EFFECT OF CRUMB RUBBER AND STEEL FIBERS ON STRENGTH CHARACTERISTICS OF PAVEMENT QUALITY CONCRETE

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ABSTRACT: A large variety of waste materials are considered feasible and even much valuable additives for concrete. Some of these materials include cellulose, fly ash, silica fumes and wood particles. Crumb rubber obtained from scrapped tyres is considered as the most recent waste materials that have been examined because of its vital use in the construction field. Every year, at an average of about 11,000,000 new vehicles are added to the Indian roads. Also, there is an increase of about 30,000,000 discarded tyres each year which pose a potential threat to the environment. Though, the tyres are being recycled yet there is a significant number of tyres added to the existing tire dumps or landfills. In such a case the reuse of rubber would be a better choice. The crumb rubber is a fine rubber particles ranging in size from 0.075 mm to no more than 4.75 mm. In this study, crumb rubber is used to replace fine aggregate in the production of concrete pedestrian blocks. Replacing fine aggregate in concrete pedestrian blocks with crumb rubber produced from waste tires will reduce the consumption of primary aggregates and produce a high value use for the wastes. It will also help minimize the use of high value aggregates in low specification applications.

In the present experimental study the fine aggregates in M35 concrete will be replaced by certain percentages of crumb rubber(0%,4%,8%,12%,16%). and using hooked steel fibres with0.75% volume fraction From this study it can be concluded that up to 8% of rubber aggregate and hooked steel fibres with0.75% volume fraction can be added into concrete mixes without considerable reduction in strength and split tensile strength is increased with addition of 8% crumb rubber. After that it was observed that as the replacement percentage of crumb rubber increased, the spit tensile decreased. The effect of crumb rubber for durability requirements like freeze thaw action, initial surface absorption etc. can be studied. Crumb rubber concrete usage in other construction areas like roads, bridges can be studied.

KEYWORDS: Crumb Rubber, Hooked Steel Fibres, Split Tensile Strength, Fineness Modulus, Compressive Strength.

I. INTRODUCTION

Tens of millions of tyres are discarded across the world every year. Disposal of waste tyres is a challenging task because tyres have a long life and are non-biodegradable. The traditional method of waste tyres management have been stockpiling or illegally dumping or land filling, all of which are short-term solution. The environmental problem from growing, recycling tyre is an innovative idea or way in this case. Recycling tyre is the processes of recycling vehicle's tyres that is no longer suitable for use on vehicles due to wear or irreparable damage such as punctures. The cracker mill process tears apart or reduces the size of tyre rubber by passing the material between rotating corrugated steel drums. By this process an irregularly shaped torn particles having large surface area are produced and this particles are commonly known as crumb rubber. (ranging in size from 0.075 mm to no more than 4.75 mm).

Research that rubberized concrete can successfully be used in secondary structural components such as culverts, crash barriers, sidewalks, running tracks, sound absorbers, etc. However, most of the developing third world countries have yet to raise their awareness regarding recycling of waste materials and have not developed effective legislation with respect to the local reuse of waste materials. The proposed work presents an experimental study of effect of use of solidwaste material (crumb rubber) in concrete by volume variation of crumb rubber. One of the objectives of this paper is to make these data regarding the basic properties of modified concrete using crumb rubber in the concrete mix available to aid in the development of preliminary guidelines for the use of crumb rubber in concrete..

Dumping of waste rubber products is becoming an environmental challenge in several developing countries due to their non-biodegradability characteristic. Majority of waste rubber products are generated from damaged or scratched automotive tyres and industrial conveyor belts (Pilusa and Muzenda 2013). Until now the way of degrading or recycling them is a major environmental challenge.Tyres made of complex mixtures of very different materials which include several rubbers, carbon black, steel cord and other organic and inorganic minor components. The increasing amount of tyre rubber dissipate is generating more and more ecological problems worldwide. The current rate of monetary growth is unbelievable without reduction of fossil energy like crude oil, natural gas and coal. Appropriate waste management is an additional important aspect of sustainable growth. Rubber misuse represent a substantial part of municipal waste, furthermore a large amounts of waste arise as a by-product or faulty product in industry and agriculture (Rostek and Biernat 2013). The quick development of the automobile industry and superior standard of living of people in India, the quantity of autos increased rapidly. Now India is facing the ecological problems related to the removal of large-scale waste tyres. Near about 1.5 billion waste tyres are generated by the world annually, in which 40% in rising markets such as China, India, South Africa, South East Asia, South America and Eastern Europe etc. And more than 33 million vehicles added to the Indian Roads in the last three years. Now, in accordance with the statistic data, 80 million scrap tyres were created in 2002, and with 12% of enlargement rate every year, the whole number of abandoned tyres reached 120 million in 2005 and 200 million in 2010 (Malarvizhi et al 2012). However with the deal of vast number of waste tyres has become a vital problem of environment in India.

Due to the health and environmental risks presented from used tyre waste a significant body of recent research has focused on utilizing used tyre rubber in concrete as a partial replacement of its mineral aggregates, resulting in a class of concrete called crumb rubber concrete (CRC). Previous experimental studies on CRC materials have shown that using rubber in concrete enhanced its ductility, toughness, impact resistance, energy dissipation, and damping ratio However, it reduced its compressive strength, tensile strength, and modulus of elasticity compared to conventional concrete .To increase the effectiveness of using rubber in concrete, several approaches have been previously introduced and showed that the CRC properties improved with cement content in- crease up to 400 kg/m3. Beyond 400 kg/m3 cement content, only slight improvements were observed. However, the slump was negatively affected when using 400 kg/m3 and showed that 24 hr is the best treatment period for the rubber as it resulted in the highest compressive strength and flexural strength. However, this pre-treatment had no effect on concrete slump. Other researchers reported less positive or contradictory results from these approaches and used modified rubber by saturating it in NaOH solution for 20 min. Their results showed al- most no difference between the compressive and tensile strengths of pre-treated and non-treated rub- ber mixes. However, 12% increase in the flexural strength was reported for the pre-treated rubber mix. CRC compressive strength using NaOH pre-treated rubber for 24 hours followed by tap water wash for 3 hours compared to non-treated rubber. The contradictions and variations in the previous research findings indicate the need for future re-search in CRC performance enhancement.

Recycling discarded automobile tyres has become an increasingly important issue, since the disposal of used tyres has been banned from landfills. As a consequence of this ban and the lack of an alternative technology to dispose of large quantities of used tyres, there are millions of used tyres stockpiled, some illegally. The growing stockpiles of discarded tyres represent potential fire and health hazards. Recycling waste tyre rubber conserves valuable natural resources and reduces the amount of waste entering landfills. The main method of recycling these waste materials has consisted of using tyre rubber particles as coarse or fine aggregate in concrete. Results indicate that rubberized concrete mixtures possess lower density, increased toughness and ductility, lower compressive and tensile strengths and more efficient sound insulation (Siddique et al., 2008). Raghavan et al. (1998) reported that mortars incorporating rubber shreds achieved workability comparable to or better than a control mortar without rubber particles. Because of the low specific gravity of rubber particles, the unit weight of the mixture containing rubber decreases with the increase in the rubber content. They also observed that rubber shreds incorporated into mortar help reduce plastic shrinkage cracking in comparison to control mortar. Eldin and Senouci (1993) studied the mechanical behavior of concrete containing rubber tyres.

In this study, crumb rubber is used to replace fine aggregate in the production of concrete pedestrian blocks. Replacing fine aggregate in concrete pedestrian blocks with crumb rubber produced from waste tyres will reduce the consumption of primary aggregates and produce a high value use for the wastes. It will also help minimize the use of high value aggregates in low specification applications.

Bytheyear2030,this number is expected to reach 1200 million. Disposal of waste tyres has become a global problem. In many countries, burying the waste tyres is a common disposal method, which shortens the service life of the burial ground and causes a very serious threat to ecology. Therefore, effectively reusing waste tyres is an urgent and important issue for saving energy and protecting the environment. Several methods of recycling waste tyres have been proposed, including use as a fuel in cement kilns and to produce carbon black. These are technically feasible, while bringing great economic waste and environmental pollution. Using recycled rubber as additives to or replacements of construction materials is a highly preferable option. The initial trial of crumb rubber was used as a modifier of asphalt. However, the high viscosity and the higher temperature required in production made it unpractical to be widely used. In order to reuse waste tyre rubber effectively, one of the possible solutions is to incorporate it into cement-based material. Partial replacement of mineral aggregates in concrete with waste tyre rubber could control environmental pollution and save sandstone.

Concerning the reuse of waste rubber in concrete, extensive studies had been conducted. Two major opposite effects existed when the rubber was introduced into the concrete mixture. The mechanical strength was reduced, while the durability, toughness, impact resistance, strain capacity and sound insulation properties were enhanced . Due to the compressive and flexural strengths being two major design criteria in concrete structures, the reduction in the strength of rubberized concrete limited its application. However, the desirable characteristics, including lower density, higher ductility, better sound insulation and resistance against cracking, made it a valid option for non-structural concrete with a low strength requirement. The properties of crumb rubber concrete were significantly affected by rubber content. During investigated the durability properties of self-compacting concrete containing waste tyre rubber, which indicated that the anti-sulfate corrosion was improved with the increasing of rubber content. Holme conducted acoustic tests for concrete with different levels of fine aggregate replacement by crumb rubber Testing results found that the sound absorbance property of rubberized concrete performed well with higher proportions of rubber. Therefore, the investigation of the advantages and disadvantages of replacing mineral aggregate by crumb rubber is necessary. Additionally, the selected optimal content of crumb rubber in the concrete mixture will bring excellent performance to crumb rubber concrete. In order to minimize the loss in strength caused by introducing crumb rubber into concrete, prior surface treatment of rubber particles by modifiers was utilized.

II. EXPERIMENTAL WORK

2.1 Materials

Cement

Ordinary Portland cement of Ambuja Cement conforming to IS 269-1976 and IS 4031-1968 was adopted in this work. The cement used is of 43 grade. –Cement is a fine, grey powder. It is a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulphate (which controls the set time) and up to 5% minor constituent it is mixed with water and materials such as coarse aggregates and fine aggregates to make concrete. . It was fresh and free from any lumps. The test results are shown in table 1

Table-1 The various tests results conducted on cement

S. No.	**Characteristics**	**Values obtained**	**Standard value**
1.	Normal consistency	30 %	25% - 33%
2.	Initial setting time (minutes)	55 min.	Not less than 30
3.	Final setting time (minutes)	280 min.	Not more than 600
4.	Specific gravity	3.15	3 To 3.25

Fine Aggregate

Natural sand which is easily available and low in price was used in the work. It has cubical or rounded shape with smooth surface texture. Being cubical, rounded and smooth texture it give good workability. Sand which is used here is taken from stone crushing plant. Particles of this sand have smooth texture and are brownish colour. Sieve analysis was done to find out fineness modulus which comes out to be 3.29% which is under limit as per IS 383-1970

Table -2 Properties of fine aggregates

S. No.	**Characteristics**	**Value**
1.	Type	Crushed
2.	Specific gravity	2.70

Table-3 Sieve analysis of fine aggregate

S.No	**Sieve Size**	**Cum. weight retained(%)**	**Weight passing (%)**	**Prescribed limit % wt. passing Zone II**
1.	**10 mm**	-	100	100
2.	**4.75 mm**	-	100	90 – 100
3.	**2.36 mm**	7.0	93	75 – 100
4.	**1.18 mm**	33.8	66.2	55 – 90
5.	**600 µ**	54.4	45.6	35 – 59
6.	**300 µ**	78.1	21.9	8 – 30
7.	**150 µ**	76.7	3.3	0 – 10
		ΣC=270		

Fineness Modulus of fine aggregate = ΣC/100 = 270/100 = 2.70

Coarse Aggregate:

The aggregate used in this project mainly of basalt rock which comes under normal weight category. The aggregates are locally available. 50% of the aggregate used are of 10-12 mm size and remaining 50% are of 20mm size. Crushed stone aggregate (locally available) of nominal size 20 mm and 10 mm in the proportion of 50:50 were used throughout the experimental study. The aggregates were washed to remove dust and dirt and are dried to surface dry condition.

Table -4 The Properties of fresh coarse aggregates are reported

S. No.	Characteristics	20 mm aggregate	10 mm aggregate
1.	Type	Crushed	Crushed
2.	Maximum size	20 mm	10 mm
3.	Specific gravity	2.74	2.74

Table-5 Sieve Analysis 20 mm Aggregate

S.No	Sieve Size	Weight Retained (%)	Cumulative weight Retained (%)	Weight Passing (%)	Prescribed limit % wt. passing
1.	40 mm	-	-	100	100
2.	20 mm	2.0	2.0	98	85 – 100
3.	10 mm	94.4	96.4	3.6	0 – 20
4.	4.75 mm	3.6	100	0	0 – 5

Table-6 Sieve analysis of 10 mm aggregate

S.No	Sieve Size	Weight Retained (%)	Cumulative weight Retained (%)	Weight Passing (%)	Prescribed limit % wt. passing
1.	12.5 mm	3.5	3.5	96.5	100
2.	10 mm	14.90	18.4	81.6	85 – 100
3.	4.75 mm	66.2	84.60	15.40	0 – 20
4.	2.36 mm	12.5	97.1	2.9	0 – 5

Scrap Tyre
Scrap tyre aggregate powder was collected from Shriraj Engineers & consultants, Ahmadabad. With the addition of Scrap tyre aggregate the physical properties of fresh and hardened concrete studied and compared. Scrap tyre rubber chips can be also used as coarse aggregate with thereplacement of conventional coarse aggregate.
(Panda K. et al 2012). The feasibility of incorporating scrap tyre rubber chips as coarse aggregate in concrete mixes and determine the change in the properties after the incorporation of the rubber into the concrete mix is to be investigated. Due to replacement of the aggregates by rubber particles, the weight was reduced.

III. RESULTS AND DISCUSSIONS

Different mixes were designed to see the effect of crumb rubber on strength workability characteristics of concrete. These included compressive strength, split tensile strength and slump test. Results of each test have been discussed separately. Along with the graphical representation

1. Slump Test
Slump test is used to determine the workability of fresh concrete. Slump test as per IS : 1199-1959 is followed. Following Figure shows the result of slump test. From results it can be concluded that not much increase in slump value with the addition of rubber aggregates

Table-7Variation of slump value.

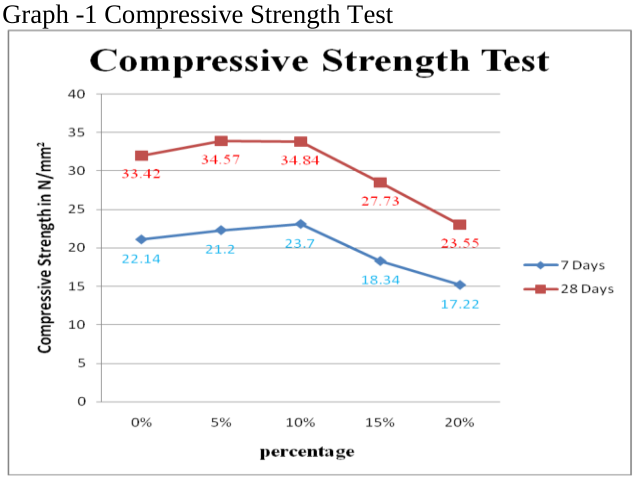
S.NO.	Trial Mix Design (M35)	Percentage of Crumb Rubber	Slump Values (mm)
01	Trial Ist –M1	0%	53
02	Trial 2nd – M2	4%	56
03	Trial 3rd – M3	8%	64
04	Trial 4th – M4	12%	57
05	Trial 5th – M5	16%	55

2. Compressive Strength Test
Three cubes of size 150×150×150 mm were tested for each mix in a compression testing machine on 7th, and 28th days of curing for its compressive strength. The results are shown in table 4 Figure shows the variation of compressive strength (7 day) with addition of rubber aggregate. Fig 4.7 shows the variation of compressive strength with addition of rubber aggregate. Fig 4.8 shows the variation of compressive strength (28 day) with addition of rubber aggregate. Gradual reduction in compressive strength was observed with the addition of used rubber tyre aggregate. From this study it can be concluded that up to 8% of rubber aggregate can be added into concrete mixes without considerable reduction in strength.

Table-8 Compressive Strength of Concrete

Mix Designation	Curing Period	Load at Failure (KN)	Compressive Strength (N/mm^2)	Average Compressive strength (N/mm^2)
M1	7days	473	22.91	22.14
		475	21.10	
		477	22.51	
	28 days	727	33.20	33.42
		729	35.081	
		721	31.95	
M2	7days	500	20.42	21.2
		506	22.31	
		503	21.20	
	28 days	761	35.00	34.57
		763	34.89	
		759	33.85	
M3	7 days	519	22.06	23.08
		522	23.14	
		516	24.04	
	28 days	767	34.87	34.84
		762	33.91	
		764	35.85	
M4	7 days	411	19.38	18.34
		413	18.27	
		416	17.30	
	28 days	646	29.50	27.73
		642	27.40	
		645	26.47	
M5	7 days	347	17.20	17.22
		343	16.21	
		344	18.20	
	28 days	519	23.99	23.55
		515	22.99	
		512	24.0	

Graph -1 Compressive Strength Test

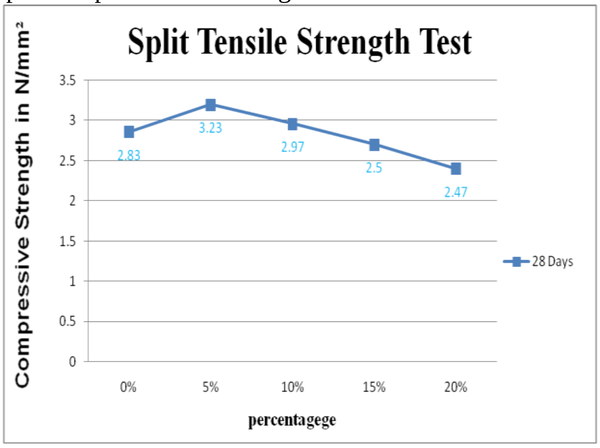


Split Tensile Strength Test
The test method covers the determination of splitting tensile strength of cylindrical concrete specimen. This method consists of applying diametric compressive force along length of cylindrical specimen. This loading induces tensile stresses on the plane containing the applied load. Tensile failures occur rather than compressive failure.

Table-8 Split Tensile Strength of concrete

Mix Designation	Curing Period	Load at Failure (KN)	Split Tensile Strength (N/mm^2)
M1	28 Days	200	2.830
M2	28 Days	229	3.23
M3	28 Days	210	2.97
M4	28 Days	195	2.75
M5	28 days	175	2.47

Graph – 2 Split Tensile Strength



IV. CONCLUSIONS

Present research was carried out to determine the compressive strength and tensile strength of concrete containing rubber aggregates. The objective of the study was to study the effect of partial replacement of fine aggregates with rubber aggregates on different percentages of rubber tyre aggregates to M35 mix. The studies show that not much increase in slump value with the addition of rubber aggregates. Gradual reduction in compressive strength and tensile strength was observed with the addition of used rubber tyre aggregate. From this study it can be concluded that up to 8% of crumb rubber aggregate can be added into concrete mixes without considerable reduction in strength. Based on this study rubber tyre aggregates can be added to concrete for structural constructions mainly for rigid constructions. Utilization of rubber tyre aggregates, which is a waste product, in concrete construction is economically viable and environmentally effective.

The following conclusions are drawn from the present study:

- Compressive strength of concrete decreased with the increase in paper sludge replacement. However, at each replacement level of sludge, an increased and decrease in strength was observed. Compressive strength however of 28 days is higher than at 7 days. Compressive strength is increased with addition of 4%-8% crumb rubber.
- It has been seen from the above study that compressive strength increases with age. This is true for all cases of replacement. As we replaced cement with crumb rubber, the strength has increased with age.
- Slump is decreased with addition crumb rubber to concrete thus decreases to workability requirements of concrete. Whereas slight addition of crumb rubber i.e. only 8% replacement of fine aggregate can still give satisfactory results
- Split tensile strength is increased with addition of 8% crumb rubber. After that It was observed that as the replacement percentage of crumb rubber increased, the spit tensile decreased.
- So crumb rubber can be used in replacement of fine aggregate thus reducing environmental hazards. But high quantities of replacements are not recommended as it leads to decrease in strength properties.

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