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Compressive Strength and Flexural Strength Study of Railway Sleepers using Recycled Waste Tyre Rubber

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Abstract—*The objective of this paper is to investigate the compression strength and flexural strength of the railway sleeper specimen using waste tyre rubber. A rubber concrete composite material is used as a railway sleeper specimen where concrete is used as matrix and crumb rubber is used as particulate fiber. Preparation of the railway sleeper specimen with different percentage of rubber is used in concrete. In rubber concrete composite the fine aggregate is replaced by the rubber. Portland cement of 53 grades is used to investigate the compressive strength and flexural strength of the railway sleeper. By adding crumb rubber i.e. ductile impurities to a high brittle material (Conventional concrete sleeper) makes it some ductile due to which rubber concrete composite sleepers have some attractive properties like high toughness, high energy absorption capacity, high impact resistance, high damping resistance and low brittleness comparing to conventional concrete sleepers. There are some positive properties increases but compressive strength and flexural strength of rubber concrete composite decreases with the percentage increase of the rubber in concrete. In this paper the investigation has been done to find the suitability of rubber up to what percentage of rubber in place of fine aggregate is suitable for the railway sleepers according to Indian railway standards.*

Keywords: *Railway sleeper, Waste Tyre Rubber, Compressive strength, flexural strength, Samples.*

1. INTRODUCTION

In the past railway sleepers are used made of wood which is natural composite. The wooden railway sleepers were best due to high compressive strength, impact resistance, damping resistance and flexural strength. But due to rapid deterioration and deforestation, it was replaced by concrete railway sleeper. Concrete railway sleeper has some defects like high brittleness due to which one cannot find any crack initiation and low impact resistance, low damping resistance and low toughness etc.

So at this stage researchers have realized a better substitution of the conventional concrete railway sleepers and the idea of a rubber concrete composite comes under considerations. In this approach the conventional concrete railway sleeper is filled with some percentage of rubber in the place of fine aggregate. Hence in this way a synthetic composite material is made in which concrete is used as matrix and particulate rubber or crumb rubber is very fine particle of rubber ranging 0.075 to 4.75 mm. The crumb rubber is shredded in small particles by ambient shredding, cryogenic shredding and pyrolysis method. M50 mix ratio is chosen for the current investigation. Experimental evaluation carried out to study mechanical properties to rubber concrete sleepers for the suitability of rubber concrete in railway sleepers as per Indian railway standards and it is recommended due to high impact strength and energy absorption [Shashikala A.P., 2015]. Impact load is 50% higher for rubber concrete railway sleepers comparing to conventional concrete railway sleepers and crumb rubber increased the crack initiation under impact load by 80-110% [Afia S. Hameed, 2016]. Other approaches for research on the replacement of sleepers using another materials such as polymer concrete, reinforced plastics, rubber and fiber composite materials [Hoger D.I., 2000; Jordan R., 1987; Miura S., 1998; Hasan J. Mohammed, 2011]. The flexural strength decreased 50% and damping increased by 37.5% by addition of rubber waste additives. By adding crumb rubber the density of concrete is reduced and the air content is increased. The compressive strength and flexural strength of the rubber concrete composite is reduced with the increase in rubber content. The material shows high toughness, impact resistance and thermal insulation. The literature study suggests that presence of small particles crumb rubber concrete increased the resistance to crack in impact load, ductility property and fatigue resistance. The material behaves slightly ductile due to which elastic failure and impact resistance is improved.

2. MATERIALS

Appropriate properties of the materials are required for high strength specimen. So the specification of the ingredients is listed in Table 1.

Table 1: List of Materials Required

S. No.	Name of Item	Specification		Quantity
1.	Waste Tyre Crumb Rubber	Range: 4.75 to 0.075mm Fineness Modulus: 2.72 Bulk Density: 670 kg/m^3		One number By Weight (Initially 40 kg)
2.	Cement	Ordinary Portland Cement of 53 grade		Four number (each bag 40 kg)
3.	Coarse Aggregate and Fine Aggregate	IS Sieve Conforming Grade Zone II	4.75 mm	Four number (each bag 40 kg)
		Crushed Stone particle	Size less than 20 mm	
4.	Super Plasticizer	Naphthalene based Super Plasticizer		Two number
5.	Water	Normal Drinking Water		

3. CONTROL MIX DESIGN

The mix design is based on IS: 10262-2009 and ACI codes are used to attain high strength concrete mixes. A hit and trial method is used for the development of high strength concrete because material properties can be different. M50 mix design ratio is used.

3.1 Mix Design Ratio for Samples of Compression Test

3.1.1 Calculations for Control Design for M50 with 0% Rubber

1) Target mean strength = 50+(5×1.65)MPa=58.25 MPa

2) Selection of water cement ratio= 0.34

3) Calculation of cement for M 50

As we use 495 kg/m^3cement and mould size is 15cm×15cm×15cm thenAmount of cement for 15×15×15cm^3= 3375 cm^3

Amount of water for 495 kg/m^3=(495×3375×10^-6)=1.670625 kg

4) Fine aggregate is 684 Kg/m^3

For 15 ×15× 15 cm^3=(684 .003375)=2.3085 kg

5) Coarse aggregate is 1097 Kg/m^3

For 15×15×15cm^3 =1097 ×.00375 = 4.1137 kg

Crushed stone size is 20 mm

6) Water ratio is 158 Kg/m^3

For 15×15 ×15 cm^3 = (158 ×.00375) = (.5925)kg

7) Super plasticizer = (36.75 mg)

8) Silica fume = 0.34×0.00375=0.1275 kg

Six sample is prepare by mold which dimension is 15 cm ×15 cm ×15 cm Therefore the amount will be needed is six times as calculated earlier. So the amount is six times as we used.

Cement: fine aggregate: coarse aggregate: water:silica fume =0.2034:0.28:0.50076:0.071:0.0155

For preparing six sample the amount should be in this ratio

Cement=11.5 kg

Fine aggregate =15.96 kg

Coarse aggregate =28.54 kg

Water = 4.047 kg

Silica fume= 0.8835 kg

3.1.2 Mix Design of R5 (with 5% Rubber)

From the earlier Ratio for R0

Cement: fine Aggregate: coarse aggregate: water: silica =(0.2034:0.28:0.50076:0.071:0.155)

For R5 sample, fine aggregate is replaced by crumb rubber 5% by weight in preparing six sample.

Amount of cement for 6 sample =10.02 kg

Amount of fine aggregate for 6 sample=15.96 kg

But we replace 5% of fine aggregate with rubber 15.96 ×0.95 =15.162 kg

Amount of rubber = 0.69 kg

Amount of Coarse aggregate =24.66 kg

Amount of water =3.4 liter

3.1.3 Mix Design of R10 (with 10% Rubber)

In R10 mix design all amount would be same as R0 except fine aggregate which reduce 10 percent by weight so fine aggregate would be =(15.95×.90)=14.36 kg

Amount of crumb rubber =15.95×.10 =1.59 kg

3.1.4 Mix Design of R15 (with 15% Rubber)

In R15 mix design all amount would be same as R0 except fine aggregate which reduce 10 percent by weight so fine aggregate would be =(15.95×.85)=13.56 kg

Amount of rubber =15.95×.15 =2.93 Kg

Figure 1: Mixing of all materials

3.2 Mix Design Ratio for Samples of Flexural Test

The ratio of the all ingredients required in the fabrication of the samples of rubber concrete composite for flexural test is same as the ratio used for the fabrication of samples for compression test. All samples are designed and mixed with same as the samples are designed for compression test. Only the quantity is required of different ingredients for the fabrication of flexural test specimen is different. The M50 mix design ratio is also used for the fabrication of samples for flexural test. The beam like mold of 100x10x10 mm is used. Six samples are fabricated for a particular percent of rubber used in the specimen.

Cement: fine aggregate: coarse aggregate: water: silica fume =0.2034 : 0.28:0.50076:0.071:0.0155

Cement =17.03 kg

Fine aggregate =23.64 kg

Coarse aggregate =42.28 kg

Water =5.99 kg

Silica fume =1.30 kg

Rubber =fine aggregate is replaced by 0,5,10 and 15% of weight

4. PREPARING THE SAMPLES

A mold of 150x150x150 mm size and a mold of 50x10x10 are prepared for the casting of the compressive strength testing specimen and the casting of the flexural strength testing specimen respectively. The mold is polished with crude oil for easy removal. Materials are mixed in ratio for M50 target strength in compression test. A high strength concrete mix is used to obtain the desired mechaical properties. The fine aggregate is replaced by crumb rubber by some percentages of weight of fine aggregate. Zero percent rubber in specimen means pure conventional concrete. Rubber concrete composite is fabricated with percent of rubber where fine aggregate is replaced by crumb rubber. The paste of mixed material is poured in mold and rammed properly with rammer. Proper ramming reduces the porosity and air bubbles in the casting. Mixing of rubber reduces the density of the conventionalconcrete. Fabricated samples are left out for 24 hours for proper solidification. After 24 hours when sample is solidified in proper shape and it should be removed from the mold.

Figure 2: Mold filled with the paste of proper mix ratio

Figure 3: Fabricated samples of compression test and flexural test

5. CURING OF SAMPLES

All six samples are put in the water. Compressive strength increases with time but after 28 days the compressive strength becomes approximately constant. When samples put in water its porosity get decreases and compressive strength increases.

Figure 4: Samples in water

6. MECHANICAL TESTS

6.1 Compression Test

Compression test perform on universal testing machine which body is metallic. The destructive test is performed on each sample in definite interval. All 24 samples are tested in the interval of 7, 14, 21, 28, 35 and 42 days approximately. The specimen cubic block put on a plane surface then holds by a surface from top side. It means the specimen cubic block is sandwiched between two surfaces. It is an automatic compressive strength testing machine in which the compressive load is gradually applied on the block. The results are shown from analytical sensor dial and it gives the fracture load in ton.

Figure 5: Compression test of prepared samples

6.2 Flexural Test

The specimen used in this test is beam. The sample size is 50 × 10 × 10 cm^3.

For cubic sample approximate weight of the sample is 9 kg and the size is 15 × 15 × 15 cm^3. Then approximate weight of a beam

9/x = (15×15×15) / (10×10×50)

Where x equals to weight of a beam. The value of x is about to 13.33 kg.

The ratio of mix design for specimen of flexural test,

Cement: fine aggregate; coarse aggregate: water = 0.2034 : 0.28 : 0.50076 : 0.071

The mix design ratio for specimen of flexural test is same as the specimen of compression test.

Figure 6: Flexural test of prepared samples

7. RESULTS

7.1 Compression Test Results

When the load is applied gradually on the test specimen after bearing some load the specimen fractured. So at which load the specimen fractures is called fracture load in compression and this load per unite cross section is called compressive strength.

Cross section area of cubic block (A) = 150x150 mm^2

Test results are the fracture load in Ton.

Force applied on the cubic block (F)= fracture load x g

= Ton x 1000 x 9.81

= Ton x 9810

= Newton

Compression Strength = F/A (MPa)

Table 2: Compression Test Results (MPa)

	Days					
Samples	**Day 7**	**Day 14**	**Day 21**	**Day 28**	**Day 35**	**Day 42**
R0	38.8	47.5	52.3	56.2	56.5	56.7
R5	36.3	44.1	50.9	52.2	52.7	52.8
R10	33.1	42.6	47.2	50.1	50.3	50.7
R15	29.64	38.5	43.1	45.6	45.9	46.2

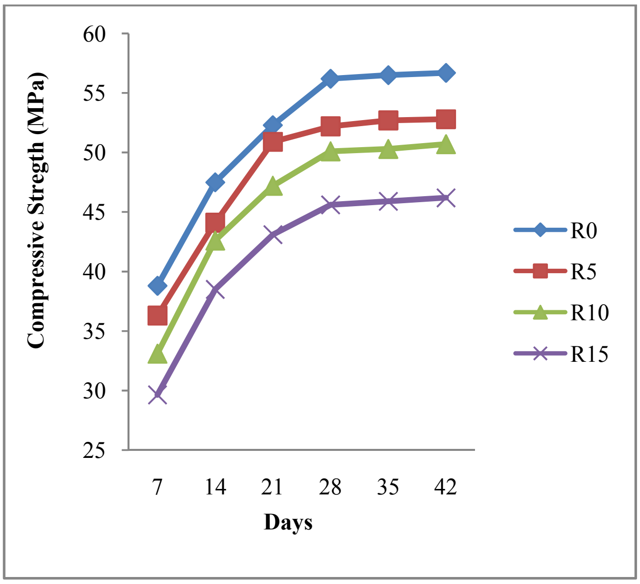

Figure 7: Variation in Compressive Strength

It has been found that there is decrement in compressive strength when rubber percentage increases when it is replaced with fine aggregate. The compressive strength increases with time of curing of samples in water. Compressive strength of concrete sample increases day by day and then saturated up to 28 days and approximately constant after 28 days due to porosity deceases by water.

7.2 Flexural Test Results

The size of sample is 50x10x10 cm^3. Two points are marked for support 5cm from both end of the beam and a point is marked on exact mid of the sample for the application of load. The beam is supported by two roller support and the load is applied on mid-point of sample by the help of roller. The load is applied gradually on the test sample so at which load the specimen fractures is called fracture load in bending and this load per unite cross section is called flexural strength.

Cross section area of cubic block (A) = 10x10 mm^2

Test results are the fracture load in kilo newton.

Flexural Strength = F/A (MPa)

Table 3: Flexural Test Results (MPa)

	Days					
Samples	**Day 7**	**Day 14**	**Day 21**	**Day 28**	**Day 35**	**Day 42**
R0	6	8	8.2	8.6	9	9.5
R5	5.8	7.5	7.55	8	8.1	8.5
R10	5.5	6	7	7.7	7.9	8
R15	4	5.8	6.6	7	7.4	7.8

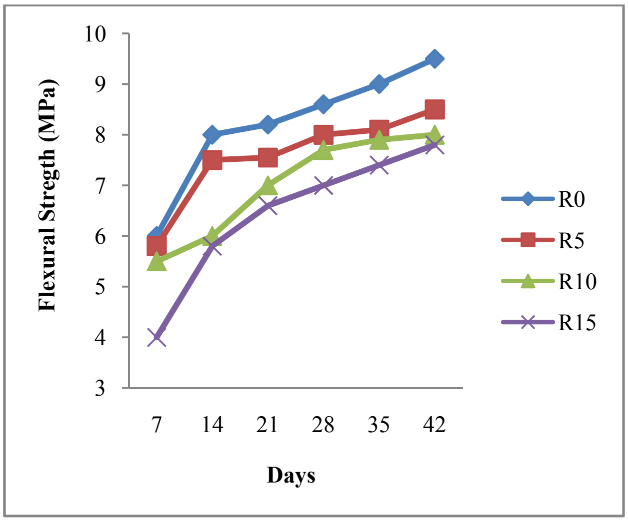

Figure 8: Variation in flexural Strength

The flexural Strength is decreases with the increase of the rubber particulate in the conventional concrete and the flexural strength increases with time of curing of samples in water due to porosity decreases by water.

8. CONCLUSIONS

Railway sleeper is a composite material in which concrete is used as matrix and powdered waste tyre rubber is used as particulate fiber and it is recommended due to high impact strength and energy absorption. There are some good properties increases but compressive strength and flexural strength of rubber concrete composite decreases with the percentage increase of the rubber in concrete. So in this present work a proper investigation and evaluation has been done for look after the changes in compressive strength and flexural strength.

Mixing of rubber particle in conventional concrete decreases density and increases porosity so the results of the compression test and flexural test shows that decrement by 10-20% for 0-15% of rubber replacement in both strength when rubber percentage increases. The variation of compressive strength and flexural strength shown in Figure 7 and Figure 8 suggests that conventional concrete with 0% of rubber particle has the highest compressive and flexural strength and it is continuously decreases with increase of rubber percentage. The compressive strength and flexural strengthincreases with time of curing of samples in water and increases continuously day by day and then saturated up to 28 days and approximately constant after 28 days due to porosity deceases by water.

In this paper up to 15% of rubber particle is mixed in conventional concrete and compressive and flexural test performed on that samples and the test results shows that up to

10% of rubber particle found within limits specified by Ministry of Railways.

So this paper suggests the use of up to 10% particulate rubber in conventional concrete sleepers for better mechanical properties like high toughness, high impact resistance, high vibration resistance and little transition to ductile for recognizing crack initiation with decreased compressive strength and flexural strength but within the limits specified according to Indian Railway Standard.

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