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Experimental Investigation on Rubberized Concrete

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ABSTRACT

In recent years, there has been a considerable interest in resolving one of the important environmental problems like the solid waste management. Out of the variety of common solid waste, the disposed waste tyre parts, abundantly found in the landfill, has been found as a non-biodegradable type. However, it is known that the reinforced rubber material shows the hysteresis behavior under cyclic loading and offers a possibility for its re-usage as a filler material whenever high damping is required. In this report an effort has been made to study experimentally the feasibility of using the waste tyre parts as coarse aggregate in cement concrete. The present investigation has been started with the consideration of M20 grade vibrated concrete as control mix or reference mix. A test program has been carried out to identify the necessary information about the mechanical properties of rubberized concretes. Tyre rubber chips have been used as coarse aggregate in the production of Rubberized concrete mixtures by partially replacing the coarse aggregate with rubber. In order to keep the brevity, five designated rubber contents varying from 1%, 2%, 3%, 4% and 5% by total aggregate volume have been used in the present investigation. Experiments have been conducted for compressive test, split tensile strength test, flexural strength test, determination of the Young's modulus, determination of Dynamic modulus of elasticity, Static ultrasonic pulse velocity test, the Dynamic ultrasonic test and Rebound hammer test etc. in accordance with the IS standards. Using this grade of Concrete a set of 250×250×100 mm size tiles have been prepared as a possible example of the application part.

It has been observed from the results that the concrete containing rubber aggregate has improved workability, requiring less amount of water for same mix design and a reduction in mechanical properties (Compressive strength) concrete a set of 250×250×100 mm size tiles have been prepared as a possible example of the application part.

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Keyword: M20 grade, rubber aggregate, workability, mix design, Compressive strength

1. INTRODUCTION

Solid waste management has gained a lot of attention to the research community in recent days. Out of the various solid waste, accumulated waste tyres, has become a problem of interest because of its non-biodegradable nature [Malladi, 2004]. Most of the waste tyre rubbers are used as a fuel in many of the industries such as the thermal power plant, cement kilns and brick kilns etc. Unfortunately, this kind of usage is not environment friendly and requires high cost. Thus, the use of scrap tyre rubber in the preparation of concrete has been thought as an alternative disposal of such waste to protect the environment. It has been observed that the rubberized concrete may be used in places where desired deformability or toughness is more important than strength like the road foundations and bridge barriers. Apart from these the rubberized concrete having the reversible elasticity properties may also be used as a material with tailorable damping properties to reduce or to minimize the structural vibration under impact effects [Siddique et al. (2004)].

The difficulties associated to the theoretical investigations to identify the mechanical properties of the rubberized concrete have necessitated the need for the experimental investigations on rubberized concrete. Therefore, in this study an attempt has been made to identify the various properties necessary for the design of concrete mix with the coarse tyre chips as aggregate in a systematic manner. Properties of rubberized concretes, in the present experimental investigation, the M20 grade concrete has been chosen as the reference concrete specimen. Coarse tyre rubber chips, has been used as coarse aggregate with the replacement of conventional coarse aggregate

1.1 Objective Of This Study

To investigate the mechanical properties associated to the rubberized concrete (using the Portland slag cement), the following items have been kept as the objective.

1. Study the feasibility of incorporating coarse tyre rubber chips as coarse aggregate in concrete mixes and determine the change in the properties after the incorporation of the rubber into the concrete mix.
2. Experimental verification of the published results on rubberized concrete, various relevant standards, various properties of rubberized concrete, and their relationship to plain concrete.
3. Investigation on the influence of the rubber content on the mechanical properties of rubberized concrete starting with the 0% rubber content (i.e., without rubber) and up to 15% rubber content in the M20 grade concrete (i.e., with a partial replacement of the coarse aggregate by 1%, 2%, 3%, 4%, and 5% by volume of the total coarse aggregate material). For convenience, the mix design for M20 grade concrete has been done according to IS: 10262(1982).
4. Measurement/determination of the mechanical properties (Compressive Strength, Tensile Strength, Flexural Strength, and Young's Modulus) of all concretes.
5. Conduct the non-destructive tests like Rebound hammer test of the rubberized concrete and conventional specimens.

2. LITERATURE REVIEW

Ahangar-Asr A., Faramarzi A, & Javadi A.A. et al (1) found that, as rubber aggregate are increase there is decrease in mechanical properties of concrete depends on type and content of rubber used. A new data mining technique, named Evolutionary Polynomial Regression (EPR) is developing to predict the mechanical behavior of rubber concrete. Three separate models were developed to predict the properties of concrete. The developed EPR models provide very accurate predictions for strength parameters of rubber concrete. (*A Ahangar-Asr 2010*)

Aiello M. A. et al (2) investigate the properties of various concrete mixture at fresh and hardened state produced by partial substitution of coarse and fine aggregate with proportion of 31.10%, 29.10%, 17.40%, 9.24%,and 8.44% by weight and having opening size 20, 16, 12.5, 10, and 8mm respectively of waste tires rubber particle having same dimension of replaced aggregate .After the analysis workability of fresh concrete is slightly improved by partial substitution of coarse and fine aggregate with rubber shreds. Reduction in the compressive strength for both type of rubcrete specimen with increase in amount of replaced aggregate. *(M.A.Aiello et al 2009)*

Azmi N. J., Mohammed B. S., Al-Mattarneh H. M. A. et al (3) had carried out a program to develop information about the mechanical properties of rubberized concretes. 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 from0% 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. *(N. J. Azmi et al 2008)*

Batayne Malek K. Marie Iqbal, Asi Ibrahim et al (4) focused on use of crumb tires as a replacement of the local fine aggregates used in the concrete mixes in Jordan. The test results showed that even though the compressive strength is reduced when using the crumb tires, it can meet the strength requirements of light weight concrete. The mechanical test results demonstrated that the tested specimens of the crumb rubber concrete remained relatively intact after failure compared to the conventional concrete specimens. Although the strength of modified concrete is reduced with an increase in the rubber content, its lower unit weight meets the criteria of light weight concrete that fulfill the strength requirements. Although it is not recommended to use this modified concrete in structural elements where high strength is required, it can be used in many other construction elements

Bignozzi M.C., Sandrolini F et al (5) prepared self-compacting concrete containing different amount of untreated tire waste to investigate and their mechanical and microstructural behavior. They concluded that self-compacting rubberized concrete required slightly higher amount of super plasticizer than self-compacting concrete to reach self-compacting properties, keeping constant water/cement and water/powder ratios. Concrete compressive strength and stiffness decreases with increasing amount of rubber phase in the mix, but the obtained values are higher than those of Ordinary Portland cement concretes admixed with similar amount of tire mix. Significant concrete deformability before failure and capability to withstand post failure loads with some further deformations are exhibited by loads with some further deformation due to tire rubber waste presence. Self-compacting rubberized concrete porosity is only poorly affected by the presence of significant amount of rubber phase in comparison with that of ordinary self-compacting concrete. (*M.C.Bignozzi et al 2006*)

Cairns R. A. & Kew H.Y. & Kenny M.J. et al (6) study investigates the potential of incorporating recycled rubber tire chips into ordinary Portland cement concrete. Plain rubber aggregate and rubber aggregate coated with cement paste were used. The results showed that, that concrete incorporating rubber aggregate has lower workability, unit wt. & exhibited a notable reduction in compressive strength. It does not exhibit a typical failure mode of plain concrete and a beneficial effect on flexural strength was observed. The use of rubberized concrete in concrete block probably shows the greatest potential for success at present. (*Cairns R. A. 2004*).

Durham Stephan A., Kardos Adam et al (7) having primary object of study to evaluate the reuse potential of crumb rubber in concrete mixtures for pavement application. Based on the result of this study confirms that upto 30% crumb rubber may be used for highway application and still produce concrete with the fresh and hardened properties required of such mixtures. (*Stephan A. Durham et al 2012*)

Eldin Neil N. et al (8) investigated the strength and toughness properties of concrete in which amount of rubber tire particle of several size were used as aggregate. The two type of rubber used in experiment named 'Edges' and 'Preston' with 25%, 50%, 75%, 100% replacement by coarse aggregate for each type. The compressive, tensile strength test are conducted on specimen. He concludes that reduction up to 85% of compressive

3. MATERIALS AND METHEDOLOGY

mix of concrete is designed using locally available materials. All required material including Cement, Sand, Gravel and rubber aggregate are characterized as per IS code methods. The tire waste is shredded in the size ranges 10 to 20 mm is added in concrete mix as a substitute of aggregate respectively in 6%, 12%, 18% proportions. The present work proposes to cast test specimen of concrete cube, cylinder for experimental study and testing. After 7 & 28 days of curing the test on various concrete specimen is taken to analyze results

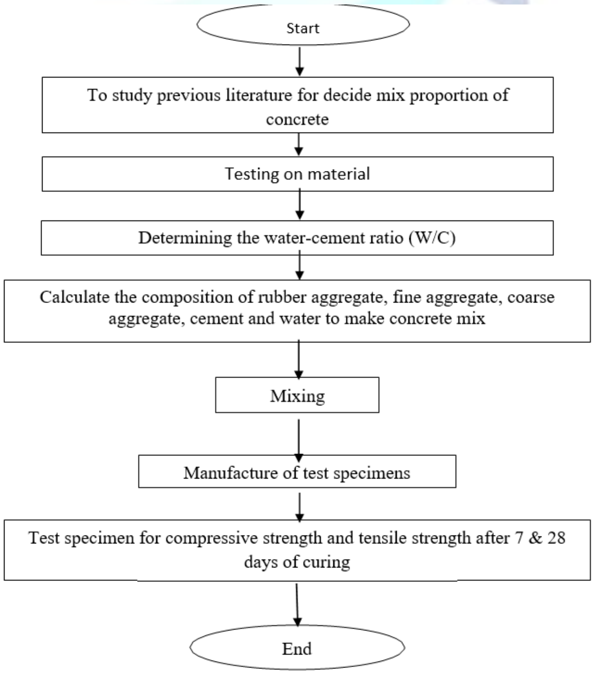


Table 1: No of specimen used for different % of 20mm Rubber aggregate replaced

20mm Rubber aggregate (%)	Specimen
1%	6 cubes & 6 Cylinders
2%	6 cubes & 6 Cylinders
3%	6 cubes & 6 Cylinders
4%	6 cubes & 6 Cylinders

3.1 Mix Design for M20 Grade Concrete

Control mixture for M-20 grade concrete was designed as per IS:10262-2009. Mix design is the process of selection of suitable ingredients of concrete and to determine their properties with object of producing concrete of certain maximum strength and durability, as economical as possible. The purpose of designing is to achieve the stipulated minimum strength, durability and to make the concrete in the most economical manner.

1. Specific Gravity of cement = 3.15
2. Specific Gravity of Coarse Aggregate = 3.14
3. Specific Gravity of Fine Aggregate = 2.5
4. Water absorption for coarse aggregate = 3.76
5. Water absorption for fine aggregate = 3.76

4. RESULTS AND DISCUSSIONS

4.1 Result of tests carried on material

Table 2: Test carried on Aggregate

Test	Fineness modulus	Specific Gravity	Water absorption	Flakiness index	Elongation index	Crushing strength	Impact value
Result	3.95	3.15	1.61%	14.06%	14.87%	13.93%	18.5%

1. As per IS 383-1970 permissible limit of Crushing strength is up to 30%. Therefore calculated Crushing strength is within permissible limit.
2. As per IS 383-1970 permissible limit of Impact value is up to 30%. Therefore Calculated impact value is within permissible limit.
3. As per IS 2386(part-3)-1963 the permissible limit of Water absorption is in between 0.5 to 2%. Therefore calculated Water absorption is within permissible limit
4. As per IS 2386(part-1)-1963 permissible limit of Flakiness index is in between 10 to 15%. Therefore calculated Flakiness index is within permissible limit.
5. As per IS 2386(part-1)-1963 permissible limit of Elongation index is up to 15%. Therefore calculated Elongation index is not within permissible limit.

Table 3: Test carried on sand

Test	Fineness modulus	Specific Gravity	Water absorption
Result	2.62	2.5	1.63

Table 4: Test carried on 20mm scrap tire Rubber

Test	Fineness Modulus	Specific Gravity	Water absorption	Flakiness index	Elongation index
Result	1.98	1.10	0.00%	13.87%	14.20%

1. As per IS 2386(part-3)-1963 the permissible limit of Water absorption is in between

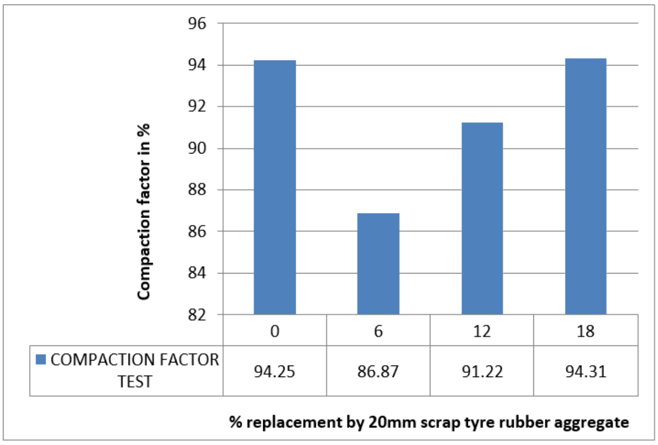
   0.5 to 2%. Therefore calculated Water absorption is not within permissible limit.
2. As per IS 2386(part-1)-1963 permissible limit of Flakiness index is in between 10 to 15%. Therefore calculated Flakiness index is within permissible limit.
3. As per IS 2386(part-1)-1963 permissible limit of Elongation index is up to 15%. Therefore calculated Elongation index is not within permissible limit.

Table 5: Test carried on cement

Test	Standard consistency	Initial setting time	Final setting time	Soundness	Fineness	Compressive strength
Result	35%	35 minutes	310 minutes	9.7%	7.6%	35.13N/mm^2

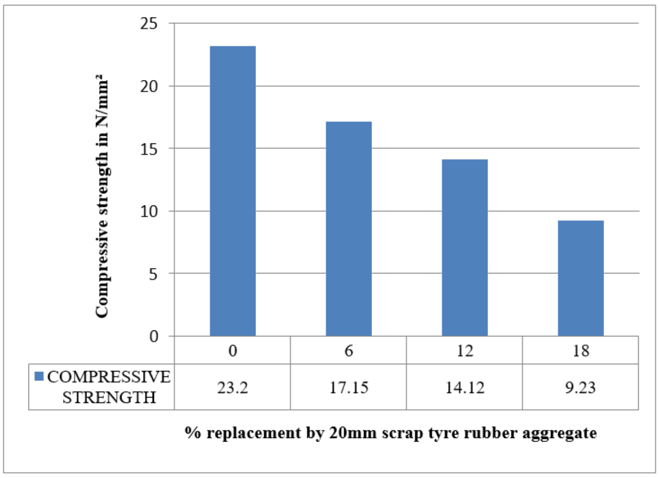
1. As per IS 12269 for 53 grade OPC permissible limit of Initial setting time is not less than 30 minutes.
2. As per IS 12269 for 53 grade OPC permissible limit of Final setting time is not more than 600 minutes.
3. As per IS 12269 for 53 grade OPC permissible limit of Soundness is up to 10 mm.
4. As per IS 12269 for 53 grade OPC permissible limit of fineness is up to 10 %.

Table 6: Result of Test on Fresh concrete by Compaction factor method



1. The minimum workability of concrete is **86.87%** at 6% replacement of 20mm scrap tire rubber aggregate.
2. The maximum workability of concrete is **94.31%** at 18 % replacement of 20mm scrap tire rubber aggregate.
3. At 6% replacement of 20mm scrap tire rubber aggregate, the workability of concrete is decreased by 7.38% as compared with Workability of traditional concrete.
4. At 12% replacement of 20mm scrap tire rubber aggregate, the workability of concrete is increased by 4.35% as compared with 6% replacement of 20mm scrap tire rubber aggregate.

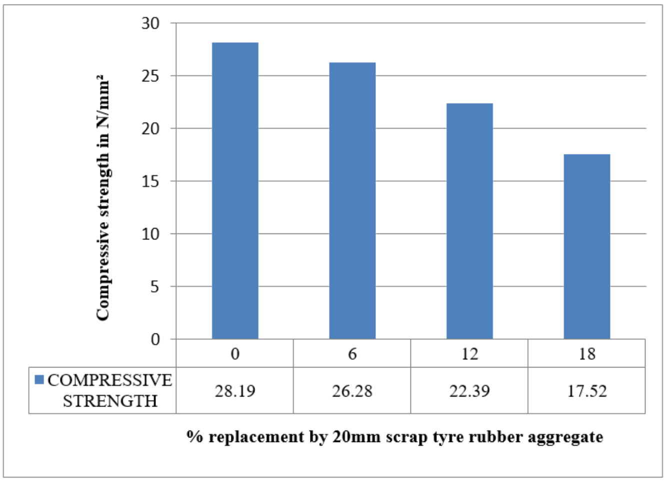
Table 7: Compressive strength of concrete cube specimen tested after 7 days of curing



1. The maximum compressive strength is **23.2 N/mm^2** at 0% replacement of 20mm Scrap tire rubber aggregate.
2. The compressive strength is at 6% replacement of 20mm Scrap tire rubber aggregate is

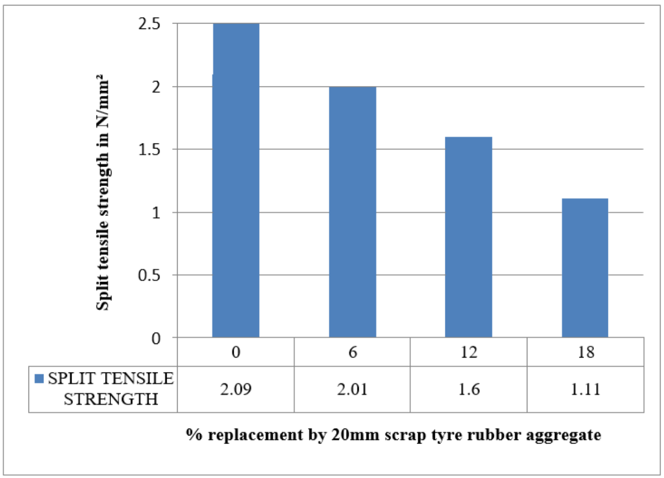
   6.05% smaller than the compressive strength of traditional concrete.
3. At 18% replacement of 20mm Scrap tire rubber aggregate compressive strength is decreased by **7.92 %** as compared with the compressive strength of concrete at replacement of 6% and by **13.97%** of Compressive strength of traditional concrete.

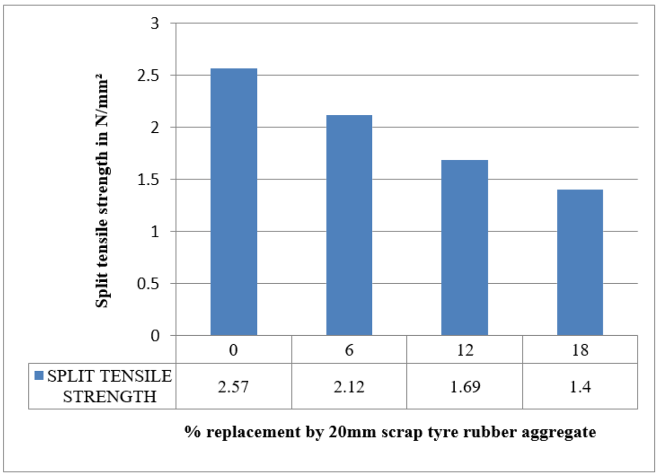
Table 6: Compressive strength of concrete cube specimen tested after 28 days of curing



1. The maximum compressive strength is **28.19 N/mm^2** at 0% replacement of 20mm Scrap tire rubber aggregate.
2. The compressive strength is at 6% replacement of 20mm Scrap tire rubber aggregate is 1.91% smaller than the compressive strength of traditional concrete.
3. At 18% replacement of 20mm Scrap tire rubber aggregate compressive strength is decreased by **8.76%** as compared with the compressive strength of concrete at replacement of 6% and by **10.67%** of Compressive strength of traditional concrete.

Table 7: Split Tensile strength of concrete cylinder specimen tested after 7 and 28 days of curing





1 The maximum Split tensile strength of concrete is **2.09 N/mm2** at 0% replacement of 20mm scrap tire rubber aggregate.

2 The Split tensile strength at 6%replacement of 20mm scrap tire rubber aggregate is

0.08% smaller than the Split tensile strength of traditional concrete.

3 For 6% replacement of 20mm scrap tire rubber aggregate the Split tensile strength is nearly equal to Split tensile strength of traditional concrete.

4 At 18% replacement of 20mm scrap tire rubber aggregate Split tensile strength is decreased by **0.9** % as compared with the Split tensile strength at 6% replacement of 20mm scrap tire rubber aggregate and by **0.98%** for traditional concrete.

1. The maximum Split tensile strength of concrete is **2.57 N/mm2** at 0% replacement of 20mm scrap tire rubber aggregate.

2. The Split tensile strength at 6%replacement of 20mm scrap tire rubber aggregate is

0.45% smaller than the Split tensile strength of traditional concrete.

3. At 18% replacement of 20mm scrap tire rubber aggregate Split tensile strength is decreased by **0.72%** as compared with the Split tensile strength at 6% replacement of 20mm scrap tire rubber aggregate and by **1.17%** for traditional concrete.

5 CONCLUSIONS

1 The test conducted on materials like Aggregate, Sand, Cement and rubber having all test results within permissible limit as per IS codes.

2 The modified concrete mix using recycled tires performs satisfactorily on various tests, with acknowledgement to the proportional relationship between its rates of strength- loss and contain of the rubber in the mix. Mixing, casting and compacting the concrete mix using 20mmscrap tire rubber aggregate with local materials can be carried out in a similar fashion to that of traditional concrete mix.

3 Modified concrete casted using 20mm scrap tire rubber aggregate as a replacement to coarse aggregate shows reduction in density of concrete compare to traditional concrete.

4 As density of concrete is reduces, self-weight (Dead load) of the structure is reduces. Therefore design becomes economical.

5 Up to 6% replacement of 20mm scrap tire rubber aggregate, compressive strength is nearly equal to compressive strength of traditional concrete at 28 days.

6 Up to 12% replacement of 20mm scrap tire rubber aggregate, split tensile strength is less than split tensile strength of traditional concrete.

7 The test result of this study indicate that there is a great potential for the utilisation of 20mmscrap tire rubber aggregate in concrete mixes up to 6%.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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