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# Experimental Investigation on Replacement of Rubberized Material in Concrete

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## ABSTRACT

Rubber is produced excessively worldwide every year. It cannot be discharge off easily in the environment as its decomposition takes much time and also produces environmental pollution. In such a case the reuse of rubber would be a better choice. In order to reuse rubber wastes, it was added to concrete as coarse aggregate and its different properties like compressive strength, Tensile strength, ductility etc. were investigated and compared with ordinary concrete. As a result it was found that rubberized concrete is durable, less ductile, has greater crack resistance but has a low compressive strength when compared with ordinary concrete. The compressive strength of rubberized concrete can be increased by adding some amount of super plasticizers to it.Recycled waste tire rubber is a promising material in the construction industry due to its light weight, elasticity, energy absorption, sound and heat insulating properties. In this paper the density and compressive strength of concrete utilizing waster tire rubber has been investigated. Recycled waste tire rubber has been used in this study to replace the coarse aggregate by weight using different percentages. The results of this project shows that although, there was a significant reduction in the compressive strength of concrete utilizing waste tire rubber than normal concrete, concrete utilizing waste tire rubber demonstrated a ductile, plastic failure rather than brittle failure.

**Keywords:** Rubber, tensile, Flexure, Rubber, Split tensile strength, Aggregate, CRC.

## I. INTRODUCTION

A large variety of waste materials are considered feasible and even much valuable additives for concrete. Some of these materials include cellulose, fly ash, silica fumes and wood particles. Rubber obtained from scrapped tires is considered as the most recent waste materials that have been examined because of its vital use in the construction field.

Worldwide, the production of rubber increases every year. Different countries of the world has different rate of producing rubber, for instance United States produces 3.6 million tons of rubber per year. Iran produces 100,000 tons of rubber per year; similarly Malaysia produces 200,000 tons of rubber per year. These numbers increases with the increase in the production of vehicles.

Investigations have shown that scrapped rubber tires contain materials that do not decompose under environmental conditions and cause serious problems. One choice of decomposition is burning, but that would also results in harmful pollution Based on these problems, tires can be used as aggregates in concrete.

It is very difficult to manage the waste produced by the rubber-tire industry and to handle the waste. It is not easily biodegradable waste form. According to Guneyisi et al. 2004 the rubber waste is not easily biodegradable even after a long span passes after the landfill treatment. The rubber tire waste has been utilized as fuel for the kilns, as a form of feed for the carbon black and it is also found that the environmental hazardous pollution caused by the combustion of rubber tire in the kilns is greatly reduced as compared to the carbon black fuel.

The utility of rubber tire in concrete industry i.e. noise barriers, electricity posts, and in the mixture plants of asphalt pavements. the recycled rubber tire waste is a promising material in the construction industry and the sole reason for this is the lightweight of the resulting concrete when the rubber tire is incorporated in it as an aggregate replacement (partial or complete). The elasticity, energy absorption capacity of concrete after the addition of rubber tire as replacement of coarse Aggregate in concrete has been showing some promising results as stated by Eldin, commented that the utilization of waste products in concrete has an attractive advantage and attention all around the globe and the reason for this is the awareness among the researchers in the form of environmental consciousness.

Batayneh, M. K., Marie, I., and Asi, I. 2008 stated that the accumulations of stockpiles of the rubber tires are very dangerous to the society as they pose a great environmental concern, hazard due to fire and provision of breeding grounds for various insects like mosquitoes which may carry very diseases from this source.

The tire pile fires have been remaining a greater environmental problem as the fires caught by tires are very hazardous and that the fires can burn for months, sending up an acrid black plume that is visible from various mile away. It is a matter of great concern that the acrid plums contain various amounts of toxic chemical and the air pollutants in it is causing a serious threat to the environment and its inhabitants.

Siddique and Naik, 2004 stated that it has been a growing practice among the researchers to use the deformed shapes of rubber tires while incorporating into the concrete mixture. The rubber tires shows better performance in concrete when they are cut in the form of normally sized coarse aggregate to take the full advantage of the shape factor of the aggregate .Due to this fact, the compressive strength of the concrete can be made more or less stronger as compared to the aggregate sizes which are not in the proper shape to be incorporated in the concrete.

## II. METHODOLOGY

Recycled scrap tires materials:

Siddique and Naik (2004), commented from their research on the use of recycled tires as materials to be used in the concrete as partial or complete replacement of aggregate that there are four types of scrap tire particles available which are classified in accordance to their particle size and the texture. These types consist of slit tire particles in the form of slits which are halved in two halves. Apart from the slit tire particles, there are shredded tire particles which are also utilized in concrete as a replacement of aggregate in the concrete.

The particle size varies from 300 to 400 millimeters long and 100-200 millimeters wide. There is also ground type of rubber tire available for the utility in research work which is cut in the sizes of 19mm to 0.15 mm. The crumb rubber used in the concrete has to be having a nominal size equal to the standard sieve dimension 4.75 mm.

The part of their research work in which he used crumb rubber as partial and complete replacement fine aggregate in concrete and reported the various performance levels of concrete subject to the different phenomenon like shrinkage, segregation, workability, flexural bending stresses, shear bending stresses, normal consistency of cement paste and the initial and final setting times determination.

The use of crumb tire particles as the partial replacement sand in the concrete has better performance levels as compared to the full or complete replacement of sand in the concrete with the crumb tire particles. The partial replacement of sand with crumb tire particles are imparting better performance levels to the concrete at various serviceability levels as compared to the complete replacement of crumb aggregate with the sand. The sand in the concrete along with the crumb tire particles are imparting better shear capacity, fire resistance and resistance to spalling due to various environmental hazards like, fire and collective segregation in concrete.

## III. OBJECTIVE

The main objective of this study is to conduct a critical review of the literature available on rubber concrete the focus of the review is on the following:

Nature of the reaction between the cement binder and the crumb rubber Interrelation between the aggregate gradation, the crumb gradation and the characteristics of cement binder. Emphasis will be placed on the advantages and disadvantages of dense graded, gap graded and open graded aggregate gradation in relation to the different type rubber binder used Issue of aging and the observed increase in temperature susceptibility of the rubber concrete with time Function of additives in improving the performance characteristics of rubber concrete Reasons why certain rubber modified processes results in sub standard performance while other perform well under particular site condition.

This report will document the rubber modified technology critical to implementing this technology in meeting the upcoming federal requirement Enhance the understanding on crumb rubber concrete material properties through laboratory testing and field evaluation.

Develop test information that may aid in the eventual goal of drafting a practical
rubber in concrete specification for non-structural / low loading usage.

Evaluate possible advantages of using crumb rubber in concrete including: resistance against cracking, reduction of thermal expansion and contraction, and lightweight concrete.

Through a series of the above-mentioned test sections, these possible advantages were evaluated and results are discussed in the following sections.

## IV. MATERIALS & TESTING

1. Cement
2. Fine Aggregate
3. Coarse Aggregate
4. Water
5. Rubber

Table I. Test results on cement

| S.NO | TEST NAME | RESULT | | |
|---|---|---|---|---|
| 1 | sieve test | 8 % | | |
| 2 | standard consistency | 29 % | | |
| 3 | Initial setting time | 52 min | | |
| 4 | Final setting time | 480 min | | |
| 5 | Soundness test | 5mm | | |
| 6 | Specific gravity test | 3.15 | | |
| 7 | Compressive strength | 3 days $N/mm^2$ | 7 days $N/mm^2$ | 28 days $N/mm^2$ |
| | | 16.26 | 17.12 | 19.23 |

Table II. Grading limits of fine aggregates IS: 383 – 1970

| I.S. Sieve Designation | Percentage passing by weight for | | | |
|---|---|---|---|---|
| | Grading Zone.I | Grading ZoneII | Grading Zone III | Grading Zone.I |
| 10mm | 100 | 100 | 100 | 100 |
| 4.75 mm | 90-100 | 90-100 | 90-100 | 95-100 |
| 2.36 mm | 60-95 | 75-100 | 85-100 | 95-100 |
| 1.18 mm | 30-70 | 55-90 | 75-100 | 90-100 |
| 600 micron | 15-34 | 35-59 | 60-79 | 80-100 |
| 300 micron | 5-20 | 8-30 | 12-40 | 15-50 |
| 150 micron | 0-10 | 0-10 | 0-10 | 0-15 |

Table III. SIEVE ANALYSIS OF FINE AGGREGATES: Analysis (100% sand)

Weight of Sample taken 1 Kg.

| Sieve size in mm | Weight retained in grams. | Cumulative weight Retained in grams. | % of cumulative weight Retained. | % of cumulative weight Passing. | Zone-II |
|---|---|---|---|---|---|
| 10 | - | - | - | 100 | 100 |
| 4.75 | 15 | 15 | 1.5 | 98.5 | 90-100 |
| 2.36 | 55 | 70 | 7.0 | 93 | 75-100 |
| 1.18 | 130 | 200 | 20.0 | 80 | 55-90 |
| 0.6 | 440 | 640 | 64.00 | 36 | 35-59 |
| 0.3 | 260 | 900 | 90.00 | 10 | 8-30 |

| | | | | | |
|---|---|---|---|---|---|
| 0.15 | 95 | 995 | 99.5 | 0.5 | 0-10 |
| Silt | 5 | 1000 | - | | |
| | | | **282** | | |

Result FM = 282 / 100 = 2.82, Zone-II

Table IV. Test result on fine aggregate

| S.NO | TEST NAME | RESULT |
|---|---|---|
| 1 | Sieve analysis | Zone ll |
| 2 | Bulking of sand by volume method | 12.5% |
| 3 | Relative density | 45% (medium dense) |

Table V. Test result on coarse aggregate

| S.NO | TEST NAME | RESULT |
|---|---|---|
| 1 | Fineness modulus | 7.5 |
| 2 | Specific gravity | 2.83 |
| 3 | Water absorption | 2.1% |
| 4 | Crushing strength | 22.43% |
| 5 | Impact test | 28.12% |

## V. RESULTS AND DISCUSSION

### REPLACEMENT OF RUBBER IN CONCRETE

TABLE VI. 0% of rubber in concrete

| Specimen | Slump (mm) | Days | Load(kN) | Compressive Strength(n/mm²) |
|---|---|---|---|---|
| 1 | 25 | **7** | 380 | 16.89 |
| 2 | 25 | 14 | 405 | 18 |
| 3 | 25 | 28 | 420 | 18.66 |

TABLE VII. 5% Of rubber in concrete

| Specimen | Slump (mm) | Days | Load(kN) | Compressive Strength(n/mm²) |
|---|---|---|---|---|
| 1 | 23 | **7** | 390 | 17.33 |
| 2 | 23 | 14 | 400 | 17.77 |
| 3 | 23 | 28 | 410 | 18.22 |

TABLE VIII. 15% of rubber in concrete

| Specimen | Slump (mm) | Days | Load(kN) | Compressive Strength(n/mm²) |
|---|---|---|---|---|
| 1 | 21 | **7** | 360 | 16 |
| 2 | 21 | 14 | 375 | 16.66 |
| 3 | 21 | 28 | 410 | 18.22 |

TABLE IX. 25% of rubber in concrete

| Specimen | Slump (mm) | Days | Load(kN) | Compressive Strength(n/mm²) |
|---|---|---|---|---|
| 1 | 20 | **7** | 340 | 15.11 |
| 2 | 20 | 14 | 355 | 15.77 |
| 3 | 20 | 28 | 360 | 16 |

TABLE X. 50% rubber in concrete

| Specimen | Slump (mm) | Days | Load(kN) | Compressive Strength(n/mm²) |
|---|---|---|---|---|
| 1 | 16 | **7** | 150 | 6.66 |
| 2 | 16 | 14 | 175 | 7.7 |
| 3 | 16 | 28 | 210 | 9.3 |

TABLE XI. 65% rubber in concrete

| Specimen | Slump (mm) | Days | Load(kN) | Compressive Strength(n/mm²) |
|---|---|---|---|---|
| 1 | 15 | **7** | 100 | 4.4 |
| 2 | 15 | 14 | 125 | 5.5 |
| 3 | 15 | 28 | 140 | 6.2 |

TABLE XII. 75% rubber in concrete

| Specimen | Slump (mm) | Days | Load(kN) | Compressive Strength(n/mm²) |
|---|---|---|---|---|
| 1 | 12 | **7** | 30 | 1.3 |
| 2 | 12 | 14 | 45 | 2 |
| 3 | 12 | 28 | 65 | 2.8 |

TABLE XIII. 100% rubber in concrete

| Specimen | Slump (mm) | Days | Load(kN) | Compressive Strength(n/mm²) |
|---|---|---|---|---|
| 1 | 10 | **7** | 15 | 0.66 |
| 2 | 10 | 14 | 20 | 0.88 |
| 3 | 10 | 28 | 25 | 1.1 |

TABLE XIV. Average compressive strength N/mm2

| Grade | Rubber replacement (%) | Compressive strength N/mm$^2$ | | |
|---|---|---|---|---|
| | | 7 days | 14 days | 28 days |
| M20 | 0 | 16.89 | 18 | 18.66 |
| M20 | 5 | 17.33 | 17.77 | 18.22 |
| M20 | 15 | 16 | 16.66 | 18.22 |
| M20 | 25 | 15.11 | 15.77 | 16 |
| M20 | 50 | 6.6 | 7.7 | 9.3 |
| M20 | 65 | 4.4 | 5.5 | 6.2 |
| M20 | 75 | 1.3 | 2 | 2.8 |
| M20 | 100 | .66 | .88 | 1.1 |

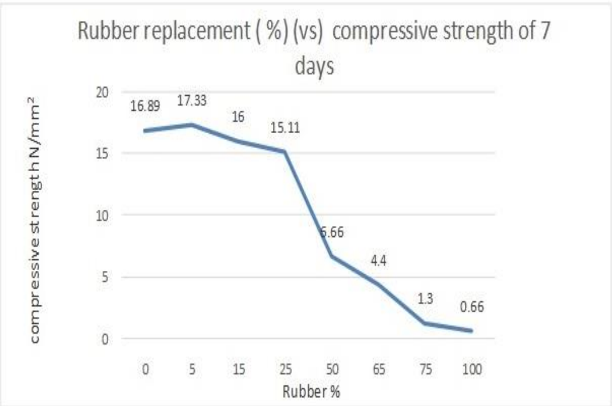


Figure 1. Rubber replacement percentage(v/s)compressive strength of 7days

It observed that compressive strength decreasing when adding rubber material in concrete maximum compressive strength at 5%

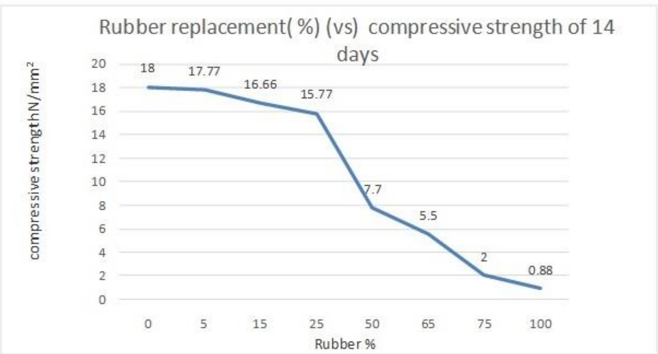


Figure 2. Rubber replacement percentage(v/s)compressive strength of 14days

It observed that compressive strength decreasing when adding rubber material in concrete maximum compressive strength at 5%

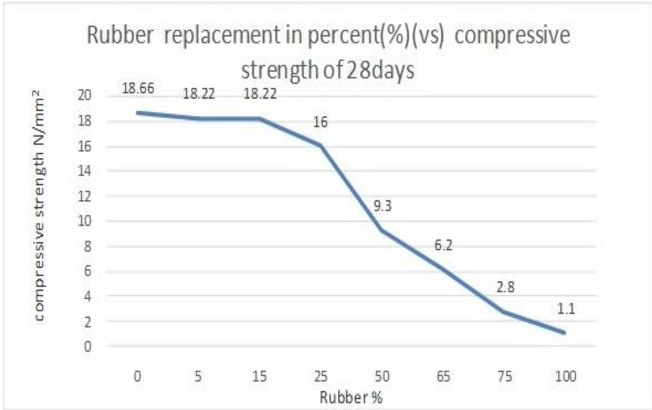


Figure 3. Rubber replacement percentage(v/s)compressive strength of 7days

It observed that compressive strength decreasing when adding rubber material in concrete maximum compressive strength at 5%

Table 15 - Observations & Calculations: compaction factor test

| Sl. No | W/C Ratio | Replacement of rubber in percent | Mass with partially compacted concrete (W2) | Mass with fully compacted concrete (W3) | Mass with partially compacted concrete (W2- W1) | Mass with partially compacted concrete (W3- W1) | C.F = $(W_2 - W_1)$ / $(W_3 - W_1)$ |
|---|---|---|---|---|---|---|---|
| 1. | 0.5 | 0% | 10.832 | 11.871 | 0.842 | 1.881 | 0.44 |
| 2. | 0.5 | 5% | 10.5 | 11.4 | 1.04 | 1.9 | 0.54 |
| 3. | 0.5 | 15% | 10.04 | 11.14 | 0.94 | 2.041 | 0.46 |
| 4 | 0.5 | 25% | 9.67 | 10.36 | 1.27 | 1.96 | 0.64 |
| 5 | 0.5 | 50% | 8.04 | 9.46 | 0.94 | 2.36 | 0.39 |
| 6 | 0.5 | 65% | 8.14 | 9.16 | 0.94 | 1.96 | 0.48 |
| 7 | 0.5 | 75% | 7.96 | 8.43 | 1.82 | 2.27 | 0.79 |
| 8 | 0.5 | 100% | 7.149 | 8.24 | 1.059 | 2.15 | 0.6 |

The average compaction factor of rubber concrete is 50%

**Observations on M20 grade mix**

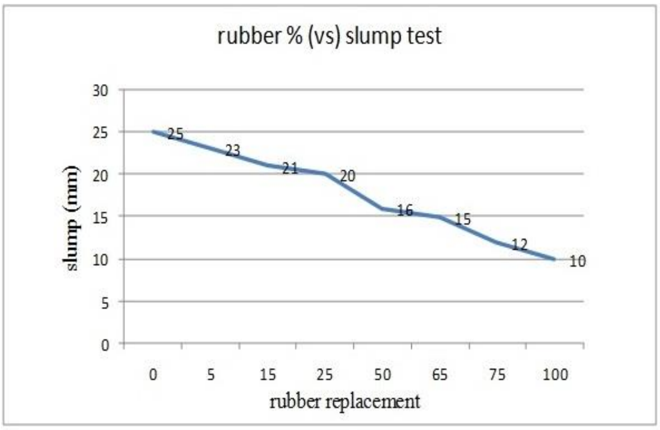


Figure 4. Slump test result

It is observed that rubber percentage increasing in concrete slump test value decreasing maximum slump value at 5%&15%

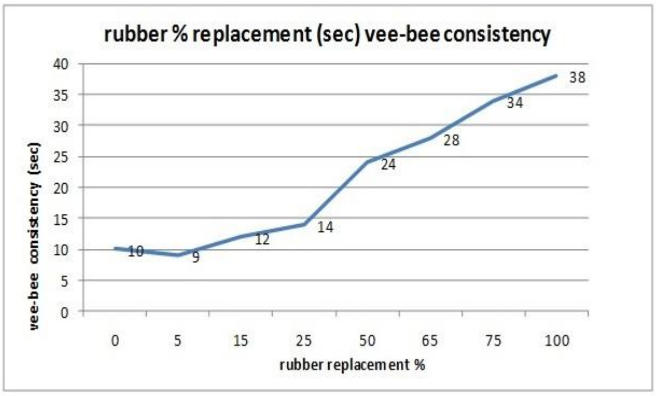


Figure 5. Vee-bee consistency results

It is observed that rubber percentage increasing in concrete vee-bee consistency test value increasing minimum vee-bee consistency at 5%

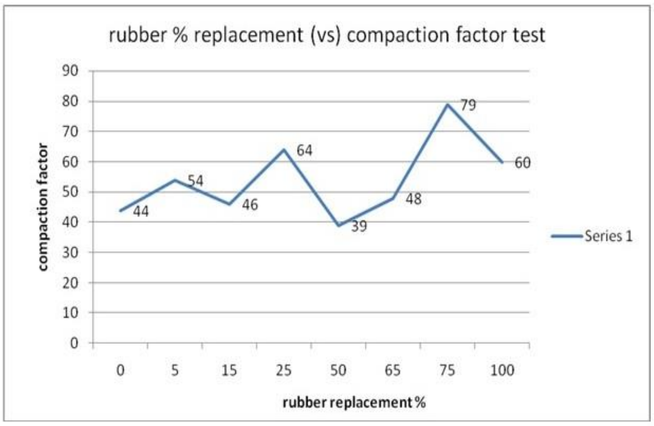


Figure 6. Compaction factor test

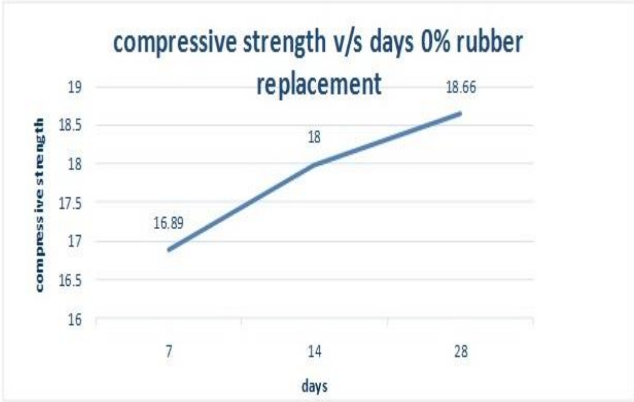


Figure 7. Compressive strength v/s day's 0% rubber replacement

It is observed that compressive strength of 0% rubber replacement in concrete the compressive strength increases with number of days 7

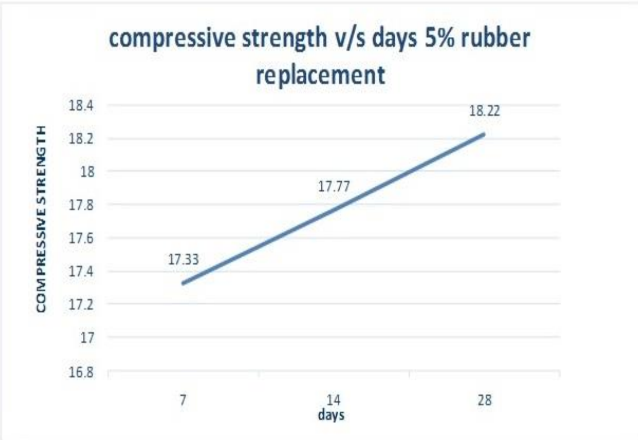


Figure 8 - Compressive strength v/s days 5% rubber replacement

It is observed that compressive strength of 5% rubber replacement in concrete the compressive strength decreasing when compare to 0% rubber replacement


Figure 9 - Compressive strength v/s days 15% rubber replacement

It is observed that compressive strength of 5% rubber replacement in concrete the compressive strength decreasing when compare to 0% rubber replacement

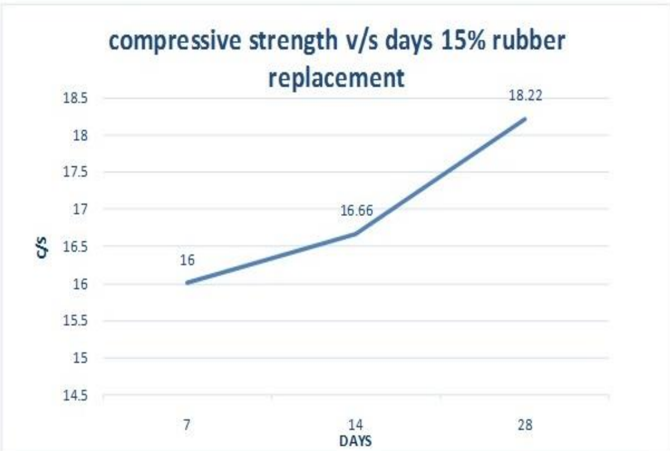


Figure 10 - Compressive strength v/s days 15% rubber replacement

It is observed that compressive strength of 15% rubber replacement in concrete the compressive strength decreasing when compare to 5% rubber replacement

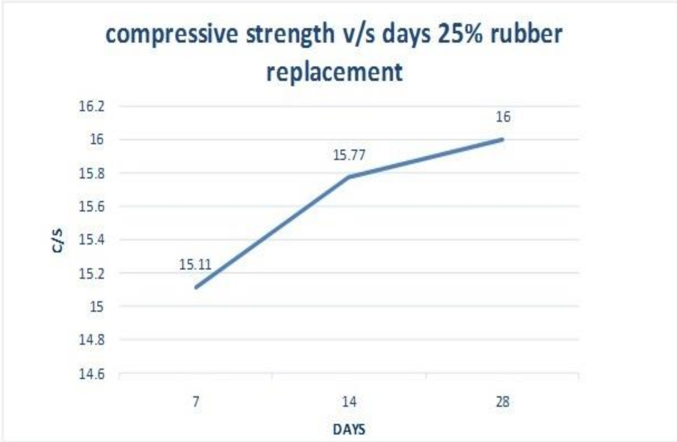


Figure 11: Compressive strength v/s days 25% rubber replacement

It is observed that compressive strength of 25% rubber replacement in concrete the compressive strength decreasing when compare to 15% rubber replacement


Figure 12: Compressive strength v/s days 50% rubber replacement

It is observed that compressive strength of 50% rubber replacement in concrete the compressive strength decreasing when compare to 25% rubber replacement

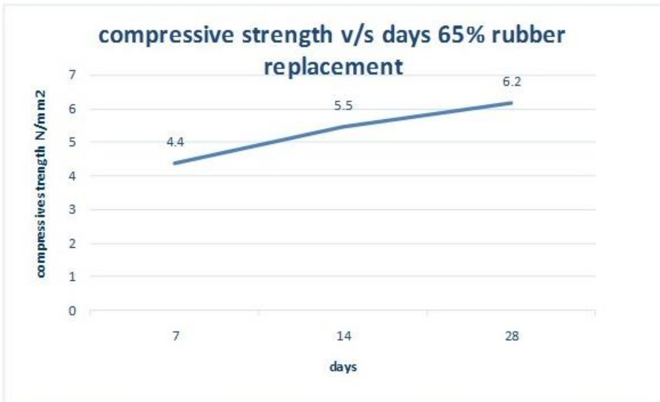


Figure 13 - Compressive strength v/s days 65% rubber replacement

It is observed that compressive strength of 65% rubber replacement in concrete the compressive strength decreasing when compare to 50% rubber replacement

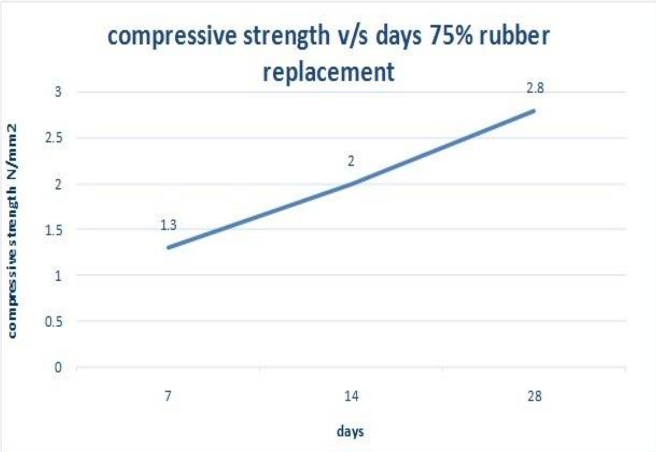


Figure 14 - Compressive strength v/s days 75% rubber replacement

It is observed that compressive strength of 75% rubber replacement in concrete the compressive strength decreasing when compare to 65% rubber replacement

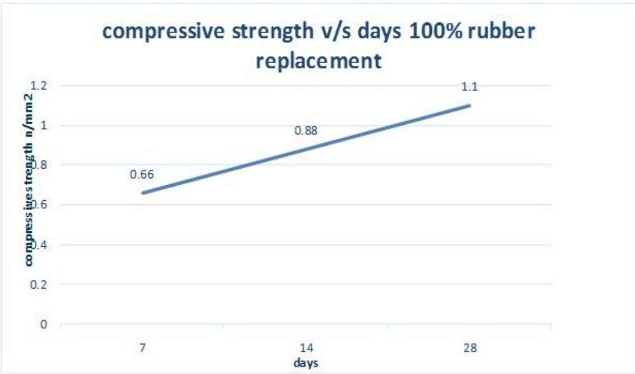


Figure 15 - Compressive strength v/s days100% rubber replacement

It is observed that compressive strength of 100% rubber replacement in concrete the compressive strength decreasing when compare to 75% rubber replacement

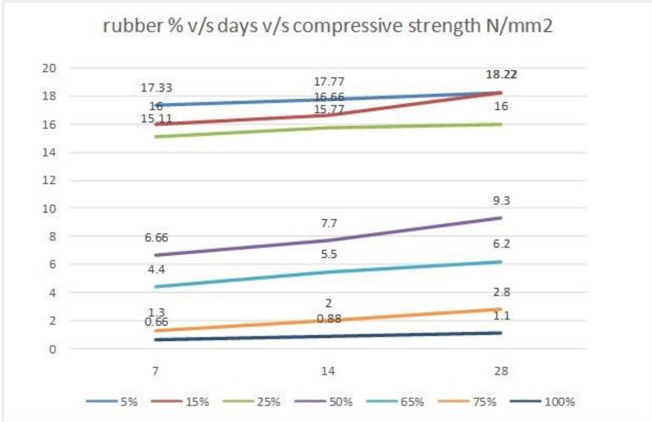


Figure 16 - Rubber % v/s days v/s compressive strength N/mm$^2$

The above graphs shows rubber replacement in percentage (v/s)compressive strength N/mm2 (v/s)days it is observed that rubber percentage increasing in concrete the compressive strength is decreasing

## VI. CONCLUSION

The following conclusions have been drawn from research on using rubber as aggregate in concrete. When rubber was used instead of aggregates in concrete it shows less compressive strength when compared with ordinary concrete. But it also shows some ductile behavior before failure. Rubberized concrete shows reduction in density of concrete when compared with control concrete specimen. Concrete made of crumb rubber as fine aggregate shows much strength when compared with concrete made of chipped rubber as coarse aggregate. No appreciable increment in the compressive strength of concrete density by using different percentage of rubber as fine aggregates in concrete. It is recommended to use super plasticizers in rubberized concrete to increase its compressive strength. It is recommended to use rubberized concrete small structures like road curbs and non-bearing walls etc.
There is no doubt that the increasing piles of tires create environmental concerns. Finding a way to dispose of the rubber in concrete would enhance the understanding on how to incorporate the crumb rubber in greater engineering usage.

It is realized that partnership with states, industries and consultants is vital for the success of such initiative. Several Crumb Rubber Concrete (CRC) test sections were built in Arizona and are being monitored for performance. Laboratory tests were conducted at ASU and industry associations to support the knowledge learned in the field. This paper summarized findings to date and some knowledge learned in the field. Preliminary conclusions of this study are ro The unit weight of the CRC mix decreased approximately 6 pcf for every 50 lbs of crumb rubber added. The compressive strength decreased as the rubber content increased. Part of the strength reduction was contributed to the entrapped air, which increased as the rubber content increased. Investigative efforts showed that the strength reduction could be substantially reduced by adding a de-airing agent into the mixing truck just prior to the placement of the concrete. The high CRC rubber content mix (tennis court) had a flexural strength almost 50% less than the control mix. However, the CRC mix had more ductility and comparable toughness values to the control mix.

As the rubber content increased, the tensile strength decreased, but the strain at failure also increased. Higher tensile strain at failure is indicative of more energy absorbent mixes. The coefficient of thermal expansion test results indicated that the CRC mixes are more resistant to thermal changes. In all failure tests, the CRC specimens stayed intact (did not shatter) indicating that the rubber particles may be absorbing forces acting upon it. Such behavior may be beneficial for a structure that requires good impact resistance properties.

Because of the long term performance of these mixes are not known in the field, especially for pavement sections, the use of such mixes are recommended in places where high strength of concrete is not as important (e.g. sidewalks). Future follow up work will strengthen the conclusions arrived at in this work and will add to the state of knowledge in this area. One specific area is the freeze-thaw durability of CRC mixes in northern or high altitude climates, where the crumb rubber would aid in reducing the need for air entraining agents.

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