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Experimental investigation on partial replacement of coarse aggregate with used tyres

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ABSTRACT

Most of the time, used tyre rubber is not noticed to be applied in a useful way. It is rather becoming a potential used and pollutant to the environment. Moreover, the collecting process of used tyres is not very costly as compared to the extraction or production of mineral aggregates used in normal concrete. The general objective of this study is to evaluate the hardened properties of the concrete produced by replacing part of the natural coarse aggregate with an aggregate produced from locally available used tyre rubber. With the increase in urbanization in India, the number of cars and consequently the amount of used tyre is going to increase significantly in the near future. Hence, the no environmental nature of these used tyres is going to be a potential threat. This study concentrated on the performance of a single gradation of used tyres. The used tyres are collected from local sources and manually cut into pieces to achieve uniform size of 20 mm, which is the maximum aggregate size in the mix design. The influence of different gradations of the tyre aggregate on concrete properties was not evaluated in this study but it should be considered in future researches. All the used tyres collected were chosen from those collected to avoid any inconsistent properties that may arise by mixing materials from different sources. The properties of used tyres from other tyre manufacturers were not included in this study. The study was done on M20 concrete grade. The influence of using used tyres in high strength concrete was not covered in the present study. The percentage replacements were limited to 5 categories i.e. 10%, 20%, 30%, 40% and 50% replacement of the natural coarse aggregate. The different effects, which can be observed in different percentages of replacements.

INTRODUCTION

Tyres can be recycled into, among other things, the

hot melt asphalt, typically as crumb
rubber modifier—recycled asphalt pavement
(CRM—RAP), and as an aggregate in Portland

Cement concrete. Tyres can also be recycled into other tyres. Tyres have also been cut up and used in garden beds as bark mulch to hold in the water and to prevent weeds from growing. There are

some "green" buildings that are being made both private and public buildings that are made from old tyres. Pyrolysis can be used to reprocess the tyres into gas oils, solid residue (char), and low-grade

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carbon black, which cannot be used in tyre manufacture.

A pyrolysis method which produces activated carbon and high-grade carbon black has been suggested. Recent developments in de vulcanization enable dealing with substantial volumes, taking 40 mesh whole tyre crumbs and converting it into value-added compounds without degrading the polymer and without generating any pollution. This new generation in de vulcanization technologies operates with very high productivity while maintaining a low energy footprint. The compounds produced from processed tyre scrap can be blended with virgin rubber compounds, maintaining performance while substantially reducing the raw material cost. The substantial economies of scale and value addition now make it possible to make burning of tyres entirely unnecessary.

Rubber aggregates are obtained by reduction of scrap tyres to aggregate sizes using two general processing technologies: mechanical grinding or cryogenic grinding. Mechanical grinding is the most common process. This method consists of using a variety of grinding techniques such as 'cracker mills' and 'granulators' to mechanically break down the rubber shred into small particle sizes ranging

from several centimeters to fractions of a centimeter.

The steel bead and wire mesh in the tyres is magnetically separated from the crumb during the various stages of granulation, and sieve shakers separate the fiber in the tar. At the early stages of research related to the use of recycled tyres, chips were available and most of the time the particles contained steel wires and polyester fibers. With the advances InTechnology, now the recyclers are capable of removing all the wires and polyester fibers. In addition, the tyre chips that were used at the early stages are disappearing and being replaced by crumbed rubber which has small or no residue of fibers and wires.

Shredded tyres can be used as filler material for soils, foundations and pavements. Crumbed or pulverized tyre rubber can be combined with other polymeric material to form mats, playground tiles, or road barriers among others. By itself, it can be used as an aggregate for asphalt pavements or concrete mixes. Similar to the recycling of polymers, a solution is to substitute part of the aggregate in concrete mixes with pulverized tyre rubber or shredded tyres.



Fig 1: Stockpiles of Used Tyres Affecting

Environment

Statement of the problem

According to the census of 2001, 270 million out of the 1027 million people in India live in urban areas. It is estimated that by the year 2011 the total of the urban population shall reach the figure of 400 million. The total used generated by the people in urban areas is around 40 million tons per year. The composition of this used varies from biodegradable

organic vegetable matter to inorganic materials like metal and rubber.

No official or enforced system of segregation at source has been put in place, either by recycling or reuse, but some persons have found great use for the used and thus nowadays whatever can be used or recycled is taken out of the garbage before throwing it away. Rubber is one of the most difficult materials to recycle and the safe disposal and reuse of industrial and consumer rubber used continues to

pose a serious threat to environmental safety and health. Dumping of heaps of mountains of used tyres confirm the belief that chemically cross linked rubber is one of the most difficult materials to recycle. That coupled with a long history of failed attempts to create quality products from rubber has resulted in such a resistance to new ideas concerning rubber recycling. Scrap Tyre disposal methods used currently can be listed as below ranked on their environmental preference:

Use material for its originally intended purpose. Grind scrap tyres into crumb rubber, separate steel and fiber. Sell rubber as raw material.

Use whole scrap tyres for energy recovery. Burn whole scrap tyres as fuel supplement in cement kilns. Use mechanically processed tyres for energy recovery. Eg. Tyre chips added to coal as fuel supplement in power plants, paper mills, cement kilns, etc.

Alter the chemical structure of scrap tyres and use the products for energy recovery.

All the required materials were collected and delivered to the laboratory.

Cement	-	OPC 53 Grade
Fine Aggregate	-	Sand (Lake Sand)
Coarse Aggregate-		Gravel (20mm)
Replacement	-	Used Tyres

(Locally Available ~ 20mm)

Mix design

Mix Design for M20 Grade Concrete by Indian Standard Recommended Method of Concrete Mix Design as per Design Code IS 10262-1982

Design Stipulations		
a)	Characteristic Compressive Strength	
b)	Required in Field at 28 Days	20N/mm ²
c)	Maximum Size of Aggregate (Angular)	20mm
d)	Degree of Workability	0.8
e)	Degree of Quality Control	Good
f)	Type of Exposure	Mild
Test Data for Materials		
a)	Cement Used	OPC
b)	Specific Gravity of Cement	3.15
1.	Specific Gravity of C.A.	2.73
2.	Specific Gravity of F.A.	2.59
c)	Water Absorption	
1.	Coarse Aggregate	1%
2.	Fine Aggregate	0.09%
d)	Free (Surface) Moisture	
1.	Coarse Aggregate	0.086
2.	Fine Aggregate	0.11%
d)	Sieve Analysis	
1.	Coarse Aggregate:	Conforming to Table 2 of IS: 383-1970
2.	Fine Aggregate:	Conforming to Zone III

Table 1: Mix Design Table

	Cement	F.A.	C.A.	Water
1	1.48	3.34	0.53	

RESULT DISCUSSIONS

This section describes the results of the tests carried out to investigate the various properties of the rubberized concrete mixes prepared in contrast with the control mixes. In the succeeding parts, the result for compressive strength is presented. Analysis and discussions are also made on the findings.

Compressive strength test

This is an important test as most of the properties of concrete are qualitatively related to it. It is a most common method. The test is conducted on cubical specimens. The cube specimen is of size 15×15×15 cm. The largest nominal size of the aggregates does not exceed 20 mm. The moulds are to be of metal moulds, preferably of steel or cast iron. The moulds are made in such a way that the specimen are taken out without damage. A tamping steel bar of 16 mm diameter 0.6 m long with a bullet end is used for compacting. The test cube specimens are made as soon as practicable. The concrete is filled into the mould in 5 cm deep approximately. Each layer is compacted by tamping rod (25 to 35 strokes depending on 15 cm depth) or by vibration.

After the top layer has been compacted the top of the mould is leveled using a trowel. The top is converted with a glass or metal plate to prevent evaporation. The specimens are demoulded after 24 hours and submerged in fresh clean water or saturated lime solution and kept there until taken out just prior to test. The water should be maintained approximately at 27°C ± 2°C and on no account the specimens are allowed to dry. The specimens are tested in a compression testing machine at the completion of 3 days, 7 days and 28 days. Compression on the cube undergoes lateral expansion owing to Poisson's ratio effect. The

compressive strength of the specimen is expressed as the,

$$f_{ck} = P/A$$

Where,

f_{ck} = compressive stress in N/mm² P = ultimate load in KN

A = c/s area of the concrete cube in mm²

Test results

The compressive strengths of concrete specimens were determined after 3, 7, 28 and 56 days of standard curing. For rubberized concrete, the results show that the addition of rubber aggregate resulted in a significant reduction in concrete compressive strength compared with the control concrete. This reduction increased with increasing percentage of rubber aggregate. Tables 2, 3, 4 below show the results of the 3rd, 7th and 28th day compressive strength tests.

From table 2, it is observed that CC has the high compressive strength of 12.89 N/mm². The replacement of used tyre specimen CC1 has the highest value of 10.22 N/mm² and CC5 has the lowest value of 03.55 N/mm² in 3 days. In the Table 3, i.e. 7 days curing cubes results shows that the specimen CC has the higher strength, whereas the replacement of used tyre specimen CC1 & CC5 has a value of 21.33 N/mm² and 07.11 N/mm² respectively.

Further from the Table 4 of 28 days curing results, we finally observe that the specimen CC, CC1 & CC2 are the three specimens that attain the actual strength of mix design. Specimen CC5 has the very least value of all the specimen of the test results.

Table 5 explains in detail about the comparison of test results based on various days of curing i.e. 3, 7, and 28 days.

Table 2: Results of Compressive Strength Tests after 3 Days Curing

Specimen Type	Trial I	Trial II	Trial III	Stress, σ N/mm ²
CC	12.44	13.33	12.89	12.89
CC1	10.67	10.22	09.78	10.22
CC2	07.55	08.00	08.44	08.00
CC3	06.67	07.11	07.55	07.11
CC4	05.78	05.33	06.2	05.78
CC5	04.44	03.55	02.67	03.55

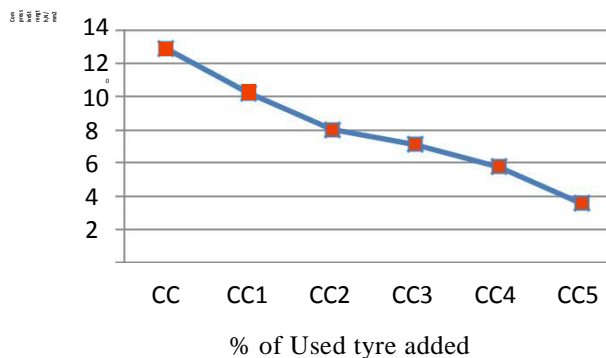
Table 3: Results of Compressive Strength Tests after 7 Days Curing

Specimen Type	Trial I	Trial II	Trial III	Stress, σ N/mm ²
CC	24.00	24.89	25.78	24.84
CC1	21.78	20.89	21.33	21.33
CC2	17.33	17.78	16.89	17.33
CC3	12.44	14.22	13.33	13.33
CC4	10.22	09.78	10.67	10.22
CC5	06.67	07.11	07.55	07.11

Table 4: Results of Compressive Strength Tests after 28 Days Curing

Specimen Type	Trial I	Trial II	Trial III	Stress, σ N/mm ²
CC	33.33	35.11	34.22	34.22
CC1	28.44	27.56	29.33	28.44
CC2	20.44	21.33	22.22	21.56
CC3	17.33	18.67	17.33	17.78
CC4	12.89	12.89	12.89	12.89
CC5	08.44	11.11	09.78	09.78

Compressive Strength attained in 3Days

**Figure 2: Graph for Compressive Strength after 3Days Curing**

Compressive Strength attained in 7Days

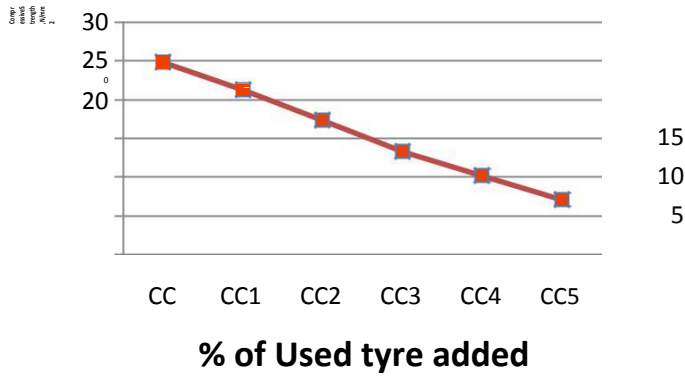


Figure 3: Graph for Compressive Strength after 7Days Curing

Compressive Strength attained in 28Days

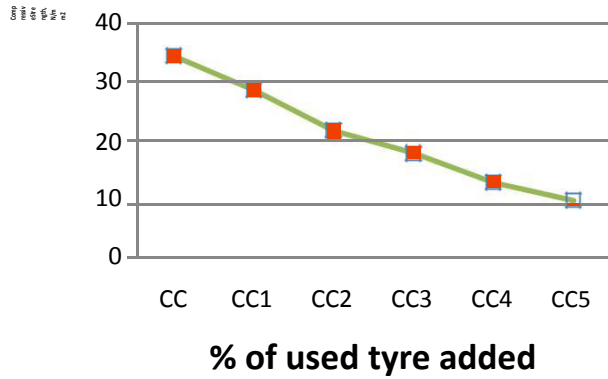


Figure 4: Graph for Compressive Strength after 28Days Curing

Comparison of Compressive Strength

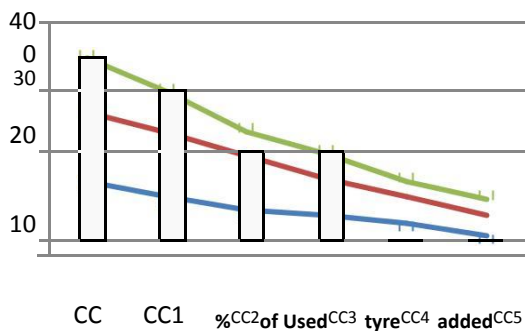


Figure 5: Graph for Comparison of Characteristic Compressive Strength



Figure 6: Used Tyres

The reason for the compressive strength reductions could be attributed both to a reduction of quantity of the solid load carrying material and to the lack of adhesion at the boundaries of the rubber aggregate. Soft rubber particles behave as voids in the concrete matrix. Considering the very different mechanical properties of mineral aggregates and rubber aggregates, mineral aggregates usually have high crushing strength.

They are relatively incompressible, whereas rubber aggregates are ductile, compressible and resilient. Used tyre rubber has a very low modulus of elasticity and a Poisson's ratio. Therefore, used tyre aggregates tend to behave like weak inclusions or voids in the concrete, resulting in a reduction in compressive strength. It is well known that the presence of voids in concrete greatly reduces its strength.

The existence of 5 % of voids can lower strength by as much as 30 % and even 2 % voids can result in a drop of strength of more than 10%. Another observation while carrying out the compressive strength test was the nature of crack formation. In used tyre concrete, crack formation is different from plain concrete because bond strength between rubber and cement paste is poor than that of between aggregate and cement paste. Therefore, initial cracks were formed around rubber aggregates and cement paste in rubberized concrete. Although the compressive strength values have considerably decreased with the addition of used tyre pieces as seen in Table 4.4, their values are still in a reasonable range for a 10% and 20% replacement



Figure 7: Preparation of Concrete Specimens

values because the intended compressive strength 20MPa was achieved in this category.

Cost comparison

It is done to find out the difference between the conventional concrete mix and replaced concrete mix. It is found out for the volume of 1m^3 of concrete. Since the actual value of used tyre is not known exactly, we have used an approximate value for it, which is higher than the actual value.

The ratio of M20 concrete grade is **1: 1.48: 3.34**

CONCLUSION

The general objective of this project was to evaluate the fresh and hardened properties of concrete produced by replacing part of the natural coarse aggregates with an aggregate produced from locally available used tyre and subjected to local conditions. From the test results of the samples, as compared to the respective conventional concrete properties, the following conclusions and recommendations are drawn out.

For rubberized concrete, the test results show that the addition of rubber aggregate resulted in a significant reduction in concrete compressive strength compared with the control concrete. This reduction increased with increasing percentage of rubber aggregate. Losses in compressive strength were observed. The reason for the strength reduction could be attributed both to a reduction of quantity of the solid load carrying material and lack of adhesion

at the boundaries of the rubber aggregate, soft rubber particles behave as voids in the concrete matrix.

Therefore, rubber aggregate tends to behave like weak inclusions or voids in the concrete resulting in a reduction in compressive strength. Although the compressive strength values have considerably decreased with the addition of used tyre pieces, their values are still in the reasonable range for a 10 % and 20 % replacement values because the intended compressive strengths of 20MPa was achieved in this type of specimen.

RECOMMENDATIONS

A reduced compressive strength of concrete due to the inclusion of rubber aggregates limits its use in

some structural applications. Nevertheless, it has few desirable characteristics such as lower density, higher impact and toughness resistance, enhanced ductility, and a slight increase in flexural strength in the lower strength concretes.

Since the use of rubber aggregates in concrete construction is not a common trend in our country, more studies and research works need to be done in this area and academic institutions should play a great role. This research was done by preparing single graded rubber aggregates of size 20 mm. The effects of different sizes should be studied in the future. Besides to this, the effects in different percentage replacements other than those made in this research needs to be investigated.