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Design and Development of Railway Sleepers using Recycled Waste Tyre Rubber

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Abstract—*In the present work Railway sleeper is a composite material in which concrete is used as matrix and powdered waste tyre rubber is used as particulate fiber. The powdered rubber (crumb rubber) is shredded into small particles from scrap tyres. The conventional concrete sleepers have some defects like low impact resistance, low damping resistant, low toughness, low energy absorption capacity and high brittleness due to which any crack initiation in sleeper cannot be found. As any crack initiation cannot be found, the sleepers cannot be replaced at right time and chances of accident due to sudden failure of conventional concrete sleepers is very high. The rubber concrete composite sleepers have good properties that are required in the ideal railway sleeper. So the motive of this paper is to design and development of railway sleepers by using the waste recycled tyre rubber to remove defects of conventional concrete sleepers. In this paper waste management or recycling of waste tyres has been done by developing composite materials based on it. The various methods of recycling of waste tyres like ambient shredding, cryogenic grinding and pyrolysis have been discussed in this paper. The rubber concrete composite railway sleepers using waste tyre rubber has been fabricated and this paper suggests use of Rubber Concrete particulate composite material for removing the defects of conventional concrete sleepers.*

Keywords*: Rubber concrete composite, Railway sleepers, Crumb Rubber, Waste tyre rubber.*

1. INTRODUCTION

Approximately one billion waste tyres are permanently removed from vehicles and huge volume of waste tyres is generated. Tyres are thermoset and are virtually resistant to biological degradation and fire hazard because these are highly inflammable. It occupies big volumes in landfill and air pollution occurs due to burning of waste tyre. Burning of waste tyre increases greenhouse gases. Water pollution also occurs due to decomposition of tyre in sea or river. Water pollution is harmful for Aquatic animal.

So removal of waste tyres become a major environmental problem and waste management and safe disposal is required.

The use of recycled waste tyre rubber which is crumb rubber in portland cement concrete is an attractive and beneficial option technically. The crumb rubber is used in production of tyre rubber particulate railway sleeper composite in which crumb rubber is used as reinforcement or particulate fiber. Rubber concrete composite sleepers made from waste tyres are environment friendly and cost effective. This composite can be categorized as green product and it is eco-friendly because it reuses of the waste material in an efficient manner.

Strength, Density, Rigidity of concrete, train travel noise and vibration smooth running are reduced with increase in rubber aggregate volume content. But the material exhibits enhanced toughness, a slight transition from brittle to ductile failure mode, light weight, impact resistance, thermal insulation and damping. 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]. Rubber concrete can be used for isolation of noise in buildings and in industrial floors [J. Zhao, 2010]. Reclamation and recycling of waste rubber and European Tyre Recycling Association (ETRA) publishes the methods of recycling of waste tyres.

2. WASTE MANAGEMENT OF WASTE TYRES

There are 15 million tons of tyres become wastes in the world per year and one million tons of tyres also waste in India. These wastes are utilizing in following sections.

1. Recycling for rubber goods

2. Pyrolysis

3. Road construction

2.1 Recycling Methods of Waste Tyres

2.1.1 Ambient Shredding

The shredding of a scrap tyre happens at ambient temperature in this process. Tyre breaks into chips when passed through a shedder. The chips are fed into a granulator that breaks them into small pieces. The steel and fibers are removed in the process. Remaining steel is removed magnetically and fiber through a combination of shaking screens and wind sifters. Finer rubber particles can be obtained through further grinding in secondary granulator and high-speed rotary mills.

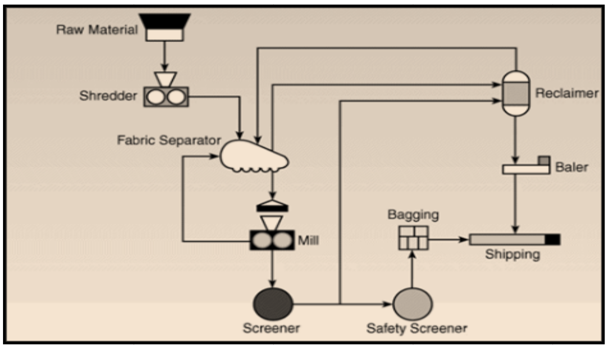

Figure 1: Line Diagram of Ambient Shredding Process
Reference: Scrap Tire News

2.1.2 Cryogenic Grinding

Cryogenic means creation or production by means of cold .grinding is the process of reducing the size of solid material by mechanical action. So in case of cryogenic grinding waste tyre is converted into very small size particle under very low temperature. This temperature range is about to -80°C. Cryogenic processing generally uses car or truck tyres as feedstock in the form of chips. When the tyres are exposed to such low temperatures, they become brittle and can be easily crushed and broken. It can be a four-phase system which includes initial size reduction, cooling, separation, and milling. This process requires less energy than others and produces crumb rubber of much finer quality. Crumb rubber obtained from ambient/cryogenic grinding of scrap tires, is used for manufacturing of new tyres or in a variety of landscaping applications including path paving projects, playground surface cover, running tracks, and athletic field turfs.

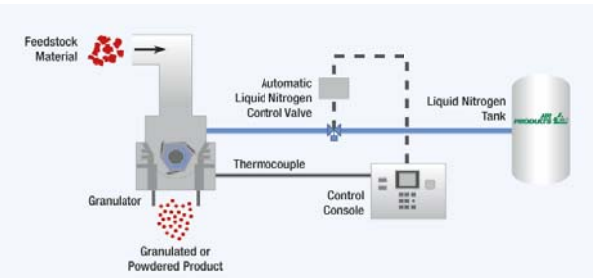

Figure 2: Line Diagram of Cryogenic Grinding Process
Reference: Polar Fit Cryogenic

2.1.3 Pyrolysis

It is a thermal decomposition process at high temperature. It is irreversible process and the decomposition occurs in with and without vacuum. Pyrolysis is the process of breaking down large polymer molecule into smaller oil/lubricant, gas and carbon molecule using heat. pyrolysis also known as de polymerization thermal cracking and thermolysis . The pyrolysis method for recycling used tires is a technique which heats whole or shredded tires in a reactor vessel containing an oxygen-free atmosphere.

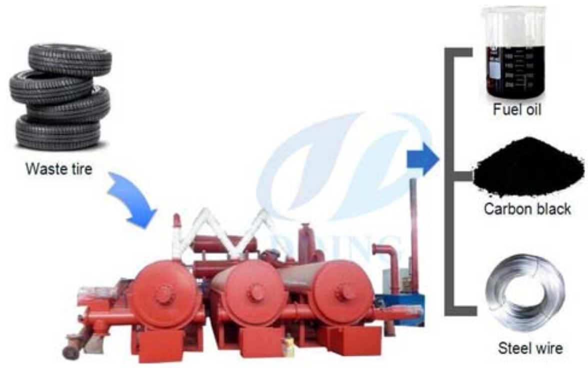

Figure 3: Pyrolysis Plant
Reference: Doing Energy

3. METHODOLOGY

3.1 Materials

All materials used in the costruction of rubber cocnrete composite are cement, fine aggregate, coarse aggregate and water in addition with super plasticizer and crumb rubber. Appropriate properties of the materials are required for high strength specimen. So the specification of the ingredients is listed in Table 1.

Table 1: Materials Required with Specification

S. No.	Name of Item	Specification	
1.	Waste Tyre Crumb Rubber	Range = 4.75 to 0.075mm Fineness Modulus = 2.72 Bulk Density = 670 kg/m^3	
2.	Cement	Ordinary Portland Cement of 53 grade	
3.	Coarse Aggregate and Fine Aggregate	IS Sieve Conforming Grade Zone II	4.75 mm
		Crushed Stone particle	Size less than 20 mm and 10 mm
4.	Super Plasticizer	Naphthalene based Super Plasticizer	
5.	Water	Normal Drinking Water	

3.2 Preparing the Mix Design Ratio

High strength mix like M50 should be prepared for manufacturing concrete sleepers. So M50 is used in this present work. 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. All quantities in Table 2. is listed as kg required for unite m^3 of the volume.

Table 2: Mix Design Ratio

S. No.	Ingradients (kg)	M50
1.	Cement	495
2.	Fine Aggregate	684
3.	Coarse Aggregate	1097
4.	Rubber	0,5,10 and 15% of fine aggregate
5.	Water	158
6.	Super Plasticizer	0.0098

3.3 Preparing the Samples

A mold of 150x150x150 mm size is selected for the casting of the compressive strength testing specimen and a mold of 100x10x10 is selected for the casting of the flexural strength testing specimen. The mold is polished with crude oil for easy removal of the casted specimen. All materials are mixed in proper 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 0,5,10,15 percentages of weight of fine aggregate. Zero percent rubber in specimen means pure conventional concrete. Rubber concrete composite is fabricated with 5,10,15 percent of rubber where fine aggregate is replaced by crumb rubber. After proper mixing 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 conventional concrete. When the samples are filled and rammed properly then wait for 24 hours for setting up specimen. After 24 hours when sample is set in proper shape then removed from the mold.

Figure 4: Make a polish for easy withdrawal of prepared sample

Figure 5: Mold filled with proper mix design material

3.4 Curing of the Samples in Water

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

Figure 6: Samples in water

4. RESULTS AND 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. 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 a lot of positive properties increases but compressive strength and flexural strength of rubber concrete composite decreases with the percentage increase of the rubber in concrete. So a proper investigation and evaluation should be done for look after the changes in compressive strength and flexural strength. The railway sleeper specimen is prepared and the casting method and process of fabrication is discussed. The waste management and recycling method of scrap tyres are discussed and it should be done for clean environment. The recycled waste tyre rubber can be used in rubber concrete composite, road construction, sports ground and shock absorbing utility like bumpers.

So this paper recommends the use of 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 but with some caution of decreasing compressive strength and flexural strength.

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