A Review on Utilization of Crumb rubber in various ingredients of Concrete

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Abstract*: Urbanisation and the day to day exponential increase in the number of automobileshas increased the usage of rubber. Due to this, the amount of scrap rubber is also increasingwhich is generally left for scrap deposition in landfills. According to a recent survey, it is estimated that the rubber scrap will reach nearly 1.2 billion tonnes annually by end of 2030. Scrap tyres are also harm to environment as they are non–biodegradable and a good catchment area for breading of mosquitoes androdents. Large amounts of cross-ply rubber are also being deposited along the path of aircraft runways which is a huge threat in terms of skid resistance factor of aircrafts.Further, there is a limitation in recycling of these in the use of crumb rubber as well as polymer fibre material. As anattempt to reusethis waste, many experimental studies are carried out using it as a filler material in concrete industry. This paper presents a review of the work carried out by the past and recent researchers who studied the fresh and hardened properties of concrete with crumb rubber as anauxiliary material.

***Index Choice:* Bias tyre, Crumb rubber, Pre-treatment, Radial tyre.**

I. INTRODUCTION

Ecological development has become the foremost focus for engineers and planners, who are collectively working for developing and assimilating environment approachable solutions for materials recycling and scraps management into the construction wing of civil infrastructure. For the past three decades, there has been a melodramatic change in the way of thinking about the approach and evolution of new and pioneering materials.

Discarding of waste tyre rubber is one of the major concerns for all over the world. With day to day increase of automobiles in India during the past few decades, the demand of utilization of tyres has reached up very high. Thedisposed vehicle tyre in to the landfills constitutesone of the important part of solid waste from the remaining. Among the disposal methods, burning of tyres in open air is causing serious fire hazards. Besides this, the left over final residue after ignition pollutes the contiguous atmosphere by reducing the oxygen levels as well as the natural earth by its deposition. By the end of 2030, the number of tyres deposition in to landfills from automobiles is about to reach 1200 million assuming that almost 5000 million tyres will be discharged. Despite this, India is the second largest producer of reclaimed rubber after China.

Crumb rubber is usually classified into two types:Radial tyres and Cross-ply/Bias tyres (Fig. 1).

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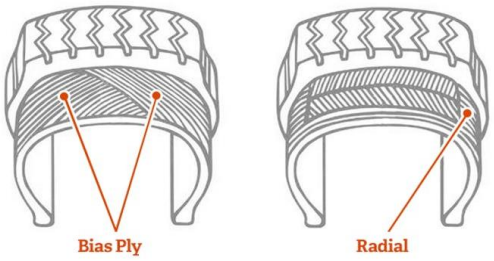


Fig.1: Radial Ply tyre vs Bias Ply tyre *(Source: Revzilla Motorsports)*

The proportion and manufacture of both these tyres is again an important concern while using as replacement material as their compositionsaredifferent. Radial tyres are utilized for LCV as well as HCV, whereas Cross-ply/bias can be utilized for some HCV's and mainly aircraft tyres.

The rubber deposits of Cross-ply tyres are not only in landfills but also on the airfield pavements due to hydroplaning effect between pavement surface and cross-ply tyre of the aircraft during landing and take-off of aircrafts. Due to its deposition on runway pavement,it is causing a major concern for smooth running of airfield operations.

This review paper aims at the utilization of Radial and Cross-ply/bias tyre rubber as a replacement material to various ingredients of concrete.

II. CRUMB RUBBER

Crumb rubber is extracted from two type's i.e. Radial ply and Bias ply tyres. Radial ply tyres are extracted fromtyres of two wheelers, four wheelers, bicycles etc. Bias ply tyres are extracted from trucks as well as air crafts tyres. Further the composition involved in the manufacture of Radial ply tyres when compared with Bias ply tyres is also different. The foremostvariance between a Radial ply and Bias/cross ply tyre is that the cords beneath the tyre are run in diverse directions.

But during the time of dumping in landfills, they are not segregated in terms of Radial ply and Bias ply. Moreover they are combined together and termed as crumb rubber.

III. SOURCE OF RADIAL TYRES DEPOSITION AND AVAILABILITY

Discard of these waste tyres is thought-provoking task because waste tyres have a protracted existence and are non-biodegradable. The customary method of managing waste tyres is stockpiling or unlawfully dumping or landfilling.All of these are for short-term elucidation and not environment friendly.

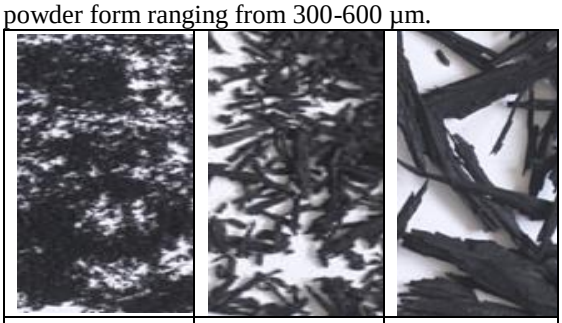
When these tyres are meant for recycling, they are collected from landfills and grinded in the production mills for further utilization. After the process of vulcanization and pulverization, they are available in various forms for recycling process as presented in Table 1.

Form of availability	Size(mm)
Derived rubber	40 – 60
Shredded rubber	15 – 30
Rubber mulch	2 – 4
Ground rubber	10 – 32

Table 1: Various forms of rubber for re-use

IV. SOURCE OF BIAS PLY TYRES DEPOSITION AND AVAILABILITY

Bias ply tyres are also available in landfills along with radial ply tyres as these bias ply tyres are mostly collected from trucks. Besides this, these tyres are used for aircrafts and they are also available in various forms just like Radial ply tyres. But the only difference is that they are also available in fine powder form ranging from 300-600 µm.



Rubber mulch | **Grounded rubber** | **Shredded rubber**

Fig. 2 General Forms of availability of crumb rubber (Source: Indian-mart)

Ingredient	Passenger Car	Lorry Tyre	Bias Tyre
Rubber/ Elastomers[1]	47%	45%	47%
Carbon black[2]	21.5%	22%	22%
Metal	16.5%	25%	12%
Textile	5.5%	-	10%
Zinc Oxide	1%	2%	2%
Sulphur	1%	1%	1%
Additives[3]	7.5%	5%	6%
Carbon-based materials, total[4]	74%	67%	76%

Table. 2 Composition of Radial Tyre and Bias Ply/Cross Ply (Source: WRAP: Creating markets for recycled soures)

1. Lorry &Bias tyres contain higher proportions of natural rubber than passenger car tyres.
2. Silica replaces part of the carbon black in certain types of tyres.
3. Some of the additives include clays, which may be replaced in part in some tyres with recycled rubber crumb from waste tyres
4. These approximate totals would be slightly higher if clays were replaced by recycled crumb rubber from waste tyres.

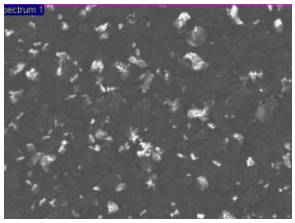


Fig. 3 Electron image of Bias/Cross ply tyre(Source: Material testing lab-Andhra University)

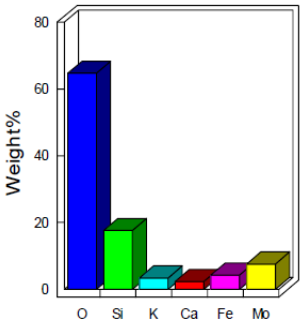


Fig. 4 Quantitate Results of Bias/Cross ply tyre(Source: Material testing lab-Andhra University)

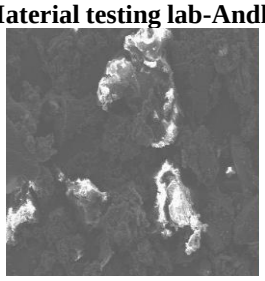


Fig. 5 Electron image of Radial tyre(Source: Material testing lab-Andhra University)

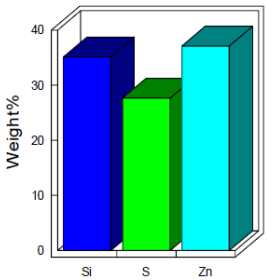


Fig. 6 Quantitate Results of Radial tyre(Source: Material testing lab-Andhra University)

V. UTILIZATION OF CRUMB RUBBER AS A REPLACEMENT MATERIAL IN CONSTRUCTION ASPECTS

Worldwide, crumb rubber is utilized for various purposes depending on the demand.

It is being used in various construction purposes as a binder material, as rubber surfaces in sports and many other applications.In this section, the various works carried out by various researchers in different aspects were outlined.

Utilization Of Crumb Rubber As Aggregate In Concrete

Till date, many studies have been carried out with replacement of land filled rubber, which is a mixture of both Radial as well as Bias ply tyres. The following are some of the works carried out in this regard to study the properties of concrete.

Musa Adamu*etal.* (2017) considered the fine aggregate replacement with crumb rubber for 10, 20 and 30 %.The study was also carried out by analysing the effect of superplastizer on properties of roller compacted concrete in pavements by 0, 1 and 2% by weight of cement. Further studies have shown that the replacement of crumb rubber decreased the consistency and compressive strength whereas the flexural strength is increased gradually.But on addition of superplastizer, there was gradual decrease in consistency and compressive strength was observed to have increased.

Musa Adamu*etal.* (2017) investigated the effect of replacing fine sand as mineral filler with silica fume and fly ash in line to crumb rubber at 0, 10, 20 and 30%.Further investigation showed that fresh density of roller compacted rubbercrete with silica fume and fly ash are lower when compared to roller compacted rubbercrete with natural fine sand.The mechanical properties of roller compacted rubbercrete exhibited high values in case of silica fume at 20% replacement of crumb rubber and a loss of strength for flyash by 10% replacement of crumb rubber was observed.

Retama and Ayala (2017) considered the characterisation of mechanical properties of RCC for 3 control mixes with variable content of crumb rubber.Further results showed that the fracture energy and other properties are directly related to the rubber used in the mixture. Numerical model was used to simulate the damage evolution by embedded discontinuity method and was found to be a good approximation of experimental curves in elastic and softening points.

Mohammed Safan*et al.* (2017)conducted experiments on crumb rubber as well as pre-treated rubber. The rubber is treated with NAOH.Silica fume was used as an addition to increase the compressive strength of concrete and water to cement ratio was fixed as 0.42.Concentration of NaOH was taken as 15,20 and 30%.Further results showed that crumb rubber on treatment with 20% concentration of NAOH has gained additional strength and improved mechanical properties when compared with concrete with non-treated crumb rubber.

Khubshbu Tak and Uttam Panchori(2017) have studied the influence of mechanical properties of concrete by surface modification to crumb rubber.As a part of this, the crumb rubber was first cleaned with NaOH and then oxidised with $KMnO_4$ solution and then sulphonated with $NaHSO_3$solution. Further they found by Fourier-transform infrared spectroscopy(FT-IR) that treatment greatly improved the interfacial bonding strength between crumb rubber and cement paste by 41.1%.Further,based on the study of mechanical properties, it was observed that with 4% modified powder compressive strength was 48.7% higher than that with ordinary crumb rubber.

Sendwa and Shakimon (2017)conducted various investigations to improve the bond between cement paste and the crumb rubber and finally found that rubber on treatment with NAOH at 5% replacement with fine aggregate showed good results.During Compression and tension, it was evident that no brittle failure was noticed by which it is clear that rubberized concrete was able to absorb a large amount of plastic energy.

Samaneh *et al.*(2017)studied the behaviour of crumb rubber surface texture when treated with chemicals and concluded from the results of microstructural analysis that pre-treated rubber with chemical will yield good bond with crumb rubber and cement paste when compared to untreated rubber. Among the chemicals used, it was found that poassium permanganate was found to be a promising material for treatment of rubber.

Abdullah *etal.* (2017) by his studies on partial replacement of concrete by crumb rubber found that it increases the crack mouth opening displacement at maximum load for notched specimens and the energy absorption was found to be good during application of load.

Nilesh and Rathi (2017) studied the properties of crumb rubber in concrete by treating with NAOH and found from his study that rubberized concrete can be used as popular material for non-load bearing members and architectural units where strength is not the prime requirement.

Nikhil Ramchandra*etal.* (2017)considered in two forms: namely crumb and chipped rubber for their investigation ontheir suitability with concrete mix for structural as well as non-structural members. From the analysis of results, it was evident that, on increase of replacement of rubber percentage, strength decreases beyond many properties like durability, sound absorption etc.

Hanbing Liu *etal.* (2016) studied the effect of the volume content of crumb rubber and treated rubber on performance of concrete. The modifiers used in the study for treatment of rubber were Emulsion, Ethoxyline resign, Synthetic resign, Amino acrylate, Chloroprene adhesive, Unsaturated resigns, Further results with respect to mechanical properties were improved by addition of Synthetic and Ethoxyline resign. Finally a 20% replacement of fine aggregate and a 5% replacement of the total mixture with crumb rubber led to safe strength requirements.

Musa Adamu*et al.* (2016) studied the problems like fatigue and flexural strength in pavements subjected to dynamic fatigue load from moving vehicles on to the surface.They incorporated crumb rubber in concrete that resulted in improvement of ductility, bending formation and brittle nature of RCC. Eventually they have noticed a dramatic decrease in mechanical and durability properties of concrete due to negative impact of bonding between the rubber particle and cement.

In order to overcome the problem, they have incorporated nano-silica in concrete to improve the interfacial transition zone between crumb rubber and cement which resulted in high fatigue performance and high energy absorption with low risk of distress.

Nabeel Hamid Shah*etal.* (2016)investigated on replacing fine aggregate with ratios of 0%,5%,10% and15% with both untreated and vulcanized rubber in M40 grade concrete. The vulcanized rubber is the one which is treated with Sulphur. On increasing the percentage replacement of fine aggregate with crumb rubber, it was noticed that compressive strength decreases. However, the decrease in strength with vulcanized rubber was not much.While the decrease with 5 % crumb rubber replacement was 30 %, the decrease was 22 % with 5 % vulcanized rubber replacement. In case of split tensile it was evident that with replacement of 5% vulcanized rubber showed more tensile and bond property was observed to be good in flexure. Finally it was suggested to use vulcanized rubberfor non-structural components as it resulted the properties of M30 due to decrease in strength by increasing the percentage of replacement.

Osama Youssf*etal.* (2016) have proposed three methods to access the mechanical properties of crumb rubber blended concrete by pre- treatment of rubber with NAOH solution and by addition of silica fume @0-15%.Further results showed that 0.5 hours of rubber pre-treatment using NAOH solution with 0% of silica fume by weight of cement were best in enhancing the properties of crumb rubber blended concrete's performance.

VI. EXPERIMENTAL RESULTS BASED ON LITERATURE

The tests on mechanical properties of concrete of concrete with its fine aggregate replaced by crumb rubber were conducted as per IS: 516-1959(Methods of test for Strength of Concrete)

The results of trial mix conducted based on the review of literature for M40 grade of concrete are presented in Table 3, 4 and 5 and Figures 7, 8 and 9.

Mix	% Replacement	Compressive Strength	
		7 Days	28 Days
RB0	0	32.12	41.62
RB1	2	34.65	44.16
RB2	4	22.21	33.35
RB3	6	20.55	33.16
RB4	8	29.31	31.16

Table.3: Compressive strength test results of concrete with different proportions

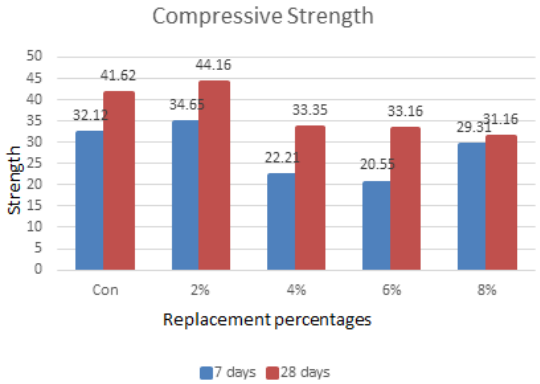


Fig. 7 Compressive strength of concrete with different proportions

Mix	% Replacement	Split Tensile Strength	
		7 Days	28 Days
RB0	0	1.98	2.54
RB1	2	2.05	2.55
RB2	4	1.94	2.24
RB3	6	2.13	2.19
RB4	8	1.76	1.90

Table.4: Split Tensile strength test results of concrete with different proportions

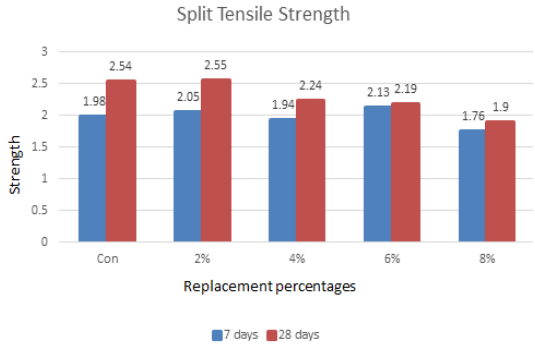


Fig. 8Split Tensile strength of concrete with different proportions

Mix	% Replacement	Flexural Strength	
		7 Days	28 Days
RB0	0	2.22	3.47
RB1	2	2.58	3.91
RB2	4	2.40	3.73
RB3	6	1.96	3.11
RB4	8	1.78	2.93

Table.5 Flexural strength test results of concrete with different proportions

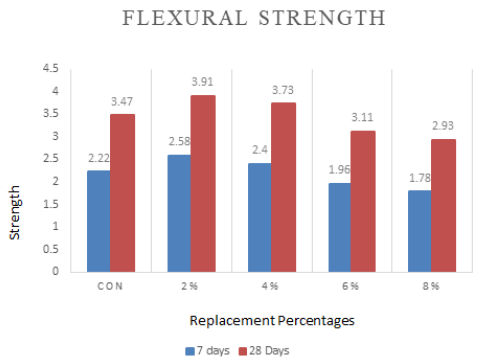


Fig. 9Flexural strength of concrete with different proportions

VII. CONCLUSIONS

From the review of available literature and based on trial mix results, the following specific conclusions can be drawn.

1. With the increase of percentage replacement of fine aggregate with Crumb rubber, compressive strength is found to decrease.
2. In spite of decrease in compressive strength, a considerable gain in flexural strength was noticed.
3. 2 – 4% replacement of fine aggregate with crumb rubber was found to be optimum replacement in terms of mechanical properties.
4. Water absorption increased with increase of percentage replacement of fine aggregate with crumb rubber.
5. Surface texture of crumb rubber was found to be improved by treatment of chemical like NAOH and $KMnO_4$.
6. By applying epoxy to pre-treated Crumb rubber in concrete, it was found that bonding was good with cement paste.
7. In spite of decrease in strength addition of pre-treated crumb rubber played a vital role in absorption of impact energy and sound.
8. Crumb rubber when combined with silica fume has shown improved performance in all aspects and is a promising alternative for future studies.

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