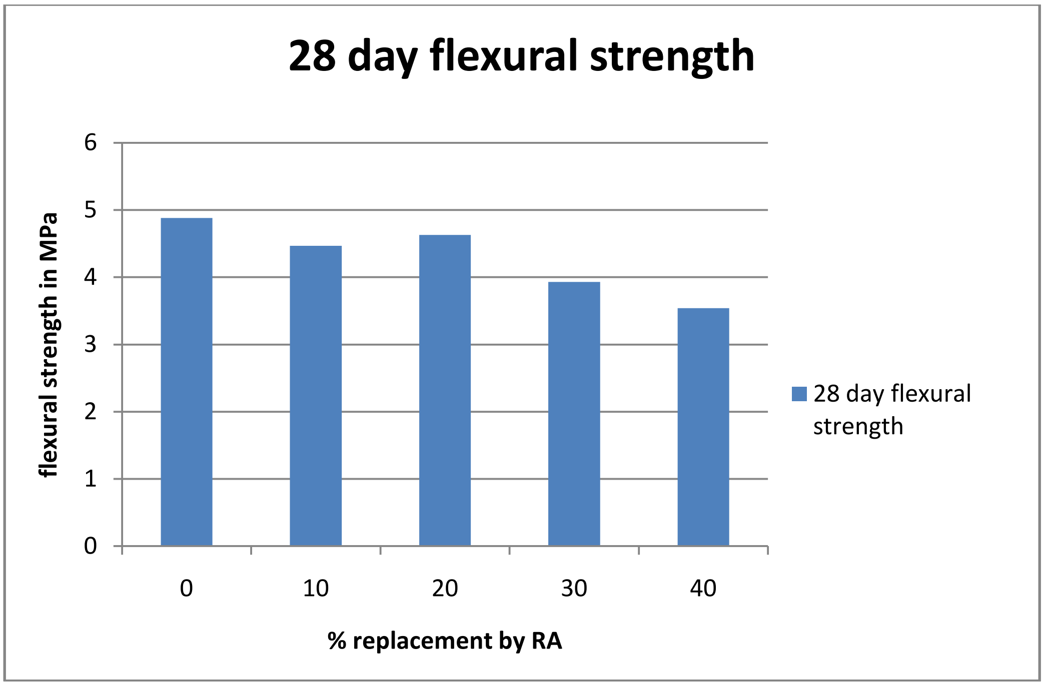

Figure 10: 28 day flexure strength of concrete

Flexure strength results from the above figure 6.13 shows similar trend as that of compressive strength and split tensile strength. With increase in replacement of recycled aggregates the strength gained reduces. Maximum strength developed is for natural aggregate concrete with strength of 4.88N/mm^2. The maximum flexural strength developed in recycled aggregate concrete is again for a replacement of 10% being 4.47N/mm^2 and the strength reduction being 8.40% and the least strength developed is with 40% replacement being 3.54N/mm^2 and the strength reduction is 27.46%.

5.3. RAPID CHLORIDE PERMEABLITY TEST

Table shows that results of this experiment In this experiment the chloride passes through the concrete sample which taken at the curing periods 28 days , this passing chloride shows that the permeability of the concrete ,the charge passed through coloumbs values are taken from the equipment display, and this values are compared with the standard values which are mentioned by ASTM C1202 .

As observed the highest charge passed through the sample which is replacement with copper slag 50% (3645) ,and the lowest value passed through the sample which is replaced by the copper slag with 30%(2011).finally all values are shown that moderate values when compared with the table according to ASTM C1202.

Table 7: RCPT VALUES OF CONCRETE

Specimen Designation	Charge Passed Through InColoumbs (C)	Chloride Permeability Results As Per ASTM C 1202
CS10%s	2908	MODERATE
CS20%	2212	MODERATE
CS30%	2011	MODERATE
CS40%	2564	MODERATE
CS50%	3645	MODERATE
CS60%	3541	MODERATE
CS70%	2254	MODERATE
CS80%	3362	MODERATE
CS90%	3331	MODERATE
CS100%	2145	MODERATE

5.4. SORPTIVITY

Table shows that the results of the sorptivity experiment, as the results the values of sorptivity it is reported that the values of sorptivity of the concrete is highest at the replacement of the copper slag 90% and the water absorption rate is also observed as the more , and lowest value reported at the replacement of copper slag 30%.

Table 8: **Compression test results of concrete**

Specimen Designation	Sorptivity Value (x 10^{-6}) mm/ $min^{0.5}$	Absorption Rate I = S.t ½ mm
CS 0%	4.50	101.62
CS10%s	4.60	100.14
CS20%	5.36	111.23
CS30%	4.55	104.2
CS40%	6.28	125.6
CS50%	6.94	134.01
CS60%	8.23	141.03
CS70%	7.12	139.2
CS80%	8.66	154.17
CS90%	9.23	174.23
CS100%	7.48	152.9

The values of sorptivity and water absorption is same as normal conventional concrete at the replacement levels of copper slag are CS 10% and CS 30%.

CONCLUSIONS

From the compressive strength results of the concrete, it can be concluded that both the natural and recycled aggregate concrete gain strength with age.

- But at any instant the strength of recycled aggregate concrete is lower than the strength of natural aggregate concrete.
- The greater the replacement ratio, the lesser is the strength developed in the concrete.
- The compressive strength of 40% recycled aggregate concrete is 14.36% lower than that of natural aggregate concrete while that of 10% recycled aggregate concrete is just 0.55% lower than that of natural aggregate concrete
- From the compression test results it can be concluded that up to 30% replacement of natural aggregates with recycled aggregates there is no considerable reduction in strength of concrete and hence can be considered as optimum replacement without compromise on strength.
- The same above conclusions follow for split tensile strength and flexural strength of concrete.
- The split tensile strength of 40% RAC is 26.46% lower than that of NAC while the split tensile strength of 10% RAC is 6.75% lower than that of NAC.
- The flexural strength of 40% RAC is 27.45% lower than that of NAC while that of 10% RAC is 3.48% lower than that of NAC.
- Hence from the strength results, 30% replacement is considered as optimum and two sets of cubes- one of NAC and other of 30% replacement RAC were casted for durability tests for a period of 28 days.
- In case of water absorption, the RAC exhibit higher water absorption values as compared to NAC. This is due to the presence of attached mortar present in the aggregates. The greater is the attached mortar, the more is the water absorption in the concrete.

From the above observations it can be concluded that although the values of strength results of RAC is lower than the NAC, they are still within the useable range and by limiting thereplacement ratio, the desirable strength can be easily obtained using recycled aggregate concrete also

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