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Flexural Behavior of Frc Using Recycled Aggregates with Quarry Dust Replacement

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Abstract: Application of recycled materials in the building industry is essential for permanently sustainable development of each country. The use of primary sources and materials is becoming unbearable both economically and ecologically and therefore it is necessary to seek the possibility of reuse of those materials once their durability expired. For reducing cost of concrete and also to meet the demand, locally available waste materials such as quarry dust and recycled materials had been utilized in concrete. This project deals with the comparative study of flexural behaviour of fibre reinforced concrete with recycled aggregates and quarry dust used as a full replacement for natural aggregates and natural sand respectively. The aim of this project is to study the change in strength aspects like flexural strength, split tensile strength and modulus of rupture due to the replacement of aggregates by waste products upon addition of polypropylene fibres. The compressive strength, split tensile strength and modulus of rupture of concrete reaches the maximum value at a replacement level of 0.5% of polypropylene fibers while replacing sand with quarry dust. The flexural strength of concrete beams also attained the maximum value at a replacement level of 0.5% of fibers with sand replaced by quarry dust.

Key words: Fiber Reinforced concrete · Polypropylene fibres · Recycled aggregates · Quarry dust · Compressive strength · Split tensile · Flexural strength

INTRODUCTION

India has taken a major initiative on developing the infrastructures such as express highways, power projects and industrial structures etc., to meet the requirements of globalization in the construction of buildings and other structures concrete plays the rightful role and a large quantum of concrete is being utilized.

Recycling concrete is a viable option to decrease the demand on high quality natural resources and to limit the amount of waste that is disposed in landfills. Recycled concrete has been primarily used as an unbound material in embankments, bases and sub-bases. Engineers have also used recycled concrete as an aggregate in the construction of new structures such as concrete pavements but with limited frequency. The use of recycled concrete in load bearing structures has not gained wide acceptance probably because of the lack of accessible information on the subject, such as expected fresh and hardened material properties.

Any construction activity requires several materials such as concrete, steel, brick, stone, glass, clay, mud, wood and so on. However, the cement concrete remains the main construction material used in construction industries. For its suitability and adaptability with respect to the changing environment, the concrete must be such that it can conserve resources, protect the environment, economize and lead to proper utilization of energy. To achieve this, major emphasis must be laid on the use of wastes and by products in cement and concrete used for new constructions. The utilization of recycled aggregate is particularly very promising as 75 per cent of concrete is made of aggregates. In that case, the aggregates considered are slag, power plant wastes, recycled concrete, mining and quarrying wastes, waste glass, incinerator residue, red mud, burnt clay, sawdust, combustor ash and foundry sand. The enormous quantities of demolished concrete are available at various construction sites, which are now posing a serious problem of disposal in urban areas.

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This can easily be recycled as aggregate and used in concrete. Research and Development activities have been taken up all over the world for proving its feasibility, economic viability and cost effectiveness.

The recycling and reuse of construction and demolition wastes seems feasible solution in rehabilitation and new constructions after the natural disaster or demolition of old structures. Recycling concrete is a viable option to decrease the demand on high quality natural resources and to limit the amount of waste that is disposed in landfills.

Dumitru Zdrilic and Smorchevsky Boral, G. [1] studied that, Quarry dust has been used in and continues to be used for concrete productions a replacement for natural sands. In this work investigations have been undertaken using Barmac B3000 VSI crusher to produce manufactured quarry fines with an improved particle shape and grading, for use as a total or partial replacement for natural sands in concrete mixes.

Ilangovan *et al.* [2], put forward that the Quarry rock dust can be an economic alternative to the river sand. This paper presents the feasibility of the usage of Quarry Rock Dust as hundred percent substitutes for Natural Sand in concrete. Tests were conducted on cubes and beams to study the strength of concrete made of Quarry Rock Dust and the results were compared with the Natural Sand Concrete.

Victor Cervantes, *et al.* [3], studied the comparison between recycled aggregate with and without the addition of synthetic fibers and virgin coarse aggregate. Different concrete mixtures (i.e.) completely with virgin coarse aggregate, recycled coarse aggregate (RCA) and blend of virgin and recycled coarse aggregate was made. The blending of RCA and virgin coarse aggregate at a 50-50 volume percentage produced a concrete with similar fracture and shrinkage properties to that of the virgin coarse aggregate concrete. The compressive strengths ranged from 22.9 MPa for the 50-50 Blend to 31.2 MPa for the virgin coarse aggregate concrete.

Luis R. Evangelista *et al.* [4] produced concrete with different ratios of substitution (10%, 20%, 30%, 50% and 100%) of natural sand with fine recycled concrete aggregates to compare the behaviour of concrete with that same substitution ratio of fine recycled aggregates with the behaviour of a reference concrete produced exclusively with fine natural aggregates. In all compositions, the coarse portion is made of natural limestone aggregates. The work describes the first and second parts out of above three cases and the criteria used to limit the maximum replacement ratio, based on compressive strength, short-term shrinkage and water absorption.

HasbiYaprak, *et al.* [5], studied the effects of the recycled fine recycled concrete aggregate (FRA) that was manufactured from concrete wastes. In concrete mixtures 0, 10, 20, 30, 40, 50 and 100% by weight FRA were used instead of river sand. In accordance to 28-day compressive strength it was seen that FRA can be used up to 10 % ratio for producing C30 concrete, between 20-50% ratios for producing C25 concrete. Thus, environmental impacts and consumption of the natural resources can be significantly reduced by using recycled fine concrete aggregates in concrete applications.

Vytlacilova and Vodicka [6] studied the application of recycled materials in the building industry is essential for permanently sustainable development of each country. This paper is focused on the experimental program aimed at verifying selected material properties of fibre reinforced concrete in which all of the natural stone aggregates is replaced by recycled aggregates-masonry and concrete. From this paper, optimum compressive strength, split tensile strength and flexural strength are 13.75 Mpa, 1.71 Mpa and 2.16 Mpa respectively.

Prahallada and prakash [7] explained the importance of fibre reinforced concrete (FRC) as a new construction material. It was obserced that higher strength and workability characteristics of waste plastic fibre reinforced concrete using recycled aggregates and conventional aggregates can be obtained with 1% addition of fibres into it.

Ghorpade Vaishali and sudarsana Rao [8] conducted an experiment to evaluate the strength and permeability of FRHPC produced with recycled coarse and fine aggregates. Three types of fibers viz., steel, glass and poly propylene fibers are used. Compressive, tensile, flexural and shear strengths of Fiber Reinforced High Performance Recycled Aggregate Concrete (FRHPRAC) have been evaluated from the experimentation. Chloride ion permeability has been determined as measure of permeability of FRHPRAC. The results of the study show that recycled coarse and fine aggregates can be successfully used in the production of fiber reinforced high performance concrete. From the results, the compressive, tensile, flexural and shear strengths of fiber reinforced high performance recycled aggregate concrete mixes increased with the increase of fiber up to 1.0% and decreased beyond 1.0% fiber volume fraction. Balling of fibers at 1.25% volume fraction is mainly responsible for reduction in strengths. Maximum compressive, tensile, flexural and shear strengths are achieved at 1.0% fiber volume for all the three types of fibers used. Out of the three, steel fibers contributed for higher strengths when compared to glass and poly propylene fibers. The use of recycled coarse aggregate resulted in loss of compressive, tensile, flexural and shears strengths in FRHPC mixes. When compared to FRHPC mixes prepared with RCA, use of RCA+RFA resulted only in marginal loss of strengths. Hence, recycled fines can be used safely in the production of FRHPC.

Masaya Nakamu and Ken Watanable [9] reported the investigation of Ductile Fiber Reinforced Cementitious composites (DFRCC) using recycled fine aggregate. In this study, uniaxial compression tests, split tensile tests and notched beam 3-point bending tests for the fiber reinforced mortar and fiber reinforced concrete specimens were carried out. Six types of matrix were used: mortar using natural fine aggregate with a crushed sand and pit sand mixing ratio of 7:3 (NM); mortar using recycled fine aggregate (RM); concrete using crushed stone with maximum sizes of 10 mm and 20 mm (NC, 2NC); and concrete using recycled coarse aggregate with maximum sizes of 10 mm and 20 mm (RC, 2RC). The target slump test value was 18.0 cm.

Objective: The main objective of this project is to study the flexural behavior of fiber reinforced concrete beam with recycled aggregates and quarry dust with full replacement of natural aggregates and natural sand. Fibers are added at different percentages (0%, 0.5%, 1% and 1.5%) to enhance the tensile strength of the concrete.

Initially the mechanical characteristics of concrete such as compressive strength, split tensile strength and modulus of rupture are studied by varying the percentage of fiber from 0%, 0.5%, 1% and 1.5% to find the optimum quantity of fiber to be added to increase the strength. Then the flexural behaviour of reinforced concrete beams with various combinations of recycled and natural aggregate with quarry dust and 0.5% polypropylene was studied. Finally the combination which exhibits good flexural behaviour is compared with that of control specimen.

Experimental Programme: The experimental programme was designed to find the optimum percentage of polypropylene fibre to be added with the concrete by studying the mechanical properties of concrete such as compressive strength, split tensile strength and modulus of rupture for the following specimens used in this experimental study,

Control Specimen:
C - Natural aggregate + Quarry dust

NQ Series:
NQ -Natural aggregates. + Quarry dust.
NQ1-Natural aggregates + Quarry dust + 0.5% Fibre
NQ2-Natural aggregates + Quarry dust + 1.0% Fibre
NQ3-Natural aggregates + Quarry dust + 1.5% Fibre

RQ Series:
RQ-Recycled aggregates + Quarry dust
RQ1-Recycled aggregates + Quarry dust+ 0.5% Fibre
RQ2-Recycled aggregates + Quarry dust+ 1.0% Fibre
RQ3-Recycled aggregates + Quarry dust+ 1.5% Fibre

The flexural behaviour of RCC beams were studied for the optimum percentage of fibre obtained from compressive strength, split tensile strength and modulus of rupture.

Materials Used

Cement: In this investigation, cement used was 53 grade ordinary Portland cement confirming IS: 12269: 1987.

Coarse Aggregate

Natural Aggregate: Crushed granite was used as coarse aggregate. The coarse aggregate according to IS: 383-1970 was used. Maximum coarse aggregate size used is 20 mm.

Recycled Aggregate: The R.C.C. demolition waste was processed in a crusher and then sieved. The fraction between 10 to 20mm was used as Recycled Coarse Aggregate. Sample of recycled aggregate was shown in Fig. 1

Table 1 shows the physical properties of coarse aggregate.

Fig. 1: Recycled aggregate

Table 1: Physical Properties of Coarse aggregates

Coarse Aggregate	Density(g/cm^3)	Water Absorption (%)	Fineness Modulus
Natural	2.76	2.55	7.48
Recycled	2.64	6.18	7.24

Table 2: Physical Properties of Fine aggregates

Property	Quarry dust	Natural sand
Specific gravity	2.54-2.60	2.60
Bulk relative density (kg/m^3)	1720-1810	1460
Absorption (%)	1.20-1.50	Nil
Moisture content (%)	Nil	1.50
Fine particles less than 0.075mm (%)	12-15	06
Sieve analysis	Zone II	Zone II

Fig. 2: Quarry dust

Fine Aggregate

Natural Sand: Aggregate obtained from a nearby river source was used as a fine aggregate. The fine aggregate conforming to zone III according to IS: 383-1970 was used.

Quarry Dust: Quarry dust is a residue obtained from extraction and processing of rocks which forms finer particles less than 4.75 mm. Sample of quarry dust was shown in Fig. 2

Table 2 shows the physical properties of fine aggregate.

Water: Potable water was used in the experimental work for both mixing and curing purposes.

Polypropylene Fibre: Polypropylene fibre provides good bulk and cover. The greatest volume of fibre for given weight. It is the lightest of the all the fibres and is lighter than water. It is retain more heat for a longer period of time. Polypropylene fibres are not attacked by bacteria or micro organisms. Have excellent insulation properties. Sample of polypropylene fiber was shown in Fig. 3.

Fig. 3: Polypropylene fiber

Preparation of Test Specimens: Casting programme was split into two sets. Initially cubes of size 150 x 150 x 150mm, cylinders of 150mm diameter and 300mm height cube, cylinder and prism of size 100 x 100 x 500mm were casted in accordance to the specimen details mentioned above.

Once the optimum percentage of fibre to be added was confirmed from the test for mechanical properties, RCC beams of size 150 x 300 x1500mm was casted for the optimum percentage of fibre arrived from preliminary strength tests.

Casting of the specimens was done as per IS: 10086-1982. The mixing, compacting and curing of concrete are done according to IS 516: 1959. The samples of cubes, cylinders, prisms and RCC beams were cured for 28 days in water pond. M25 grade of concrete is designed and the proportion arrived is 1:1.36:2.68:0.45

Mechanical Properties

Testing of Specimens

Slump Test: Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It does not measure all factors contributing to workability. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch.

Compressive Strength: The cube specimens were tested on compression testing machine. The bearing surface of machine was wiped off clean and sand or other material removed from the surface of the specimen. The specimen was placed in machine in such a manner that the load was applied to opposite sides of the cubes as casted that is, not top and bottom.

Split Tensile Strength: The cylinder specimens were tested on compression testing machine. The bearing surface of machine was wiped off clean and looses other sand or other material removed from the surface of the specimen. The load applied was increased continuously at a constant rate until the resistance of the specimen to the increasing load breaks down and no longer can be sustained. The maximum load applied on specimen was recorded. f_{split} =2P/ðDL, where P=load, D= diameter of cylinder, L=length of the cylinder.

Modulus of Rupture: The beam specimens were tested on universal testing machine for two-point loading to create a pure bending. The bearing surface of machine was wiped off clean and sand or other material is removed from the surface of the specimen. The two point bending load applied was increased continuously at a constant rate until the specimen breaks down and no longer can be sustained. The maximum load applied on specimen was recorded. The modulus of rupture depends on where the specimen breaks along the span. If the specimen breaks at the middle third of the span then the modulus of rupture is given by frup. = $(WL)/(bd^2)$. If the specimen breaks at a distance of 'a' from any of the supports then the modulus of rupture is given by $f_{rup} = (3Wa)/(bd^2)$, where W = load at failure, a = crack width (mm), L = length of specimen (400mm), b = width of specimen (100mm), d=depth of specimen (100mm).

RESULTS AND DISCUSSIONS

The result obtained from the test for mechanical properties of concrete like compressive strength, split tensile strength and modulus of rupture was shown in Table 3.

Table 3: Test results of mechanical properties

	Compressive Strength			
Specimen	7Days (N/mm^2)	28Days (N/mm^2)	Split-Tensile (N/mm^2)	Modulus of rupture (N/mm^2)
Control Specimen	25.78	33.48	2.28	4.23
NQ	24.67	32.11	2.25	3.95
NQ1	26.22	34.92	2.7	4.32
NQ2	24.35	28.67	2.55	3.89
NQ3	23.2	26.22	2.5	3.9
RQ	23.67	30.2	2.3	3.8
RQ1	24.70	31.11	2.47	3.9
RQ2	23.11	29.77	2.35	3.76
RQ3	22	28	2.3	3.66

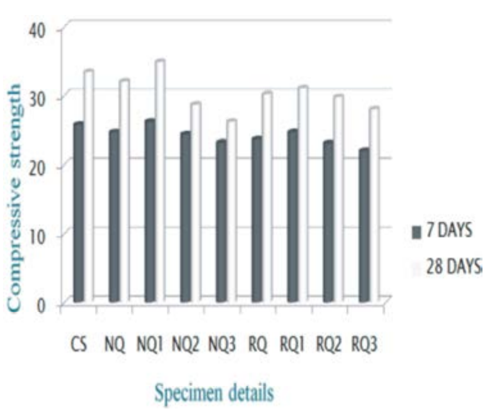

Fig. 1: Compressive strength at 7 and 28 days

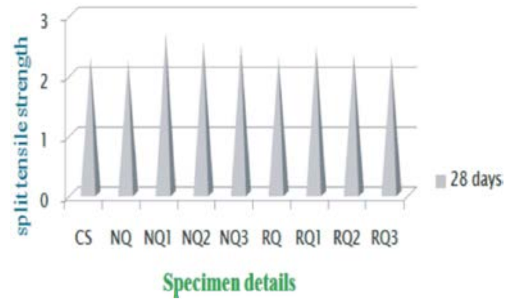

Fig. 2: Split tensile strength at 28 days

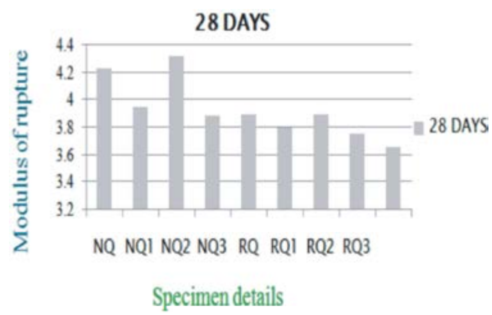

Fig. 3: Modulus of rupture at 28 days

Fig. 1 shows the compressive strength test results for 7 and 28 days

Fig. 2 shows the split tensile strength for 28 days

Fig. 3 shows the modulus of rupture for 28 days

From the test results it is observed that the strength in various aspects like compressive strength, split tensile strength and modulus of rupture increased upto 0.5% addition of polypropylene fiber for both series with natural aggregate + quarry dust (NQ) and recycled aggregates + quarry dust (RQ). The results of the 'NQ'series specimens with 0.5% polypropylene fiber (i.e.) NQ1 showed high strength when compared to control specimen.

The specimen NQ1 (natural aggregate + quarry dust + 0.5% polypropylene fiber) showed the following results in comparison with control specimen (natural aggregate + natural sand),

- The compressive strength was increased by 4.3%
- The split tensile strength was increased by 18.421%
- The modulus of rupture was increased by 2.128%

Hence the optimum percentage of fiber is taken as 0.5%

Flexural Behaviour

Details of Specimens Selected for Flexural Test: Upon arriving the optimum percentage of fiber as 0.5%, the flexural behaviour of specimens with combinations of natural and recycled aggregate with 0% and 0.5% of fiber was compared with that of the control specimen.

Following are the details of specimen included for the comparison of their flexural behaviour,

Control Specimen:
C - Natural aggregate + Quarry dust

NQ Series:
NQ -Natural aggregates. + Quarry dust.
NQ1-Natural aggregates + Quarry dust + 0.5% Fibre

RQ Series:
RQ-Recycled aggregates + Quarry dust
RQ1-Recycled aggregates + Quarry dust+ 0.5% Fibre

Experimental Set up: In order to study the performance of the beam with fully replacement of fine aggregates and coarse aggregates, the experiment is carried out as below. The aim of this work is to study the flexural behaviour and splitting tensile strength of the beams. All the tests have been carried out in loading frame with a capacity of 1000 KN. The beam is simply supported and the two point loading is applied. Demountable mechanical Strain gauges are used to measure the strains in the beam specimens. Then LVDT is used to measure deflection of the beams. Also loads are calculated using Load cell. The load is to be applied in small increments of 10 KN. At each load increment the deflection measured is recorded. All the specimens are loaded upto the failure.

RESULT AND DISCUSSIONS

Load Carrying Capacity: From the test results it is clear that NQ1 (i.e.) concrete with natural aggregate + quarry dust + 0.5% fiber has high ultimate load carrying capacity than other specimens.

Table 4: gives the flexural test results for the specimens

Specimen	Ultimate Load (kN)	Midspan Deflection (mm)	L/3 Deflection (mm)
CS	135	13.5	6.4
NQ	140	14	6.858
NQ1	150	15.5	7.048
RQ	130	12.86	6.26
RQ1	140	13	6.66

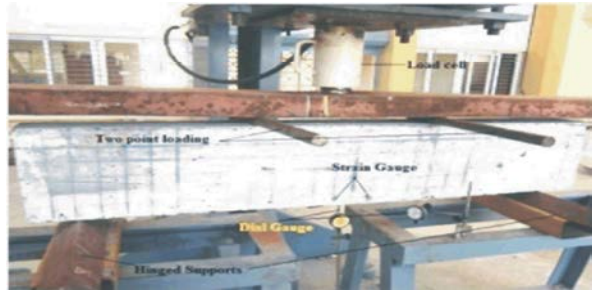

Fig. 4: Loading setup

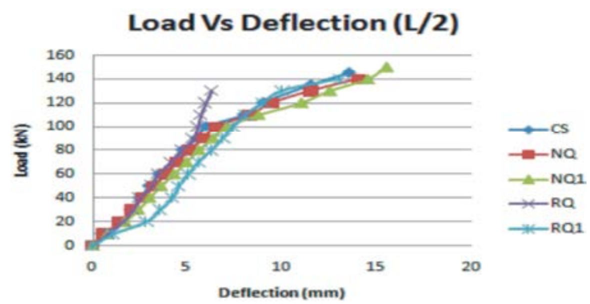

Fig. 5: Load vs. mid span deflection

Load vs. Deflection: The variation of load with deflection was given on Fig. 5. The mid span deflection was linear upto a particular limit and varied in a non linear manner.

CONCLUSION

From this experimental study it is clear that the combination of natural aggregate with quarry dust and 0.5% fiber showed high strength when compared to other combinations. Moreover the combination of recycled aggregate with quarry dust showed high strength next to that of with natural aggregate. Hence the combination recycled aggregate and quarry dust with certain percentage of fiber suits when considering economic aspects.

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