Rubber Modified Concrete- A Green Approach For Sustainable Infrastructural Development

Manoj Chauhan[1], Dr. Hemant Sood[2]

[1]M.Tech Student, Department of Civil Engineering, N.I.T.T.T.R, Chandigarh, India
[2]Professor and Head, Department of Civil Engineering, N.I.T.T.T.R, Chandigarh, India

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Abstract - *Among industrial wastes, the tyre rubber wastes or scrap tyres are one of the hazardous wastes which are being generated and accumulated on very large scale worldwide every year. As tyre rubber waste is classified as non-biodegradable waste, thus its non-decaying nature creates a huge problem in proper and safe disposal. The conceivable solution of waste rubber tyres disposal crisis has been exhibited by the utilisation of scrap tyres as a construction material in concrete. Waste rubber tyres can be incorporated in concrete either as coarse aggregates or fine aggregates. Properties like sound insulation, thermal insulation, and impact resistance gets enhanced on the addition of waste rubber tyres in concrete. Rubberized concrete can find its successful application in non-structural components such as crash barriers, pavement blocks, sidewalks, culverts in road construction. This paper reviews some of the studies which have been carried out for developing rubber modified concrete. The effect of using rubber aggregates as repalcement to natural agggregates on the mechanical and fresh state properties have been discussed.*

Key Words: (Size 10 & Bold) Key word1, Key word2, Key word3, etc (Minimum 5 to 8 key words)…

1.INTRODUCTION

It has been realized that the generation of solid waste and the disposal problem related to it is a standout amongst the most vital issues which our human progress is confronting in present era, [1]. Population growth, urbanization and the industrialization causes increased growth in the utilization of various sorts of materials which has resulted in the huge amount of solid waste generation, [2]. Among solid wastes, the tyre rubber wastes or scrap tyres are one of the hazardous wastes which are being generated and accumulated on very large scale worldwide every year. As tyre rubber waste is classified as non-biodegradable waste, thus its non-decaying nature creates a huge problem in proper and safe disposal. Every year, more than one billion tyres are manufactured around the world, and equivalent number of tires is permanently expelled from vehicles, getting to be distinctly squandered. The U.S. is the biggest producer of waste tires, around 290 million a year, European Union contributes around 180 million tons to the scrap tyres volume. India's waste tyres represent around 6-7% of the worldwide aggregate. The waste rubber tyres in India are rising with the 12% per annum growth in the local tyre industry. Globally, in 2011, just 7% of waste tires were recycled at site, 11% were used for fuel, 5% were sent out for processing somewhere else and the remaining 77% were sent to landfills, stockpiled, or illicitly dumped; the equivalent of some 765 million tyres a year wasted, [3]. Thus stockpiling and land filling is not an effective way to dispose the waste rubber tyres as it greatly contributes in degradation of our ecology and causes various health hazards. On realizing the negative impact of waste rubber tyres due to disposal crisis on our society and the other problem related to it, the European Union completely restricted the disposal of whole tyres into the environment since 2003 and the shredded waste tyre since 2006 as per the norms stated under the EU Directive 199/31 EC, [2].

The conceivable solution of waste rubber tyres disposal crisis is exhibited by applying the philosophy of sustainable development. Among various aspects of sustainable development the recycling and reuse of waste products are the major ones, as it helps in decreasing the number of landfills due to the reuse of waste materials. Scrap tires have been utilized effectively in cement kilns as proposed prior by different researchers [4]. Other effective employments of scrap tires included their utilization in hot mix asphalt as a highway construction material [5, 6].

Fig -1: Scrap tyres in an open area

While these fields of utilizations gave positive outcomes for recycling and reusing scrap tyres, utilization of scrap tires with respect to the present volumes of tyres in landfills is very little. Moreover, concrete constitute the biggest segment of construction materials around the world, it has been recommended to utilize scrap tyres as a construction material in concrete. The yearly production of concrete worldwide consumes around 9 billion tons of aggregate and more than 2 billion tons of cement. Thus utilising huge amount of natural resources, which in turn exploiting our enviroment. This problem compels the researchers all over the world, to discover new alternative source of raw materials for concrete. Use of waste rubber tyres particles as a replacement to aggregates in concrete is one of such alternative method, which can address the problems of disposal crisis of tyre waste and developing environment friendly concrete at the same time [2]. As concrete is the most widely used construction material, therefore the partial addition of waste rubber tyres in concrete would consume billions of waste tyres.

In this paper rubber modified concrete and its application has been explained in brief and an extensive review is presented on various researches which have been carried out on the development of rubber modified concrete moreover, the effect of using rubber aggregates as repalcement to natural agggregates on the mechanical and fresh state properties have been discussed.

1.1 Rubber Modified Concrete

At global scale a lot of research has been carried out on the use of waste rubber tyres in concrete [7, 8]. Countries like USA and France has made it mandatory to utilise crumb rubber in highway construction [9, 10]. Waste rubber tyres can be incorporated in concrete either as coarse aggregates or fine aggregates. Waste rubber aggregates have been categorized in to four types based upon their particle size. This includes, 1) shredded fibers, 2) shredded/chipped tyres (approximately 2 to 20mm), 3) ground rubber (100% passing 0.425mm), and 4) crumb rubber (4.75-0.425mm); [11]. Rubber aggregates are acquired from waste tyres utilizing two different technologies, 1) mechanical grinding at ambient temperature, and 2) cryogenic grinding at a temperature underneath the glass transition temperature,[12]. On average, 10 to 12 pounds of crumb rubber can be derived from one passenger tire. Overall, a typical scrap tire contains (by weight); 1) 70 percent recoverable rubber, 2) 15 percent steel, 3) 3 percent fibre, and 4) 12 percent extraneous material (e.g. inert fillers), [13]. The material has been characterised elsewhere as having low particle density, negligible water absorption, low thermal conductivity, and high resistance to weathering, [14].

Rubber-modified concrete represents high deformation under post-failure load (strain capacity enhancement), low unit weight, high impact resistance, high thermal resistance and sound insulation properties. Incorporating granulated tyre waste as an elastic aggregate modifies the brittle failure of concrete and increasing its ability to absorb high amount of energy before undergoing failure [11].

Fig -2: Waste tyre crumb rubber

1.2 Application of Rubber Modified Concrete

All the above stated characteristics of rubberized concrete make it suitable for its application in wide range of construction activities. Rubberized concrete can find its successful application in non-structural components such as crash barriers, pavement blocks, Sidewalks, culverts in road construction, precast roofs for green buildings and roofing tiles with lighter weight. Rubber modified concrete can also be used in non load bearing members such as light weight concrete walls, building facades. Moreover it is found suitable to use rubber modified concrete for recreational courts and skid resistant ramps, [15, 16, 17]. Studies also showed that rubberized concrete is effective for vibration damping in structures and platforms thus can be used in buildings as an earthquake shock–wave absorber, [7, 18].

2.METHODOLOGY ADOPTED FOR THE DEVELOPMENT OF RUBBER MODIFIED CONCRETE

Nadim A. Emira and Nasser S. Bajaba (2012) [15], studied the viability of addition of waste rubber tyres aggregate as a replacement for natural aggregates in concrete, moreover, effect of curing time on the engineering properties were studied. Different concrete groups were prepared using plain Portland cement, crumb rubber as replacement for fine aggregates (0%, 10%, 20 % and 30%) by volume. Different sizes of crumb rubber were used which has been divided into three groups namely; (0.01-0.5) mm, (0.5-2) mm, and (2-3) mm. The specimens of all the different groups were investigated after different curing time namely; 7, 14, 21 and 28 days. The grade for normal concrete used in the study was M25.

Malek K. Batayneh et al. (2008) [1], focused its investigation on utilising crumb rubber as substitution for natural aggregates used in concrete mix in Jordan. Size of crumb rubber used in testing varied from 4.75 to 0.15 mm. The replacement is done in different percentages by volume (20%, 40%, 60 %, 80% and 100%). Type I ordinary Portland cement was used. The grade for normal concrete used in the study was M25. Effect on workability, unit weight, compressive strength and split tensile strength were studied, and also, stress strain relationship analysis was also done.

M. M. Reda Taha et al. (2008) [19], carried out an experimental investigation using chipped and crumb rubber as a partial replacement to coarse and fine aggregates. The size of chipped rubber tyres varies from 5 to 20 mm and that of crumb rubber tyres varies from 1 to 5 mm. The replacement levels were 25, 50, 75 and 100% by volume of the coarse and fine aggregates. Ordinary Portland cement was used; the grade for normal concrete used in the study was M25. The fresh concrete properties (unit weight, slump, air content) and mechanical properties (compressive strength and impact strength) were examined for different specimens incorporating different percentage of chipped and crumb rubber tyres. The effect on fracture toughness was also studied for chipped rubber tyre aggregates.

Shanmugapriya M (2015) [17], conducted an investigation to check the feasibility on the use of rubber modified concrete in light weight structures. Ordinary Portland cement of 53 grade and rubber tyre aggregates with their size ranging from 12 to 20 mm was used. The replacement with tyre aggregates is done in 3, 6, 9 and 12% (by weight). The grade for normal concrete used in the study was M25. The mechanical properties, such as, compressive strength, tensile strength and toughness index were examined, in addition to this, stress strain response was also studied.

Khalid Battal Najim, (2013) [20], experimentally determined the effect of varying w/c at constant cement content and aggregate specific surface area, on the fresh state properties and hardened state properties of rubberized concrete. Feasibility of designing rubber modified concrete with acceptable workability level was assessed. High strength Portland cement was used; fine aggregates, coarse aggregates and (coarse + fine) aggregates was replaced with rubber tyre particles for different percentages of 10, 20, 30 and 50% (by weight).

K.J. Rao and M.A. Mujeeb (2015) [21], studied the effect of crumb rubber on properties of Ordinary Portland Cement (OPC) Concrete and Ternary Blended Cement (TBC) Concrete of M40 grade with fly ash and silica fume as powders along with cement. Ordinary Portland cement of 53 grade was used. Crumb rubber percentage was varied as 0%, 5%, 10% and 15% in concrete mix samples. The compressive strength, impact strength and conductivity test were conducted, moreover, ultrasonic pulse velocity test was also performed and ultrasonic modulus was calculated. The impact tests were carried out on modified drop weight test equipment.

3.TEST RESULTS FROM VARIOUS EXPERIMENTAL PROGRAMMES

A. Unit weight

In various investigations on rubber modified concrete, it was found that the unit weight of concrete decreases with the increasing percentage of rubber content. Also, the air content was found to be more in concrete containing high percentage of waste tire rubber aggregate. The reduction in the unit weight is mainly because of 1) the difference in the specific gravity of natural aggregate and waster tire rubber aggregate and, 2) increase in the air content, [1, 15, 19, 20]. The higher reduction in unit weight is observed when coarse aggregates were replaced with the waste tire rubber aggregates. Although unit weight of concrete mix decreases, the lower unit weight of rubber modified concrete meets the criteria of light weight concrete for up to 20% to 30% (by volume) replacement of fine aggregates, [1, 15, 19].

B. workability

In most of the studies it was found that the workability of concrete mix decreases as the rubber aggregate content increases in the mix, [1, 19, 20]. Effect on workability is more pronounced when chipped rubber tyre particles were used as compared to the crumbed rubber. It has been reported by Malek K. Batayneh et al and M. M. Reda Taha et al. in their respective investigations that the desirable workable mix in correlation to conventional mix was produced when the replacement percentage was not more than 20% and 25% (by volume) respectively.

C. Compressive and Split Tensile Strength

Extensive research work shows that there was decrement in the compressive and split tensile strength of concrete when rubber aggregates were added to the normal concrete mix. The reduction in strength rised with the increase in the rubber aggregate content. Also, the reduction in strength is more when coarse aggregates were replaced, [1, 15, 17, 19, 20, 21].

The explanation to the decrement in strength was given in Iman Mohammadi et al. 2015 [22] in his research work, according to which the reasons for reduction in strength were attributed to the 1) significant difference between the specific gravity of rubber and other constituent materials of concrete, 2) rubber particles when introduced in concrete entraps air due to its hydrophobic nature, causing increase in air content, this leads to the reduction of concrete strength, 3) significant difference between the elastic modulus of rubber and other constituent materials of concrete causes loss of strength, 4) low adhesion or week bond between the cement matrix and the rubber particles, which results in the acceleration of crack propagation through rubber-cement paste interface, when load acts upon the concrete.

D. Toughness

Various investigations on rubber modified concrete indicate that the impact resistance chracterstics of concrete get enhanced on incorporating waste rubber tire aggregates in concrete mix. Malek K. Batayneh et al. (2008) [1], reported that adding rubber aggregates in concrete increased its ability to support load even after the formation of cracks, the failure is not abrupt but gradual. M. M. Reda Taha et al. (2008) [19], in his investigation concluded that the energy required for failure increases with the increase in the rubber tyre particles content. This effect is mainly attributed to the higher flexibility of rubber concrete composite due to which it was able to absorb high energy. Shanmugapriya M (2015) [17], found that Toughness index value is more for the concrete containing the rubber tyre particles as compared to the normal concrete, this showed that rubber concrete composites are able to withstand the deformation even after the peak load is reached, thus failure is ductile in nature. K.J. Rao and M.A. Mujeeb (2015) [21], found that the impact strength was increased as the percentage of crumb rubber increases from 0 to 15%. The toughness of the material increased to about 14 times in OPC concrete. Gupta et al. 2015 [23], in his study foud that waste rubber fibres can be conveniently used as a material to improve the ductility and impact resistance of concrete.

Important details such as the material used and the results obtained from various experimental programme carried out by different researchers has been summarized in Table: 1

Table 1: Comparison of various Experimental studies on Rubber modified concrete

Sr. No.	Research Programe	Material Used			Test Results			
		Cement type	Untreated Rubber Aggregates	Replacement Level	Unit Weight	Workability	Strength Properties	Toughness
1	Nadim A. Emira and Nasser S. Bajaba	Ordinary Portland Cement	Crumb rubber of different size group; (0.01-0.5) mm, (0.5-2) mm, and (2-3) mm.	0%, 10%, 20% and 30% by volume of fine aggregates	**Reduces** - Upto 30% replacement rubberized concrete can be used for light structural members	**Reduces**	**Reduces** - Loss of strength is more when bigger size rubber aggregates were used	-
2	Malek K. Batayneh et al.	ordinary Portland cement	Crumb rubber size varies from 4.75 to 0.15 mm	20%, 40%, 60%, 80% and 100% by volume of fine aggregates	**Reduces** - meets the criteria of light weight concrete for up to 20%(by volume) replacement of fine aggregates.	**Reduces** desirable workable mix upto 20% replacement (by volume).	**Reduces**	-
3	M. M. Reda Taha et al.	Ordinary Portland cement	chipped rubber varies from 5 to 20 mm and crumb rubber varies from 1 to 5 mm.	25, 50, 75 and 100% by volume of the coarse and fine aggregates both.	**Reduces**	**Reduces** Reduction is more in case of chipped rubber aggregates	**Reduces**	**Enhanced**
4	Shanmugapriya M	Ordinary Portland cement	Rubber aggregate size varies from 12 to 20 mm	3, 6, 9 and 12% (by weight) of coarse aggregates	**Reduces** - meets the criteria of light weight concrete for up to 12%(by weight) replacement	**Reduces**	**Reduces**	**Enhanced**
5	Khalid Battal Najim	High strength Portland Cement	Both Coarse and fine rubber aggregates used	10, 20, 30 and 50% (by weight) of both fine aggregate and coarse aggregates	**Reduces**	**Reduces** - reduction is more when coarse rubber aggregates used - workable mix upto 10% replacement (by weight).	**Reduces** -Loss of strength is more when bigger size rubber aggregates were used	**Enhanced**
6	K.J. Rao and M.A. Mujeeb	Ordinary Portland cement	Crumb rubber used	0%, 5%, 10% and 15% of fine aggregates	-	-	**Reduces**	**Enhanced** -toughness of the material increases to about 14 times in OPC concrete

4. CONCLUSIONS

Following conclusions have been derived after reviewing various experimental programmes:

1) Mechanical properties like compressive strength, split tensile strength reduces on the incorporation of rubber tyre particles into the concrete mix. The strength reduction rate increases as the percentage of rubber tyre content increases in the concrete mix.
2) Toughness and impact resistance ability of rubber modified concrete is more than the conventional concrete.
3) Addition of rubber tyre particles gives ductile characteristics to the concrete, thus failure is gradual, moreover, rubberized concrete develops an ability to support load even after the formation of cracks and peak load is reached.
4) Density (unit weight) of conventional concrete drops down on the inclusion of rubber tyre particles into the concrete mix.
5) Criteria for light weight structural member can be achieved by replacing natural aggregates from 20% to 30% (by volume) by waste tire rubber aggregates.
6) There is reduction in slump when rubber tyre particles are added to the concrete mix; however, workable concrete mix can still be created in correspond to the conventional concrete upto the replacement level (20-30) % by volume.
7) The effect of density reduction and slump reduction is more pronounced in the concrete mix containing coarse rubber tyre aggregates than crumb rubber aggregate.
8) Replacement level up to (20-30) % by volume and (8-12) % by weight generates the rubberized concrete mix with acceptable workability and strength and unit weight.
9) Most of the studies utilised untreated rubber tyre aggregates.
10) Rubber tyre aggregates compatibility and viability with the different cement other than OPC had not been investigated in most of the studies.

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