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COMPARATIVE STUDY OF 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.

This project deals with the Comparative study of flexural behavior of fibre reinforced concrete using recycled aggregates with quarry dust replacement. For reducing cost of concrete and also to meet the demand, locally available waste materials such as quarry dust and recycled materials have been utilized in concrete. The aim of this project is to study enhancement of flexural strength, splitting tensile strength and modulus of elasticity due to the addition of POLYPROPYLENE fibres and recycled aggregates in concrete and the replacement of crusher dust in concrete.

The compressive strength of concrete reaches the maximum value at a replacement level of 0.5% of fibers and same behavior is observed while replacing completely with recycled aggregates and quarry dust.The split tensile strength of concrete reaches the maximum value at a replacement level of 0.5% of fibers and same behavior is observed while replacing completely with recycled aggregates and quarry dust.The flexural strength of concrete beams attains max value of 54kN ultimate load at a replacement level of 0.5% of fibers.

The load deflection behavior shows a ductile behavior at 0.5% of fiber replacement level.The stiffness and energy absorption capacity at ultimate load are more in the 0.5% of fibre proportion.Hence it is concluded that recycled building waste can be effectively used as a fully replacement for natural aggregate.

Keywords— *Recycled aggregates*, *Recycled materials, polypropylene fibres, Recycled building waste.*

I. 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 a 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.

II. LITERATURE REVIEW

1) CRITERIA FOR THE USE OF FINERECYCLED CONCRETE AGGREGATES IN CONCRETE PRODUCTION

Luis R. Evangelista, Jorge C. de Brito (2009)

In this work, concrete has been produced with different ratios of substitution (10%, 20%, 30%, 50% and 100%) of natural sand with fine recycled concrete aggregates, has been divided in three parts: tune-fining the workability of the admixtures in order to keep it approximately constant; choosing the maximum allowable substitution ratio according to performance criteria; performing a large set of laboratory tests 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.

2) MATERIAL PROPERTIES OF FRC WITH RECYCLED AGGREGATE

Jirina TRCKOVA and Petr PROCHAZKA (2011)

The sustainable ecology belongs to the most important issues today. In this field a use of recycled materials is of great interest to people. Consequently, incorporation of industrial waste, concrete and brick scraps and other rubbish into products for Civil Engineering use is very important. Certain results from experiments carried out in laboratory on standard samples are emerged in this paper. Since the material is not yet enough approved, three main targets are addressed. The first involves the behaviour of fiber reinforced concrete based on aggregates from various recycled material. Then the influence of distance among two or more fibers is observed. For completeness the results from shear tests are presented in the end of this paper. The results were attained in the study of effects of number of fibers positioned next to each other. It appeared that there is a peak (optimum) in the relation between the number of fibers and the admissible force. Also of great importance is the shear test, which provides a bigger toughness and an additional significant peak in the damage section of the relation force – displacement. It seems that this peak is due to a kind of refreshment of the composite material. From this paper, I know about properties of materials related to my project. Also this experiments targeted on the study of concrete composites, their matrix is created from various waste materials, such as brick recycled material crushed from pulling down old bricks, concrete recycled material crushed from old concrete floor, industrial recycled material processed in recycling company WEKO, s.r.o., and siliceous sand. The matrix was prepared from recycled aggregate and Portland cement CEM II/B-M (V-LL) 32.5 R.

3) DUCTILE-FIBER-REINFORCED CONCRETE USING RECYCLED AGGREGATE

Masaya Nakamura, Ken Watanabe (2011)

Nowadays it is essential to take global environmental issues into consideration when planning industrial projects. In concrete industries, studies on recycled aggregate concretes extensively have been carried out. For example, the investigation concerning applicability of Ductile Fiber Reinforced Cementitious composites (DFRCC) using recycled fine aggregate was reported. DFRCCs are composites of cementitious material reinforced with fibers, which is superior to the existing fiber reinforced concrete (FRC), especially in terms of crack-dispersing
Property and mechanical ductility. Although the use of the DFRCC for actual construction work has been reported, the number of such applications is still small. This is partly because of problems of high cost and material properties. In this study they have examined potential applicability of ductile fiber reinforced concrete (DFRC) using recycled 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 water-binder ratio (W/B) was 45, 50, or 55%, the sand-aggregate ratio (s/a) was 100, 80, or 60%, and the target slump test value was 18.0 cm. A mixture of PVA fiber (0.2 mm in diameter, 18 mm in length) and steel fiber (0.55 mm in diameter, 30 mm in length) was used.

2.1 OBJECTIVE AND SCOPE

2.1.1 OBJECTIVE

The main objective of this project is to study the flexural behavior of fibre reinforced concrete beam with recycled aggregates. Fibres are added at different percentages (0%, 0.5%, 1% and 1.5%) and natural aggregates are completely replaced with recycled aggregates.

- ❖ To study the compressive strength of concrete cubes at 7, 28 days.
- ❖ To study the tensile strength of concrete cylinders at 7, 28 days.
- ❖ To study flexural behavior of reinforced concrete beams.
- ❖ To study the crack pattern and deflection.
- ❖ To study the stress strain relation of the beams.

III. METHODOLOGY

3.1 GENERAL

The specimens are subjected to loading separately up to the failure. The load carrying capacity, deflection and crack pattern of the concrete beams are studied. This chapter briefly explains the methodology adopted in this experimental work. In the first phase, the physical properties of ingredients of concrete and fresh concrete properties have been found and a mix design for M25 concrete was calculated.

3.2 EXPERIMENTAL METHOD

The following methodology has been followed in this experimental investigation,

- ❖ Preliminary tests on cement recycled aggregate, quarry dust and polypropylene fibre.
- ❖ Mix design for M25 concrete.
- ❖ Mix proportion for fibre reinforced concrete by using the recycled aggregates and quarry dust.
- ❖ Determination of compressive strength of design mixes.
- ❖ Casting of cubes and cylinders with recycled aggregate concrete and normal concrete.
- ❖ Conducting compressive test and split tensile test on specimens.
- ❖ Casting of beams with recycled aggregate concrete and normal concrete.
- ❖ Conducting flexure test on specimens.
- ❖ This testing methods & procedure is described briefly in the continuous of phase – 2 project.

IV. EXPERIMENTAL INVESTIGATION

4.1 GENERAL

This chapter presents the details of materials used, mix design, details of test specimens and testing method adopted. Basic tests were conducted on recycled aggregate, quarry dust, fine aggregate, coarse aggregate, cement and water to check their suitability for concrete making.

4.2 PREPARATION OF RECYCLED AGGREGATE

Fig 5.1 Recycled aggregates

Recycled aggregates are collected from construction sites and they were broken into pieces. Then the debries were cleaned completely and sieve analysis has been carried out.

4.3 PROPERTIES OF MATERIALS
4.3.1 RECYCLED AGGREGATE
4.3.1.1 Particle Size Distribution

The sieve analysis was carried out as per IS 2386 for different types of crushed recycled concrete aggregate and natural aggregates. It is found that recycled coarse aggregate are reduced to various sizes during the process of crushing and sieving (by a sieve of 4.75mm), which gives best particle size distribution. The amount of fine particles (<4.75mm) after recycling of demolished were in the order of 5-20% depending upon the original grade of demolished concrete. The best quality natural aggregate can obtained by primary, secondary & tertiary crushing whereas the same can be obtained after primary & secondary crushing incase of recycled aggregate. The single crushing process is also effective in the case of recycled aggregate. The particle shape analysis of recycled aggregate indicates similar particle shape of natural aggregate obtained from crushed rock. The recycled aggregate generally meets all the standard requirements of aggregate used in concrete.

4.3.1.2 Specific Gravity and Water Absorption

The specific gravity (saturated surface dry condition) of recycled concrete aggregate was found from 2.64 which are lower as compared to natural aggregates. Since the RCA from demolished concrete consist of crushed stone aggregate with old mortar adhering to it, the water absorption ranges from 3.05% to 7.40%, which is relatively higher than that of the natural aggregates. In general, as the water absorption characteristics of recycled aggregates are higher, it is advisable to maintain saturated surface dry (SSD) conditions of aggregate before start of the mixing operations.

4.3.1.3 Bulk Density

The rodded & loose bulk density of recycled aggregate is lower than that of natural aggregate except recycled aggregate-RCA4, which is obtained from demolished newly constructed culvert. Recycled aggregate had passed through the sieve of 4.75mm due to which voids increased in rodded condition. The lower value of loose bulk density of recycled aggregate may be attributed to its higher porosity than that of natural aggregate.

4.3.1.4 PROPERTIES OF THE FILLING MASSES.

Table 4.1 Properties Of The Filling Masses.

Filling mass	Bulk Density (gm/cm^3)	Particle Size (gm/cm^3)	Water absorption (gm/cm^3)
Siliceous sand (mixture NS)	2.08	2.63	1.86
Concrete recycled material	1.74	2.52	10.26
Brick recycled material	1.79	2.67	15.41
Industrial recycled material	1.55	2.76	50.43

Usually replacement of only 10% to 30% virgin sand is used for new concrete. Using 100% recycled coarse aggregate produces acceptable quality concrete. Recycled fine aggregate is angular, with a high porosity and low specific gravity. Concrete produced with recycled aggregate has lower of the strength of a comparable natural aggregate concrete.

Table 4.2 Physical Properties of Recycled Aggregates

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

4.3.2 QUARRY DUST

Quarry dust is a residue obtained from extraction and processing of rocks which forms finer particles less than 4.75 mm. Quarry dust is used in highways as a surface finishing material. Long term growing demand for aggregates to produce concrete has presented increased problems of supplying of sand. Besides this, environmental rules and regulations and scarcity of natural aggregates results in a continuously increasing trend towards the use of quarry dust in concrete.

Table 4.3 Physical properties of quarry rock dust and natural sand.

Property	**Quarry dust**	**Natural sand**	**Test method**
Specific gravity	2.54-2.60	2.60	IS 2386 (Part III) 1963
Bulk relative density (kg/m^3)	1720-1810	1460	IS 2386 (Part III) 1963
Absorption (%)	1.20-1.50	Nil	IS 2386 (Part III) 1963
Moisture content (%)	Nil	1.50	IS 2386 (Part III) 1963
Fine particles less than 0.075mm (%)	12-15	06	IS 2386 (Part I) 1963
Sieve analysis	Zone II	Zone II	IS 383 - 1970

Table 4.4 Typical Chemical Composition of Quarry Rock Dust and Natural Sand.

Constituent	Quarry rock dust (%)	Natural sand (%)	Test method
SiO_2	62.48	80.78	IS: 4032-1968
Al_2O_3	18.72	10.52	
Fe_2O_3	06.54	01.75	
CaO	04.83	03.21	
MgO	02.56	00.77	
Na_2O	Nil	01.37	
K_2O	03.18	01.23	
TiO_2	01.21	Nil	
Loss of ignition	00.48	00.37	

Table 4.5 Particle Size Analysis of Quarry Dust

S.No	IS Sieve size	Weight retained(kg)	Cumulative weight retained(kg)	% cumulative retained(kg)	% passing
1	4.75 mm	0	0	0	100
2	2.36 mm	0.0019	0.0019	0.19	99.99
3	1.18 mm	0.0673	0.0692	6.92	93.08
4	600µm	0.1760	0.2452	24.52	75.48
5	300 µm	0.2756	0.5208	52.08	47.92
6	150 µm	0.3948	0.9159	91.56	8.44
7	75 µm	0.08	0.9959	99.59	0.41
			Total	274.86	

CALCULATION

Fineness modulus of quarry dust =

$$\frac{Sum\ of\ cumulative\ \%\ retained\ in\ IS\ Sieve}{100} = \frac{274.86}{100}$$

= 2.74

4.3.3 POLYPROPYLENE FIBRE

Today it is very common to add polypropylene fibres into concrete for strengthening concrete and for protection of concrete against micro cracks. Most common count for this application is a PP with a relatively short cut of 12 mm. Other cuts used but less common are 6, 18 and 24 mm. The function of the PP fibre mixed into concrete is not to replace the steel but to avoid the creation of micro cracks in the concrete.

Fibres are coated with spinning oil to improve wetting, improve dispersion within the cement paste, increase the extent of contact and improve bond to the hardened concrete. The fibres are manufactured in a continuous process by extrusion of polypropylene. The extruded material is heated, stretched to improve tensile strength, coated with spinning oil and cut to the required lengths. The manufacturing process includes control checks on heating and cooling temperatures, operating speeds and pressures, stretch ratio and quality of cut and stretching. Quality assurance checks are conducted on spinning oil content, moisture content, weight and denier.The fibres are packed in measured quantities in dispersible paper bags, suitable for 1 m3 of concrete. The bagged fibres are delivered in cardboard boxes. Boxes of fibres must be stored on a clean surface, in dry conditions under cover and away from the possibility of damage. Each box bears the manufacturer's and product name, batch number.

The function of the polypropylene fibre mixed into concrete is not to replace the steel but to avoid the creation of micro cracks in the concrete. Polypropylene fibres are used in concrete to obtain a much better, more stable surface and more resistant piece of concrete.Mixing of the fibres always to be as short as possible in order not to damage the fibres. The ratio of fibres depends on the requirement. It can vary from 0.9 to 5 kg / m3 If transport from mixing plant to construction site is more than 2.5 hours then the mixing of the fibre should take place on the construction site. The more polypropylene fibres are mixed into the concrete the better the quality of the construction and reduction anti micro cracks.

- Avoid micro cracks in concrete
- Improved closed surface of concrete
- Excellent crack reduction in early-age concrete.
- Better concrete durability & reduced surface dusting.
- Improves impact and abrasion resistance.
- Improves mix cohesiveness.
- Reduces segregation of the mix.
- Significant improvement in freeze-thaw cycle resistance.
- Saves time.
- Improves water migration.
- Reduces shotcrete rebound.
- Less concrete waste.

Fig 4.2 Polypropylene Fibre

4.3.4 COARSE AGGREGATE

Locally available coarse aggregates having the maximum size of 10 to 20mm was used in this present work. The results of test conducted on coarse aggregate are given in table 5.2.

Table 4.6 Properties of Coarse Aggregate

SI.NO	Characteristics	value
1	Type	crushed
2	Specific gravity	2.76
3	Fineness modulus	7.48
4	Size	max 20mm size

4.3.5 CEMENT

The cement used in this study is 43 grade OPC manufactured by chettinad cements.

4.3.6 WATER

The portable water available in the college campus has been used.

4.4 MIX PROPORTION

Concrete mix design is a process by which the proportions of various raw materials of concrete are determined with an aim to achieve a certain minimum strength and durability, as economically as possible. The Indian standard method of mix design is used for the design of concrete mix of grade M25.

4.5 DETAILS OF TEST SPECIMEN

C1 - 0.5% Fibre + Natural aggregates + Quarry dust.
C2 – 1.0% Fibre + Natural aggregates + Quarry dust.
C3 - 1.5% Fibre + Natural aggregates + Quarry dust.
C4 - 0.5% Fibre + Recycled aggregates + Quarry dust.
C5 – 1.0% Fibre + Recycled aggregates + Quarry dust.
C6 - 1.5% Fibre + Recycled aggregates + Quarry dust.

4.6 TESTING OF THE SPECIMEN

Laboratory tests were carried out to determine characteristic compressive strength, split tensile strength, load deflection characteristics and stress strain behavior.

4.7 PREPARATION OF SPECIMENS

Before placing the concrete in the mould, its interior surfaces should be oiled. The concrete is filled in to the mould in layers of approximately 5 cm deep. Each layer is compacted either by hand or by vibration. For compaction by hand, the standard tamping bar should be used and the number of shocks should be even. Then all specimens have been cured for 28 days.

4.8 COMPRESSIVE STRENGTH TEST

The specimens are tested for compressive strength on compression testing machine provided with two steel bearing plates with hardened faces. The cubes are placed in the machine such a manner that the load is applied to the opposite sides of the cubes as cast. The load should be applied without shock and increased continuously at a rate of approximately 140kg/cm^2 / min. until the resistance of the specimen to the increasing load breaks down and greater load can be sustained. The measured compressive strength of the specimen is calculated by dividing the maximum load applied to the specimen during the test by the cross – sectional area, calculated from the mean dimensions of the section.

Compressive Strength = Ultimate Load / Cross sectional area of specimen

Figure 5.3 Compressive Strength Test on Concrete Cube

4.9 SPLIT TENSILE STRENGTH TEST

The split tensile strength of concrete incorporating that using Recycled aggregates with Polypropylene fibres and Quarry dust replacement at the end of 7 days and 28 days strengths are found,

Split tensile strength in N/mm^2 = $2P/\pi dl$

Where,

P = maximum load
πdl = surface area of the specimen

Figure 5.4 Split Tensile Test on Concrete Cylinder

4.10 EXPERIMENTAL PROGRAM

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 behavior and splitting tensile strength of the beams. All the tests have been carried out in loading frame with a capacity of 500 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 2 KN. At each load increment the deflection measured is recorded. All the specimens are loaded up to the failure.

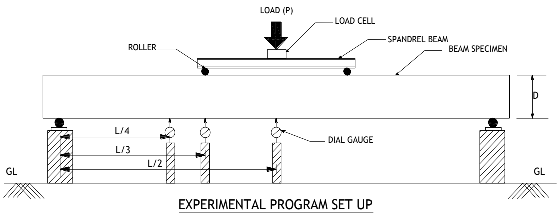


Figure 5.5 Experimental Test Setup

V. RESULTS AND DISCUSSION

5.1 GENERAL

The results of the experimental investigation on cube specimens, prism specimens and six beam specimens are presented in this chapter. The behavior of beam specimen in terms of crack development, failure mode and ultimate loads were observed during the test.

5.2 COMPRESSIVE STRENGTH OF CUBES

The Compressive Strength Results of Concrete cube Specimens for 7 and 28 days are presented in the Table 6.1 and the comparisons of the results are shown in Figure 6.1.

Table 5.1 Compressive Strength Test Results

SPECIMENS	7 days [N / mm^2]	28 days [N / mm^2]
Control specimen	20.32	32.14
C1	29.33	33.92
C2	24.29	26.67
C3	19.26	22.82
C4	28.88	33.62
C5	24.00	27.26
C6	18.67	22.37

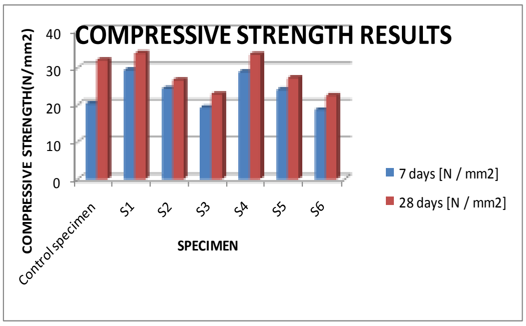


Figure 5.1 Compressive Strength Results

From the results of compressive strength it is observed that the compressive strength of concrete with recycled aggregate is same as that of natural aggregates. Hence Recycled aggregates can be used to replace natural aggregates completely.

5.3 SPLIT TENSILE STRENGTH OF CYLINDERS

The Split Tensile Strength Results of Concrete Cylinder Specimens for 28 days are presented in the Table 6.2 and comparisons of results are shown in Figure 6.2.

Table 5.2 Split Tensile Test on Cylinders

SPECIMENS	SPLIT TENSILE STRENGTH FOR 7 DAYS [N/mm^2]	SPLIT TENSIL STRENGTH FOR 28 DAYS [N/mm^2]
Control specimen	2.26	2.28
C 1	2.31	2.32
C 2	2.28	2.42
C 3	2.19	2.24
C 4	2.34	2.34
C 5	2.31	2.36
C 6	2.24	2.28

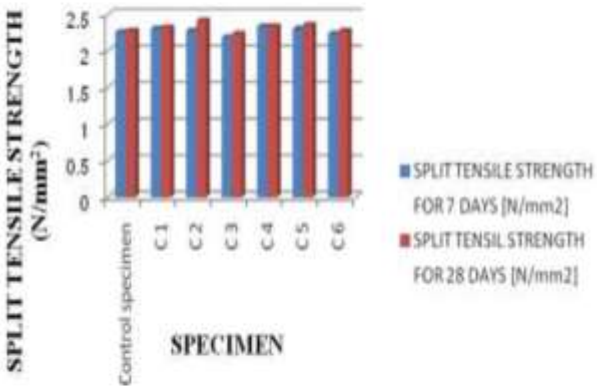


Figure 5.2 Split Tensile Test Results

From the results of split tensile strength it is observed that the split tensile strength of concrete with recycled aggregate is same as that of natural aggregates. Hence Recycled aggregates can be used to replace natural aggregates completely.

5.4 FLEXURAL STRENGTH OF BEAMS

The Flexural Test Results for the Beams Specimens are presented in the Table6.3,

BEAM DETAILS

S1 – 0% Fibre + Recycled aggregates + Quarry dust.

S2 – 0.5% Fibre + Recycled aggregates + Quarry dust.

S3 - 1% Fibre + Recycled aggregates + Quarry dust.

S4 – 1.5% Fibre + Recycled aggregates + Quarry dust.

S5 – Control beam specimen

Table 5.3 Flexural Test Results

S.No	Specimen Type	Initial Crack	Ultimate Load
1	S1	12	48.545
2	S2	14	54.971
3	S3	10	46.243
4	S4	8	42.618
5	S5	10	44.712

From the results of flexure test it is observed that the optimum percentage of replacement of fibre is 0.5% with complete replacement of natural aggregates with recycled aggregates.

5.5 DEFLECTIONS FOR BEAMS

Table 5.4 Experimental Results for Specimen S1

Load in kN	**Deflection at L/2 in mm**	**Deflection at L/3 in mm**	**Deflection at L/4 in mm**	**Remarks**
0	0	0	0.055	
2.134	0.282	0.261	0.315	
4.256	0.624	0.532	0.785	
6.381	0.951	0.786	1.095	
8.158	1.264	1.096	1.587	
10.131	1.728	1.456	1.897	
12.054	2.180	1.854	2.367	
14.281	2.981	2.548	2.632	Initial crack
16.081	3.391	2.936	2.935	
18.125	4.080	3.451	3.542	
20.148	4.580	3.982	3.722	
22.075	5.091	4.432	3.991	
24.136	5.570	4.954	4.064	
26.098	6.081	5.358	4.345	
28.286	6.742	5.916	4.730	
30.068	7.392	6.484	5.075	
32.154	8.482	7.402	5.457	
34.282	10.254	8.946	6.020	
36.082	13.156	11.358	7.105	
38.146	14.213	13.998	9.835	
44.521	14.692	14.587	11.635	
54.971	16.754	14.867	14.675	Ultimate

Load deflection behaviour of S1 specimen shows that the maximum deflection occurs at mid span of the beam and minimum at one fourth of the beam. Then it is compared to control specimen.

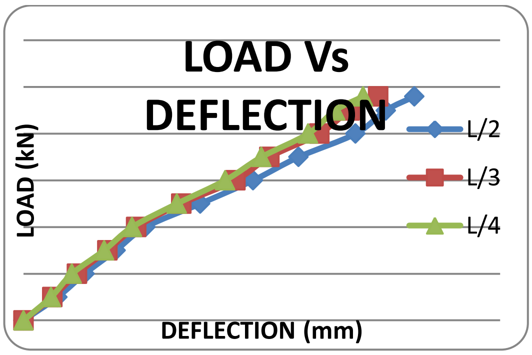


Figure 5.3 Load Vs Deflection for S1

Table 5.5 Experimental Results for Specimen S2

Load in kN	Deflection at L/2 in mm	Deflection at L/3 in mm	Deflection at L/4 in mm	Remarks
0	0	0	0.055	
2.134	0.282	0.261	0.315	
4.256	0.624	0.532	0.785	
6.381	0.951	0.786	1.095	
8.158	1.264	1.096	1.587	
10.131	1.728	1.456	1.897	
12.054	2.180	1.854	2.367	Initial Crack
14.281	2.981	2.548	2.632	
16.081	3.391	2.936	2.935	
18.125	4.080	3.451	3.542	
20.148	4.580	3.982	3.722	
22.075	5.091	4.432	3.991	
24.136	5.570	4.954	4.064	
26.098	6.081	5.358	4.345	
28.286	6.742	5.916	4.730	
30.068	7.392	6.484	5.075	
32.154	8.482	7.402	5.457	
34.282	10.254	8.946	6.020	
36.082	13.156	11.358	7.105	
38.146	15.241	14.875	9.835	
43.621	16.672	14.987	11.635	
48.545	17.167	15.146	14.879	Ultimate

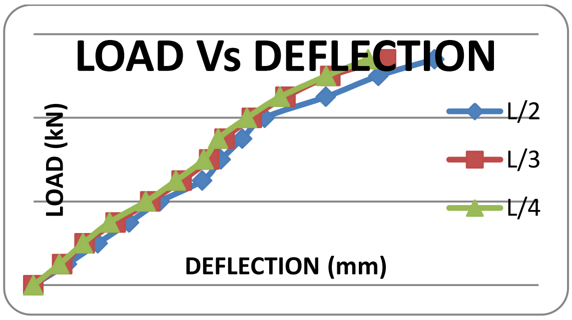


Figure 5.4 Load Vs Deflection for S2

Load deflection behaviour of S2 specimen shows that the maximum deflection occurs at mid span of the beam and minimum at one fourth of the beam. Then it is compared to control specimen.

Table 5.6 Experimental Results for Specimen S3

Load in kN	Deflection at L/2 in mm	Deflection at L/3 in mm	Deflection at L/4 in mm	Remarks
0	-0.022	-0.003	0.61	
2.227	0.541	-0.046	0.927	
4.061	0.967	-0.093	1.362	
6.157	1.462	-0.110	1.650	
8.122	1.836	-0.118	1.962	
10.087	2.275	-0.104	2.562	Initial Crack
12.183	2.368	-0.089	2.910	
14.148	2.428	-0.049	3.253	
16.113	2.539	0.017	3.715	
18.209	2.655	0.122	4.165	
20.043	2.787	0.269	4.520	
22.139	2.964	0.403	4.872	
24.235	3.135	0.559	5.192	
26.069	3.593	0.719	5.617	
28.165	3.945	0.957	5.920	
30.130	4.365	1.145	6.255	
32.095	4.925	1.383	6.697	
34.191	5.347	1.716	7.012	
36.287	5.915	1.981	7.432	
38.121	6.983	2.343	8.122	
40.086	8.708	3.074	9.162	
42.051	12.050	4.382	11.187	
44.016	15.327	9.958	13.130	
46.243	18.241	17.846	17.264	Ultimate

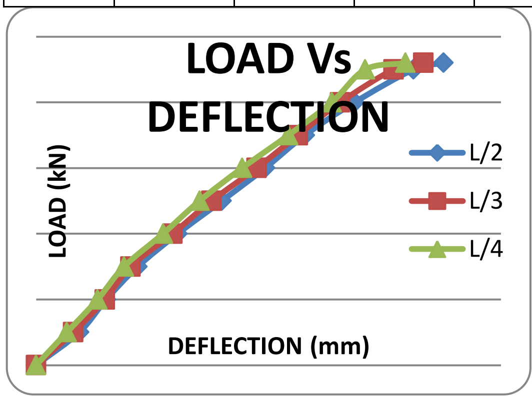


Figure 5.5 Load Vs Deflection for S3

Load deflection behaviour of S3 specimen shows that the maximum deflection occurs at mid span of the beam and minimum at one fourth of the beam. Then it is compared to control specimen.

Table 5.7 Experimental Results for Specimen S4

Load in kN	Deflection at L/2 in mm	Deflection at L/3 in mm	Deflection at L/4 in mm	Remarks
0	-0.035	-0.017	-0.1595	
2.358	0.394	-0.032	-0.058	
4.192	0.743	-0.105	-0.0522	
6.157	1.423	-0.046	-0.0435	
8.122	1.682	-0.049	-0.0696	Initial Crack
10.087	0.992	0.004	-0.0783	
12.052	1.175	0.367	-0.0348	
14.148	1.550	0.958	0.0406	
16.244	1.732	1.450	0.1334	
18.078	2.060	2.017	0.2668	
20.174	2.297	2.659	0.3915	
22.139	2.635	3.285	0.5452	
24.366	3.032	3.651	0.7743	
26.200	3.345	3.934	1.1455	
28.165	3.807	4.298	1.5428	
30.130	4.175	4.705	2.2446	
32.095	4.525	5.798	3.4191	
34.191	5.060	6.935	5.133	
34.879	5.332	7.653	5.275	
35.647	6.230	8.837	5.873	
36.201	7.952	10.79	8.820	
36.984	9.842	11.853	10.652	
37.566	12.335	13.377	12.983	
38.256	16.915	16.467	14.639	
40.485	17.754	16.958	15.262	
42.618	18.056	17.643	16.665	Ultimate

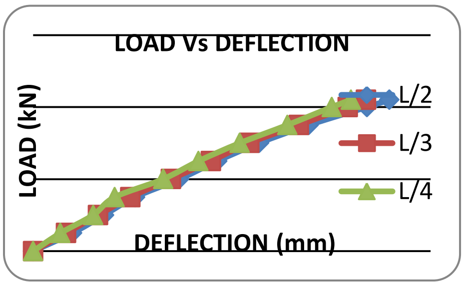


Figure 5.6 Load Vs Deflection for S4

Load deflection behaviour of S4 specimen shows that the maximum deflection occurs at mid span of the beam and minimum at one fourth of the beam. Then it is compared to control specimen.

Load in kN	Deflection at l/2 in mm	Deflection at l/3 in mm	Deflection at l/4 in mm	Remarks
0	0	0.000	0	
2.138	0.364	0.318	0.243	
4.244	0.891	0.785	0.624	
6.381	1.543	1.095	0.951	
8.158	2.096	1.587	1.264	
10.131	2.456	1.897	1.728	Initial crack
12.054	2.521	2.367	2.180	
14.281	2.724	2.632	2.981	
16.081	2.936	2.935	3.391	
18.125	3.451	3.542	4.080	
20.148	3.982	3.722	4.580	
22.075	4.432	3.991	5.091	
24.136	4.954	4.064	5.570	
26.098	5.358	4.345	6.081	
28.286	5.916	4.730	6.742	
30.068	6.484	5.075	7.392	
32.154	7.402	7.632	8.482	
34.282	8.946	9.487	10.254	
36.082	11.358	12.589	13.156	
38.146	14.875	14.325	17.360	
40.218	16.812	16.481	20.412	
44. 712	18.324	17.415	16.896	Ultimate

Table 5.8 Experimental Results for Specimen S5

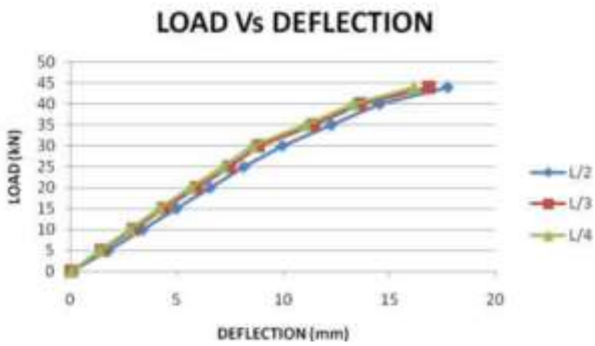


Figure 5.7 Load Vs Deflection for S5

Load deflection behaviour of S5 specimen shows that the maximum deflection occurs at mid span of the beam and minimum at one fourth of the beam.

5.6 LOAD Vs DEFLECTION CURVE FOR BEAMS

Figure 5.8 Load Vs Deflection Curve at L/2 for S1 to S5

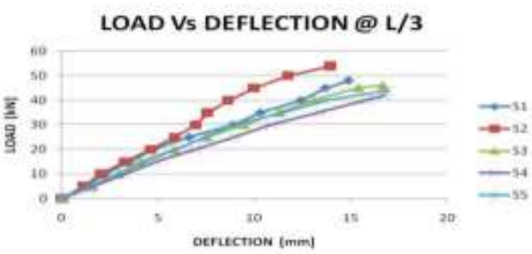


Figure 5.9 Load Vs Deflection Curve at L/3 for S1 to S5

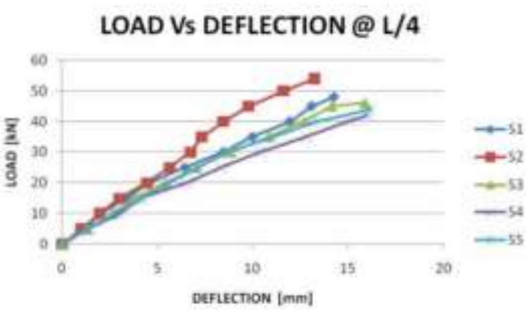


Figure 5.10 Load Vs Deflection Curve at L/4 for S1 to S5

DISCUSSION ON COMPARISION CURVES

The load Vs mid span deflection of the beam is shown in Figure 6.8. It can be seen that S3 and S4 specimens are subjected to maximum deflection under the load. The specimen S3 is subjected to a maximum deflection of 18.241 mm and next to the specimen of S4 which had a maximum deflection of 18.056 mm. The specimens S1, S2 and S5 were undergone small deflections compared to the specimens S3 and S4.

The load Vs one third span deflection of the beam is shown in Figure 6.9. It can be seen that S3 and S4 specimens are subjected to maximum deflection under the load. The specimen S3 is subjected to a maximum deflection of 17.846 mm and next to the specimen of S4 which had a maximum deflection of 17.643 mm. The specimens S1, S2 and S5 were undergone small deflections compared to the specimens S3 and S4.

The load Vs one fourth span deflection of the beam is shown in Figure 6.9. It can be seen that S3 and S4 specimens are subjected to maximum deflection under the load. The specimen S3 is subjected to a maximum deflection of 17.264 mm and next to the specimen of S4 which had a maximum deflection of 16.665 mm. The specimens S1, S2 and S5 were undergone small deflections compared to the specimens S3 and S4.

5.7 STRESS Vs STRAIN BEHAVIOUR

Fig 5.11 Stress – Strain Curve for S1

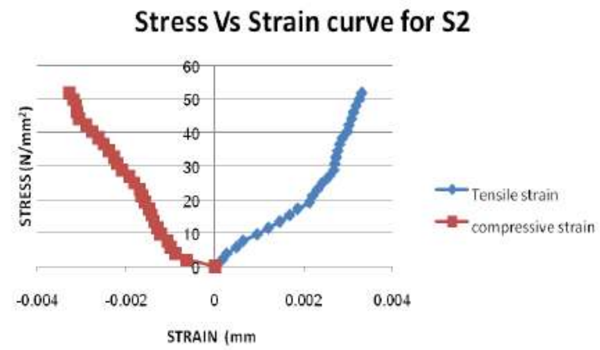


Fig 5.12 Stress – Strain Curve for S2

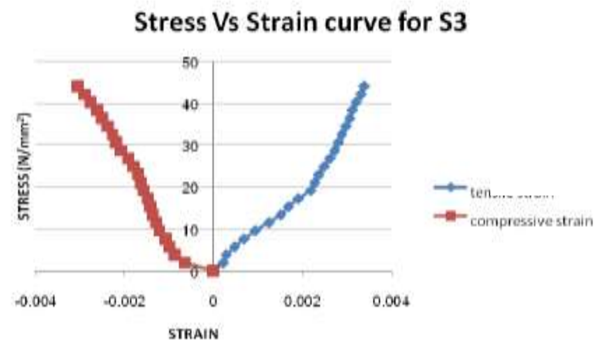


Fig 5.13 Stress – Strain Curve for S3

Figure 5.14 Stress – Strain Curve for S4

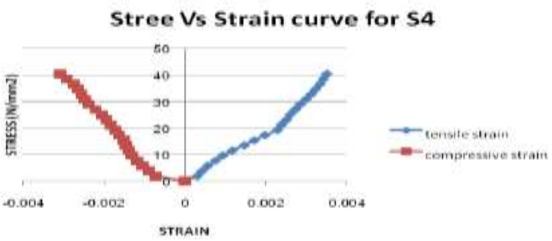
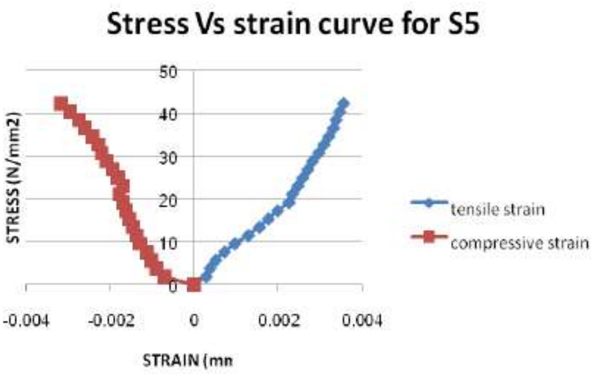


Figure 5.15 Stress – Strain Curve for S5



5.8 STRESS –STRAIN RELATIONS FOR BEAMS

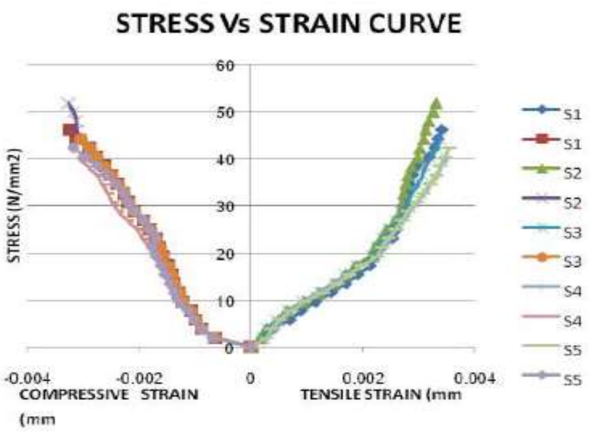


Figure 5.16 Stress – Strain Curve for S1 to S5

DISCSSION ON STRESS – STRAIN CURVES

The stress Vs strain is shown in figure 6.16. It can be seen that the specimen S2 undergone large maximum strain under the load. The specimen S2 is having high longitudinal compressive strain capacity of 0.0031⁻ ' tensile stain capacity is 0.00356.

5.9 DUCTILITY

Ductility is described as the ability of a structural element to sustain inelastic deformation without significant loss in resistance. If the structure possesses ductile behaviour, it will be able to experience large deflections while still holding near ultimate loads and providing sample warning to the imminence of failure. In this study, the displacement ductility was investigated.

Table 5.9 Comparison of Deflections and Ductility Index

Beam Designation	First crack mid span deflection δy (mm)	Ultimate mid span deflection δu (mm)	Ductility index D.I = δu/ δy
0% fibre	2.180	17.167	7.87
0.5% fibre	2.981	16.754	5.62
1% fibre	2.275	18.241	8.02
1.5% fibre	1.682	18.056	10.73
Control	2.456	18.324	7.46

Table 5.9 shows the ductility of the tested beams. The displacement ductility ratio is taken in terms of D.I = δu / δy, which is the ratio of ultimate to first yield deflection, where δu is the deflection at ultimate moment and δy is the deflection when steel yields. In general, high ductility ratios indicate that a structural member is capable of undergoing large deflections prior to failure. In this investigation, it was observed that for beams with reinforcement, the ductility ratio was more than 5.5, which shows relatively good ductility. One of the factors contributing to the good ductility behaviour of the beams was the more surface area of reinforcement.

5.10 STIFFNESS

Stiffness may be defined as load required to cause unit deflection. The stiffness values of control specimen and other beam specimens at ultimate load and first crack load are presented in the table 5.10 and 5.11 respectively.

Beam Designation	First crack Load (kN)	First crack mid span deflection (mm)	Stiffness kN/mm
0% fibre	12	2.180	5.50
0.5% fibre	14	2.981	4.69
1% fibre	10	2.275	4.39
1.5% fibre	8	1.682	4.75
Control	10	2.456	4.07

Table 6.10 Stiffness values at First crack load

Beam Designation	Ultimate Load(kN)	Mid span deflection at Ultimate load (mm)	Stiffness kN/mm
0% fibre	48	17.167	2.79
0.5% fibre	54	16.754	3.22
1% fibre	46	18.241	2.52
1.5% fibre	42	18.056	2.32
Control	44	18.324	2.40

Table 5.11 Stiffness values at Ultimate load

Table 5.10 and 5.11 shows that the stiffness values of beam. Here (0.5% fibre) beam shows stiffer than other beams. This shows that deflection of this beam is less than that of other beams and the initiation of crack is also delayed in (0.5% fibre) beam compare than others.

5.11 ENERGY ABSORPTION CAPACITY

Energy absorption is the energy absorbed or stored by a member when work is done on it to deform it and is called strain energy or Resilience. Energy absorption is calculated as the area under the load versus mid span deflection curve upto first crack load. The energy absorption values of control beam and fibre reinforced concrete beams with recycled aggregates are shown in table 5.12

Energy absorption capacity =1/2PΔ

Table 5.12 Energy Absorption for Various Specimens at first crack load

Beam Designation	Energy Absorption in kN-mm
0% fibre	13.08
0.5% fibre	20.867
1% fibre	11.375
1.5% fibre	6.728
Control	12.28

Table 5.13 Energy Absorption for Various Specimens at ultimate load

Beam Designation	Energy Absorption in kN-mm
0% fibre	412.008
0.5% fibre	452.358
1% fibre	419.543
1.5% fibre	379.176
Control	403.128

Table 5.13 shows that energy absorption capacities of all the beams including control beam and fibre reinforced concrete beams with recycled aggregates. Here it shows that (0.5% fibre) beam have more energy absorption capacity than that of other beams. This shows that this beam offered more resistance to the applied load.

5.12 ENERGY DUCTILITY

The energy ductility may be defined as the ratio of the energy absorbed up to first crack to energy absorbed up to ultimate load. It may be obtained by dividing the area under the load – deflection curve up to ultimate load, by the area under the load- deflection curve up to first crack load. The flexural toughness indices of control beam and RC beams are shown in table 5.14.

Table 5.14 Energy Ductility for various Specimens

Beam Designation	Energy Absorption upto first crack load (A) kN-mm	Energy absorption upto ultimate load (B) kN-mm	Energy Ductility I= B/A
0% fibre	13.08	412.008	31.499
0.5% fibre	20.867	452.358	21.678
1% fibre	11.375	419.543	36.882
1.5% fibre	6.728	379.176	56.357
Control	12.28	403.128	32.828

Table 5.14 shows that the energy ductility of various beams. It shows that S4 (1.5% fibre) higher energy ductility than that of control beam. Due to the good bonding between steel and concrete, it shows better performance of ductility.

5.13 MODES OF FAILURE

The following modes of failure found from the testing of beams under two point loading condition,

- All Reinforced cocnrete beams failed in flexure zone.
- After the first crack load, the reinforcement started yielding and more number of cracks have formed in the flexure zone and extended towards the point loads with increment in loads.
- At the ultimate load, the failure of all reinforced concrete beam occurred with crushing of concrete in compression zone.
- In the Specimens S4 and S5 more number of cracks formed in flexure zone.

Fig 5.17 Flexural Failure of Beam

VI. CONCLUSION

In this project recycled aggregates are used to minimize the cost and to ensure sustainable development and also quarry dust is completely replaced with natural sand. This will suggest a suitable recycling methodology for above waste materials. Additionally polypropylene fibers are used to develop strength and ductility and the effect of replacing recycled aggregates and quarry dust on fiber reinforced concrete have been studied.

The compressive strength of concrete reaches the maximum value at a replacement level of 0.5% of fibers and same behavior is observed while replacing completely with recycled aggregates and quarry dust.

The split tensile strength of concrete reaches the maximum value at a replacement level of 0.5% of fibers and same behavior is observed while replacing completely with recycled aggregates and quarry dust.

The load deflection behavior shows a ductile behavior at 0.5% of fiber replacement level. The stiffness and energy absorption capacity at ultimate load are more in the 0.5% of fibre proportion.

Hence it is concluded that recycled building waste can be effectively used as a fully replacement for natural aggregate.

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