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A Study on Crumb Rubber: Opportunities for Development of Sustainable Concrete in the New Millennium

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ABSTRACT

Crumb rubber is a term usually applied to recycled rubber from automotive and truck scrap tyres. During the recycling process steel and fluff is removed leaving Tyre rubber with a granular consistency. Continued processing with a granulator and/or cracker mill, possibly with the aid of cryogenics or mechanical means, reduces the size of the particles further. It is not possible to discharge the rubbers in the environment because they decompose very slowly and cause lots of pollution. So, it is necessary to have a relevant use of these wastages. These waste materials can be used to improve some mechanical properties of concrete. Addition of rubber to concrete results in the improvements of some mechanical and dynamical properties. Such as more energy absorption, better ductility and better crack resistance. By using the waste tyre (crumb rubber) one can reduce the harmful effect on environment and provide sustainable concrete.

KEYWORDS: crumb rubber, utilization, compressive strength, low cost, sustainable

INTRODUCTION

Utilization of industrial waste products in concrete has attracted attention all around the world due to the rise of environmental consciousness. Accumulations of stockpiles of Tyres are dangerous because they pose a potential environmental concern, fire hazards and provide breeding grounds for mosquitoes that may carry disease. Tyre pile fires have been an even greater environmental problem.

Tyre pile fires can burn for months, sending up an acrid black plume that can be seen for dozens of miles. That plume contains toxic chemicals and air pollutants, just as toxic chemicals are released into surrounding water supplies by oily runoff from Tyre fires.

In order to prevent the environmental problem from growing, recycling Tyre is an innovative idea or way in this case. Recycling Tyre is the processes of recycling vehicles Tyres that are 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.

A review of the literature revealed that several investigations into rubber concrete have been previously performed. Fattuhi et al. mentioned in his report that the concrete made with low grade rubber concrete had lower compressive strength compared with high grade rubber concrete. These similar observations were also made by Topcu and this could be caused by weak interfacial bonds between the cement paste and Tyre rubber.

Tarun have reported that the compressive strength of rubberized concrete can be improve when fine aggregate was fully replaced by fine crumb rubber. He also indicated that if the rubberParticles have rougher surface or given a pretreatment, the better and improved bonding may develop with the surrounding matrix, and that may result in higher compressive strength.

Piti el outlined that crumb rubber responses were found to denote greater flexibility andToughness with larger deflection at peak load, longer post-peak load responses and higher fracture energy.

Waste Tyres are a tremendous problem throughout the world. It is hardly surprising that in many countries it has been deduced that the best option is to simply burn them in cement kilns. At least in this way, the reasoning goes, some of the energy invested in the Tyre is reclaimed.



Figure 1: crumb rubber in cracker mill

Sources: www.googleimages .com/ crumb rubber

INDIAN TYRES INDUSTRY:
TABLE – 1
GENERAL DETAILS

Consumption world ranking	4th
Total number of Tyre Companies	36
Total number of Tyre Factories	51
Tyre Production 2012-13 (Estimated)	110 Million
Industry Turnover (Estimated)	Rs. 31000 crores
Capacity Utilization (Estimated)	84%
Growth in Truck & Bus tyre production	15%

Source: Indian rubber industry statistics

CLASSIFICATION OF WASTE TYRE ACCORDING TO PARTICAL SIZE:
TABLE: 2
CLASSIFICATIONS OF WASTE TYRES

Material	Size
Cuts	>300mm
Shred	50–300 mm
Chips	10–50mm

Granulate	1–10mm
Powder	<1mm
Finepowder	<500µm
Buffing's	0–40mm
Reclaim	Dependsoninput
Devulcanisate	Dependsonpowder
Pyroliticchar	<10mm
Carbonproducts	<500µm

Source: http://ebooks.narotama.ac.id

CHEMICAL COMPOSITION OF WASTE TYRES:
TABLE: 3
CHEMICAL COMPOSITIONS OF WASTE TYRES

Constituent	Percent (%)
Rubber (Natural and synthetic)	38
Fillers (Carbon black, silica, carbon chalk)	30
Reinforcing materials (steel, rayon, nylon)	16
Plasticizers (oils and resins)	10
Chemicals for vulcanisation (sulphur, zinc oxide, various chemicals)	4
Chemicals as antioxidants to counter ozone effects and material fatigue	1
Miscellaneous	1

Source:- http://ebooks.narotama.ac.id

APPLICATIONS OF WASTE TYRES IN CIVIL CONSTRUCTION

- **Tyre rubber in concrete and mortars**

Research on cement-based products modified with Tyre rubber – such as concrete and mortar – has been carried out for many years in order to examine the potential utilisation of waste Tyres in concrete production. Waste Tyres have been used to partially replace the aggregates in mortars and concrete. Tyre rubber can be used to produce workable concrete for specific applications, provided that adequate selection processes are undertaken – including the amount, gradation and shape of Tyre particles. This section deals with the properties of either mortar or concrete modified with waste Tyre rubber.

- **Specific weight**

The specific weight of concrete modified with waste rubber reduces as the level of substitution of aggregates with Tyre particles increases. This reduction can be attributed to the specific weight of Tyre rubber being lower than that of traditional aggregates (0.9–1.16 g/cm3 for Tyre rubber compared with 2.65–2.67 g/cm3for aggregates) (Oikonomou et al., 2006; Khaloo et al., 2008). However, Khatib and Bayomy (1999) showed that the decrease in specific weight is almost negligible for rubber contents lower than 10–20% of the total aggregate volume.

- **Workability**

The workability, defined as the ease with which concrete can be mixed, transported and been put into moulds, is affected by the interactions of Tyre rubber particles and mineral aggregates. Rubberized concrete has been found to be less workable than conventional concrete as the rubber content increases (Khatib and Bayomy, 1999; Albano et al., 2005; Oikonomou et al., 2006). It was also observed that mixtures made with fine crumb rubber were more workable than those made with coarse Tyre chips or a combination of Tyre chips and crumb rubber (Khatib and Bayomy, 1999).

Conversely, studies by on cement mortars showed that the workability of mortars with coarse rubber particles (maximum size of 4 mm) is better that that of mortars including fine rubber particles (0–1.18 mm). On the other hand, Raghavan et al. (1998) reported that mortars modified with Tyre shreds achieved workability comparable with or better than conventional mortars.

- **Water Absorption**

The durability of a material is often related to its capacity to resist water absorption. The primary transport mechanism by which water enters cement composites is capillarity by suction.Smaller the capillarity, higher the durability of the composite.

According to Segre and Joekes (2000), cement paste modified with Tyre rubber particles is characterised by a decrease in both the amount of capillary water absorption and its speed with an increase in rubber content. This could be due to the ability of rubber to repel water.

Oikonomou et al. (2006) have studied the addition of Tyre rubber to cement mortars as a replacement for the aggregates (sand) and found that open porosity and capillarity by suction decrease with the use of Tyre rubber. This decrease can be attributed to the smaller volume of pores in the mortars and to the fact that these pores cannot be easily reached by the water. Moreover, Benazzouk et al. (2007) investigated the water absorption of cement composites containing shredded rubber wastes; Tyre rubber has been used as a partial replacement for cement in order to develop lightweight construction materials. Test results for the hydraulic transport properties showed that incorporation of Tyre rubber into such composites tends to reduce the water absorption of the composites.

- **Durability**

There has not been a great deal of research on the durability of concrete modified with waste rubber. Cement mortars containing waste rubber showed a decrease in chloride ion penetration as the percentage of Tyre rubber increases. There is a further decrease in chloride ion penetration when adding commercial products comprising an anionic bitumen emulsion and SBR latex (N. Oikonomou and S. Mavridou, unpublished observations, 2007). On the other hand, according to Gesoglu and Güneyisi (2007), for a given water:cement ratio and with a moist curing period of 3 and 7 days, the use of rubber increased the chloride ion penetration through concrete and the degree of ion permeability depended on the rubber percentage used. After 28 days of curing there was a greater reduction in the magnitude of the chloride ion penetration into the mortar.

- **Tyre rubber in asphalt mixtures:**

Rubberized asphalt mixtures consist of asphalt, aggregates and Tyre rubber granules. Rubber aggregates can be used as bitumen modifiers or as substitutes for natural aggregates. There are two ways of producing rubberized asphalt mixtures. In the first method, the 'wet process', rubber particles are mixed with bitumen at elevated temperature prior to mixing with the hot aggregates; in the second method, the 'dry process', rubber particles replace a small portion of the mineral aggregate in the asphalt mix before the addition of the bitumen.

Many studies have been conducted investigating asphalt mixtures made using both the wet and the dry processes. Tyre rubber has been used in asphalt concrete mixtures providing rubberized asphalt with better skid resistance, reduced fatigue cracking, improved resistance to rutting, improved tensile strength and toughness, longer pavement life and reduced maintenance costs compared with conventional mixtures (Khosla and Trogdon, 1990; Fedroff et al., 1996; Khatib and Bayomy, 1999; Airey et al., 2004).

Rubberized asphalt mixtures show better performance at high temperatures, they can be used in a variety of climate conditions and they are more flexible at low and sub-under zero temperatures, while the thickness of an asphalt layer can be reduced from 50 to 38 mm. (http://www.ruberizedasphalt.org).

- **Other applications of waste Tyres:**

A certain proportion of wastes Tyres are reused as treads or are reclaimed for other forms of reuse/recycling. Waste Tyres can be used in cement kilns as an alternative fuel, or in the production of electricity, despite the fact that the incineration of Tyres, which is an undesirable option, cannot be achieved without pollution and contribution to climate change.

In addition to these general non-civil engineering applications, several studies have been carried out in order to examine the feasibility of the addition of these wastes in cement and asphalt concrete as well as in geotechnical works, where Tyres take the place of conventional construction materials such as fills or aggregates. The design engineer is responsible for determining the appropriateness of using scrap Tyres in a particular application and for selecting applicable tests and specifications to facilitate construction and environmental protection.

Recent trends in Europe and worldwide have seen Tyres used in many applications: as coatings, as a means for preventing soils from sliding, for sea embankments, as a means for inhibiting erosion near sea, as artificial reefs in marine environments, for temporary and heavy-load

roads, as off-shore breakwaters, in retaining walls, as sound barriers, in drainage culvert beds, for riverbank and coastal stabilization, as bridge abutment fill, in tram-rail beds, for thermal insulation and insulating backfill to limit heat loss from buildings, for insulation to limit frost penetration beneath roads, as porous bitumen additives, as a means of absorbing seismic waves and for slope stabilization.

The addition of rubber in a wide range of applications in civil engineering is based upon the unique characteristics of Tyre rubber as listed below:

1 High durability constituents of Tyres, such as carbon black and antioxidants, enhance the resistance to wear, chemical decomposition and sunlight.
2 Moisture absorption – they are relatively impervious to absorption.
3 Low compacted dry density and thermal conductivity – a Tyre is a poor thermal conductor so they are a better thermal insulator than soil or aggregates.
4 High hydraulic conductivity.
5 High compressibility, enough to absorb vibrations.
6 Low acoustic insulation.

Finally, reuse of Tyre rubber in the applications mentioned above can lead to the achievement of an environmental goal, which is the protection of the environment by recycling this kind of solid waste. At the same time, the use of large volumes of waste Tyres as a substitute for natural aggregates (sand, gravel, etc.) represents a great advantage from the point of view of sustainability in construction, while the Tyre Mountain would cease to exist.

LIMITATIONS

- Lack of awareness (general public,contractors, and public officials)
- Lack of access to specifications

CASE STUDY

In the present study, effect of crumb rubber as fine aggregate replacement on the compressive strength of concrete having mix proportions of 1:1.31:1.14 was investigated. The percentages of replacements were 0%, 10 %, 20% and30%by weight of fine aggregate. Tests were performed for compressive strength or all replacement levels of crumb rubber at different curing periods (7-days & 28-days).

TABLE: 4
PROPORTION OF M20 GRADE CONCRETE

Mix	C Kg/m3	F.A. kg/m3	C.A. Kg/m3	C.R. Kg/m3	W (Lts/m3)
M-1	592.68	775.96	673.35	0	243
M-2	592.68	698.37	673.35	16.41	243
M-3	592.68	659.56	673.35	24.62	243
M-4	592.68	620.77	673.35	32.83	243
M-5	592.68	543.18	673.35	49.24	243

C=Cement, F.A. =Fine Aggregate, C.A. =Course Aggregate, C.R.=Crum rubber, W=Water,

Source: ICCBT 2008 - B - (34) – pp373-382

TABLE: 5
COMPRESSIVE STRENGTH (MPA) OF CONCRETE WITH CRUMB RUBBER

Crumb rubber Content, %	Mix	Avg. Compressive Strength, (MPa)	
		7 days	28days
0	M1	30.45	39.68
10	M2	22.59	26.50
15	M3	18.70	20.13
20	M4	15.50	18.50
30	M5	12.20	15.98

Source: ICCBT 2008 - B - (34) – pp373-382

CONCLUSIONS

We can say that for 1m3 M20 grade of concrete consumption of fine aggregate is 775.96 kg. Here in specimen M-3 we replace fine aggregate by 24.62 kg of crumb rubber for 1m3M20 grades of concrete. So, we can say that up to 15% foundry sand utilized for economical and sustainable development of concrete. Uses of crumb rubber in concrete can reduce the harmfulness to the environment and produce a 'greener' concrete for construction. An innovative supplementary Construction Material is formed through this study.

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