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Use of vulcanized rubber in concrete as a partial replacement of coarse aggregates

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ABSTRACT

One resulting from cutting worn tyres in the cement concretes. On this subject, several studies concerning the use of rubber aggregates resulting from crushing worn tyres were carried out. These research works showed that the benefits of associating rubber-concrete with high deformability and on the durability of these composites. Moreover, the benefit which we can gain from using the cement concretes for the roadways makes us think about multiplying the studies on the cement composites that incorporate rubber aggregates since the rigidity of the cement concretes can make it possible either to decrease the granular layer necessary to the asphalt road- way or to allow the use of less resistant concretes. This is the case with the use of concretes having a considerable part of rubber aggregates resulting from worn tyres. Even though there are many sustainable destinies for used tyres, the construction industry has shown little understanding of the potential of this waste. However, a number of promising possibilities have been emerging that have some weight in the market: asphalt, kindergarten and sports area pavements, impact barriers on roads, and breakwaters. These applications prove how interesting it is to pursue new research fields that could show how end- of-life tyres can be reused competitively in the sector.

Keywords: *Plant Leaf Detection, Image Processing, Feature Extraction*

1. INTRODUCTION

Concrete is the premier civil engineering material. Concrete manufacturing involves consumption of ingredients like cement, aggregates, water & admixtures. Among all the ingredients, aggregates form the major part. More than 50000 billion tonnes of aggregate are produced each year in the world. Use of natural aggregates in such a rate leads to a question about the preservation of natural aggregate sources. In addition, operation associated with aggregates extraction and processing is the principal causes for environmental concern. The most widely used fine aggregate for the making of concrete is the natural sand mined from the riverbeds. However, the availability of river sand for the preparation of concrete is becoming scarce due to the excessive non-scientific methods of mining from the riverbeds, lowering of water table, sinking of the bridge piers, etc. are becoming common. The present scenario demands identification of substitute materials for the river sand for making concrete. Recently in the environmental issues, restrictions of local and natural access or sources and disposal of waste material are gaining great importance. Today, it becomes more difficult to find a natural resource. Use of the waste materials not only helps in getting them utilized in cement, concrete and other construction materials, but also has numerous indirect benefits such as reduction in land fill cost, saving in energy, and protecting environment from possible pollution effect. It also helps in reducing the cost of concrete manufacturing. With increasing concern over the excessive exploitation of natural aggregates, synthetic lightweight aggregate produced from environmental waste is a viable new source of structural aggregate material. The uses of structural grade lightweight concrete reduce considerably the self-load of a structure and permit larger precast units to be handled.

In light of this in the contemporary civil engineering construction, using alternative materials in place of natural aggregate in concrete production makes concrete a sustainable and environmentally friendly construction material. Different alternative waste materials and industrial by-products such as fly ash, bottom ash, recycled aggregates, foundry sand, china clay sand, crumb rubber, waste glass, coconut shells etc can replace natural aggregates.

There are approximately 270 million waste tires generated annually in the United States, of these, 230 million are passenger car tires and 40 million are truck tires. According to the industry figures, there are over 800 million scrap tires currently on the stockpiles in the United States. A typical scrap tire (passenger car) weighs approximately 9 kilograms (20 pounds) and will provide approximately 60% rubber, 20% steel and 20% fiber and other waste products. The paving industry uses 1 to 2 million tyres per year. Each metric ton of Hot Mix Asphalt (HMA) which contains rubber can utilize 2 to 6 tyres. For example, if 50 million scrap tyres were going to be utilized in asphaltic concrete mixtures, then 8 to 25 million metric tons of HMA would require modifications. There are many factors to consider when a state agency uses rubber in its pavements including cost, specifications, type of equipment to be used, expertise of the contractor, potential recyclability of materials, etc. The reported advantages for using rubber in asphaltic concrete mixtures include: thinner lift, increased pavement life, retarded reflection cracking. The amount of waste rubber produced has gradually increased over the recent years due to an ever growing use of rubber tyres. Most waste rubber has and is being dumped into land- fill sites. The land filling of waste rubber is undesirable because waste rubber is non-biodegradable which makes them environmentally less friendly. Utilization of this waste is the need of the hour. There is huge potential for using waste rubber in the concrete construction sector. When waste rubbers are reused in making concrete products, the production cost of concrete will go down. With increase in waste rubber content, water absorption decreases indicating increase in durability. Density of concrete decreases with increase in waste rubber content thus making concrete light weight in nature.

In this work, the effect of waste rubber as partial replacement of coarse aggregate on the properties of concrete was studied. The characteristic properties of concrete such as com- pressive strength, flexural strength, split tensile strength and water absorption of various mixes were reviewed in this present work.

1.1 Importance and feasibility of the study

In a growing country like India, a huge amount of industrial waste is polluting the environ- mental. With a view to the above, this study aims at utilization of such materials for value added application i.e. waste management. In addition, the waste can improve the properties of construction materials. The high cost of conventional aggregate material affects economy of a structure. With increasing concern over the excessive exploitation of natural aggregates, synthetic lightweight aggregate produced from environmental waste is a viable new source of structural aggregate material.

At present the disposal of waste tyres is becoming a major waste management problem in the world. It is estimated that 1.2 billion of waste tyre rubber produced globally per year. It is estimated that 11% of post-consumer tyres are exported and 27% are sent to landfill, stockpiled or dumped illegally and only 4% is used for civil engineering projects. Hence efforts have been taken to identify the potential application of waste tyres in civil engineering projects. In this context, our present study aims to investigate the optimal use of waste tyre rubber as coarse aggregate in concrete composite.

1.2 Procedures for using different coarse aggregates in concrete

Concrete is basically a cement, sand and aggregate ratio. In this project we are using M20 grade(1:1.5:3) and we are replacing coarse aggregate by waste products partially. The concrete is thus prepared by combining:

- **Cement:** Cement is a binder, a substance that sets and hardens independently, and can bind other materials together. The ordinary Portland cement of grade 53 will be used in the study.
- **Sand:** Fine sand is to be used after proper sieving. Sand is mainly used as an inert material to give volume in concrete for economy.
- **Gravel:** Well graded gravel is used as a coarse aggregate.
- Rubber: It is used as a partial replacement of coarse aggregate in concrete.
- **Water:** The binding property of cement activates in presence of water and thus mortar is prepared.
- **The cement:** sand: aggregate ratio in concrete is 1:1.5:3. In this project, we are replacing coarse aggregate by certain percentage of waste rubber(5,10 &15 % 0f volume of coarse aggregate). The mixing is then done followed by moulding and then curing is done after 24 hours. The casted cubes, beams and cylinders are then tested after 7 and 28 days for flexural strength, compressive strength and tensile split strength respectively.
- **Corrode steel:** The specific gravity is lower leading to lower unit weights resulting in lower earth pressures.

Various literature reviews covering published research reports, journal articles, and other documents that discussed the utilization of scrap tires in civil engineering applications focusing on rubberized concrete with tyre chips incorporated have been worked out by various researchers.

2. LITERATURE REVIEW

Gintautas Skripkiunas, Audriusgrinys [1]: The aim of investigation was to study the deformation properties of Portland cement concrete with rubber waste additive. Concrete mixtures with the same compressive strength as concrete without this additive were tested. Used tyre rubber wastes were crumbed into fraction 0.1. The rubber additive was used as fine aggregate replacement in concrete mixtures by 3.2% of aggregates mass. The effect of rubber waste additive on technological properties, air content in fresh concrete, density and deformation properties under the static and dynamic load of concrete was investigated.

Mohammad Reza Sohrabi, Mohammad Karbalaie: A lot of rubber is produced worldwide. For example, 3.6 million tons rubber is produced annually only in US. 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, improvement of some mechanical and dynamical properties, such as more energy adsorption, better ductility, and better crack resistance. In this paper, the 7-day and 28-day compressive strength of concretes containing crumb rubber; silica fume and crumb rubber; Nano silica and crumb rubber; and Nano silica, silica fume and crumb rubber is investigated.

Akinwonmi, Ademolasamuel, Emmanuel, Seckley [6]: This paper presents a re- search into the mechanical strength of concrete with shredded tyre and crumb tyre as aggregate replacement. The materials used to make concrete for this experiment are coarse aggregate, cement, sand, shredded tyre, crumb tyre, potable water and Ordinary Portland Cement. A total of fifteen main mixtures were cast as solid bricks with 0% replacement as control then followed by 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, 20% separately for both shred and crumb rubber materials. The compressive tests for the concrete cubes were carried out by applying a constant uniform pressure to the cubes of the concrete blocks until failure occurred. The results of the compressive test show that by replacing the aggregate by 2.5 % shredded tyre, the compressive strength increased by about 8.5% but at 5% re- placement and beyond, the compressive strength decreased. For the Crumb tyre aggregates, the compressive strength decreased generally as the percentage replacement in- creased. Thus, crumb tyre is not advisable to be used as aggregate replacement due to its weak compressive strength. Shredded tyre could be used as replacement of aggregates in concrete production up to 2.5% replacement in order to help reduce the cost of concrete production arising from the increasing cost of cement, and reduce the volume of waste generated from unused tyres.

Parveen, Sachin Dass, Ankit Sharma: The disposal of used tyres is a major environmental problem throughout the world which causes environmental hazards. Crumb rubber is a waste material that is ideal for use in concrete applications. The aim of this study is achieved to use of rubber waste as partial replacement of fine aggregate to produce rubberized concrete in M30 mix. Different partial replacements of crumb rubber (0, 5, 10, 15 and 20%) by volume of fine aggregate are cast and test for compressive strength, flexural strength, split tensile strength and stress-strain behaviour. The results showed that there is a reduction in all type of strength for crumb rubber mixture, but slump values increase as the crumb rubber content increase from 0% to 20%. Meaning that crumb rubber mixture is more workable compare to normal concrete and also it is useful in making light weight concrete. It is recommended to use the rubberized concrete for non-structural applications.

N. J. Azmi B. S. Mohammed [7]: The test program was carried out to develop information about the mechanical properties of rubberized concretes. A control Portland cement concrete mix (PCC) is designed using American Concrete Institute mix design methods and crumb rubber contents of 10, 15, 20 and 30% by volume were chosen by partially replacing the fine aggregate with crumb rubber. Totally 15 concrete mixes with three different water cement ratio (0.41, 0.57 and 0.68) were cast and tested for compressive strength, splitting tensile strength, flexural strength and modulus elasticity. The results revealed that although there is a reduction in strength for crumb rubber mixture, but slump values increase as the crumb rubber content increase from 0% to 30%. Means that crumb rubber mixture is more workable compare to normal concrete and can be acceptable to produce crumb rubber concretes. The results also indicated that inclusion crumb rubber in concrete reduced the static modulus elasticity. Although there is a reduction in modulus of elasticity but the de- formability in crumb rubber concrete increased compared to normal concrete.

GANJIAN et al: In 2008, they investigated the performance of concrete mixture incorporating 5%, 7.5% and 10% tyre rubber by weight as a replacement of aggregate and cement. Two set of concrete mixes were made. In the first set, chipped rubber replaced the coarse aggregate and in the second set, scrap tyre powder replaced cement. The durability and mechanical tests were performed. The result showed that up to 5% replacement in both sets no major changes occurred in concrete characteristic.

Bakri et al: In 2007, they replaced the coarse aggregate by waste tyre rubber to produce early age concrete. Two different concrete mixes viz. rubberized concrete and rubber filler in concrete were used. In rubberized concrete they replaced the coarse aggregate with the rubber. It was suggested that the compressive strength and density of concrete depend on the amount of rubber added in the concrete. In the rubberized concrete containing little amount of added rubber, the density and compressive strength were reduced to nearly 80%, as compared to ordinary concrete.

Zheng et al: In 2008, they worked on rubberized concrete and replaced the coarse aggregate in normal concrete with ground and crushed scrap tyre in various volume ratios. Ground rubber powder and the crushed tyre chips particles range in size from about 15 to 4 mm were used. The effect of rubber type and rubber content on strength, modulus of elasticity was tested and studied. The stress–strain hysteresis loops were obtained by loading, unloading and reloading of specimens. Brittleness index values were calculated by hysteresis loops. Studies showed that compressive strength and modulus of elasticity of crushed rubberized concrete were lower than the ground rubberized concrete.

Taha et al: In 2008, they used chipped tyre rubber and crumb tyre rubber to replace the coarse and fine aggregate respectively in the concrete at replacement levels of 25%, 50%,75%, and 100% by volume. The tyre rubber was chipped in two groups of size 5 to 10 mm and 10 to 20 mm. the crumb tyre rubber of size 1 to 5 mm was used.

Khallo et al: In 2008. they determined the hardened properties of concrete using different types of tyre rubber particle as a replacement of aggregate in concrete. The different types of rubber particles used were tyre chips, crumb rubber and combination of tyre chips and crumb rubber. These particles were used to replace 12.5%, 25%, 37.5%, and 50% of the total mineral aggregate by volume. The results showed that the fresh rubberized concrete had lower unit weight and workability compared to plain concrete. Result showed large reduction in strength and modulus of elasticity in concrete when combination of tyre rubber chips and crumb rubber were used as compared to that when these were used individually. It was found that the brittle behaviour of concrete was decreased with increased rubber content. The maximum toughness index indicated the post failure strength of concrete with 25% rubber content.

The results show the variation in Compressive strengths, Flexural strengths, split tensile strength of various mixes in which the coarse aggregates are replaced by various percentages of tyre rubbe. (Refer Table 3.1). The results also show the variation in Compressive strength.

3. STANDARD CONSISTENCY TEST

3.1 For standard cement

Table 4.1: standard consistency result.

Sample	Consistency(%)	Mean
PC	26	27.6
PC	29	
PC	28	

Table 4.2 : setting time results.

Initial setting time (hrs).	Final setting time (hrs).	Mean of initial settinng time.	Mean of final setting time.
0.52	5.72	0.55	5.57
0.55	5.41		
0.59	5.58		

3.2 Abrasion and Crushing Tests for Coarse Aggregates:

Table 4.3: Result of abrasion test.

Tests	Natural Aggregates	Rubber aggregates	Mean of natural aggregates	Mean of rubber aggregates
Abrasion value (%).	2.0	0.32	1.87	0.3
	1.9	0.27		
	1.7	0.31		
Crushing value (%).	7.1		6.46	
	6.5			
	5.8			

3.3 Water Absorption Tests for Coarse and Fine Aggregates

Table 4.4: water absorption results.

	Water Absorption value (%)		Mean
Coarse Aggregates	Gravel.	0.73	0.66
		0.65	
		0.61	
	Rubber Wastes	0.2	0.18
		0.17	
		0.15	
Fine Aggregates	River Sand.	0.29	0.31
		0.34	
		0.31	

3.4 Workability test results for varying rubber content as aggregate:

Table 4.5: workability results

Sample.	Slump(mm).	%age reduction of slump.
PC	50	0
UTR-5	47	6
UTR-10	45	10
UTR-15	43	14
NTR-5	48	4
NTR-10	44	12
NTR-15	40	20
CTR-5	45	10
CTR-10	42	16
CTR-15	35	30

3.4 Compression test

(a) 7 days Compressive strength concrete with 5, 10, 15 % replacements of coarse agg. by tyre rubber.

Table 4.6: 7 days compressive strength of cubes.

Sample	Strength(N/mm^2)
PC	19.11
UTR-5	13.87
UTR-10	16.44
UTR-15	15.6
NTR-5	16.4
NTR-10	17.7
NTR-15	11.11
CTR-5	15.6
CTR-10	15.11
CTR-15	17.33

(b) 28 days Compressive strength concrete with 5, 10, 15 % replacements of coarse agg. by tyre rubber.

Table 4.7: 28 days compressive strength of cubes.

Sample	Strength(N/mm^2)
PC	27.33
UTR-5	19.8
UTR-10	23.5
UTR-15	20.4
NTR-5	23.3
NTR-10	25.3
NTR-15	15.6
CTR-5	22.2
CTR-10	15.5
CTR-15	21.7

3.5 Flexure test

The flexural strength of specimen is expressed as the modulus of rupture F_b which if „a" equal the distance between the ine of fracture and the nearer support ,measured on the centre line of the tensile side of specimen ,in cm is calculated as follows:

$$f_b = \underline{f \times l}\ bd^2$$

where" a" is greater than 20 cm for 15 cm specimen.

Table 4.8: 28 days flexural strength

Samples	Strength(N/mm^2)
PC	8.1
UTR-5	7.95
UTR-10	6.9
UTR-15	7.4
NTR-5	9.3
NTR-10	8.75
NTR-15	7.51
CTR-5	9.25
CTR-10	8.51
CTR-15	8

Table 4.9: Load vs displacement during flexure.

Sample	Ultimate load(KN)	Displacement(mm)
PC	16.2	0.96
UTR-5	15.9	1.12
UTR-10	13.8	1.1
UTR-15	14.8	0.8
NTR-5	18.6	1.3
NTR-10	17.5	1.5
NTR-15	15.02	1.38
CTR-5	18.5	1.6
CTR-10	17.02	1.45
CTR-15	16	1.3

3.6 Split tensile strength test

When load is applied along the generatrix ,an element on the vertical diameter of the cyind- er is subjected to horizontal stress of magnitude ;

Table 4.10: 28 days split tensile strength.

Sample	Strength(N/mm^2)
PC	2.38
UTR-5	2.1
UTR-10	1.9
UTR-15	1.6
NTR-5	3.82
NTR-10	5.72
NTR-15	6.36
CTR-5	4.76
CTR-10	4.28
CTR-15	4.076

Workability: While carrying our project work, it was visualized that workability of concrete decreased with increase in percentage replacement of coarse aggregate by rubber content. Different treatments were given to rubber to improve the test results but it gave negative impacts to the workability. The workability of concrete due to partial replacement of coarse aggregate by untreated rubber decreases the workability with respect to standard. The workability decreases to small extent due to addition of untreated rubber. When treatment of rubber was given to rubber there was a lot decrease in workability. Treatment was given by two methods. First rubber was treated with 0.1 m solution of NaOH for about 20 minutes and then it was used in concrete. This treatment improves hardened properties to some ex- tent but workability was decreased with respect to untreated rubber as well as plain concrete. Second treatment involves treatment with cement paste and this treatment also de- creases workability more compared to NaOH treatment. In cement paste treatment, de crease in workability was maximum among all mixes and was found for CTR-15 4.5) which was almost about 30%. In NaOH treatment, maximum decrease in workability was found for NTR-15 (20%) and minimum for NTR-5 (4%). Thus, it was seen that due to use of rubber aggregates as partial replacement of coarse aggregates, workability decreases with respect to plain concrete.

Reason for low workability of rubber-crete: Low workability of rubber-crete (un-treated) is due to hinderance of movement of concrete particles by rubber-crete and due to improper bonding. When bonding is improved by NaOH treatment, decrease in workability is due to increase in viscosity. When cement paste treatment is given to rubber, workability decreased due to adherence of cement particles on rubber particles which absorb water from concrete and make less water available to provide workability.

b) Hardened concrete

Compressive strength: There is decrease in compressive strength of concrete on % re- placement of coarse aggregate by rubber. 7 days compressive strength of NTR-10 is found to be highest among all the replaced mixes but lower than plain concrete. Similarly, 28 days compressive strength is found to be highest for NTR-10 but again lower than plain concrete. There is less compressive strengths of untreated and cement treated rubber concrete as compared to NTR-10 and plain concrete. Hence there is an overall reduction in compressive strength of rubber concrete irrespective of the treatment of rubber, whether it is sodium-hydroxide treatment or cement paste treatment, then plain concrete. Reason for low compressive strength: Reduction of compressive strength of rubber concrete than plain concrete is due to lack of proper bonding between concrete and rubber particles. Less compressive strength of rubber concrete is also due to low adhesion be- tween concrete and rubber and cement matrix. It is also contributed due to low strength of rubber particles than concrete matrix around them and thus when force is applied, the cracks first of all appear in contact zone of rubber and concrete matrix. Low compressive strength of rubber concrete is also due to large difference of elastic modulas been rubber (0.01-0.1GPa) and concrete and other concrete elements. Flexure strength: Flexure strength of rubber concrete shows varying trend. 28 days flexure strength of NTR-5 is found to be highest among all replacement mixes as well as plain concrete. Untreated rubber concrete showed decrease in flexure strength while as treated rubber showed varying trend. In NaOH treatment of rubber, the maximum flexure strength is found to be at 5% replacement while as minimum flexure strength is found to be at 15%. In case of cement treatment, the maximum flexure strength is found to be at 5% replacement and minimum at 15% replacement.

Hence, there is an overall increase in flexural strength of concrete at 5% replacement of coarse aggregates by both sodium hydroxide treated and cement treated rubber. Reason: The mixtures with less cement content are less stiff. As the tyre chips can bridge cracks caused by flexural loading, the less stiff specimens with tyre chips can withstand additional loading after cracking. Thus decrease in tyre chip content increases the flexural strength but only up to a range of 5%.

Split tensile strength: Split tensile strength of rubber concrete also increases in both the treatments. However, maximum tensile strength was found to be in case of sodium hydroxide treatment at 15% replacement of coarse aggregate by rubber aggregate. In case of NaOH treated rubber minimum split tensile strength was found to be at 5% replacement. In case of cement paste treatment, maximum split tensile strength was found to be at 5% re- placement by rubber while as minimum split tensile strength was found to be at 15 % re- placement. Hence, there is an overall increase in tensile split strength of rubber concrete by both the treatments i.e. by NaOH treatment and cement paste treatment.

Reason for increase in split tensile strength: Increase in split tensile strength of rubber concrete after giving treatment to rubber is due to combined effect of improved bonding by treatment and flexible nature gained by concrete due to incoration of rubber particles.

4. CONCLUSION

The purpose of this study was to determine if waste materials such as rubber enhances the characteristic properties of concrete. The data presented in this project shows that there is great potential for the utilization of waste rubber. It is considered that the waste rubber form would provide much greater opportunities for value adding and cost recovery, as it could be used as a replacement for expensive materials such as coarse aggregate.

In this project, the performance of concrete made rubber aggregates was studied. The following conclusions were drawn:

1. Fresh concrete properties such as Unit weight and Slump decreased with the higher replacement levels of rubber.
2. Increase in rubber content decreased the compressive strength of the concrete significantly.
3. There is a great potential for rubber to be used in the concrete, thus saves area from becoming as landfill and is thus eco-friendly with environment.
4. The combined action of air and rubber creates a discreet thermal insulation that pre- vents the transport of heat. If we analyze such properties in relation to density in the hardened state, we can note an increase of the thermal conductivity with the density increasing, the increase of density corresponds to a more compact structure, so to a reduction of its porosity
5. In reference to the test concerning the resistance of rubbercrete to Sulphatic attack, it is evident that, all the blends have lower compressive strength compared to the normal condition, consequently they are all vulnerable to attack by sulphate ions.

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