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An Experimental Study on Effect of Polypropelene Fibres on Self Compacting Rubberised Concrete

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Abstract: The worldwide growth of automobile industry and increased use of vehicles lead to increase in volume of waste tyre rubber. Up to now a small part is recycled and millions of tyres are just stockpiled, land filled or buried. Since, concrete is the most widely used construction material on earth, sustainable technologies for concrete construction allow for reduced cost, conservation of resources, utilization of waste materials and the development of eco-friendly durable concrete. Considering the above aspects, a cementitious composite known as Self Compacting Rubberised Concrete (SCRC) for M_{30} concrete was developed by adding crumb rubber as fine aggregate in Self Compacting Concrete (SCC). The investigations on the engineering properties of SCRC revealed that there is a systematic reduction in compressive of SCC on addition of scrap rubber. Addition scrap rubber up to 15% is permissible to get an M_{30} Self Compacting Concrete. In order to improve the fore said engineering properties of SCRC, polypropylene fibres were added to the composite and the properties of fibre Reinforced Self Compacting Rubberised Concrete (SFRSCRC) were evaluated.

Index Terms: SCC, SCRC, Fibre reinforced self-compacting concrete, Polypropylene fibre, crumb rubber, Super plasticizer.

1. INTRODUCTION

Self-Compacting Concrete (SCC), a new kind of High Performance Concrete (HPC) with excellent deformability and segregation resistance, was first developed in Japan in 1986. It is a special kind concrete that can flow through and fill the gaps of reinforcement and corners of molds without any need for vibration and compaction during the placing process.

In recent decades, worldwide growth of automobile industry and increasing use of car as the main means of transport have tremendously boosted tyre production. This has generated massive stockpiles of used tyres. Therefore effectively recovering and reusing waste tires is an urgent and important issue. Landfill disposal, which is the most common method, will be drastically reduced in the near future. In order to properly dispose of these millions of tires, the use of innovative techniques to recycle them is important. Rubber tire can be used in a variety of civil and non-civil engineering applications such as inroad construction, in geotechnical works, as a fuel in cement kiln sand incineration for production of electricity or as an aggregate in cement-based products. Concerning the use of recycled rubber in mortars and concrete, extensive studies have been conducted on used tyre modified concrete and mortars. The reuse of waste tyre rubber in the production of concrete, where tyre rubber can be used as a partial replacement to natural aggregates is an emerging field in this context. The use of rubber aggregates saves natural resources and dumping spaces, and helps to maintain a clean environment. Hence, over the past few years, various researches have been focused on the use of waste tyres in different shapes and sizes in concrete. Preliminary studies show that workable Rubberised Portland Cement Concrete (Rubcrete) mixtures can be made provided that appropriate percentages of tyre rubber are used in such mixtures. Developing such construction materials could have both environmental and economic advantages. However, concrete with scrap tyre aggregates must satisfy the minimum requirements of strength and durability. The idea of developing Self Compacting Concrete (SCC) incorporating rubber aggregates is a novel approach to combine the advantages of both SCC and rubberised concrete.

The use of polypropylene fibres in SCC improves the engineering properties such as ductility, post crack resistance and energy absorption capacity. Fibres bridge cracks and retard their propagation. However, no attempts have been made so far to evaluate the effect of addition of polypropylene fibres to SCRC. This paper reports the strength characteristics of self compacting rubberised concretes with and without polypropylene fibres.

2. EXPERIMENTAL DETAILS

2.1 Materials

2.1.1 Portland Cement

Ordinary Portland Cement-53 grade cement conforming to IS: 12269 is used. The different laboratory tests were conducted on cement to determine standard consistency, initial and final setting time, and compressive strength as per IS 4031.

2.1.2 Aggregate

Crushed aggregate available from local sources having a nominal maximum size of 12mm was used as coarse aggregate. The specific gravity of coarse aggregate was 2.8. River Sand having a nominal maximum size of 4.75 mm was used fine aggregate in mix. The specific gravity of fine aggregate was 2.65.

2.1.3 Crumb rubber

It is used to replace the fine aggregate. Crumb rubber passing through 4.75mm sieve and confirms to zone two was used. The specific gravity of Chipped Rubber is 0.91. Crumb rubber passing through 4.75mm sieve and confirms to zone two was used.

Fig. 1. Crumb rubber

2.1.4 Polypropylene Fibre

These are polypropylene fibres with 6mm cut length. Polypropylene fibres form a network of reinforcement that gets uniformly dispersed and improves the strength characteristics of concrete and reducing the shrinkage cracks and water permeability.

Fig. 2. Polypropylene fibre

Table 1. Properties of polypropylene fibre.

Properties	
Material	100% virgin polypropylene
Specific Gravity	0.91
Ignition Point	360^0C
Melt Point	162^0C
Conductivity	Low
Moisture Absorption	Nil
Alkali Resistance	100% Alkali Proof
Acid & Salt Resistance	High

2.1.5 Chemical Admixtures

To enhance workability of cement, high performance super plasticizer Sika viscocrete 20 HE was used and the dosage level was fixed as 200ml per 50kg cement according to the supplier's brochure. It is a high range water reducer based on Poly Carboxylate Ether(PCE).

2.1.6 Poly Vinyl Alcohol (PVA)

Poly Vinyl Alcohol (PVA) was added to compensate for the strength loss due to the addition of rubber. PVA undergoes polymerization in the presence of water and roughens the surface of the rubber aggregate bringing about a better interfacial bond between the matrix and rubber particles.

2.2 Mix Proportions

There is no standard method for SCC mix design and many pre cast and contracting companies have developed their own mix proportioning methods. So the mix design was done by trial and error method to get a target strength of 30MPa at 28 day. The water powder ratio (w/p) was varied to obtain the strengths. The mixes were checked for self compatibility following EFNARC acceptance criteria. The self compatibility of the mixes was checked by V-funnel test and L-Box test. Final mix proportion obtained is 1:0.27:2.17:1.73. Different mixes were prepared by varying the amount of crumb rubber, fine aggregate, and water powder ratio and polypropylene fibres . After several trials, SCC mix satisfying the test criteria was obtained. The details of the design mix are given in Table 2.

2.3 Tests on Fresh Concrete

2.3.1 J-Ring Test

J-ring test denotes the passing ability of the concrete. About 6 litres of concrete is needed for the test. Moisten the inside of the slump cone and base plate. Place the J-Ring centrally on the base plate and the slump cone centrally inside the J-ring. Fill the slump cone with scoop. Do not tamp. Simply strike off the concrete level with trowel. Remove all surplus concrete. Raise the cone vertically and allow the concrete to flow out through the J-ring.

Measure the final diameter in two perpendicular directions. Calculate the average diameter. Measure the difference in height between the concrete just inside J-Ring bars and just outside the J Ring bars. Calculate the average of the difference in height at four locations in mms.

Note any border of mortar or cement paste without coarse aggregate at the edge of the concrete. The acceptable difference in height between inside and outside should be between 0 and 10 mm.

2.3.2 V-Funnel Test

The flow ability of the fresh concrete can be tested with the V-funnel test. The funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus is measured. Further, T5min is also measured with V-funnel, which indicates the tendency for segregation, wherein the funnel can be refilled with concrete and left for 5 minutes to settle. If the concrete shows segregation, the flow time will increase significantly. According to Khayat and Manai, a funnel test flow time less than 6s is recommended for a concrete to qualify for an SCC.

2.3.3 L-Box

The passing ability is determined using the L- box test. The vertical section of the L-Box is filled with concrete, and then the gate lifted to let the concrete flow into the horizontal section. The height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (h2/h1). This is an indication of passing ability. The specified requisite is the ratio between the heights of the concrete at each end or blocking ratio to be ≥ 0.8.

2.4 Preparation and casting of Specimen

The following mixing sequence was arrived after several trials for optimizing the workability. The fine aggregate mixed well with crumbed rubber. All the ingredients were first mixed in dry condition. Water was mixed thoroughly with the super-plasticizer and PVA. Then calculated amount of water was added to the dry mix and mixed thoroughly for few minutes. For preparing fibre reinforced self compacting concrete added polypropylene fibre in a bucket of water and mixed vigorously. Then spread water along with fibre over the dry mixture.

In making SCRC with crumb rubber the proportion of rubber is varied from 0% to 15% by volume of fine aggregate. For making Fibre Reinforced Self Compacting Rubberised Concrete, Fibre is varied from 0.16% to 0.24% by weight of cement. The details of mixes are given in table 2. Concrete moulds are cleaned properly and the screws are tightened to make sure that no slurry will escape through the joint. After tightening, the moulds are oiled properly for easy striping of the specimen.

2.5 *Tests on Hardened Concrete*

2.5.1 Compressive Test

Compressive strength of concrete is defined as the load, which causes the failure of a standard specimen divided by the area of cross section in uniaxial compression under a given rate of loading. The test of compressive strength should be made on 150mm size cubes using the compressive strength machine.

$$\text{Compressive strength} = \frac{\text{Applied load (N)}}{\text{Area of cube}(\text{mm}^2)}$$

2.5.2 Split tensile strength

A concrete cylinder of size 150mm dia×300mm height is subjected to the action of the compressive force along two opposite edges, by applying the force in this manner .The cylinder is subjected to compression near the loaded region and the length of the cylinder is subjected to uniform tensile stress.

$$\text{Horizontal tensile stress} = \frac{2\text{P}}{\pi\text{x(length of the cylinder)x(diameter of cylinder)}}$$

Where P=the compressive load on the cylinder.

3. RESULTS AND DISCUSSION

The detailed mix proportion for self compacting concrete, self compacting rubberized concrete and fibre reinforced self compacting concrete is given in table 2.

Table 2. Detailed mix proportion

Mix Designation	Cement Kg/m^3	Fly ash Kg/m^3	Fine Aggregate Kg/m^3	Rubber aggregate Kg/m^3	Coarse Aggregate Kg/m^3	w/p ratio	Polypropylene (% by weight of powder content)
SCC	410	110	890	0	710	0.65	0
F1SCC	410	110	890	0	710	0.65	0.16
F2SCC	410	110	890	0	710	0.65	0.2
F3SCC	410	110	890	0	710	0.65	0.24
SCRC1	410	110	845.5	16.8	710	0.6	0
F1SCRC1	410	110	845.5	16.8	710	0.6	0.16
F2SCRC1	410	110	845.5	16.8	710	0.6	0.2
F3SCRC1	410	110	845.5	16.8	710	0.6	0.24
SCRC2	410	110	801	32.96	710	0.6	0
F1SCRC2	410	110	801	32.96	710	0.6	0.16
F2SCRC2	410	110	801	32.96	710	0.6	0.2
F3SCRC2	410	110	801	32.96	710	0.6	0.24
SCRC3	410	110	756.5	49.44	710	0.55	0
F1SCRC3	410	110	756.5	49.44	710	0.55	0.16
F2SCRC3	410	110	756.5	49.44	710	0.55	0.2
F3SCRC3	410	110	756.5	49.44	710	0.55	0.24

Dosage of PVA: 2% by weight of cement
Dosage of Super plasticizer: 200ml for 50kg cement

The Properties of fresh and hardened self compacting concrete, self compacting rubberized concrete and fibre reinforced self compacting concrete is given in table 3.

Table 3. Properties of fresh and hardened concrete

Mix Designation	J-Ring test		L-box test (h_2/h_1 ratio)	Compressive strength (28 day,N/mm^2)	Split tensile strength (28 day,N/mm^2)	Weight (Kg)
	Flow diameter(cm)	Difference in height(mm)				
SCC	56.5	10	0.81	36.2	3.71	8.09
F1SCC	56.2	7	0.85	36.4	3.75	8.093
F2SCC	55	8	0.89	37.4	3.8	8.0942
F3SCC	55.2	8	0.85	37.1	3.78	8.0945
SCRC1	54.5	6	0.9	34.8	3.6	7.897
F1SCRC1	53.5	6	0.92	35.1	3.61	7.9
F2SCRC1	54	8	0.95	36.5	3.67	7.907
F3SCRC1	53.5	7	0.93	36.2	3.67	7.909
SCRC2	56	7	0.91	33.3	3.48	7.801
F1SCRC2	57	8	0.98	33.6	3.51	7.858
F2SCRC2	56.5	7	0.93	34.3	3.57	7.86
F3SCRC2	56.5	6	0.94	34.1	3.55	7.863
SCRC3	58	6	0.98	31.2	3.3	7.731
F1SCRC3	56	7	0.98	31.3	3.33	7.734
F2SCRC3	57.5	9	0.95	32	3.4	7.738
F3SCRC3	57	8	0.93	31.8	3.38	7.739

3.1 Compressive Strength

The cubes were cast and tested after 28 days of curing period. Results were represented in figure 2 and figure 3.it was indicating the strength pattern when Fine aggregate was replaced with crumb Rubber and effect of addition polypropylene fibre in compressive strength. It was observed that the 13.8% of Compressive Strength was reduced with increase of replacement of fine aggregate with tyre rubber powder by 15%. The addition of polypropylene fibres to the mix at a dosage of 0.2% increased the 28 day's compressive strength of the mix by 2.5% to 4.6% due the confinement provided by fibres. The compressive strength at 2% dosage is slightly higher than strength at 2.4% dosage. Compressive strength increases for all dosage of fibres than normal self compacting concrete. Reason is that due to confinement provided by fibre, bonding characteristics of concrete increases and hence compressive strength increases with the increases in the fibre content.

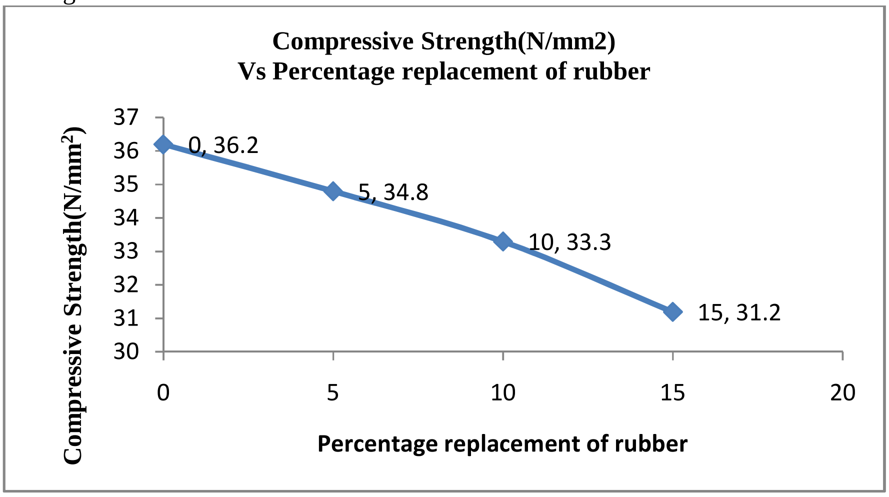

Fig. 3. Compressive Strength(N/mm2) Vs Percentage replacement of rubber

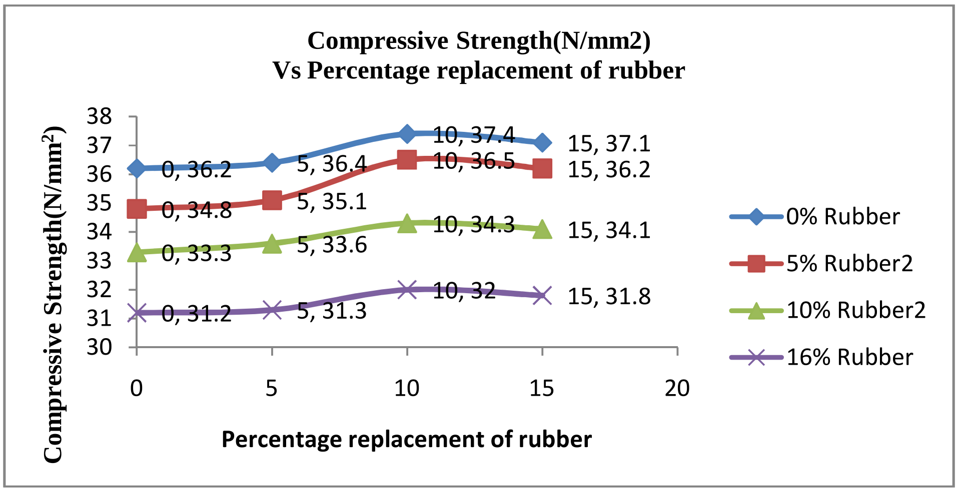

Fig. 4. Compressive Strength(N/mm2) Vs Percentage replacement of rubber

3.2 *Split Tensile Strength*

The cylinders were cast and tested in the laboratory after the curing period of 28 days. Results are represented in figure 3 and figure 4. Results indicates the strength pattern, when Fine aggregate was replaced with Crumb Rubber. It was observed that 11 % of split tensile strength was reduced, with increasing the percentage replacement of sand with Crumb Rubber up to 15%. Also 2.3% average increase of split tensile strength was observed, when 0.2% of polypropylene fibre was added.

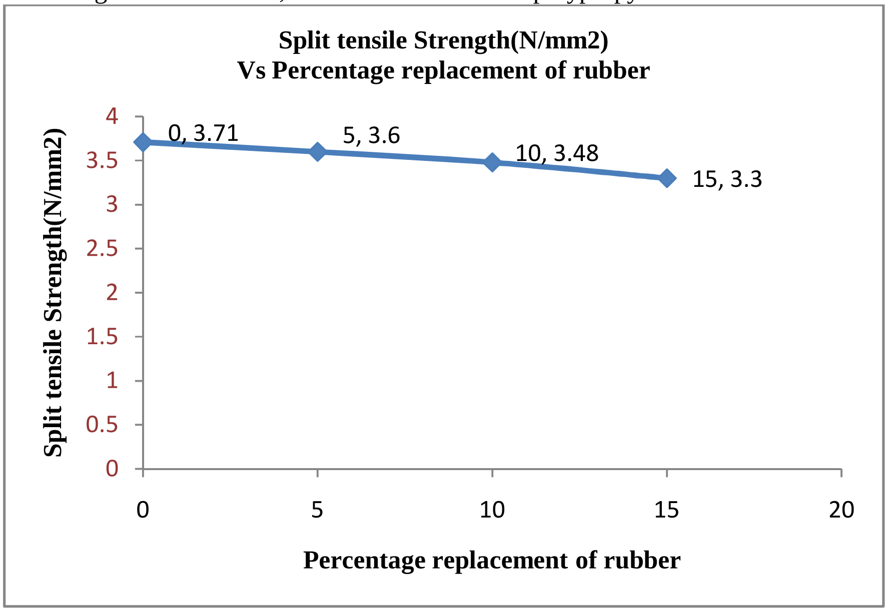

Fig. 5. Split tensile Strength(N/mm2) Vs Percentage replacement of rubber

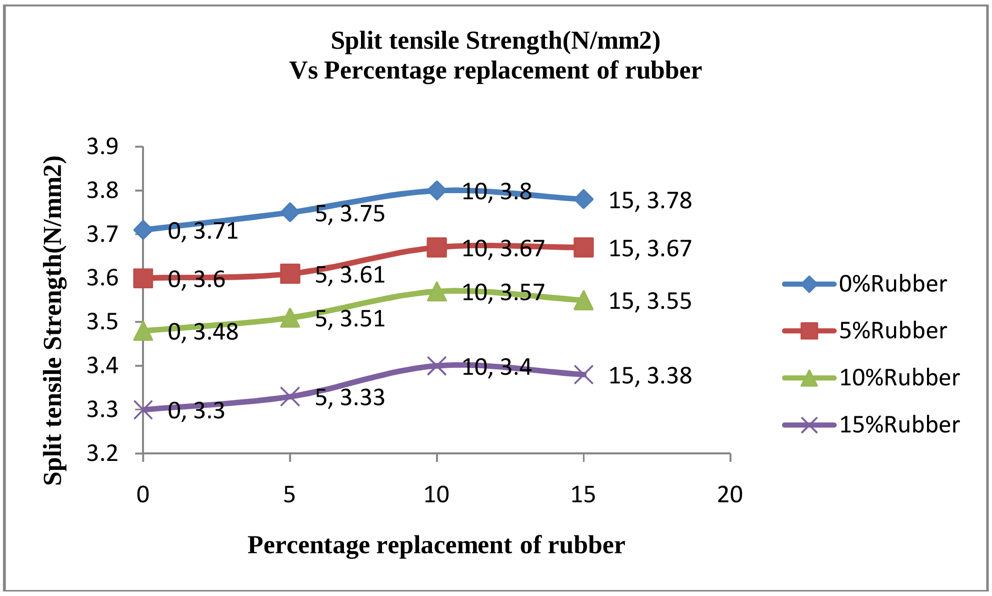

Fig. 6. Split tensile Strength(N/mm2) Vs Percentage replacement of rubber

3.3 Weight

It was observed that 4.4% of weight of cube was reduced with increase of replacement of fine aggregate with tyre rubber powder by 15%.

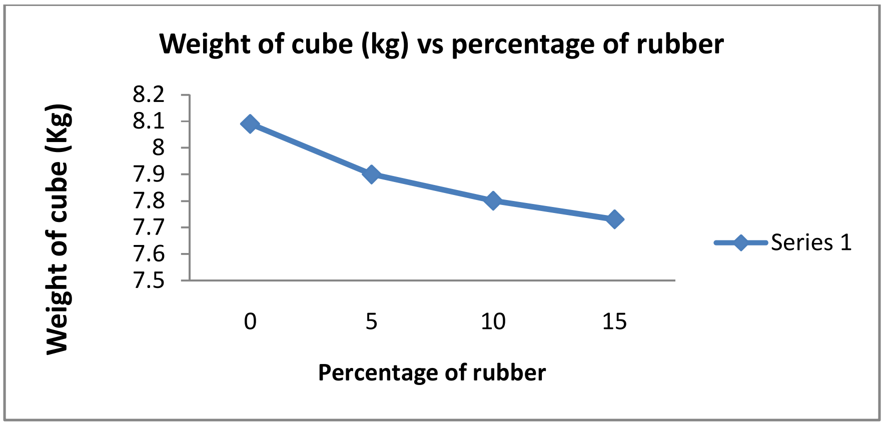

Fig. 6. Weight of cube (kg) vs percentage of rubber

4. CONCLUSION

Based on the experimental research and behavior studies of Self- Compacting Rubberised Concrete (SCRC) with and without polypropylene fibre, the following conclusions can be drawn.

- The workability increases with increase in the percentage of rubber in place of normal fine aggregate.
- The weight of the cube decreases with increase in the percentage of rubber as fine aggregate. The decrease is up to 4.4%nominal.
- Compressive strength and split tensile strength of concrete decrease with increase in the percentage of rubber. The decrease is nominal, so that the concrete with crumb rubber up to15% of fine aggregate can be used for preparing M_{30} concrete.
- Addition of polypropylene fibre up to 0.2% by weight of powder content improves the compressive strength and split tensile strength of SCRC

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