EFFICACY OF RUBBER IN REPLACING THE AGGREGATES IN ORDINARY CONCRETE MIXES

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Abstract: *The construction industry is currently concerned about a lack of aggregate as well as economical prices. Deforestation and the extraction of natural aggregates from lakes, rivers, and other bodies of water have resulted in a number of environmental problems over time. Topographical degradation is a major source of landslides and flooding. Furthermore, natural sand deposits are losing their ability to filter rainwater, leading in pollution of water supplies used for human use. As a result, authorities are increasingly restricting the extraction and crushing of natural aggregates in order to prevent contamination. The easiest solution is to locate alternative aggregates for construction that can replace typical natural aggregates.*

Keywords: Rubberized Concrete, *Styrene-butadiene rubber, Poly-butadiene rubber.*

1. Introduction

1.1 General

The building sector is currently raising concerns about the lack of aggregate as well as affordable pricing. Deforestation and the extraction of natural aggregates from lakes, rivers, and other bodies of water have caused several environmental issues over the time. One of the main causes of landslides and flooding is topographical degradation. Furthermore, the filtration of rain water achieved by natural sand deposits is being lost, resulting in contamination of water supplies utilized for human consumption. As a result, in order to prevent pollution, authorities are putting increasingly tight limits on the extraction and crushing of natural aggregates. The simplest method to solve this problem is to identify alternative aggregates for building that can replace traditional natural aggregates. In cement concrete construction, rubber aggregates made from waste tyre rubber can be used in place of natural aggregates in sizes ranging from 20-10 mm to 10-4.75 mm and 4.75 mm. On Indian highways, about one crore ten thousand new cars of all kinds are added annually. The annual increase of approximately three crores discarded tyres poses a potential threat to the environment. Natural rubber (also known as virgin rubber), styrene-butadiene rubber (SBR), poly-butadiene rubber (PBR), carbon black, nylon tyre cord, rubber chemicals, steel tyre card, and butyl rubber are all components of a new tyre.

Several investigations have discovered evidence that use of rubber as aggregate in concrete buildings have a considerable positive with respect to environmental factors. The experimental studies' findings demonstrated that the crumb rubber mixture's strength decreases in all forms, but that slump values rise from 0% to 20%. This means that the crumb rubber combination can be used to make lightweight concrete and is more workable than regular concrete. *Sachin Dass et al. (2013)*

Research discovered a slight increase in the splitting tensile strength and ascribed it to the adhesiveness of the crumb rubber and cement paste. Despite having a lower compressive strength than traditional concrete, there is a greater absorption of plastic energy. They noticed that the weight of the concrete drops as the proportion of rubber tire particles rises. Moreover, if the aggregates from rubber tires are utilized in place of some of the typical ballast, the compressive strength falls. *Grinys A. et al. (2012)*.

The feasibility of using waste rubber tyre aggregate as a replacement for natural aggregates in concrete was investigated, as well as the effect of curing time on engineering qualities. Different concrete groups were created utilizing plain Portland cement and crumb rubber as a fine aggregate replacement (0%, 10%, 20%, and 30% by volume). Different sizes of crumb rubber were employed, which were classified as (0.01-0.5) mm, (0.5-2) mm, and (2-3) mm. The specimens from each group were examined after varying curing times of 7, 14, 21, and 28 days. M25 was the typical concrete grade employed in the investigation. *Nasser S. Bajaba (2012)*

In another experimental investigation, two types of discarded tyres are utilized to replace coarse aggregate and fine aggregate (crumb rubber and chipped rubber) in concrete by percentages of (0%, 10%, 15%, and 20%). As a result, the goal of this project was to investigate the application of rub-crete concrete in structural and non-structural members and demonstrate how it is suitable for the concrete, its uses, hurdles and benefits, and future research directions and to ascertain the properties of concrete containing tyre components. According to the results, there is a drop in the compressive strength of the concrete, but an improvement in their toughness with good approach qualities, and they also alleviate a severe problem created by waste tyres normal concrete using natural rock aggregates. *Pravin J. Gorde4 (2017)*

Landfills are where most used tires are disposed of. However, in the near future, landfill disposal will be significantly decreased due to the recent passage of European Union laws regulating this practice while increasing material and energy recovery. Later on. Utilizing cutting-edge methods to recycle used tires is an important concern. A sizeable number of old tires are being utilized in civil engineering applications, including as embankments and foundations for roads and rail foundations (*ETRMA, 2011*). According to *Siddique and Naik (2004)*, recycled waste tires can also be used to generate energy in cement kilns, burned to produce electricity, added to cement-based materials *(Del Rio Merino et al., 2007; Al-Akhras and Smadi, 2004; Benazzouk et al., 2007)*, used as a lightweight filler *(Chen et al., 2013)*, and used as crush barriers, bumpers, and artificial reefs *(Shu and Huang, 2014)*.

Reusing wastes as fine aggregates is also encouraged by the scarcity of natural resources like sand. In addition to lowering the need for the extraction of natural raw materials, waste rubber can be used in place of some or all of the fine aggregate portion in construction materials, saving landfill space.

2. Properties of concrete with rubberised mixes

2.1 Workability and setting time

Al-Akhras and Smadi (2004) investigated the impact of tire rubber ash (size up to 0.15 mm) on various cement mortar qualities by substituting tire rubber ash for virgin sand at weight percentages of 0%, 2.5%, 5%, 7.5%, and 10%. The workability decreased as the amount of rubber ash sand increased, according to the data. When rubber ash sand was added at a maximum rate of 10%, the flow was reduced by up to 25%. By adding more rubber, the setting time increased.

Topç¸u and Demir (2007) investigated the flowability of mortar that replaced virgin sand at 0%, 10%, 20%, 30%, and 40% by volume with rubber particles distributed in sizes of either 0.1 or 1.4 mm. The findings indicated that as rubber content increased up to 24%, workability decreased.

In self-consolidating mortar mixes, *Uygunoglu and Topc¸u (2010)* substituted scrap tyre rubber (size 1.4 mm) for natural sand (size 0~4 mm) up to 50% by weight at different water/binder ratios. They found that adding rubber particles to the mixes in both low and large volumes reduced their workability. The 50% substitution of sand with rubber particles significantly reduced the workability of the rubberized mix.

2.2 Density

Balaha et al. (2007) observed that adding ground waste tire rubber (size, 4 mm) at 5%, 10%, 15%, and 20% by volume reduced the fresh unit weight of concrete mixes. As the amount of rubber sand rose, this reduction increased as well.

Taha et al. (2008) found that adding rubber instead of natural sand reduced the fresh unit weight of concrete mixtures. By weight, the reduction was approximately 11%, 14%, 17%, and 21% when 25%, 50%, 75%, and 100% of rubber sand were added, respectively.

According to *Ozbay et al. (2011)'s* experimental investigations, adding crumb rubber (size 0.3 mm) as a natural substitute for fine aggregate reduced the fresh unit weight of concrete mixtures. When 5%, 15%, and 25% of rubber sand were added, the fresh unit weight decreased by 0.91%, 3.32%, and 5%, respectively.

2.3 Hardened Density

Pelisser et al. (2011) discovered that using 10% recycled tire rubber (size 4.8 mm) in place of some natural sand reduced the density of the concrete by 13%.

Styrene butadiene rubber (SBR) and waste rubber-shoe (SR) were utilized by Corinaldesi et al. (2011) as a component of fine aggregate in mortars. Up to 30% of the volume of natural sand (size 0~5 mm) was substituted with either SBR (size 0~12 mm) or SR (size 0~8 mm). When 10% and 30% of SBR sand were added, the dry unit weight decreased by 3.84% and 16.35%, respectively, whereas it decreased by 2.86% and 13.54% when 10% and 30% of SR sand were added.

Sukontasukkul (2009) used two distinct rubber particle sizes (passing sieve n6 and n26) at 0%, 10%, 20%, and 30% by volume to partially replace natural sand in concrete. Concrete specimens' hardened densities were found to have decreased. The reduction was around 14%, 17%, and 20% when 10%, 20%, and 30% of large-sized rubber sand were added, respectively, but it was 17%, 22%, and 28% when small-sized rubber sand was added.

2.4 Drying shrinkage and cracking resistance

In concrete mixtures, Jingfu et al. (2009) substituted tyre rubber particles (0~1.5 mm) for natural sand at up to 120 kg/m3. The drying increased, according to the results. shrinking when rubber sand is added. Drying shrinkage went raised by raising the percentage of rubber sand.

When rubber from used tires was substituted for natural sand in concrete, Bravo and de Brito (2012) discovered that the shrinkage increased by up to 15% by volume. 15% of rubber sand caused a 43% increase in shrinkage.

Pedro et al. (2013) found that adding 15% of shredded rubber (0~2 mm) by volume in place of some of the natural sand caused the mortar specimens to shrink more. The length variation of concrete prisms with waste tire rubber (0.3–0.6 mm) added as a natural sand substitute at up to 20% by volume was noted by Yung et al. (2013). It was found that adding more rubber sand increased the shrinking. Compared to the control length, the average length change was 35% greater. The average length change was 95% greater than the control specimen when 20% of the natural sand was replaced with waste tire rubber powder.
Sukontasukkul and Tiamlom (2012) observed that, as the replacement rate increase, the lack of fine aggregate causes a greater decrease of internal restraints and led to higher shrinkage of the matrix. In terms of rubber sand particle size, the smaller size caused a higher shrinkage than the larger size

3. Methodology

This research focused on using Styrene-butadiene rubber as a replacement to coarse aggregate in Ordinary Portland Concrete. The study intended to check the enhancement if any, caused in the durability properties of Ordinary Portland concrete using rubber in replacement with the conventional aggregates. The selection of rubber to be used as a replacement was done using some criterion specified in the subsequent. The use of rubber as replacement was varied in different percentages ranging between 0%, 5%, 10%, 15% and 20%.

The mechanical properties such as characteristic strength of concrete at 7 days and 28 days were checked for the parametric comparison. Also, the split tensile strength and the flexural strength were kept as parametric datums for comparison. The concrete specimens tested here had a target mean strength of M20 grade of concrete.

Criterion for selection of rubber as a coarse aggregate replacement

The selection of waste tyre rubber used as replacement to aggregates was done on the basis of following points:

1. The tyres being used should have comparably lesser amount of thread present in it.
2. The tyres under scan should have at least 50-70% of rubber left in it.
3. The tyres should be of plain rubber without steel fibres reinforced in it.
4. The tyres shouldn't be aged more than 8 years, age beyond which softens the rubber.

On this basis the selection of tyres was done and sent for cutting in to appropriate size needed.

Sizing of the rubber waste

After the scrutinization of the rubber, the next step was the sizing of the rubber in the required size to be used in concrete as an aggregate replacer.

The rubber was cut in such a state that the length and the thickness should be equal to 25mm dimension. It was also observed that nearly thirty tyres cut gave a sum of 10kg of rubber aggregate.

Figure 1: Different type of rubbers after the cutting procedure

Figure 2: Rubber Aggregate after appropriate sizing

4. Results and Discussions

After the rubber was cut into aggregates and other materials were procured the casting of specimens for the parametric comparison was started. As stated earlier the strength targeted here for the concrete for M20. The mix design of which was done using Indian Standard Mix Design method suggested by IS:10262 (2009). After the casting of specimens required for different tests, which were compressive strength test, split-tensile test and the flexural strength test, the specimens were cured for 7 and 28 days.

The tests were carried out for 7- and 28-days strengths. The results of which has been discussed in the subsequent head.

Compressive Strength of Rubberised Concrete

The compressive strength tests were performed according to IS: 516-1959, tested on cubes of size 150 mm. After thoroughly drying the surfaces of the specimens that contained moisture, all of the cubes were examined in a dry environment. Three cubes were examined for each mix proportion (trial mix) after 7 days and 28 days utilizing a compression testing machine with a 2000 kN capacity, 149 kg/cm2 of uniform stress per minute, and the specimen being appropriately positioned and centered in the testing machine. The following are the findings from the experimental investigation carried out:

Table 1: Compressive Strength of Rubberised Concrete

Compressive Strength of Rubberised Concrete		
Coarse aggregate replacement by waste rubber (%)	**7 days strength (N/ mm²)**	**28 days strength (N/ mm²)**
0	16.09	24.93
5	13.85	23.48
10	11.96	22.22
15	10.62	18.16
20	8.81	17.86

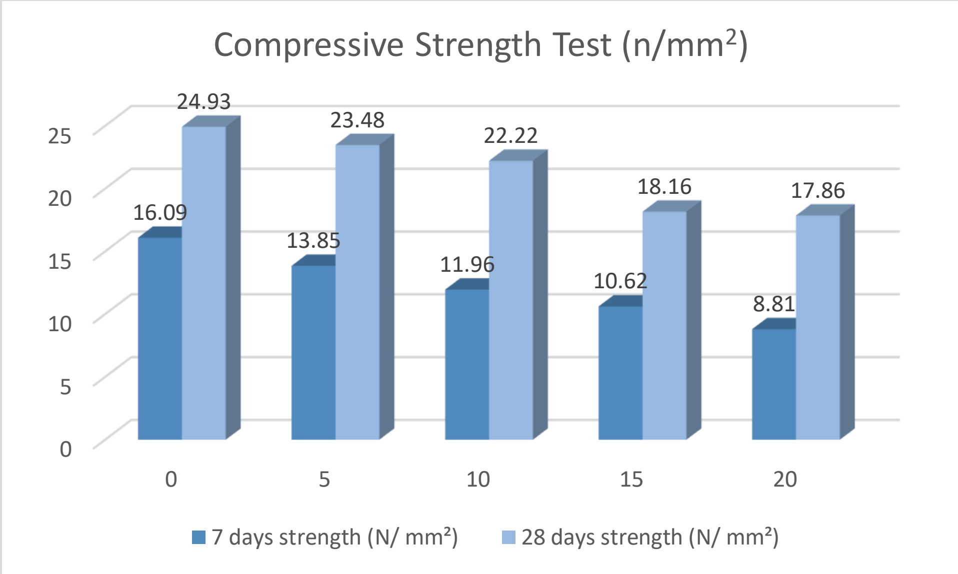


Figure 3: Compressive Strength of Rubberised Concrete

From the Experimental investigation it can be seen that, the 28-day strength of concrete with no replacement had a higher 7- and 28-days strength. Use of 5% rubber had caused a fall in strength than that compared to the 0% replacement. The fall of strength of concrete from 0% to 5% replacement was observed to be 5.81% and the same fall was seen to be increasing with every 5% increase in the replacement. Hence it can be said that 5-10% of replacement of aggregate would be ideal on the basis of this data.

Tensile Strength of Rubberised Concrete

After the compressive strength the another most important parameter of concrete is its tensile strength. Here for the tensile strength, split tensile method was used. For the tests cylinders having length = 300 mm and dia =150mm were used. The results of which has been illustrated in *Table 2*.

Table 2: Tensile Strength of Rubberised Concrete

Tensile Strength of Rubberised Concrete		
Coarse aggregate replacement by waste rubber (%)	**7 days strength (N/ mm²)**	**28 days strength (N/ mm²)**
0	1.34	1.69
5	1.23	1.56
10	1.20	1.50
15	1.13	1.43
20	1.09	1.32

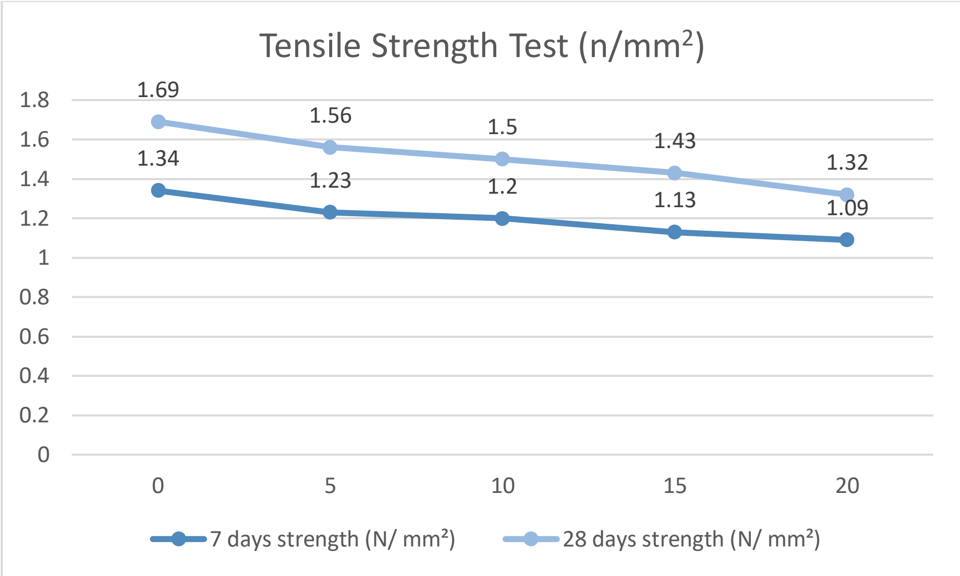


Figure 4: Tensile Strength of Rubberised Concrete

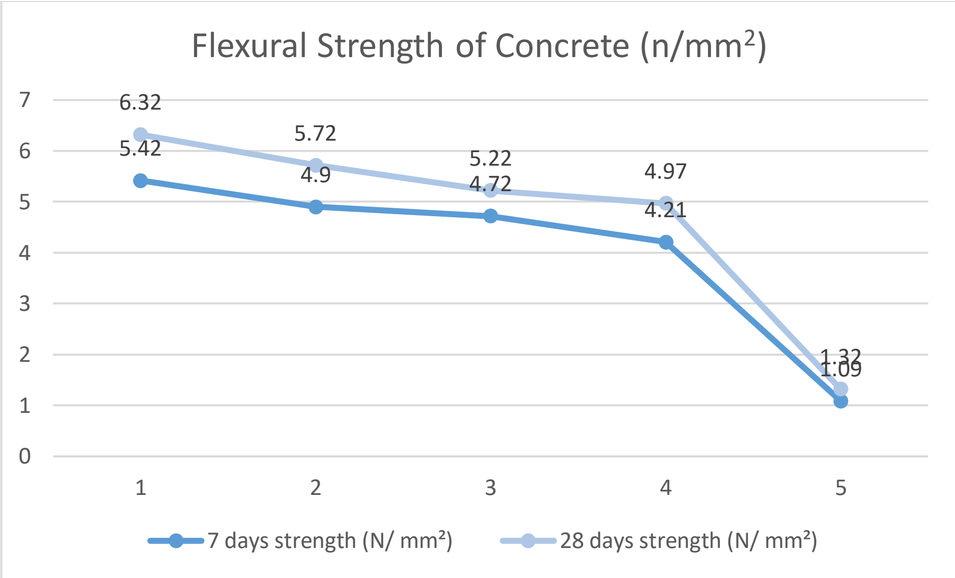
From the test results here also, it can be seen that the tensile strength of no replacement concrete is 8% higher than that of the concrete with 5% replacement and with every 5% increment of replacement 5-8% of strength is reduced. Similar to the compressive strength results, it can truly be said that the optimum percentage of replacement should be between 5-10% only.

Flexural Strength of Rubberised Concrete

Another most significant property of concrete is its flexural strength. From the results it can be seen that, the flexural strength results followed the same pattern as that of the tensile and compressive strength results. The flexural strength of 0% replacement model had a 9% higher strength with respect to the 5% replacement model. On the basis of which it can be said that with every 5% increase in replacement 5-10% of fall in the flexural strength is also expected. Hence it again can be concluded that the optimum percentage of replacement should be between 5-10% only.

Table 3: Flexural Strength of Rubberised Concrete

Flexural Strength of Rubberised Concrete		
Coarse aggregate replacement by waste rubber (%)	**7 days strength (N/ mm²)**	**28 days strength (N/ mm²)**
5.40	5.42	6.32
5	4.90	5.72
10	4.72	5.22
15	4.21	4.97
20	1.09	1.32



5. Conclusions

The following conclusions can be inferred from the parametric comparison and the data acquired from the experimental studies:

1. The most optimum content for the replacement concluded from the results will be between 5-10%.

2. It can also be said that even by using 5-10% of rubber as a replacement for aggregate will cause a considerable cost saving in big projects where the aggregate quantity used is enormous.

3. Here it can be also be concluded that, when replacement of aggregate with rubber is being done use of higher grade of concretes are suggested as the replacement causes fall of compressive, tensile and flexural strengths of concrete.

4. It can also be concluded here that apart from rubber being used as a replacement for coarse aggregates, replacement for fine aggregate may also influence the economic as well as other aspects of ordinary concrete.

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