Rubberized Concrete: *Demand Of Good Environment*

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***Abstract*— Rubberized concrete composite as a new structural material aiming for an enhanced energy dissipation capability and thus improved seismic performance by mixing recycled rubber crumb with concrete. While rubberized concrete is not new, this study represents the first investigation on damping and dynamic (including seismic) behaviours of rubberized concrete for its potential application as structural material. Small-scale column models were fabricated using rubberized concrete with different proportions of rubber crumb to evaluate the structural dynamic performance, including free vibration tests to identify damping ratios and seismic shaking table tests to investigate the structural responses to earthquake ground motion. Meanwhile, rubberized concrete cylinders were tested to evaluate compressive strength and modulus of elasticity. It was observed from various past research that the damping coefficient of the rubberized concrete increased by 62% compared with normal concrete and, as a result, the seismic response acceleration of the structure decreased by 27%. However the concrete suffered from reduction in compressive strength as rubber crumb was added. It was found that adding silica fume to rubberized concrete improved the bonding between the rubber and cement and thus the concrete strength. Overall, this study demonstrated the potential of using the environmentally-friendly rubberized concrete as structural material to enhance dynamic performance and reduce seismic response of concrete structures.**

Keywords*— *Rubberized concrete, Damping coefficient, modulus of rigidity, dynamic performance

Introduction Ever since the ancient Romans revolutionized its use, concrete has served as a construction material for civil infrastructure for more than two millennia. The introduction of steel reinforcement in the late 19 century significantly increased the tensile strength of concrete, but reinforced concrete structures are still vulnerable to severe earthquakes that release significant kinetic energy over a short period of time. A more energy-dissipative concrete is highly desired. Meanwhile, used tires are disposed at a rate of 1.1 tires per person per year, amounting to more than 303 million tires per year in the US. In 2009, about 594 thousand tons of scrapped tires were reportedly disposed in landfills. Although scrapped tire management programs started in many states, there were still 128 million tires remain stockpiled throughout the US. These stockpiles present the threat of uncontrolled fires and other environmental hazards. Because of the rapid depletion of available sites for waste disposal, scrapping of waste tires in landfills becomes extremely dangerous. Over the years, disposal of waste tires has become one of the most serious environmental issues. To alleviate this problem, new green materials are being developed using recycled tire rubber, with one example being rubberized concrete, in which rubber crumb replace some of the aggregates in concrete. Rubberized concrete has become an emerg ing research topic in recent years. So far, most of the studies have focused on the evaluation of mechanical properties of rubberized concrete mixture. It was demonstrated that addition of recycled rubber crumb could increase the deformability and ductility of the concrete. At the same time, concerns about reduction in compressive strength of rubberized concrete have been raised, which is attributed to the poor bonding between the rubber particles and the cement paste.

I. Scope

Rubberized concrete, which incorporates recycled rubber particles from tires into the concrete mix, offers several advantages, including improved durability, flexibility, and sustainability. The scope for rubberized concrete is broad and includes various potential applications:

- Rubberized concrete is known for its sound-absorbing properties. Its use in road pavements can help reduce noise levels in urban areas, making it a suitable material for highways and streets.
- Rubberized concrete's ability to absorb impact and vibrations makes it suitable for applications in structures where these properties are critical, such as bridge abutments, airport runways, and industrial flooring.
- The addition of rubber particles can enhance the durability of concrete, making it more resistant to cracking and improving its overall lifespan. This is particularly beneficial for structures subjected to dynamic loads.

II. Problem Statement

- Rubberized concrete has better impact resistance compared to traditional concrete. This makes it suitable for applications where impact loads are a concern, such as bridge abutments and industrial flooring.

- The use of rubber particles in concrete enhances its ability to absorb sound, making rubberized concrete an effective choice for noise reduction in pavements, highway barriers, and building structures.
- Rubberized concrete exhibits enhanced flexibility, making it more resistant to cracking under various conditions. The rubber particles act as a cushioning material, absorbing stress and allowing the concrete to deform without developing extensive cracks.

III. LITERATURE REVIEW.

Kaloush et al. , Ismail et al. and Ra_oul et al. did not keep constant the mix design when adding the rubber to concrete, so that the comparison with the reference material is not possible.

Kaloush et al. and Ra_oul et al. changed the w/c ratio, while Ismail et al. added polymer fibers. Xue et al and Najim et al. did mechanical characterization for other purposes.

Mendis et al. and Elghazouli et al. did not make compression tests.

Aslani et al. and Wang et al. used iron or steel fibers to enhance the mechanical performance. Whereas six publications were not included for other specific reasons, namely the study by

Rahman et al. was excluded since it focused on the effect of different plasticizers, the one by He et al. because it is mainly focused on the adhesion phenomena occurring between concrete and rubber, the two studies by Najim et al. together with the one by Siddique et al. and Roychand et al. since they are review articles, and lastly the one written by Taha et al. because it presents issues related to the mix design and the relative composition quantification.

IV. MATERIALS AND MIX PROPORTIONING

GENERAL

Generation of good quality concrete requires fastidious consideration practiced at each phase of make of concrete. In this examination, the mechanical properties of the Rubberised Concrete (RC) are gotten. The Rubberised Concrete was set up by including the materials, for example, cement, fine aggregate, coarse aggregate, crumb rubber aggregate and consumable water. The properties of these materials are touched base by leading differently related analyses.

MATERIALS

1. Cement

Cement is the most important ingredient utilized. Cement goes about as a coupling material utilized in the arrangement of concrete. It ties the coarse aggregate and fine aggregate with assistance of water, to a solid issue and furthermore it fills the voids in the solid. One of the vital criteria for the choice of cement is its capacity to deliver enhanced microstructure. Consequently the choice of appropriate grade and nature of concrete is 29 imperative for getting rich mix. Normal Portland Cement of 53 grade in compliance to IS 8112-1989 and like ASTM type III (C150-95) were utilized.

Table 3.1 Physical properties of cement

Sl.No	Properties	Value	Standard values
1	Specific gravity	3.17	3.10 - 3.20
2	Standard consistency	28%	25 - 35%
3	Initial setting time	45 minutes	>30 min
4	Final setting time	512 minutes	<600 min
5	Compressive strength of mortar cubes at 28 days	53.80 MPa	53 MPa

2. Fine Aggregate

Fine aggregate assumes a vital job in concrete in the two stages, its plastic and solidified state. Fine aggregates by and large comprise of normal sand or pounded stone with most particles going through a 3/8-inch (9.5 mm) sieve. Fine aggregate ought to be legitimately evaluated to give least void proportion and be free from harmful materials like clay, sediment substance and chloride pollution and so forth.

Table 3.2 Physical properties of fine aggregate

S.No	Properties	Value
1	Specific gravity	2.52
2	Percentage of voids	24.50%
3	Fineness modulus	2.786
4	Bulk density	1650 kg/m^3
5	Water absorption	1.20%

Table 3.3 Sieve analysis for fine aggregate (sand)

Sl.no	Sieve size (mm)	Weight retained (g)	Cumulative weight retained (g)	Cumulative % retained	% finer
1	10	0	0	0	100
2	4.75	14	14	1.4	98.6
3	2.36	35	49	4.9	95.1
4	1.18	185	234	23.4	76.6
5	0.6	339	573	57.3	42.7
6	0.3	357	930	93	7
7	0.15	56	986	98.6	1.4
8	Pan	14	1000	100	0

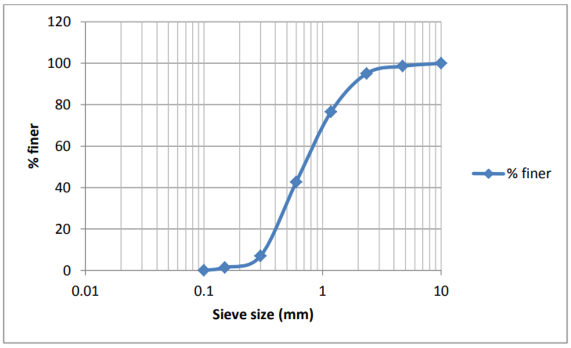


Figure 3.1 Sieve analysis chart for fine aggregate

3. Coarse Aggregate

Coarse aggregates make up about 75% of the volume of concrete, so their properties impact the properties of the concrete. Aggregates are granular materials, most usually regular rock and sands or pounded stone, albeit every so often manufactured materials, for example, slags or extended clays or shales are utilized. The job of the aggregate is to give much better dimensional soundness and wear obstruction. Likewise, in light of the fact that they are more affordable than Portland cement, aggregates lead to the generation of increasingly efficient concretes.

Table 3.4 shows the physical properties of coarse aggregate. Table 3.5 shows the Sieve analysis of coarse aggregate. Figure 3.2 shows the grading curve of coarse aggregate.

Table 3.4 Physical properties of coarse aggregate

S.No	Properties	Value
1	Specific gravity	2.74
2	Fineness modulus	5.67
3	Bulk density	1507.5 kg/m^3
4	Water absorption	0.80%

Table 3.5 Sieve analysis for coarse aggregate

Sl.no	Sieve size (mm)	Weight retained (g)	Cumulative weight retained (g)	Cumulative % retained	% finer
1	20	0	0	0	100
2	16	175	175	8.75	91.25
3	12.5	785	960	48	52
4	10	760	1720	86	14
5	4.75	260	1980	99	1
6	2.36	20	2000	100	0
7	Pan	0	2000	100	0

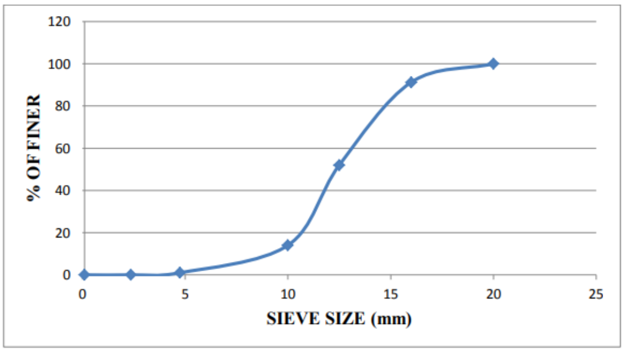


Figure 3.2 Sieve analysis chart for coarse aggregate

3.2.4 Crumb Rubber Aggregate

Tyre rubber was made by cutting the piece truck tires into sizes of 16mm and 20mm and utilized by mixing them in an extent of 2:3. The cutting of tyre was finished by hand with etches and cutters. The most extreme and least size of rubber aggregate was 20mm and 16mm separately were utilized for supplanting coarse aggregate in Rubberised Concrete. Figure 3.3 demonstrates the Crumb Rubber aggregate. Table 3.6 demonstrates the Properties of Rubber aggregate.

Figure 3.3 Crumb rubber aggregate

Table 3.6 Physical properties of Rubber aggregate

S.No	Properties	Value
1	Specific gravity	1.07
2	Bulk density	1013kg/m^3
3	Water absorption	0.33%

4. Polyvinyl Alcohol (PVA)

Polyvinyl Alcohol (PVA) in the powder shape was utilized in the concrete mix to remunerate the quality reduction because of the use of crumb rubber. From the literature, it has been picked that 0.5% PVA included with cement would give the ideal outcomes.

Figure 3.4 Polyvinyl alcohol

V. DETAILS OF THE SPECIMEN

Specimens of 250 samples were given such a role as 15 quantities of cubical sample of size 150 mm x 150 mm x 150 mm which is utilized to locate the compressive quality, 15 quantities of prism sample of size 100 mm x 100 mm x 500 mm which is utilized to discover the flexural quality, 15 quantities of 150 mm width and 300 mm height which is utilized to locate the split tensile quality and 5 quantities of 150 mm distance across and 300 mm tallness which is utilized to discover modulus of elasticity. These samples were separated into 5 varieties of Rubber. The factors of samples considered as Conventional Concrete (CC), Rubberised Concrete (RC) are named as RC4, RC8, RC10 and RC15. The level of replacement of rubber made is 0%, 4%, 8%, 10% and 15% for a volume of coarse aggregate.

For experimentation 33% scale outside Column-Beam joint of Ttype joint samples were built with the steel reinforcement fitting in with IS456:2000. The cyclic loading test was concentrated for the 0%, 8% and 12% replacement of rubber against coarse aggregate.

Specimens	**Size of the specimen(mm)**	**Designation**	**% replacement of rubber**	**No. of specimens**
Cube (compressive strength)	150 mm x150mm x150 mm	CC	0	5
		RC4	4	5
		RC8	8	5
		RC12	12	5
		RC15	15	5
Cylinder (split tensile strength)	150 mm diameter and 300 mm height	CC	0	5
		RC4	4	5
		RC8	8	5
		RC12	12	5
		RC15	15	5
Prism (flexural strength)	100 mm x 100mm x 500 mm	CC	0	5
		RC4	4	5
		RC8	8	5
		RC12	12	5
		RC15	15	5
		CC	0	5
Cylinder (young"s modulus)	150 mm diameter and 300 mm height	RC4	4	5
		RC8	8	5
		RC12	12	5
		RC15	15	5

V. RESULTS AND DISCUSSIONS

FRESH CONCRETE PROPERTIES

The workability of fresh concrete is examined by slump test, the outcomes are arranged in the Table 5.1. The Figure 5.1 demonstrates the slump variety of fresh Concrete.

Sl.No	**% of Rubber variation**	**Slump value (mm)**
1	0	60
2	4	66
3	8	79
4	12	89
5	15	96

The outcomes demonstrate that the workability of the ordinary portland cement concrete can be enhanced while including the crumb rubber substance. The crumb rubber substance in the concrete gave the most astounding workability contrasted with traditional concrete. The slump value was increasing as the crumb rubber substance increased from 0% to 15%. This means, the crumb rubber concrete samples have adequate workability as far as simplicity of taking care of, placement, and wrapping up.

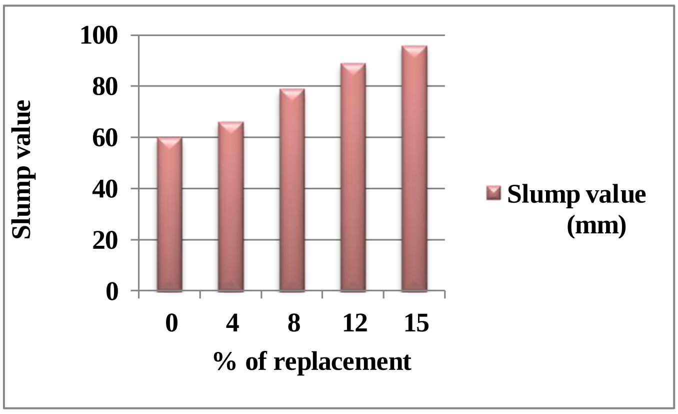


Figure 5.1 Slump comparison chart

HARDENED CONCRETE PROPERTIES OF M30 CONCRETE

5.2.1 Compressive Strength

The Compressive strength test is completed for the cubical samples. The test outcomes are arranged in Table 5.2. Figure 5.2 demonstrates the examination of compressive strength of Rubberised concrete.

In M30 concrete CC represents 1:1.62:2.764:0 cement: fine aggregate: coarse aggregate: rubber aggregate.

RC4 represents 1:1.62:2.653:0.11 cement: fine aggregate: coarse aggregate: rubber aggregate.

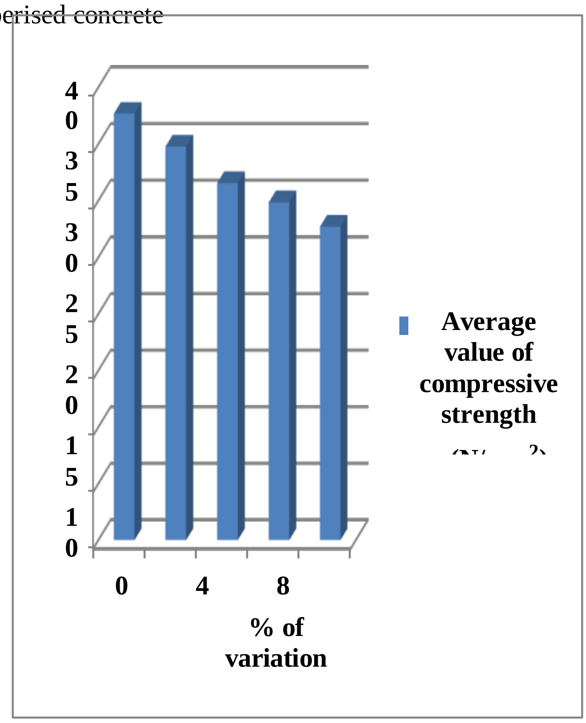
RC8 represents 1:1.62:2.543:0.221 cement: fine aggregate: coarse aggregate: rubber aggregate.

RC12 represents 1:1.62:2.432:0.332 cement: fine aggregate: coarse aggregate: rubber aggregate.

RC15 represents 1:1.62:2.349:0.415 cement: fine aggregate: coarse aggregate: rubber aggregate.

Sl. No	Designation	Average Ultimate load (kN)	Average value of compressive strength (N/mm^2)
1	CC	847.66	37.67
2	RC4	781.33	34.76
3	RC8	709.66	31.54
4	RC12	671.66	29.85
5	RC15	623.33	27.70

Figure 5.2 Comparison of compressive strength of Rubberised concrete



- The trial results uncover that a definitive load carrying limit of the concrete is diminishing while an expansion in the rate replacement of rubber.
- The Portland cement concrete mix is needy extraordinarily on the thickness, size and hardness of the coarse aggregate. Since the coarse aggregate was mostly supplanted by crumb rubber so the decrease in strength is foreseen.

5.2.2 Split tensile strength

- The split tensile strength test is completed for the cylinder shaped samples. The test outcomes are classified in Table 5.3. Figure 5.3 demonstrates the examination of split tensile strength of Rubberised concrete with the ordinary concrete.

Table 5.3 Results of split tensile strength test for cylindrical Specimen

Sl. No	Designation	Average Ultimate load (kN)	Tensile strength (N/mm^2)
1	CC	222.33	3.14
2	RC4	208.33	2.94
3	RC8	185.66	2.62
4	RC12	148.33	2.09
5	RC15	139	1.97

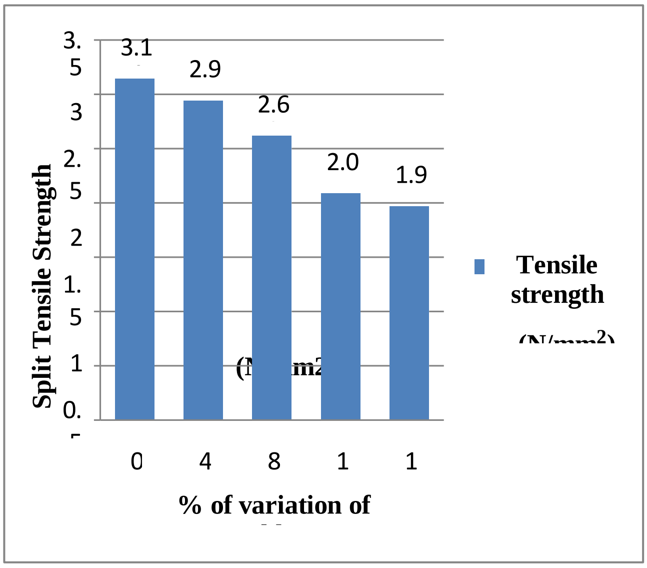


Figure 5.3 Comparison of split tensile strength of Rubberised concrete.

The decrease in splitting tensile strength can be ascribed to the presence of rubber particles.

This phenomenon can be clarified by the non-extremity of the rubber attracts in air to its surface and subsequently diminishes the bond with cementitious framework.

FLEXURAL STRENGTH:

It is demonstrated that the flexural strength diminished with the expanded of the crumb rubber substance from 0% to 15% in a manner like that saw in the compressive strength. In any case, the decrease in

compressive strength was essentially higher than that in flexural strength.

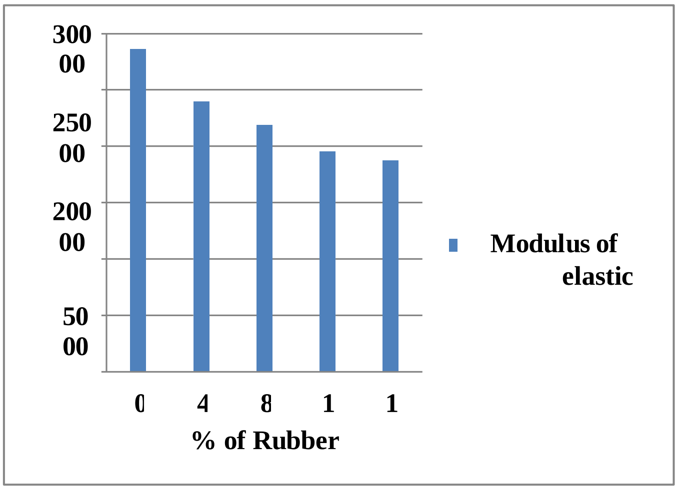
5.2.4 Modulus of Elasticity

The Modulus of Elasticity test is completed for the cylinder shaped samples by setting vertically in the UTM. The test outcomes are classified in Table 5.5. Figure 5.5 demonstrates the correlation of a split tensile strength of Rubberised concrete with the conventional concrete.

□ The consideration of crumb rubber suggests defects in the inside structure of the composite material, creating a decrease of strength and a decline in stiffness.

□ The perception has appeared there were an expansive displacement and distortion because of the way that crumb rubber can withstand huge disfigurement.

□ This can be clarified by the conduct of the crumb rubber particles inside the mix; these particles appear to go about as spring and caused a postponement in augmenting the breaks and keeping the cataclysmic failure which is generally experienced in typical concrete samples.



VI. CONCLUSIONS

6.1 OVERVIEW

The present investigation includes the following studies

1. Materials properties
2. Mechanical Properties of concrete
3. Durability Properties of concrete
4. Structural Properties

6.2 STUDY ON MATERIAL PROPERTIES

The main aim of this study is to evaluate the effect of characteristics of materials, especially crumb rubber in coarse form, in concrete. The following conclusions were derived from the investigation.

- The Impact strength of crumb rubber is very high.
- The specific gravity of crumb rubber is lesser than the natural coarse aggregate.
- Water absorption of crumb rubber is very less.

6.3 STUDY ON MECHANICAL PROPERTIES

Fresh and hardened concrete properties of rubberised concrete with percentage of rubber 4, 8, 12 and 15 as coarse aggregate were studied and the results were compared with conventional concrete.

The following conclusions were drawn from the investigation.

- For all rubberised concretes, slump value was higher than conventional concrete hence the concrete can be used in all types of concrete, especially R.C.C.
- Because of the low density of crumb rubber, the mass of concrete is reduced. Waste tyre rubber can be utilized to produce lightweight concrete.
- In the case of M30 grade concrete 8% replacement of rubber aggregate, gives optimum result.
- In case of M55 grade concrete, designed for a sleeper, up to 12% replacement of coarse aggregate by rubber aggregates were giving satisfactory results. This is due to the addition of silica fume and super plasticisers.
- Mechanical properties of concrete were decreasing with the addition of rubber aggregate. This is due to the low specific gravity of rubber aggregates.

6.4. SUGGESTIONS FOR FUTURE WORK

1. Further investigation may be carried out for the usage of rubberised concrete in the structural members requiring high strength.
2. Studies can be conducted to improve the strength properties of rubberised concrete.
3. Methods to increase the optimum percentage of replacement of natural aggregate by waste tyre aggregate can be investigated.

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