An Experimental Investigation on Flexural Behavior of Recycle Aggregate Fiber Reinforcement Concrete

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Abstract - The present investigation is intended to emphasis the behavior of recycled aggregate fiber reinforced concrete (RAFRC). Different percentages of partial replacements have been considered for M20 grade of concrete. The possibility of using the recycled aggregate in structural grade concrete has been assessed by measuring the ultimate strength and studying the structural behavior of recycled aggregate fiber reinforced concrete cubes and beams.

To meet the above objectives M20 grade concrete with 0, 25, 50, 75 and 100% recycled aggregate have been considered. A Cube of size 150 X 150 X 150 mm & beams of size 150 x 150 x 600 mm have been casted for testing for the above experimental work. The Compressive strength & Tensile strength have been obtained for various replacements. The test results of cube specimens have been compared with partial replacement of recycled aggregate made with conventional aggregate.

The test results of the present investigation have been found to be quite encouraging. The results show that variation of strength of cubes and cylinders obtained by replacement of natural coarse aggregate with recycled coarse aggregate with addition of steel fibers are satisfactory. It has been observed form the experimental work that compressive strength results are improved with increase in percentage of steel fiber with replace of recycled coarse aggregate. The mix proportions of steel fiber & recycled aggregate concrete have been calculated based on proposed recycled aggregate concrete "Mix Design M20" and mixes exhibited satisfactory workability.

The load – deflection relationship of recycled aggregate fiber reinforced concrete beams appears to have not been influenced by the presence of recycled coarse aggregate. In concrete, the recycled coarse aggregate holds good in terms of load carrying capacity. Thus, the strength behavior and performance of concrete cubes and beams made with recycled aggregate fiber reinforced concrete can be considered as on par with the natural aggregate concrete.

Key Words: Flexural Behavior, Recycle aggregates, and Fiber reinforced concrete etc...

1. Introduction of Recycle aggregates

Recycling is the act of processing the used material for use in creating new product. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. Recycled aggregate are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. These materials are generally from buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes.

1.1 HISTORICAL BACKGROUND

The applications of recycled aggregate in the construction areas are wide and they had been used long time ago.Wilmot and Vorobieff (1997) stated that recycled aggregate have been used in the road industry for the last 100 years in Australia. They also stated that the use of recycled aggregate for the construction and rehabilitation of local government roads has a great improve in the last five years. C & D Recycling Industry (n.d.), the fact file stated that from the time of the Romans, the stones from the previous roads were reused when rebuilding their vaunted set of roads. It also stated that since the end of world war two, the recycling industry had been well established in Europe.

1.1.1APPLICATIONS OF RECYCLED AGGREGATE

Traditionally, the application of recycled aggregate is used as landfill. Nowadays, the applications of recycled aggregate in construction areas are wide. The applications are different from country to country.

1. Concrete kerb and gutter mix in Australia. According to Building Innovation & Construction Technology (1999)
2. Granular base course materials- According to Market Development Study for Recycled Aggregate Products (2001),.
3. Embankments fill materials-Market Development Study for Recycled Aggregate Products (2001).
4. Paving blocks- in Hong Kong. According to Hong Kong Housing Department (n.d.)
5. Backfill materials- Mehus and Lillestol (n.d) found that Norwegian Building Research Institute (n.d) mentioned that recycled concrete aggregate can be used as backfill materials in the pipe zone along trenches after having testing in laboratory.
6. Building blocks- Mehus and Lillestol (n.d) stated

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that Optiroc AS had used recycled aggregate to produce the masonry sound insulation blocks

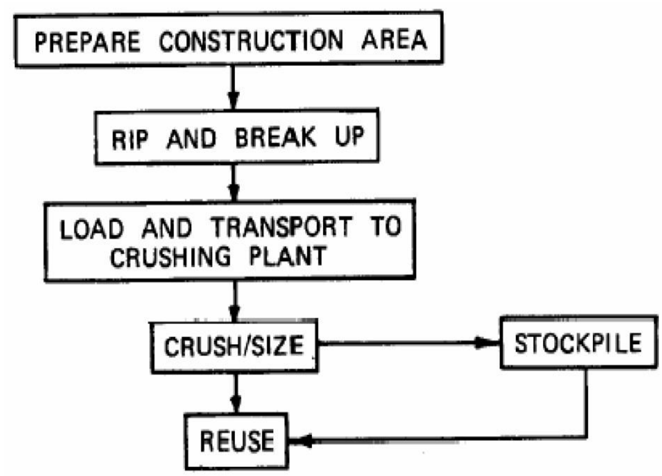
1.1.2Advantages:

1. Environmental gain
2. Save energy
3. Cost
4. Job opportunities
5. Sustainability
6. Market is wide

1.1.3Disadvantages:

1. Hard to have permit
2. Lack of specification and guidelines
3. Water pollution

2 .Recycling Portland cement Concrete Flow Chart



2.2. COMPARISON OF RECYCLED AGGREGATE AND NATURAL AGGREGATE:

2.1. Texture:

Recycled aggregate has the rough – textured, angular and elongated particles where natural aggregate is smooth and rounded compact aggregate.According to Portland Cement Association (n.d.), the properties of the freshly mixed concrete will be affected by the particle shape and surface texture of the aggregate. The rough – texture, angular and elongated particles require much water than the smooth and rounded compact aggregate when producing the workable concrete. The void content will increase with the angular aggregate where the larger sizes of well and improved grading aggregate will decrease the void content.

Natural Aggregate Recycled Aggregate

Figure: Comparison between Natural Aggregate and Recycled Aggregate

MATERIALS:

3.1.1 Cement:

Locally available Ordinary Portland Cement of 53grade has been used and properties are physical presented .in Table.

TABLE: PROPERTIES OF CEMENT

Sl.No	Property	Value
1	Fineness of cement	9.40%
2	Specific gravity of cement	3.12
3	Normal consistency	31.25%
4	Setting time 1)initial Setting time 2)final Setting time	 30 min 145 n

3.1.2. PROPERTIES OF RECYCLED COARSE AGGREGATE AND NATURAL COARSE AGGREGATE:

Sl.No.	Property	Natural Coarse Aggregate	Recycled Coarse Aggregate
1	Specific gravity	2.67	2.6
2	Water absorption	0.98%	3%
3	Crushing value	22.20%	26.50%

4	Impact value	13.10%	19.16%
5	Flakiness index	15.60%	6.65%
6	Elongation index	23.20%	16.75%
7	Bulk density (a)loose (b)compacted	 14.98 KN/m3 16.86 KN/m3	 13.46 KN/m3 15.98 KN/m3

3.1.3. SIEVE ANALYSIS OF NATURAL FINE AGGREGATE

Sl.No.	I.S.Sieve size	Wt. retained (g)	Cumulative wt. retained	Cumulative % wt. retained	Cumulative % passed
1	4.75mm	0	0	0	100
2	2.36mm	570	570	57	43
3	1.18mm	240	810	81	19
4	600µ	100	910	91	9
5	300 µ	50	960	96	4
6	150 µ	10	970	97	3
7	70 µ	10	980	98	2
			Total	520	
Fineness Modulus=520/100=5.20					

3.1.4. PROPERTIES OF NATURAL FINE AGGREGATE

Sl.No.	Property	Natural fine aggregate
1	Specific gravity	2.6
2	Fineness modulus	5.2
3	Bulk density (a)loose (b)compacted	 15.95KN/m3 18.5KN/m3
4	Grading	Zone-II

Water:

Potable water which is available at the college laboratory was used for mixing and curing.

3.1.5. FIBERS:

One of the specific objective of this work is to produce steel FIBER with locally available FIBER for increased Indian applications. Keeping this in view, the locally available low tensile strength steel wire (binding wire) has been used as FIBER in the present investigation. This is generally used for binding reinforcement in RCC works. The average diameter of the FIBER is 1.0 mm. The ultimate tensile strength of the FIBER is found to be 390 N/mm^2. The length may vary from 30mm to 60mm. The aspect ratio used is 50. The fibers are cut into required lengths using shear cutters.

Figure: Materials used for recycled aggregate fiber reinforced concrete

3.1.6 Super Plasticizer:

Super plasticizer by trade name Conplast SP-430 manufactured at Bangalore was used as water reducing agent to achieve the required workability. It is available in brown liquid instantly dispensable in water.

4.DISCUSSION OF TEST RESULTS AND ANALYSIS

4.1. Properties of recycled aggregate:

The physical and mechanical properties of recycled coarse aggregate and natural coarse aggregate are listed below.

4.1.1. Specific Gravity:

Specific gravity of recycled aggregate is found to be 2.6, which is slightly less when compared to natural aggregate (2.67). This is because of the highly porous nature of attached old mortar to recycled aggregate.

4.1.2. Water Absorption:

The water absorption of recycled aggregate is 3% and it is relatively higher than that of natural aggregate (0.98%). This is due to the porous nature of old mortar that is adhered to the recycled aggregate.

4.1.3.Resistance to Crushing and Impact Value:

Mechanical properties such as crushing value and the impact value of recycled aggregate are 26.5% and 19.16%, which are found to be higher when compared to natural aggregate(22.2% and 13.1%). This may be due to the weaker cement paste adhered to recycled coarse aggregate and also due to poor mortar aggregate bond in the recycled aggregate. Thus, recycled aggregate is found to be relatively weak against mechanical actions.

5. WORKABILITY TESTS

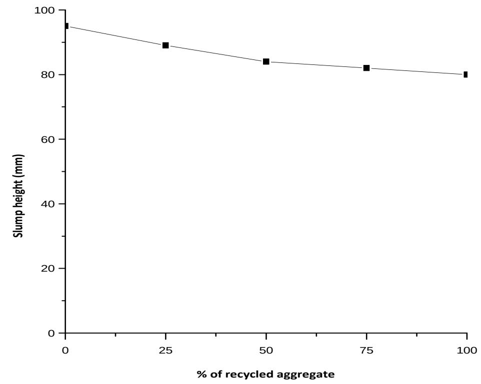
Slump test: The slump test results are presented in RCA mixes. The slump values for RAC mix indicating that, there is a decreasing trend of workability when the percentage of recycled aggregate is increased. According to the result, for RCA mixes the highest slump obtained was 89mm and the lowest slump was 80mm and when compared with NAC (95mm) mix the RCA mixes show lower value.

5.1. Compaction factor test:

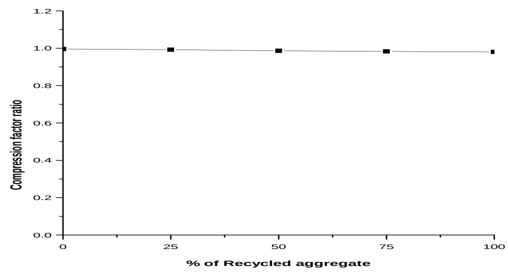
The Compaction Factor (CF) test results are presented in Table.6.1 and Figure 5.3 for RAC mix. The CF values for RAC mix indicating that, there is a decreasing trend of workability when the percentage of recycled aggregate is increased. According to the result, for RAC mixes the highest and lowest CF values are 0.994and 0.980 respectively and when compared with NAC (0.99) mix the RAC mixes show lower value. When percentage of recycle aggregate increases the workability (slump and compaction factor) show lower values this is because of, the water absorption is more for recycled aggregate when compared with the natural aggregate. The water absorption capacities for recycled and natural aggregates were already discussed.

Sl. No.	% Replacement	Nomen clature	coarse aggregate	
			Slump (mm)	Compaction Factor
1	0	NAC	95	0.99
2	25	RAC25	89	0.99
3	50	RAC50	84	0.98
4	75	RAC75	82	0.98
5	100	RAC100	80	0.98

Slump and Compaction factor values of RAC mix



Variation of slump height for RAC mixes



Variation of Compaction Factor Ratio for with RAC mixes

5.2. COMPRESSIVE TEST:

The results of compressive test with different percentage of recycled aggregate with percentage increase of steel fiber with low tensile are shown in table 6.2 to 6.5 and figures which includes the average values of three cubes for each mix and the variations obtained for each RAC mix with NAC mix respectively.

From tables 6.2 to 6.5, it is observed that in RAC mixes as the percentage of recycle aggregate increases the strength decreases. With the replacement of recycle aggregate in the range 25 to 100% with steel FIBER from 0% to 2%, the 7days compressive strength is about 32.8 to 18.9 N/mm^2. When compared with the reference mix of NAC (33.2 N/mm^2) the compressive strength of RAC decreases. The maximum percentage for 7 days compressive strength is 32.85% is obtained for 25 % replacement of recycle aggregate with 2% steel FIBER. The 28 days cube compressive strength is about 41.46 to 29.3 N/mm^2 with the replacement of recycle aggregate in the range 25 to 100% with steel FIBER from 0% to 2%. The maximum strength (41.46 N/mm^2) is obtained for 25% replacement of recycle aggregate with addition of 2% of steel FIBER. When compared with reference mix NAC 42.43 N/mm^2. the RAC mixes show lesser values. The decrease of 28 compressive strength when compared with

NAC is about 2.3 to 12.09 %. The maximum percentage decrement

in 28 cube compressive strength (12.09 %) is observed for 100% replacement.

6. MIX DESIGN

MIX DESIGN PROCEDURE for Grade of Concrete M20

Characteristic Compressive Strength	= 20 MPa
Maximum Size of aggregate (Angular)	= 20 mm
Degree of workability Compaction Factor	= 0.90
Degree of workability	= Good
Type Exposure	= Mild

1. The target mean strength is determined using following relation

$$F_t = F_{ck} + (t * S)$$

Where,
F_t = Target Mean Strength @ 28 days
F_{ck} = Characteristic Compressive Strength @ 28 days
t = A Statistical value depending upon the results and no. of tests.
S = Standard deviation shown from IS: 10262-1982

Assuming not more than 5% results are expected to fall below the Characteristic Compressive Strength. In which case the of't' is 1.65. Standard deviation for M20 grade of concrete is 4.

$$F_t = 20 + (1.65*4)$$
$$= 26.6 \text{ MPa}$$

2. From Fig. 2 of IS: 10262-1982[8] the water cement ratio required for the target mean strength of 26.6 MPa is 0.5.
3. From IS: 10262-1982[8] for the 20mm maximum size of aggregate the air content (entrapped air) is 2%.
4. From IS: 10262-1982[8] for concrete grade up to M_{20} and 20mm maximum size of aggregate and natural sand conforming to Zone – II, the water content and percentage of sand in total aggregate by absolute volume are 186 and 35% respectively.

For change in value of Water Cement ratio and Compression Factor, the following adjustments are required according to IS: 10262-1982 in water content and percentage of sand in total aggregate.

Change in Condition	Adjustment Required in Water content	Percentage of sand in Total aggregate
For degree in compaction Of 0.90-0.8 =0.1	+3%	0
For decrease in Water Cement Ratio is 0.5-0.6 = 0.	0	- 2%
Total	+3%	-2%

Therefore, required sand content as percentage of aggregate of total aggregate by absolute volume
= 35% - 2%
= 33 %

Required Water content = 186+186*3/100
= 191.58 Kg/m3

5. Water Cement Ratio = 0.5

Required Cement Content = 191.58 / 0.5
= 383.16 kg/m3

This cement content is adequate for mild exposure.

6. The quantities of fine and coarse aggregates are calculated from the following relation

V=[W+C/Sc+1/P*fa/Sfa]*1/1000 and

Ca= (1-P)*fa*Sca/(P*Sfa)

Where
V= absolute volume of fresh concrete, which is equal to gross volume (m3) minus the volume of entrapped air.
W= Mass of water (Kg)per m3 of concrete
C= Mass of cement (Kg)per m3 of concrete
Sc= Specific gravity of Cement
P = Ratio of FA to total aggregate by absolute volume
fa,Ca = Total masses of FA and CA (Kg) per m3 of concrete respectively and
Sfa,Sca = Specific gravities of saturated ,surface dry fine aggregate and coarse aggregate respectively.

0.98= {191.58+383.16/3.12+fa/0.33*2.6)*1/1000
fa = 571 Kg/m3

Ca= (1-0.33)/0.33 * 571* 2.67 / 2.6
= 1191 Kg/m3

The total quantities of ingredients for M_{20}grade Concrete are as follows Water Cement ratio = 0.5
Cement content = 383 Kg/m3
Fine Aggregate = 571Kg/m3
Coarse Aggregate = 1191 Kg/m3
Water content = 191.58 Kg/m3

Mix Proportion is cement: fine aggregate: coarse aggregate
1 : 1.49 : 3.109

1. Replacement of Natural Coarse Aggregate with Recycled Coarse Aggregate by 25,50,75 and 100% and denoted as RAC25, RAC50, RAC75 and RAC100 respectively.
2. Normal concrete denoted by NAC made with ordinary concrete and used as a reference concrete.

Mix Designation	NAC	RCA 25	RCA 50	RCA 75	RCA 100
Cement (kg/m3)	383	383	383	383	383
Natural fine aggregate (kg/m3)	571	571	571	571	571
Natural coarse aggregate(kg/m3)	1191	893.25	535.95	297.75	0
Recycled coarse aggregate(kg/m3)	0	297.75	655.05	893.25	1191
Water in total (lit)	191.58	191.58	191.58	191.58	191.58
Super plasticizer (lit)	11.87	11.87	11.87	11.87	11.87
Water Cement ratio	0.5	0.5	0.5	0.5	0.5

7. FLEXURAL TEST:

The results of flexure test with different percentage of recycled aggregate with percentage increase of steel FIBER of low tensile strength are shown in table 6.7 & 6.8 which includes the average values of three beams for each mix and the variations obtained for each RAC mix with NAC mix respectively.

From tables 6.7 & 6.8, it is observed that in RAC mixes as the percentage of recycle aggregate increases the strength decreases and with addition of fibers strength increases. With the replacement of recycle aggregate in the range 25 to 100% with steel fiber from 0% to 2%, the flexural strength is about 4.51 to 3.92 N/mm². When compared with the reference mix of NAC (4.56 N/mm²) the flexural strength of RAC decreases. The maximum percentage for 28 days flexural strength is 4.5% is obtained for 25 % replacement of recycle aggregate with 2% steel FIBER.

The reason for reduction in strength is due to inferior properties of recycle aggregate. The strength on concrete is depends partially on bond area between cement mortar and aggregates. Recycled aggregate concrete has to sustain bond areas between natural aggregate-old mortar, natural aggregate-new aggregate, and old mortar-new mortar. Thus the number of weaker bond areas will be greater in concrete containing larger proportions of recycled aggregate and hence this may lead to lower strength. In order to improve the strength addition of steel FIBER with various percentages is used to increase the strength of concrete.

% of Recycled Aggregate	0 % FIBER	1 % FIBER	1.5 % FIBER	2 % FIBER
0	4.04	4.18	4.35	4.56
25	3.98	4.13	4.3	4.51
50	3.94	4.07	4.23	4.45
75	3.88	4.02	4.19	4.39
100	3.79	3.92	4.08	4.28

Variation of Permissible stress w.r.t % of Recycled Aggregate FRC

% of Recycled Aggregate	0 % FIBER	1 % FIBER	1.5 % FIBER	2 % FIBER
0	8.45	10.56	11.78	12.47
25	8.19	9.21	10.95	12.24
50	7.09	8.28	9.76	11.98
75	6.67	7.85	9.25	10.86
100	6.42	7.12	8.86	9.87

Variation of Flexural strength w.r.t % of Recycled Aggregate FRC.

8. CONCLUSION AND FUTURE SCOPE:

8.1. CONCLUSION:

The following conclusions can be drawn from the results obtained from the experimental investigations.

1. Recycled aggregate indicated high water absorption when compared to natural aggregate,

which necessitated the presoaking of recycled aggregate before concrete mixing.

2. Specific gravity, Bulk density of recycled aggregate is found to be less, when compared to natural aggregate. Further, recycled aggregate exhibited relatively less resistance to mechanical actions.
3. Due to the presence of surface coating with cement and other materials, the recycled aggregate does not give good lubrication; hence recycled aggregate is not as workable as natural aggregate.
4. Recycled aggregate concrete exhibited relatively less workability thus posing no problems in terms of mobility and place ability control. Due to the presence of surface coating with cement and other materials, the recycled aggregate does not give good lubrication; hence recycled aggregate is not as workable as natural aggregate.
5. Cube compressive strength of RAC (M20) is about 41.46 to 21.43 N/mm2 with the replacement of recycle aggregate in range of 25 to 100%.
6. Modulus of Rupture of RAC (M20) is about 12.24 to 6.24 N/mm2 with the replacement of recycle aggregate in range of 25 to 100%.
7. The Recycled Aggregate FRC mix show decrease in compressive and flexural strengths when compared with the NAC concrete mix.
8. Keeping in view the other advantages such as conservation of natural resources and disposal of demolished rubble, the slightly inferior properties of recycled aggregate Concrete can be tolerated. Thus, recycled aggregate with fiber reinforced concrete can be considered as potential and suitable alternative construction material with a bright future.

8.2 RECOMMENDATIONS FOR FURTHER STUDIES

Further testing and studies on the recycled aggregate concrete with fibers is highly recommended to indicate the strength characteristics of recycled aggregates for application in concrete. Below are some of the recommendations for further studies:

1. It is to be recommended that the effect of admixtures such as super plasticizer and metakolin on RAC is to be studied.
2. More investigations and laboratory tests should be done on the strength characteristics of recycled aggregate.
3. It is recommended that testing can be done on concrete slabs and walls. Some mechanical properties such as creeping and abrasion were also recommended.
4. More trials with different particle sizes of recycled aggregate and percentage of replacement of recycled aggregates are recommended.

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