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ISSN 0974-5904, Volume 09, No. 01

International Journal of Earth Sciences and Engineering

February 2016, P.P.170-175

Experimental Investigation on Recycled Rubber Filled Concrete

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Abstract: *Disposal of waste rubber tyres has become a major concern in relation to the surrounding environment. This paper mainly focuses on the problems associated with waste tire disposal and the reuse of recycled rubber (RR) as coarse aggregate in new concrete construction. M20 and M40 concrete grades are mixed with recycled rubber which replaces coarse aggregate by the volume of 5, 10 and 15 percentages. Silica Fume (SF) and Plaster of Paris (POP) were replaced with cement content in various proportions such as 5, 10 and 15 percent. The experimental results show that when the percentage of recycled rubber increases the compressive strength of concrete decreases gradually. However silica fume has significant effects on the strength of concrete compared to POP.*

Keywords: *Recycled Rubber, Silica fume, Plaster of Paris, Compressive strength, Optimum Percentage*

1. Introduction

As a construction material concrete is being widely used all over the world. The demand for natural aggregates is increasing day by day since the availability of fine aggregate and coarse aggregates are scarce now giving anxiety to the construction industry. Scrap tires of various automobiles are continuously accumulated in the landfills all over the world. After the service life of truck and car tires are over their storage and disposal becomes a challenging problem for the municipal authorities. This is considered as one of the major environmental challenge because waste rubber is not easily biodegradable even after a long period of landfill treatment.

Experiments performed with various percentages of Silica fume replacing cement with a water cement ratio of 0.5 revealed that the optimum compressive strength was obtained at 20 percent replacement of cement by silica fume at all age levels (24 hours, 7 and 28 days).Test results show that compressive strength of 100mm cubes are higher than 150mm cubes at all age levels [2].Tests also revealed that a rubber content of as high as 25 percent by total aggregate volume might be used to produce rubberized concretes with compressive strength of 16 – 32 MPa since the addition of silica fume improved the mechanical properties of rubberized concretes [5]. The effects of replacing coarse aggregate with shredded tire and observed that there is no significant change in properties of concrete at 5 percent replacement of coarse aggregates [6].

Experiments reveal that the compressive strength, tensile strength and thermal conductivity of concrete decreases with the addition of rubber in concrete. It also increases the thermal resistance of the concrete mix [8]. The compressive strength of concrete containing rubber and silica fume was higher than strength of rubber with nano-silica and their mixtures at 28 days [9]. Silica fume is a puzzalonic material which is used to strengthen the transition zone in concrete. In high performance concrete 7 percent of silica fume and 0.5 percent of cellulose fiber gives an optimum compressive strength beyond which the strength decreases [10].

This study focuses on improving the strength of concrete using reclaimed rubber and silica fume as alternative construction materials for coarse aggregate and cement respectively. Experiments were conducted on cubes for various proportions of concrete and the findings will be analyzed and concluded.

2. Literature Review

Mavroulidou and Figueiredo, 2009 in their research concluded that despite the observed lower values of the mechanical properties of concrete there is a potential large market for concrete products in which inclusion of rubber aggregate would be feasible. Therefore the use of discarded tire rubber aggregates in concrete shows promise for developing an additional route for used tires.

Amudhavalli and Jeena Mathew, 2012 confirmed the optimum silica fume replacement percentage for obtaining maximum 28- days strength of concrete ranged from 10 to 20 % Cement replacement up to 10% with silica fume leads to increase in compressive strength for M30 grade of concrete and improves the mechanical properties of concrete. In this paper suitability of silica fume has been discussed by replacing cement with silica fume at varying percentage and the strength parameters were compared with conventional concrete.

Dumne, 2013 carried out a research on M20 grade concrete mix with different percentages of rubber aggregates (0, 5, 10, and 15% of the total volume of aggregate).Test results revealed that rubberized concrete gave less unit weight in addition to the reduction in workability.. On an overall the experimental results reflect the possibility of using discarded tire rubber as a partial replacement to mineral aggregates.

Debabrata Pradhan and Dutta, 2014 have conducted **e**xperiments which reveal that 28 days compressive strength is increased by 36.82, 20.4 and 20 percent for 150mm cubes and by 28.13, 18.4 and 60 percent for 100mm cubes than control concrete i.e. without silica fume. It is also investigated that the optimal compressive strength is obtained at 20 percent cement replacement level.

Wakchaure and Prashant Chavan, 2014 in their studies on compressive, tensile and flexural strengths of concrete have shown a decrease in strength at 1.5 and 2 percent replacement of crumb rubber and the same was increased by using glass fiber at 0.4 and 0.5 percent to the weight of cement with 1.5 and 2 percent replacement of crumb rubber respectively.

3. Experimental Investigation

Mix design is a process of specifying the mixture of ingredients required to meet anticipated properties of fresh and hardened concrete mix design is a well-established practice in the world. The various concrete mixes for M20 and M40 grades having w/c ratio of 0.55 and 0.40 was prepared with coarse aggregates replaced by recycled rubber and cement replaced by POP and silica fume respectively.

The concrete mix was designed as per IS10262 - 2009. The mix proportion of ingredients Cement: F.A: C.A: Water is 1: 1.16: 2.68: 0.4 for M40 grade and 1:2:3.6:0.55 for M20 grade concrete. The concrete cubes were cast and kept for 24 hours for air curing. The same samples were cured at room temperature for 14 and 28 days and tested with the help of compression testing machine.

Table1 shows the test results of M20 grade concrete cubes replacing coarse aggregates with reclaimed rubber by 0, 5, 10 and 15 percent.

Figure 1 shows that 5 percent partial replacement of aggregate with rubber achieves more than 90 percent of the strength of conventional concrete at 14 and 28 days respectively. When the rubber percentage is increased further a reduction in strength is observed as the hardness index of rubber is less compared to conventional coarse aggregates.

***Table 1.** Compressive Strength of M 20 Grade Concrete*

Sample	RR (%)	Average Compressive Strength (N/mm^2)	
		14 days	28 days
A_1	0	20.8	31.4
A_2	5	18.9	28.7
A_3	10	12.3	18.8
A_4	15	5.7	8.7

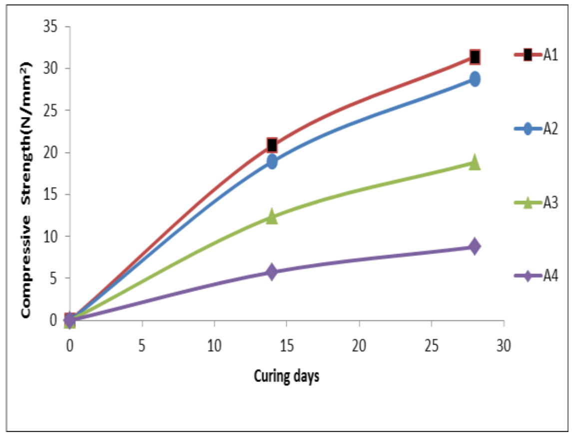

***Figure 1.**Compressive strength of various concrete mixture with RR*

Table 2 presents the test results of M20 grade concrete replacing coarse aggregates with recycled rubber and cement by Plaster of Paris in various proportions. The test results in figure 2 indicate that for every 5 percent increase in rubber there is a substantial decrease in the compressive strength of concrete hence, it could be concluded that compressive strength is not enhanced with partial replacement of cement by POP and coarse aggregate with recycled rubber.

***Table 2 .**Compression Test Results for M20 Grade Concrete Cubes*

Sample No.	RR (%)	POP (%)	Average Compressive Strength (N/mm^2)	
			14 days	28 days
B_1	5	10	10.0	15.1
B_2	10	10	7.0	10.3
B_3	15	10	4.0	6.1
B_4	5	15	5.4	8.1
B_5	10	15	4.5	6.8
B_6	15	15	2.3	3.4

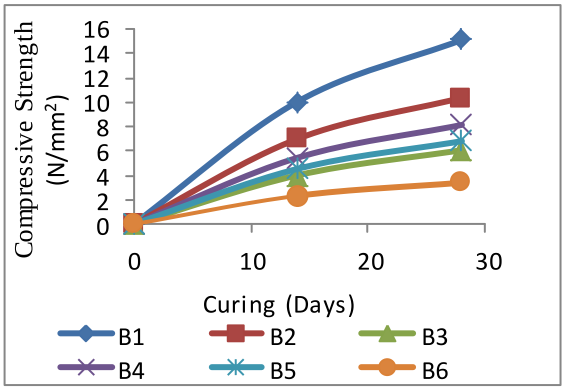

Figure 2. *Compressive Strength of various concrete mixtures with RR and POP*

Table 3 and Figure 3 depict the test results of M20 grade concrete cubes replacing coarse aggregates with recycled rubber and cement by silica fume in various proportions for 14 and 28 days.

The test results in figure 3 reveal that for every 5 percent increase in partial replacement of rubber content the decrease in compressive strength of concrete at 10 and 15 percent replacement of cement with Silica fume is found to be negligible since Silica fume is nearly 3 – 4 times finer than cement particles.

Table 3. *Compression Test Results for M20 Grade Concrete Cubes*

Sample No.	RR (%)	SF (%)	Average Compressive Strength (N/mm^2)	
			14 days	28 days
C_1	5	10	17.7	26.5
C_2	10	10	11.9	17.9
C_3	15	10	6.5	9.6
C_4	5	15	16.4	24.3
C_5	10	15	9.5	14.3
C_6	15	15	5.0	7.6

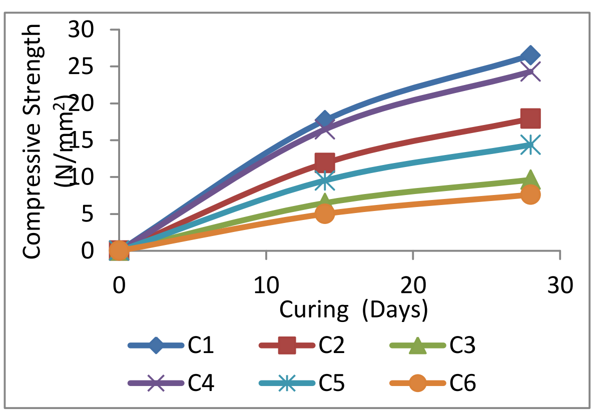

Figure 3. *Compressive Strength of Various Concrete Mix with RR and SF*

The test results of M20 grade concrete cubes replacing coarse aggregates with reclaimed rubber in various proportions are listed in table 4.

Figure 4 shows that as the percentage of rubber increases there is a decrease in the compressive strength of concrete at 14 and 28 days. It is observed that the maximum strength is achieved at 5percent replacement of rubber and the minimum strength is achieved at 15percent replacement for both 14 and 28 days of curing.

Table 4.*.Compression Test Results for M40 Grade Concrete cubes*

Sample	RR (%)	Average Compressive Strength (N/mm^2)	
		14 days	28 days
A_1	0	26.63	40.44
A_2	5	17.02	25.3
A_3	10	12.60	18.40
A_4	15	8.56	12.77

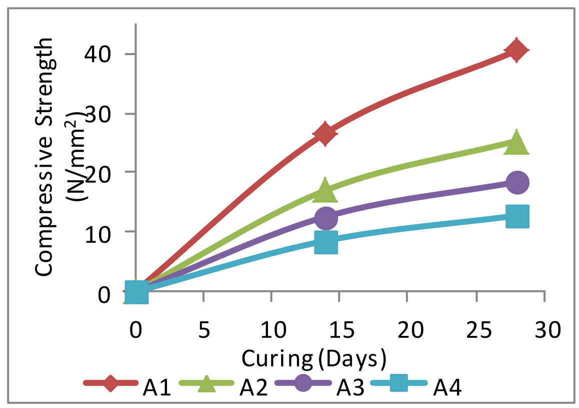

Figure 4 .*Compressive strength of various concrete mix with RR*

Table 5 shows the test results of M40 grade concrete cubes replacing coarse aggregates with reclaimed rubber and cement by POP in various proportions.

Figure 5 shows that the maximum strength is achieved at 5 percent replacement of rubber and the minimum strength is achieved at 15 percent replacement for both 14 and 28 days of curing. Moreover comparing the results for every 5 percent rubber replacement the decrease in strength is proportional to the percentage of replacement of cement by POP.

Table 5 *.Compression Test Results for M40 Grade Concrete Cubes*

Sample	RR (%)	POP (%)	Average Compressive Strength (N/mm^2)	
			14 days	28 days
B_1	5	10	10.88	16.18
B_2	10	10	5.94	8.89
B_3	15	10	4.11	6.25
B_4	5	15	5.50	8.24
B_5	10	15	1.66	2.49
B_6	15	15	0.88	1.42

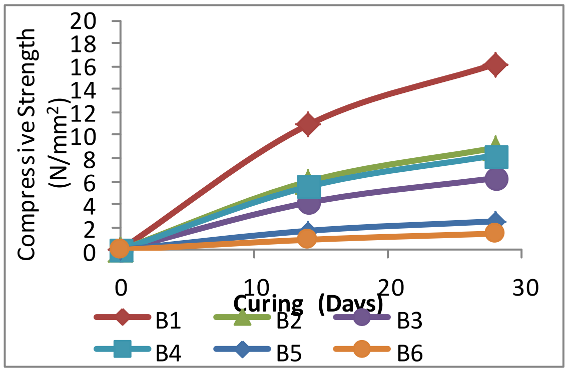

Figure 5. *Compressive strength of various concrete mixtures of RR and POP*

Table 6 shows the test results of M40 grade concrete cubes replacing coarse aggregates with recycled rubber and cement by silica fume in various proportions.

Figure 6 show that for every 5 percent increase in rubber there is a decrease in the compressive strength of concrete when silica fume content is kept constant at 10 and 15 percent respectively. Comparing the compressive strength of concrete mix (10 percent SF) at 14 days it is seen that the strength decreases from 33 percent to 45 percent when rubber content is increased by 5 percent.

Table 6 *.Compression Test Results for M 40 Grade Concrete Cubes*

Sample	RR (%)	SF (%)	Average Compressive Strength (N/mm^2)	
			14 days	28 days
C_1	5	10	18.7	28.4
C_2	10	10	12.9	19.3
C_3	15	10	8.3	12.2
C_4	5	15	21.0	32.1
C_5	10	15	10.9	16.0
C_6	15	15	6.5	9.5

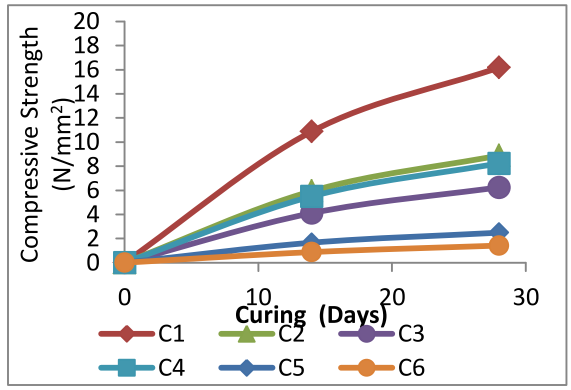

Figure 6. *Compressive Strength of Various Concrete Mix with RR and SF*

Table 7and 8 show the test results of M20 and M40 grade concrete cubes replacing coarse aggregates with recycled rubber and cement by silica fume.

Table 7. *Compression Test Results for M20 and M40 Grade Concrete Cubes*

Sample	RR (%)	RR+SF (%)	Compressive Strength at 14 days (N/mm^2)	
			M20	M40
A_1	0	-	20.8	26.6
A_2	5	-	18.9	17.0
C_1	-	5 + 10	17.7	18.7

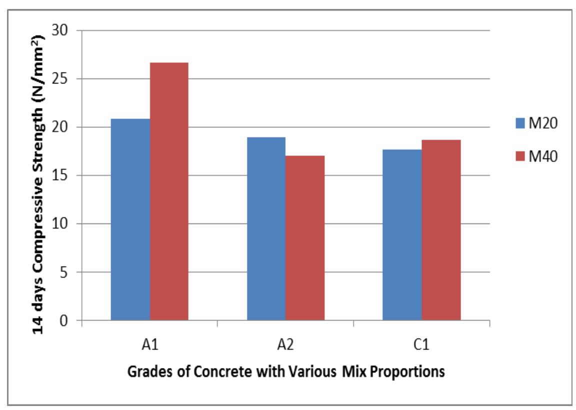

Figure 7 *Compressive Strength of Various Concrete Mix with RR and SF*

Figure 7 shows that M20 grade concrete achieves more strength compared to M40 grade conventional concrete. Moreover it is found that compressive strength of M20 grade concrete is higher than M40 grade concrete at 5 percent replacement of rubber with coarse aggregates. Similar results are obtained at 5percent partial replacement of rubber and 10 percent replacement of cement by Silica fume.

***Table 8** Compression Test Results for M20 and M40 Grade Concrete Cubes*

Sample	RR (%)	RR + SF (%)	Compressive Strength at 28days (N/mm^2)	
			M20	M40
A_1	0	-	31.4	40.4
A_2	5	-	28.7	25.3
C_1	-	5 + 10	26.5	28.4

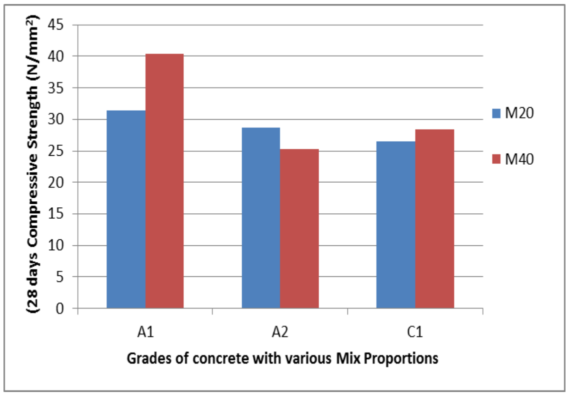

***Figure 8** Compressive Strength of Various Concrete Mix with RR and SF*

Similarly Figure 8 shows that M20grade concrete achieves more strength compared to M40grade for similar percent replacement of rubber and Silica fume with coarse aggregates and cement respectively.

4. Discussions

The test results show that the compressive strength of concrete reduces as the percentage of rubber increases in M20 and M40 grade concrete samples at 14 and 28 days when compared with conventional concrete. Compressive strength for M20 and M40 grade concrete mix with recycled rubber and plaster of paris show a decrease in strength for every 5 percent increase in recycled rubber with 10 percent replacement of cement. It is also observed that the strength of concrete reduces substantially for a further increase of 5 percent in POP.

More than 40 percent of required strength is achieved when 5 percent of coarse aggregate is replaced partially by recycled rubber in M20 grade concrete whereas in M40 grade concrete the strength reduces as the percentage of rubber increases. Nearly 95 percent of the characteristic strength is obtained when 10percent of coarse aggregate is replaced by recycled rubber. In M20 grade concrete there is a decrease in compressive strength as the percentage of recycled rubber is increased proportionately with an increase in silica fume content.

Results also reveal that there is a gradual increase in strength of M40 grade concrete when silica fume is increased at 5 percent of recycled rubber.

5. Conclusion

- The experimental results show that M20 grade concrete achieves greater strength than M40 grade for similar percentage of replacement of cement with silica fume and coarse aggregates with recycled rubber.
- Observations reveal that plaster of paris cannot be used as a replacement for cement since the strength is less compared to conventional concrete.
- Test results shows 5 percent of recycled rubber and 10 percent of silica fume can be replaced for coarse aggregate and cement respectively to achieve good strength than conventional concrete for M 20 grade.
- At 5 percent replacement of recycled rubber the compressive strength of concrete increases gradually when silica fume content is increased from 5 to 10 percent in M40 grade concrete.
- Silica flume enhancing the strength of concrete while replacing coarse aggregate with recycled rubber.
- Nearly 65 to 70 percent of early strength (14 days) is achieved in both M20 and M40 grades of concrete.
- Even though two different grade of concrete such as M20 and M40 were adopted the percentage of rubber is restricted to a maximum of 10 percent.
- Comparing 14 and 28 day compressive strength for M20 (5 percent RR+ 10 percent SF) and M40 (5 percent RR+ 10 percent SF) grade concrete with M20 (control mix) and M40 (control mix) grade concrete, the strength is reduced to 28 percent.

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