# EXPERIMENTAL INVESTIGATION ON UTILIZATION OF WASTE RUBBER TIRES AS FILLER IN CONCRETE

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## ABSTRACT

*This work has been carried out to evaluate the potential usage of waste rubber tires in concrete. Disposal of tires is a major problem and their accumulation create health and fire hazards. To incorporate waste rubber tires in construction industry is considered as a sustainable and environment friendly solution. Experiments were designed by incorporating coarse and fine rubber content as partial substitution of conventional aggregates. Seven mixtures were proportioned; one mixture with conventional aggregates was the control specimen, three mixtures were casted by replacing fine aggregate by waste rubber tires powder and remaining three were proportioned by replacing coarse aggregate by waste rubber tires chips. Fresh and hardened properties of rubberized concrete were evaluated and compared with the control specimen. The results showed that there was significant fall in workability of rubberized concrete along with slight deviation in the density and aesthetics as compared to control specimen. The compressive strength of rubberized concrete was found to be augmented when 10 % fine crumb rubber content was used. However with further increase in the rubber content, the compressive strength was abridged. On the contrary, there was continuous reduction in the compressive strength with the increase in the amount of coarse rubber content as compared to control specimen. It was verified that rubberized concrete have potential to use in concrete up to some extent.*

**KEYWORDS:** *Rubberized Concrete; Fine Rubber Content; Coarse Rubber Content; Workability; Compressive Strength.*

## INTRODUCTION

Construction industry pays a key role in strengthen the economy of any country. This industry is consider to develop the infrastructure of any region and other facilities may installed later on. Concrete is basic unit of construction and widely used in almost all types of structure due to its durability under severe or aggressive environmental conditions. Large number of natural resources are depleted for the production of concrete constituents. Lots of energy is also required to extract constituents of concrete from natural resources. For sustainable development, natural resource must be conserved. With this aim several researchers added the treated waste materials in concrete by partially replacing cement, sand and crush[1,2].

Number of vehicles increased annually due to industrialization and development or strengthening of infrastructure. Which resulted in exponential demand and consumption of tires. The intended service life of tire is very short, although it depend upon several parameters. As a result large number of waste rubber tires are produced annually. This increasing trend and consumption of rubber tire have created a challenge of disposing such an enormous quantity of waste tires without unfavorably disturbing the surroundings. The rubber waste removal has become a big challenge for the waste disposal authorities. Burning will create a lot of pollution in environment, that is very harmful for any society, dumping consumes lot of precious land and also waste rubber tires are not bio-degradable material and not recommended for dumping. Stockpile of waste rubber tires are acting as fuel in case of fire.

Waste tire rubber are reduced to crumb rubber by cryogenics or mechanical grinding. After shredding of waste rubber tire, steel beads were separated by magnetic separator[3]. Steel amount in tires are 14 to 15% any may be used in concrete separately to make fiber reinforced concrete[4]. Natural and synthetic rubber from waste tires are also being used in concrete by partially or fully replacement of conventional aggregates.

## LITERATURE REVIEW

Several studies are available in which waste rubber tires are used by partially replacing of aggregates. An

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overview of existing studies were made and reported here;

Aggregate was substituted with rubber chunk in chunk rubber asphalt concrete and it was found suitable for low volume road construction. Different design mixes were set and then experimented with chunk rubber content, fly ash and emulsion content. These mixtures were found suitable as binder courses or drainable bases for low volume loads[5].

Rubberized concrete were prepared by incorporating fine and coarse rubber content[6-10]. It was concluded that workability of rubberized concrete was less than the conventional concrete, compressive strength of rubberized concrete was also less than conventional concrete. Reduction in compressive strength was increased with the increase in the amount of rubber content. Xi et al. (2003) conducted research to modify/enhance the compressive strength along with toughness of rubberized concrete with different particle sizes of rubber content, tensile strength test, fatigue test, and ultrasonic pulse velocity test indicated that rubberized concrete had elevated energy dissipation capability along with high ductility and toughness than that of conventional concrete[11].

Khatib and Bayomy[6] showed that the decrease in unit weight of the mixture was negligible when the replacement of rubber content was 10-20% of the total volume of the aggregate. It was further concluded that there was a decrease in slump with an increase in rubber content of the concrete mixture. Concrete would be more workable if it was made with fine rubber content as compared to the rubberized concrete with coarse rubber content.

In several works[4,9,10,12-16], it was concluded that compressive strength was modified by the particle size, surface quality and extent of rubber waste[9] found that compressive strength was decreased by 85% when coarse aggregate was fully replaced by coarse rubber content and 65% when fine aggregate was fully replaced by fine rubber content[10] discussed that significant improvement in compressive strength could be achieved through enhancing the bonding properties of rubber particle with cement paste. This could be done by pre-treating the rubber particles with acid solution to increase the adhesiveness of rubber.

With such background, this work was designed to evaluate the optimum amount of fine and coarse rubber content in concrete. Workability of rubberized concrete was evaluated, bulk density and compressive strength of rubberized concrete were evaluated and compared with the conventional concrete. The reasons for the reduction in compressive strength were also enlisted in this work.

## EXPERIMENTAL PROGRAM

The experimental setup was established to assess the behavior of fresh and hardened rubberized concrete by incorporating rubber wastes as coarse and fine aggregate. The workability, density and compressive strength were obtained and compared with those of conventional concrete.

### Materials and Specimen Preparation

A single ordinary Portland cement of ASTM type-I was used as binder and locally available river sand (Lawrancepur Sand) was used as fine aggregate. Specific gravity was 2.6 and gradation curve is showed in Figure-1. Crushed stone (Margalla crush) having gradation curve shown in Figure-2 was used as coarse aggregate. Two sizes of rubber waste were used to observe the effect on the physical and mechanical properties of the concrete. The fine crumb rubber “FCR” (Figure-3) was used as an alternate material for fine aggregate and coarse crumb rubber “CCR” was used as partial replacement for crush (Figure-4). Sieve analysis for both the materials has been conducted to check their gradation as per ASTM C-136[17]. Figure 1 and Figure 2 show the comparative gradation curves of rubber aggregates with natural aggregates.

The mixture proportion for the rubberized concrete mix (RCM) were kept same as that conventional concrete, however the quantities of aggregates has been altered due to difference in specific gravity of conventional and rubber aggregate. Three RCM mixtures were prepared by the substitution of FCR and other three with replacement of crush by CCR. Replacement amounts of coarse aggregates were 10, 20 and 30% of conventional aggregates.

### Testing

Workability was evaluated after mixing of all constituents of rubberized concrete by conducting slump test[18]. Bulk density was evaluated after 28 and 90 days,

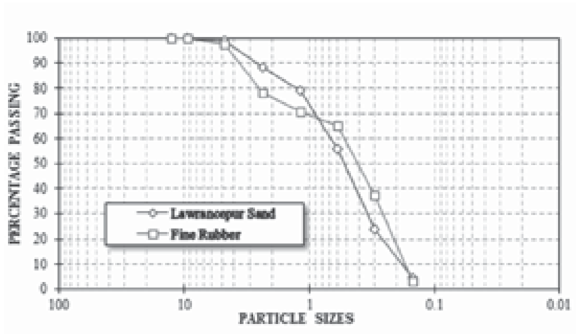


**Figure 1. Gradation curves for fine aggregates.**

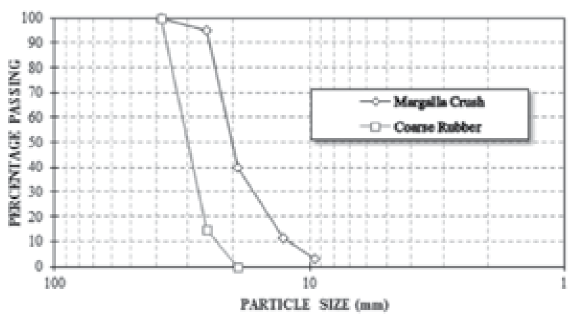


**Figure 2. Gradation curves for coarse aggregates.**

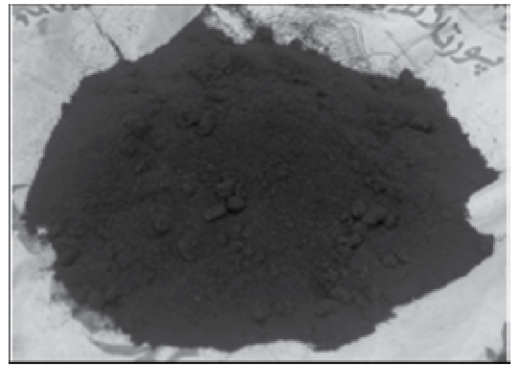

**Figure 3. Powder rubber waste**

**Figure 4. Coarse rubber waste.**

compressive strength was also evaluated by after 28 and 90 days of casting. Compressive strength was conducting according to[19]. Testing and acronyms used in this work are mention in Table 1.

## RESULTS AND DATA DISCUSSION

The obtained experimental results reveal the influence of the RCM on the behavior of fresh and hardened concrete. Slump test carried out on fresh properties and hardened density and compressive strength were examined and compare these results with CCM. At end, results were also compared with the previous investigations by different researchers. All results were discussed in following sections;

### Variation in Workability

Workability of RCM was significantly reduced and upon substitution of natural aggregate to about 30 %,

**Table 1. Summary of tests and number of specimens used in experimentation.**

| Mixture | Acronym | Slump test | Density | | Compressive strength | |
|---|---|---|---|---|---|---|
| | | | 28 Days | 90 Days | 28 Days | 90 Days |
| Control | CCM | 1 | 3 | 3 | 3 | 3 |
| Concrete with fine rubber content ($RCM_f$) | FCR | 1 | 3 | 3 | 3 | 3 |
| | FCR | 1 | 3 | 3 | 3 | 3 |
| | FCR | 1 | 3 | 3 | 3 | 3 |
| Concrete with coarse rubber content ($RCM_c$) | CCR | 1 | 3 | 3 | 3 | 3 |
| | CCR | 1 | 3 | 3 | 3 | 3 |
| | CCR | 1 | 3 | 3 | 3 | 3 |

the slump value reduced to almost 80%. The workability reduction trend was more for FCR than CCR. The Figure 5 indicates the declivity of workability of RCM.

**Effect on Aesthetics**

It was observed that there was no significant variation in the aesthetics of RCM samples. No change in color or any visual variation was discovered even on replacment of 30% of natural aggregate with rubber waste. Figure 6 illustrates the visual appearance of RCM with the

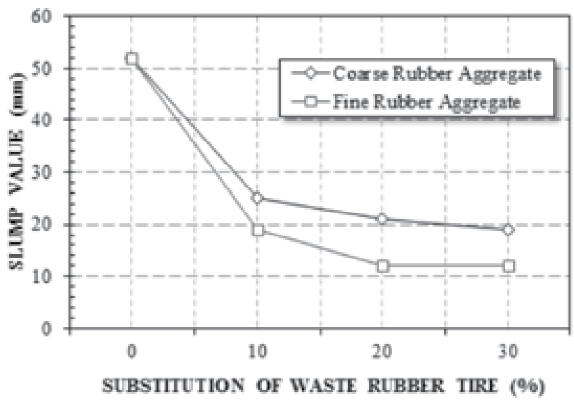


**Figure 5. Influence of rubber content on workability of rubberized concrete**

maximum 30% replacement of coarse aggregate by CCR.

**Influences on Density**

The average density of RCM samples was reduced upon substitution of fine and coarse aggregate with FCR and CCR respectively. The gradual decrease in density was mainly due to the reduction in weight of the aggregate. It was also observed that this decline in density was more in case of CCR as compared to CCM. Upon 10% replacement of sand with FCR there was a slight increase in density due to reduction in the porosity of RCM, however on further increase there was gradual decline in density of RCM. In case of CCR replacement to about 30% there was an average 14% decrease in density however with FCR the decrease in density was about 8.7%. Figure 7 showed the variation in density of RCM concretes.

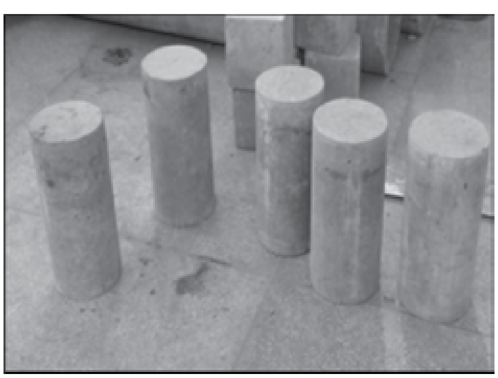

**Figure 6. Visual appearance of RCM.**

**Effect on Compressive Strength**

Compression load testing was carried out on RCM samples age of 28 and 90 day and the same was compared with CCM to analyze the variation pattern. The

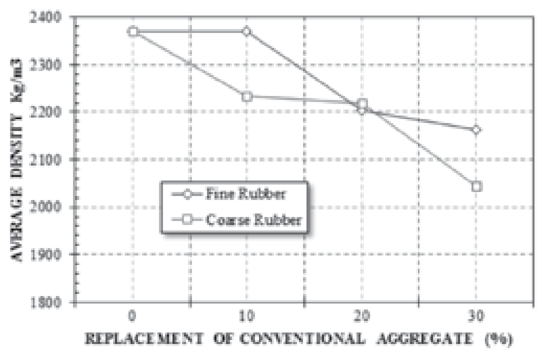


**Figure 7. Variation in density of RCM**

enhancement of about 12% was observed when 10% of FCR was used as replacement of sand. This increase in strength was due to the decrease in air voids in RCM. On increasing the percentage from 10% to onward, there was gradual decline in compressive strength up to 57% of its original value. On the contrary, RCM with CCR showed continues decline in compressive strength to about 75% at 30% replacement. The Figure 8 and Figure 9 demonstrate the behavior of compressive strength by using FCR and CCR in CCM at specified ages.

The pattern of reduction in compressive strength is showed in Figure 10. The portion of the lines above 1.0 of the relative compressive strength indicates the increase in compressive strength, and this was observed only at 10% substitution of FCR. In rest of all cases, reduction in compressive strength was observed.

To quantify changes in compressive strength of RCM

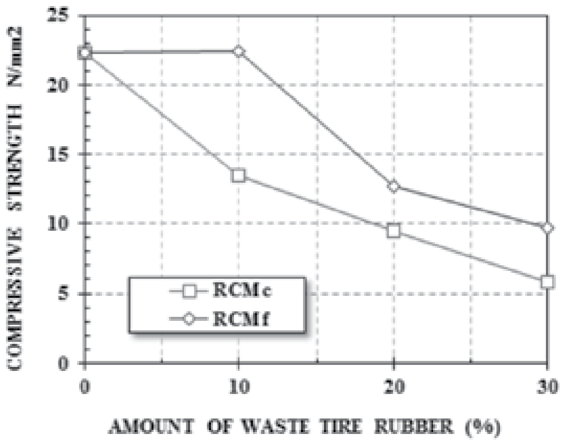


**Figure 8. Compressive strength of concrete at 28 days with various amount of rubber content.**

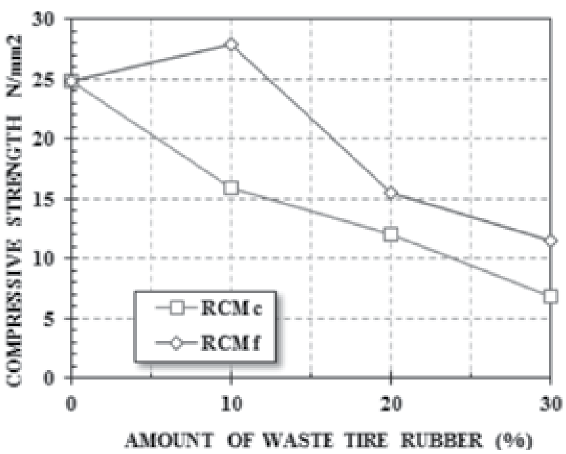


**Figure 9. Compressive strength of concrete at 90 days with various amount of rubber content.**

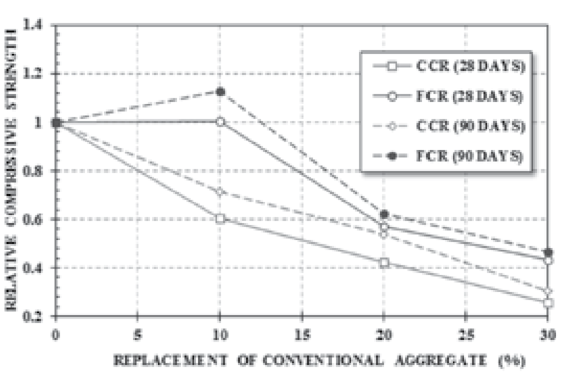


**Figure 10. Relative strength of rubberized concrete at concerned ages.**

in comparison to the CCM the relative strength was used. The pattern of variation in compressive strength is showed in Figure 10. The results for compressive strength of the present study have been compared with previous investigations by evaluating the relative strength at different replacement levels of FCR. It can be seen from Figure 11 that the results of this research are consistent with the previous investigations. However, the relative strength varied in different pattern for different researchers. This variation may be due to the fact that different content of waste rubber and different target strengths were assumed. The overall trend showed that there would be reduction in strength, if rubber content was increased.

**Reasons for Variation in Compressive Strength**

Following are the major reasons for the variation in compressive strength;

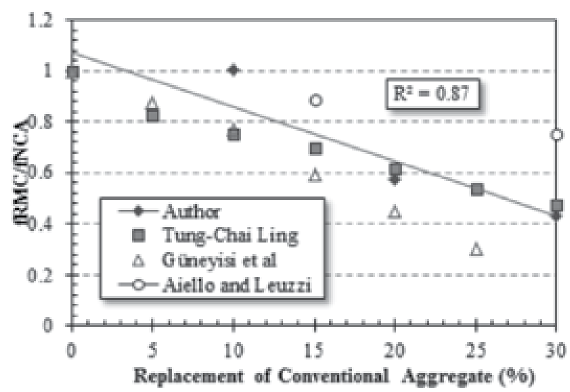


**Figure 11. Compressive strength variation of RCM.**

The increase in compressive strength at substitution of 10% of sand with FCR is due to the fact that there was a reduction in porosity and enhancement in the density. This development was due to the fineness of materials as the sand used in the research was coarser than the rubber.

The inter particle bonding with cement paste had played a major role in increasing the compressibility of RCM which was found to be optimum at 10% replacement with FCR.

There was inadequate bonding between the coarse rubber aggregates and cement paste which caused a reduction in compressive strength of RCM.

Non-porosity and lack of adhesion property of coarse rubber waste aggregate had made it unsuitable for use as aggregate in concrete.

## CONCLUSIONS

Rubberized concrete (RCM) were casted by incorporating 10, 20 and 30% of rubber content. Both types of conventional aggregates, fine and coarse, were partially replaced by fine and coarse rubber content, workability density and compressive strength were evaluated of rubberized concrete and conventional concrete, and following conclusions were extracted.

The workability of RCM was reduced by increasing the rubber content. Reduction in workability was more in case of coarse rubber content as compared to fine rubber content (FCR).

Due to reduced weight of the rubber aggregate the overall weight and density of RCM has been reduced. Addition of rubber content in RCM has not disturbed the aesthetics of concrete fair face

The replacement of 10% of fine aggregate with FCR has augmented the compressive strength and can be used for structural purposes. But with further increase in rubber content, compressive strength was reduced significantly.

Reduction in compressive strength with coarse rubber content was severe as compared to fine rubber content.

Up to 20% of the substitution of natural aggregate with waste rubber can be consumed for non-structural roles that include road curbs, internal floors, lean concrete and prefabricated concrete blocks etc. The decline in strength is mainly due to poor adhering between CCR and cement paste. The utilization of cheap waste material as a replacement of natural aggregate has reduced the overall economics/cost of the material. Further investigation is still needed to evaluate the durability of rubberized concrete. And also everyone must be focused on the ductility of rubberized concrete and may be used for dampness of earthquake resistant structures.

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