

Experimental Investigation on Fibre Glass Concrete by Partially Replacing Cement by Hydrated Lime and Coarse Aggregates by Recycled Coarse Aggregates

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ABSTRACT: Concrete is the most widely used construction material in civil engineering industry because of its high structural strength and stability. In the view of global warming, efforts are been carried to reduce the emission of CO₂ to the environment. Cement industry is the major contributor in the emission of CO₂ to the atmosphere as well as using high level of energy resources in the production of concrete. The global consumption of natural sand is too high due to its extensive use in concrete. The demand for natural sand is quite high in developing countries owing to rapid growth in infrastructures which results in the supply scarcity. Hence the capacity would become lesser than demand. To overcome this crisis, new alternatives for the conventional river sand and natural coarse aggregates are being discovered with the available resources.

KEYWORDS: Hydrated Lime, Fibre Glass, Recycled Coarse Aggregates, Natural Coarse Aggregates

I. INTRODUCTION

The impact of crushed stone aggregates and its extraction in many parts of the country is increasing day by day on environment. Few impacts on environment like deforestation, blasting, vibration, industrialization, noise and pollution, land slides of weak hill slope. India, as a developing country faces lot of problems to protect environment, because of the various kinds of pollution taking place.

Hydrated lime, the active substance is identically practical to the biocidal products. Hydrated lime (Ca(OH)₂) as a solid is highly alkaline, when this substance gets added to the mix it prevents the cement from separation and sand which is waterproof. Shrinkage cracking often can be eliminated using hydrated lime. 10 to 15% addition to the total volume of cement leads to optimum results. Fibrous containing concrete material that increases structural integrity is commonly known to be like Fibre-reinforced concrete (FRC). Discrete short fibres that are uniformly oriented and distributed randomly are present in FRC. These FRC fibres are included with different fibrous materials each of which show different unique properties and fibres vary like synthetic and glass fibres, steel and natural fibre with concrete addition. Geometrics, densities, distribution and other fibre materials also vary with different percentages of addition.

Construction materials are required in huge quantities in developing countries due to continued infrastructural growth and hence huge amount of construction and demolition wastes get generated in India, a developing country. Disposal of huge quantities is a major problem on one side and on the other it affects environment. In general, recycle and reuse of construction waste is concentrated in reuse of recycled aggregates and replacement. Replacing specified amount of natural coarse aggregate (NCA) by recycled aggregates (RCA) into the mixture which results in recycled concrete which conserves less energy and materials for concrete production.

Glass Fibres Reinforced Concrete (FRC), Hydrated lime and concrete debris i.e., recycled aggregates with required proportion are used for preparing modified ingredient concrete. Using this as a better constructive method, modified ingredient concrete is cast/prepared by which compressive, flexure and split tensile strength of the concrete specimen is found out. Using recycled aggregates helps reducing the use of materials in certain quantity even GFRC which is used as an additive to increase the strength in concrete mainly has extensive application as panels in architectural purpose and also as a precast concrete which makes concrete light weight with better bonding strength.

Researches are being carried out on hydrated lime, fibrous glass material to use it as one of the ingredient in concrete to achieve maximum strength within specified number of days. Hydrated lime, recycled aggregates and

fibrous glass materials are now being used in many researches. With these addition light weight concrete is being obtained with savings in the nominal requirement in the materials.

The objectives of the study are:

- To Characterize physical and chemical properties of hydrated lime, glass fibres and recycled coarse aggregates.
- To identify the optimum mix and recycled aggregates and glass fibers percentage precursor binding materials for manufacture of modified ingredient concrete as per test for coarse and fine aggregates specified in BIS code IS:383-1970.
- To compare the basic properties of recycled coarse aggregate with that of naturally available coarse aggregate.

II. LITERATURE REVIEW

In E.V.M. Carrasco et.al (2017) investigated mortar characterization with fibers and powder shingles by destructive and non-destructive tests. From this paper, following conclusions drawn were, analysis of mortar has been done using these materials which has further resulted in cost effective technique. Input power approach used was cost effective technique. Modulus of elasticity and strength of cement mortar resulted in good values compared to conventional cement mortars.[6]

JumahMudif Their et.al (2018) investigated and carried out a study to understand modified ingredient concrete preparation using recycled aggregate, glass fiber and hydrated lime .It was observed that recycled concrete prepared using these aggregate materials could give compressive strength of 28.23 N/mm² and 36.62 N/mm² at 28 and 90 days respectively. 2% glass fibers and 1% steel fiber volume fraction were important for improving the properties.[12]Suzy Magaly Alves Cabral de Freitas et.al (2018) investigated and carried out a study to understand the production of light weight concrete using glass fibers, shingles and recycled aggregates. From this paper, the following conclusions were drawn. Results showed that the paper provided valorization of basic oxygen furnace slag and solid waste generated. Approach to find out the use of steel slag in construction gave the idea for consuming 84% of slag which was generated at Brazil.[22]

III. METHODOLOGY

Preparing of aggregates is done in 2 phases, phase-I is to fix the ratio of hydrated lime to cement at the constant rate of 5% and phase-II is to prepare the aggregates in the incremental stages with the nominal weight of aggregates.

Phase-I: TO FIX THE RATIO OF HYDRATED LIME TO CEMENT.

- To fix ratio of hydrated lime to cement, cement is being replaced by cement with constant 5% are adopted.
- Above mentioned ratios of hydrated lime to cement are mixed with water to maintain the workability and poured into cubes of 150*150*150mm.
- After casting, 24 hours cubes are kept to room temperature, de-moulded kept for water curing for 28 days to gain strength and cubes are tested.
- After dry curing, cubes are tested to fix cement: hydrated lime ratio.
- Test result shows that 95:5 ratio gives higher strength of 1.85 N/mm² compared to other mix ratios of hydrated lime and cement.
- Hence 95:5 ratio of cement and hydrated lime respectively was adopted to prepare modified concrete.

Along with these 2% to the total volume of concrete specimen, fibre glass are added to strengthen the mixture.

Phase-II: TO PREPARE THE MODIFIED CONCRETE FOR THE VARYING QUANTITY OF DEBRIS ON NOMINAL COARSE AGGREGATES

- Concrete debris and coarse aggregates are taken in ratio of 10:90 respectively and mixed thoroughly so that dry mix is prepared.
- Varying the ratios of the above aggregates viz 20:80, 30:70, 35:65, 40:60 are being weight and mixed thoroughly.
- Dry mix is now mixed with the hydrated lime and cement thoroughly so that homogeneous mix is obtained.
- This mix is then poured into the moulds in three layers consecutively with each layer being 25 times tamped,



- finally filling the mould. Excess mix is trimmed using trowel.
- Cubes are kept in dry atmosphere for dry curing.
- After 28 days, cubes are broken by hammer so that the aggregates of size 20 mm to 4.75mm are obtained by sieving.

Preparation of Concrete Specimens:

Following below steps are followed for preparing the concrete specimens:

- Cement, hydrated lime, fibers, natural coarse aggregates and sand are mixed with required quantities and mixed thoroughly so that dry mix is prepared.
- After the uniform mix is obtained, water is added in required quantity and mixed thoroughly so that the uniform wet mix is obtained.
- Prepared concrete mix is casted in 150 mm cube moulds.
- Concrete is then poured into the mould in three layers consecutively with each layer being 25 times tamped.
- Final layer is finished and then the excess concrete is removed by trowel.

Compressive strength for concrete specimens:

- After specified number of days of curing of cubes in curing tank, cubes were taken out of curing tank and cubes were dried.
- The dimensions of the cube was measured by available equipments.
- After the cubes were dried, cubes were kept on Compression testing machine (CTM) for testing the cubes.
- Cubes were kept in position and load was applied till specimen fails.
- This procedure was repeated for all the cubes.

Ratio of NCA : RCA	Mortar cubes compressive strength (Average) (N/mm ²)
90:10	1.45
80:20	1.85
70:30	1.35
60:40	0.75

Graph 1 :Compressive average strength of the concrete with different ratios of RCA and NCA

Split Tensile Strength for concrete specimens:

- Concrete was casted in Cylinder size with 150mm diameter and 300 mm length. Similarly three specimens were casted.
- Cylinders were demoulded after twenty four hours of casting.
- Cylinders were cured for specified number of days in curing tank.
- After specified number of days curing of specimens, cylinders were tested on Compression testing machine (CTM).
- Cylinder specimen was kept on the machine and placed properly before testing.
- Load was applied till specimen fails.
- Average of split tensile strength value was obtained by averaging the values of three identical specimens.
- Split tensile strength of the specimens is calculated by the equation,

$$F = 2P / (\pi DL)$$

Where,

F = Split tensile strength of concrete (in N/mm²)



P = Failure load (in N)
 L = Cylinder specimen length (in mm)
 D = Cylinder specimen diameter (in mm)

Flexural strength for concrete specimens:

- Concrete was casted in beam size with 100 X 100 X 500mm. Similarly three specimens were casted.
- Beams were demoulded after twenty four hours of casting.
- Beams were cured specified number of days in curing tank.
- After required curing of specimens, beams were tested.
- Beam specimen was kept on the machine and placed properly before testing.
- Two point loading applied for 400 mm effective span till specimen fails.
- Flexural strength of the specimens calculated by the equation,

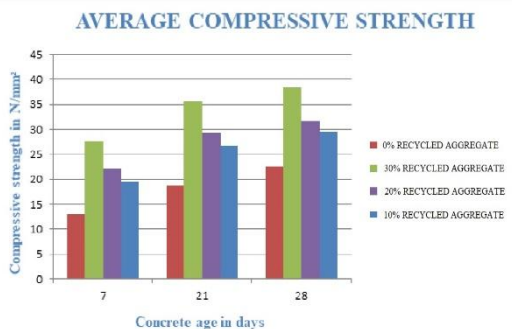
$$F = PL/bd^2$$

Where,

F= Flexural strength of concrete (in N/mm²)
 P= Load where the specimen fails (in N)
 L= Effective span of beam (in mm)
 b= Beam breadth (in mm)
 d= Beam depth (in mm)

Beams With 30% replacement of NCA with RCA	7 th day test result (N/mm ²)	28 th day test result (N/mm ²)
1	3.667	4.225
2	3.200	4.845
3	3.466	5.221
Average	3.444	4.763

Graph 1 provides average cube compressive strength results for concrete cube specimens tested for different ratios of natural coarse aggregate and recycled coarse aggregate for M-35 grade of concrete for 7th, 21st, 28th day for 100%, 80%, 70% and 60% of natural aggregates being replaced with 0%, 20%, 30% and 40% of recycled aggregates, the results obtained are **13.28, 18.91, 26.64, 21.63** N/mm², 21st day strength are **18.65, 27.04, 35.01, 28.98** N/mm² and 28th day strength are **21.57, 29.15, 38.11, 31.94** N/mm² respectively. Hence the test results have shown that the strength is maximum for the third replacement that is replacing the entire amount of natural coarse aggregates by 30% which obtained good results than other ratios



Graph1: Average Compressive strength of concrete

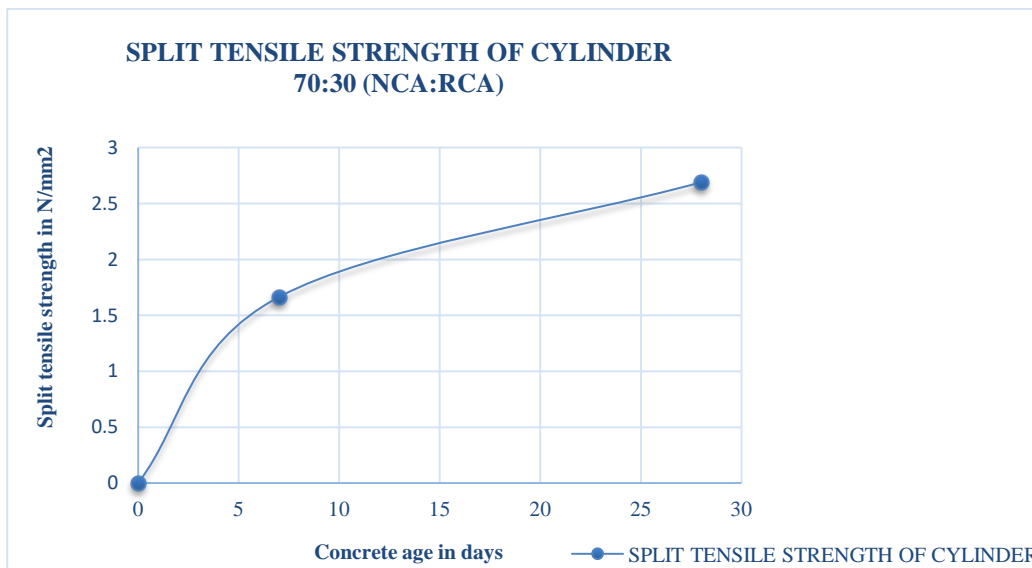
Flexural strength results for beams of modified ingredient concrete in replacement with natural aggregates with recycled aggregates for percentage of 40% are measured for 7 days and 28 days shows 3.444 N/mm² and 4.763 N/mm² respectively.

By replacing natural coarse aggregates by 30% of recycled aggregates split tensile strength test was conducted for modified ingredient concrete.

Split tensile strength for recycled aggregate concrete for natural aggregates replacement with 30% of recycled aggregates are measured for 7th and 28th days shows 1.635 N/mm² and 2.693 N/mm² respectively.

• Split tensile strength values for recycled aggregate concrete mix for 7 and 28 days

Cylinder With 30% replacement of Natural Aggregates with recycled coarse aggregates	7 th day test result (N/mm ²)	28 th day test result (N/mm ²)
1	1.584	2.650
2	1.780	2.540
3	1.543	2.890
Average	1.635	2.693



Graph 6.3: Split tensile strength of Cylinder on 7th and 28th day for 30% replacement of NCA with RCA

Sl.No	NCA:RCA	Age of M35 concrete in Days	Average Compressive Strength in (N/mm ²)
1	100:0	7	13.28
		21	18.65
		28	21.57
2	90:10	7	18.91
		21	27.04
		28	29.15



3	80:20	7	26.64
		21	35.01
		28	38.11
4	70:30	7	21.63
		21	28.98
		28	31.94

The data taken for the mix design is as follows:

Mix design for concrete using Indian Standard code 10262:2019

Data:

- Grade Designation = M35
- Cement OPC = 43
- Maximum nominal size of aggregates = 20 mm
- Exposure condition = Moderate
- Minimum cement content = 320 kg/m³

Materials:

- Specific gravity of cement = 3.15
- Specific gravity of Coarse aggregates = 2.65
- Specific gravity of fine aggregates = 2.85
- Specific gravity of recycled aggregates = 2.38

Water absorption:

- Coarse aggregate = Nil
- Fine aggregates = 2.25%
- Recycled aggregates = 5.94%

PROPORTIONING OF CONCRETE WITH 70% NATURAL COARSE AGGREGATES AND 30% RECYCLED COARSE AGGREGATES:

The mass of naturally available coarse aggregates will change and all the parameters will remain the same. Here we are considering 30% of recycled coarse aggregates in place of natural aggregates.

Mass of Coarse aggregates = $d \times \text{volume of coarse aggregates (Natural + Artificial)} \times \text{specific Gravity of coarse aggregates} \times 1000$

$$= (0.69 \times 0.30 \times 1.9 \times 1000) + (0.69 \times 0.30 \times 2.70 \times 1000)$$

$$= 398.3 + 548.9$$

Recycled coarse aggregates (RCA) = 398.3 kg/m³

Natural coarse aggregates (NCA) = 548.9 kg/m³

Quantity of materials required for 1m³ of concrete

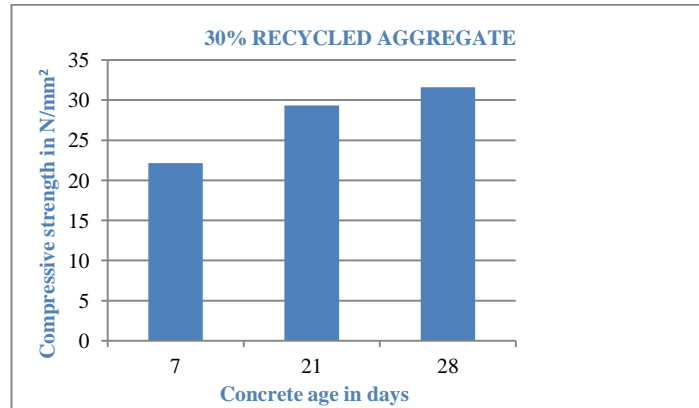
- Cement = 21.96 Kg
- Hydrated lime = 1.09 Kg (5% replacement)
- Water = 8.329 liters
- Fine aggregate = 23.04 Kg
- Recycled CA = 23.47 Kg
- Natural CA = 28.7 Kg
- Free W/C = 0.48

Ratio for the mix design calculated is Cement : FA : CA = 1:1:2.37

IV. EXPERIMENTAL RESULTS

- **Compressive strength of concrete specimen**

Below graphs 4 shows the bar charts of compressive strength results for concrete cube specimens for various mix proportion of natural aggregates replaced with 0%, 20%, 30% and 40% of recycled aggregates respectively for various curing in specified number of days. Comparing to all other mix ratios 70:30 (NCA:RCA) has good compressive strength but no concrete mix has achieved the target mean strength.



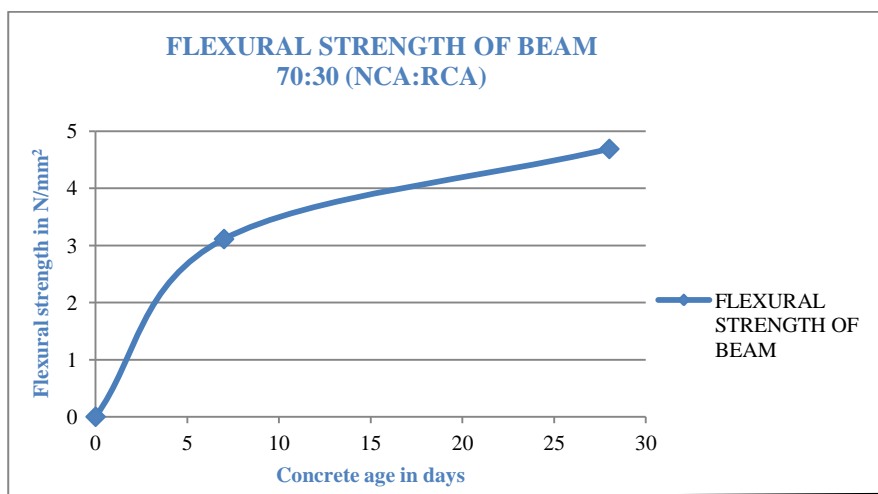
Graph 4: Bar chart for modified ingredient compressive strength of concrete by partially replacing natural coarse aggregates by 30% of recycled aggregates.

The maximum results were obtained by replacing cement by hydrated lime with constant 5%, Replacing coarse aggregates by recycled debris and adding glass fibres to the entire volume by 2% to the volume of concrete has achieved maximum strength than the mean target strength of concrete.

- **Flexural strength of beams**

The below graph will show the variation in strength of concrete specimen by partially replacing natural coarse aggregates by 30% of recycled aggregates for beams.

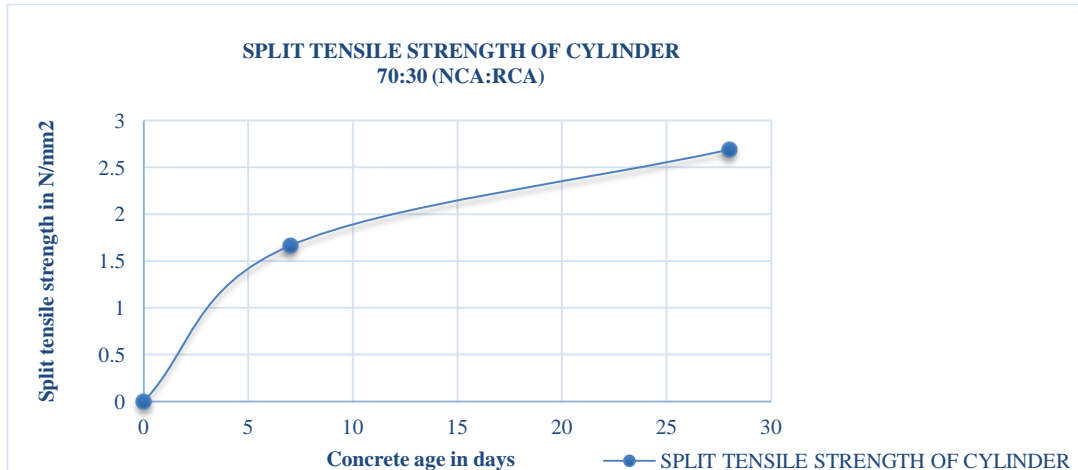
Flexural strength results for beams of modified ingredient concrete in replacement with natural aggregates with recycled aggregates for percentage of 40% are measured for 7 days and 28 days shows 3.444 N/mm² and 4.763 N/mm² respectively.



Graph 6.2: Flexure Strength of Beams on 7th and 28th days for 30% replacement of NCA with RCA

- **Split tensile strength for cylinders**

Split tensile strength for recycled aggregate concrete for natural aggregates replacement with 30% of recycled aggregates are measured for 7th and 28th days shows 1.635 N/mm² and 2.693 N/mm² respectively.



Graph 6.12: Split tensile strength of Cylinder on 7th and 28th day for 30% replacement of NCA with RCA

V. CONCLUSION

Natural coarse aggregates with recycled aggregates replacement as 90:10,80:20,70:30 and 40:60 respectively is used for determining the ratios for which maximum strength is obtained. 70% natural coarse aggregates and 30% of recycled aggregates with the constant replacement to the cement with hydrated lime as 5% and addition of fiberglass as a whole as 2% to the total volume of the specimen yields maximum strength. Thus optimum mix used for the preparation of modified ingredient concrete is 70% of natural coarse aggregates and 30% of recycled aggregates. Fiberglass is used as binding material in the mix.

As Compared to Natural coarse aggregates, recycled coarse Aggregates have more water absorption. Hence during Concrete mix process, more quantity of water is needed, because of its flaky shape, recycled coarse aggregates have good workability than the workability of natural coarse aggregates. Impact tests showed that the natural coarse aggregates had more impact value than that of recycled coarse aggregates. Since the recycled coarse aggregates are flaky in shape, in concrete they form less voids. So we need less amount of fine aggregates for same volume of concrete mix. Since recycled coarse aggregates are light in weight, dead load of structure is less when compared to natural coarse aggregates concrete. Thus prepared recycled coarse aggregates, modified ingredient concrete reduces requirement of other construction materials.

As the replacements are being made at various percentages, maximum strength have been obtained by replacing natural coarse aggregates by 30% of recycled aggregates keeping the replacement percentages of cement by hydrated lime and glass fibers constant. Hence 30% replacement can be adopted as an optimum dosage of replacement. By making use of these ratios when concrete cubes are being cast the maximum compressive strength of tested cube specimen obtained is 38.11N/mm². The cubes which are light weight can be used as partition walls, compound walls, gardening purpose, etc.,

The maximum strength of flexural test for beams was found to be 4.763 38.11N/mm² and split tensile strength for cylinders at the age of 28 days was found to be 2.693N/mm².

Fiberglass used in the concrete mix, called fiberglass reinforced concrete used at the rate of 2% to the overall volume of the mix has found to impart better strength, light weight and bonding with the aggregates and other materials in the mix.

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