An Experimental Study on Performance of Recycled Tyre Rubber-Filled Concrete

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Abstract

Disposal of discarded rubber tyres becomes an emerging research issue which needs to reuse of waste rubber tyres in place of mineral coarse aggregates in concrete. This paper studied an experimental work using recycled rubber tyre aggregates as partial replacement to the coarse aggregates in concrete mix. The performance study is carried out using tests such as slump, unit weight and compressive strength on different concrete mixes in order to determine properties of concrete mix. For comparative analysis, concrete mix of M_{20} grade is prepared for various concrete mixes by varying percentage replacement of mineral coarse aggregates by 0, 5, 10 and 15 rubber aggregates. The test results show that rubberized concrete gives lesser unit weight in addition to the reduction in workability. It is also observed that there is a reduction in compressive strength of rubberized concrete which restrict its structural applications but it preserves some desirable characteristics. Overall, results of experimental test reflect that it is possible to use discarded rubber tyre aggregates in concrete as a partial replacement to mineral coarse aggregates but percentage replacement should be limited in order to restrict its application.

Keywords: coarse aggregates, rubber aggregates, conventional concrete, rubberized concrete, workability, unit weight, compressive strength.

1. Introduction

Concrete is one of the most widely and continuously using as a construction materials in the world wide in which cement and aggregates are the most vital constituents. Further, these aggregates have been customarily treated as inert filler in concrete but in fact, aggregates not truly inert but its physical, thermal, and sometimes chemical properties influence the concrete. Due to tremendous demand of concrete as a construction material from society, it is need to preserve the natural coarse aggregates by using alternative materials which can obtain from recycled or waste materials. Therefore, the best management strategy for scrap tyres is the recycling which leads to utilization of scrap tyres with minimizing environmental impact and maximize the conservation of natural resources. Over the two decades, researchers have underscored to use waste tyre rubbers in concrete and were remarked that recycling of waste rubber tyre is most viable in concrete as a partial replacement to mineral coarse aggregates [1]. The twofold advantage that is, it can prevent the depletion of scarce natural resources and the other will be the prevention of different used materials from their severe threats to the environment [2]. Partial replacing the coarse aggregates of concrete with recycled waste tyre aggregates can improve the qualities such as low unit weight, high resistance to abrasion, durability, absorbing the shocks and vibrations, high ductility etc [3]. It was estimated that in India alone, more than 13 millions car and truck tyres are being discarded annually which becomes one of the major environmental challenge the world facing because waste rubber is not easily biodegradable even after a long period of landfill treatment [4]. In recent past, decrease in slump with increasing in rubber aggregate contents by total aggregate volume and results show that for rubber aggregate content of 40% then slump is close to zero. Further, increasing the size of rubber aggregates decreases the workability of mix and subsequently reduction in the slump value [5]. Further, slump values of mixes containing long, angular rubber aggregates were lower than those for mixes containing round rubber aggregates. The results of low and high volumes of rubber aggregates indicated that concrete densities were reduced to 87% and 77% of their original values, respectively. It has been also observed that reduction in compressive strength by 85% and tensile splitting strength by 50% but showed the ability to absorb a large amount of plastic energy under tensile and compressive loads [6]. Through the series of experiments using partial replacement of rubber tyre aggregates in concrete causes decrease in compressive strength but which will be compensated by adding Nano silica. It is also noted that there is still a possibility of improving the compressive strength by using de-airing agents. Therefore, rubberized concrete has widely used for the development related projects such as roadways or road intersections, recreational courts and pathways and skid resistant ramps. With this new property, it is projected that these concretes can be used in architectural applications; panels that require low

unit weight, rail-roads to fix rails to the ground, roofing tiles etc [7]. Significant problem of rubber tyre waste disposal and other side shortage of natural coarse aggregates in construction field then to overcome these issue, it is essence to use recycled waste tyres as an aggregate which can provide the solution for two major problems [8], that is, environmental problem created by waste tyres and depletion of natural resources by aggregate production consequently the shortage of natural aggregates in some countries.

In this paper, general objectives of study is to evaluate the fresh and hardened properties of concrete produced by replacing part of natural coarse aggregates with an aggregates produced from locally available recycled tyre rubber. The specific objectives of this study are, (i) observation of some physical properties of concrete mix contained waste tyre aggregates (ii) interpretation of test results obtained from the prepared specimen of mix in the laboratory (iii) comparison of test results obtained from rubberized concrete with the conventional concrete.

Outline of study

The various concrete mixes of M_{20} grade having water-cement ratio of 0.55 is prepared with mineral coarse aggregates replaced by 0, 5, 10 and 15% of discarded tyre rubber aggregates separately and casted in standard cement concrete cubes. The comparative analysis is carried out through various tests such as slump, unit weight and compressive strength. The test data obtained from experiments are compared with the conventional concrete using tables, pictures; graphs etc and finally discussion of test result are presented along with concluding remark.

2. Material Properties

Fine and Coarse aggregates

The fine and coarse aggregate samples for conducting the experiments are used from the store room of Government Polytechnic, Nashik. To investigate its properties and suitability for the intended application, the various tests are performed as (1) Sieve analysis and fineness modulus (2) Specific gravity (3) Moisture content (4) Silt content. The test results obtained for fine aggregates are, fineness modulus= 3.19, specific gravity= 2.61, moisture content= 2.04 % and silt content = 0.89 % whereas for coarse aggregates, fineness modulus= 7.40, specific gravity= 2.70, moisture content= 1.37 % and silt content = 0.25 %.

Rubber aggregates

In this study, source of rubber aggregates is the discarded tyre that is, bicycle tyre which is collected from the local market and rubber tyre aggregates are prepared manually as shown in figure 1. In general, discarded tyre rubber aggregates are available in the range of grading from 0.5 mm to 30 mm.

Figure 1 Stockpile of waste tyres and process of rubber aggregates preparation manually

The rubber aggregates used in the present study are prepared manually by cutting the tyre to maximum nominal size equal to 20 mm as shown in figure 2 and kept for air drying after cleaning with potable water. The specific gravity is obtained from test equal to 1.18.

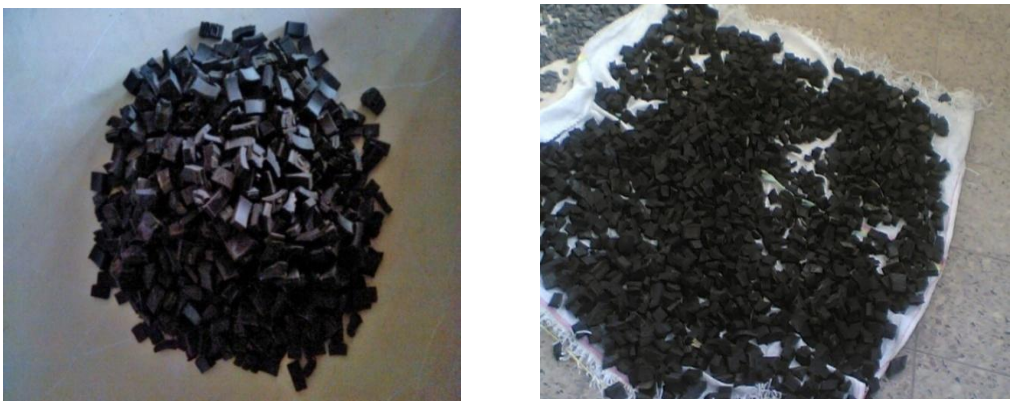

Figure 2 Discarded bicycle tyre rubber aggregates with nominal size of 20 mm and air drying process

Test arrangement

The various tests are performed in laboratory of Applied Mechanics Department, Government Polytechnic Nashik. In this study, three different concrete mixes of same concrete grade are prepared with partial replacement of coarse aggregates by 5, 10 and 15 percent with rubber aggregates by an equal volume of rubber aggregates to form rubberized concrete. In addition, a conventional concrete of same grade is also prepared with no replacement of coarse aggregates. The complete process of mixing is carried out manually and further, table vibrator is employed for casting these cubes. In this study, the tests are performed are, slump test, unit weight and compressive strength at 7^{th} and 28^{th} days on various concrete mix.

3. Test Results and Discussion

This section described the test results of rubberized concrete mixes in addition to the conventional concrete mix of same grade. In succeeding part, the test results on various tests are presented in a lucid manner using tables and graphics. Finally, analysis and discussions are also explored on the findings. The M_{20} grade of concrete mixes with 0, 5, 10 and 15 percent replacement of rubber aggregates to natural aggregates which are designated as A, A_1, A_2, and A_3 respectively for further discussion and interpretation.

Slump test

Ingredients of mixes are properly mixed so as to produce homogeneous and uniform fresh concrete in macro-scale in order to know its workability using slump test as shown in figure 3. The results of same test for the conventional concrete and various rubberized concrete are shown in table 1.

Figure 3 Process of Concrete Mixing and Slump Test

Table 1 Slump Test

Specimen	% rubber	slump (mm)
A	0	92
A_1	5	60
A_2	10	29
A_3	15	5

It is noted that slump has been decreased due to increase in percentage of rubber aggregates in all samples of concrete mix. In normal concrete mix, slump is seen to 92 mm and when the coarse aggregates are replaced with 15% tyre chips then the slump is about 5 mm which becomes nearly zero slump value.

Unit weight

From the test, specific gravity of rubber tyre aggregates and mineral coarse aggregates are of 1.18 and 2.70 respectively. From the observation, it is noted that unit weight of rubberized concrete decreases due to increase in rubber tyre aggregates as shown in Table 2.

Table 2 Unit weight of conventional concrete and various rubberized concrete mix

Specimen	% rubber	Unit wt. in Kg	% reduction
A	0	8.541	0.000
A_1	5	8.345	2.294
A_2	10	7.979	6.580
A_3	15	7.317	14.330

Compressive strength

The concrete mix was prepared with proportion of ingredients that is, Cement: F.A: C.A.: water is 1: 2.10: 3.90 with water-cement ratio of 0.55 then accordingly quantities required for three CC cubes respectively are 4 Kg: 8.4 Kg: 15.6 Kg: 2.2 Liters. The concrete cubes are casted with the help of table vibrator and are kept for 24 hours to air curing as shown in figure 4.

Figure 4 Casting of concrete mix using table vibrator and its air curing process

After air curing for 24 hours, the same cubes are cured in water curing tank in laboratory at normal room temperature and are tested at 7^{th} and 28^{th} days with the help of Compression Testing Machine which is shown in figure 5. The results of crushing strength of conventional and rubberized concrete mix of same concrete grade are

shown in Table 3. During test of compressive strength, it is observed that nature of crack formation in rubberized concrete different from conventional concrete because bond strength between rubber aggregates and cement paste is poor than that of between mineral aggregates and cement paste. Therefore, initial cracks were formed around rubber aggregates and cement paste.

Figure 5 Testing of cement concrete cubes during and after test

Table 3 Compressive strength of various concrete mix

Specimen	% age Rubber aggregates	Actual Comp. Strength (MPa)		Av. Compressive Strength (MPa)		% age Strength loss	
		7 days	28 days	7 days	28 days	7 days	28 days
A	0	17.778	25.778	17.48	27.11	0.00	0.00
		16.889	26.667				
		17.779	28.889				
A_1	5	16.000	17.333	16.15	19.26	20.40	28.95
		16.889	19.556				
		15.556	20.889				
A_2	10	13.333	14.667	13.62	15.48	32.87	42.89
		14.222	16.000				
		13.333	15.778				
A_3	15	10.000	12.667	10.37	12.14	48.89	55.21
		10.667	11.556				
		10.444	12.222				

The test results show that addition of rubber aggregates resulting to significant reduction in compressive strength compared to conventional concrete at 7^{th} and 28^{th} days. Figure 6 illustrates the trend of strength development in different concrete specimens at 7^{th} and 28^{th} days whereas figure 7 shows the comparison of compressive strength of subsequent concrete mix at 7^{th} and 28^{th} days in comparison to conventional concrete. Further, gain of compressive strength of various prepared concrete mix with respect to the days from the stage of its curing is shown in figure 8. From the scenario of this graph, one can conclude that rapid in strength gain takes place up to its 7 days of curing later on its gaining rate becomes slower.

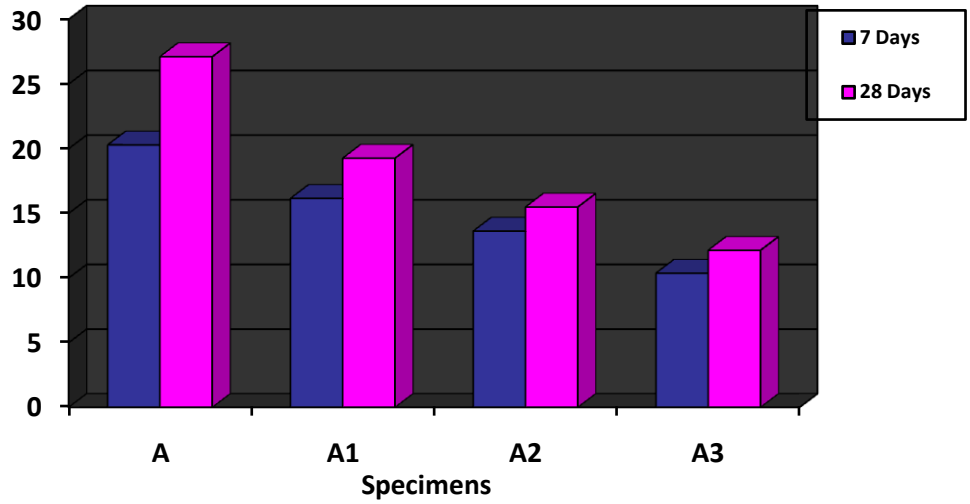

Figure 6 Compressive strength of various concrete mixes

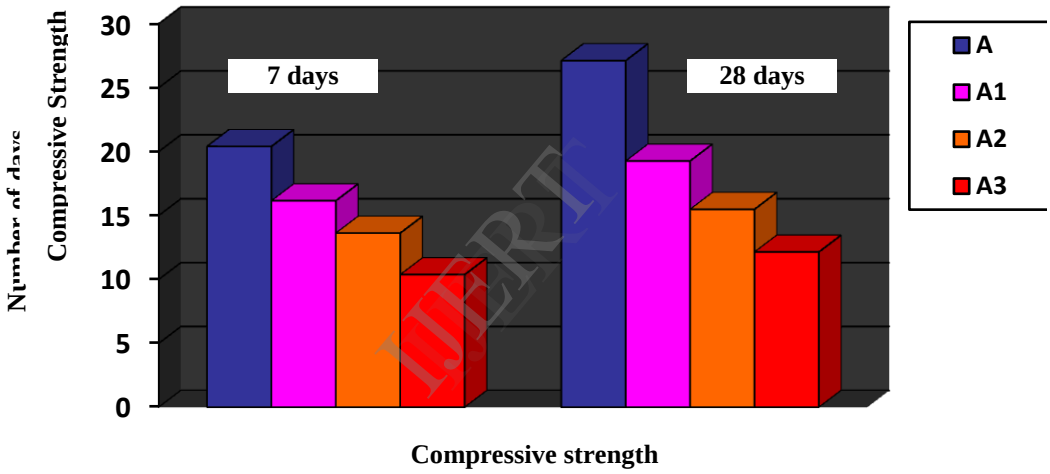

Figure 7 Compressive strength of various concrete at 7th and 28th days

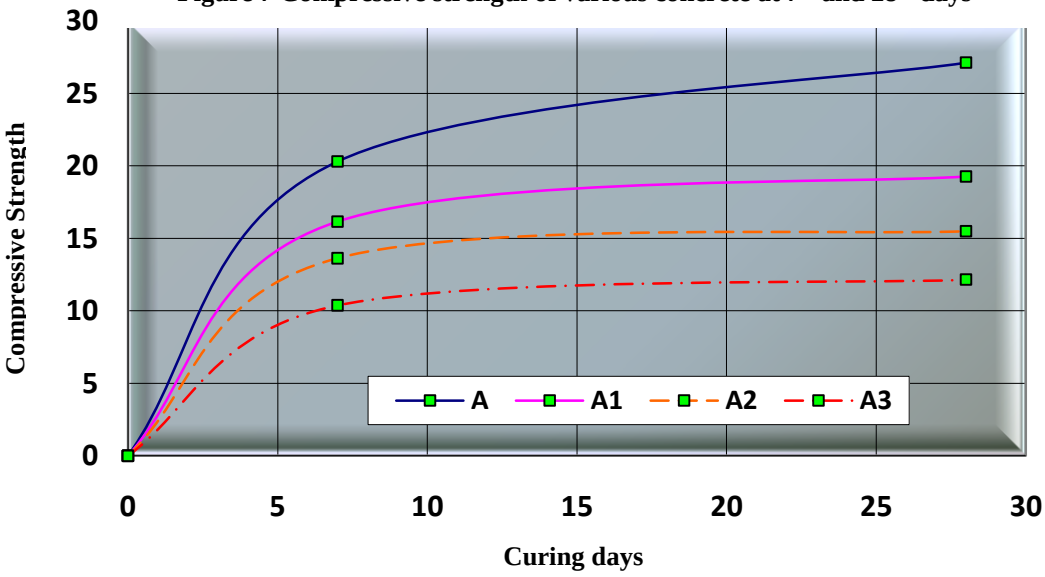

Figure 8 Compressive strength of various concrete mixes with curing in days

4. Conclusions

From the test results of various mix samples, the following conclusions are drawn

1. Introduction of recycled rubber tyres into concrete mix leads to decrease in slump and workability for the various mix samples.
2. Reduction in unit weight of 14.33 % was observed corresponding to 15% by volume of coarse aggregates was replaced by rubber aggregate in sample A_3 which is with a targeted compressive strength of 12.14 Mpa. A much similar trend of reduction in unit weight of rubberized concrete were observed in all other samples containing rubber aggregates.
3. For rubberized concrete, test results show that addition of rubber aggregates resulting to significant reduction in compressive strength compared to conventional concrete which is in the range of 28.95 % to 55.21%. Although the compressive strength is still in the reasonable range for the 5% replacement.
4. Rubberized concrete can be used in non-load bearing members i.e. lightweight concrete walls, other light architectural units, thus rubberized concrete mixes could give a viable alternative to where the requirements of normal loads, low unit weight, Medium strength, high toughness etc.
5. The overall results of this study show that it is possible to use recycled rubber tyre aggregates in concrete construction as partial replacement to mineral coarse aggregates.

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