Re-Use of Waste Tire Rubber Pieces in the Production of Light Weight Concrete

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Abstract: ***At present disposal of waste tires is becoming a one of the major problem in the world. It is estimated that nearly 1.2 Billions of waste tire rubber is produced globally per year. It is estimated 11%of post consumer tires are exported and 27% are sent to landfill or dumped illegally and only 4% is used for civil engineering projects. Hence efforts have been taken into identify the potential application of tires in civil engineering projects. In this research, a study was carried out on the use of rubber tire pieces as a partial replacement for coarse aggregate in concrete construction. The research was carried out by conducting test on the raw materials to determine their properties and suitability for the experiment. The concrete mix designs are prepared by using the DOE method and a total of 8 mixes were prepared consisting of two concrete grades (M15, M25). The specimens were produced with percentage replacements of the coarse aggregate by 10, 25 and 50% of rubber aggregates. Moreover, a control mix with no replacement of the coarse aggregates was produced to make a comparative analysis. The prepared concrete samples consisting of concrete cubes and cylinders. Laboratory test carried out on the prepared concrete samples. The lists of tests conducted are; slump, unit weight, compressive strength, split tensile strength. The data collection is mainly based upon the prepared specimens in the laboratory.***

Keywords: Recycled tires, Aggregate, Concrete, Compressive strength, Rubberized concrete, Unit weight, Workability, Split tensile strength

1. Introduction

Cement and aggregate, which are the most important constituents used in concrete production, are the vital materials needed for the construction industry. This necessity led to a continuous and increasing demand of natural materials used for their production. Parallel to the need for the utilization of the natural resources emerges a growing concern for protecting the environment and a need to preserve natural resources, such as aggregate, by using alternative materials that are either recycled or discarded as a waste. Disposal of waste tires is the one of the major problem in the world.In the past waste tires were greatly used as a fuel source and they have been one of the major markets for scrap tires. However, landfills became the most popular low-cost option for disposal of tires after using them as a fuel source was prohibited in many countries due to their high amount of environmental pollution. The scrap tire recovery rate declined, promoting new legislation that supported research into methods for increasing tire recovery, reuse, and recycling. As states reduce tire stockpiles and subsequently shift the focus of their legislation concerning scrap tire management, scrap tire markets will likely be strengthened and encouraged. Figure 1.1 below shows stockpiles of waste tires.

Figure 1.1: Stockpiles of Waste tires

Hence, all the above studies suggest that there is a strong need to use of recycled materials in concrete and specifically waste tires should be used in an environmental friendly way. For this, concrete construction can be considered as a very realistic and convenient area of application.

2. Methodology of the Study

Concrete mix designs were prepared using the Department of Experiment (DOE) method. A total of 8 mixes with two types of concrete grades (M15, M25) were produced. They were prepared with coarse aggregate replacements by 10, 25 and 50 % of the rubber aggregate. A control mix with no rubber aggregate replacement was produced to make a comparative analysis purpose. The concrete specimens were prepared in the Siddhartha institute of technology and engineering, Civil Engineering Department Material Testing laboratory. The prepared samples consist of concrete cubes and cylinders.Laboratory tests were carried out on the prepared concrete samples. The tests conducted were slump, unit weight, compressive strength, splitting tensile strength. The data collection was mainly based on the tests conducted on the prepared specimens in the laboratory.The test results of the samples were compared with the respective control concrete properties and the results were presented using tables, pictures and bar charts. Conclusions and recommendations were finally forwarded based on the findings and observations.

3. Test Results and Discussions

3.1 General

This section describes the results of the tests carried out to investigate the various properties of the rubberized concrete mixes prepared in contrast with the control mixes. In the succeeding parts, the results for workability, unit weight, compressive strength, splitting tensile strength are presented.

3.2 Fresh Concrete Properties

Workability Test

A concrete mix must be made of the right amount of cement, aggregates and water to make the concrete workable enough for easy compaction and placing and strong enough for good performance in resisting stresses after hardening. If the mix is too dry, then its compaction will be too difficult and if it is too wet, then the concrete is likely to be weak. During mixing, the mix might vary without the change very noticeable at first. In the slump test, the distance that a cone full of concrete slumps down is measured when the cone is lifted from around the concrete. The slump can vary from nil on dry mixes to complete collapse on very wet ones. One drawback with the test is that it is not helpful for very dry mixes.
The slump test carried out was done using the apparatus shown in Figure 1 below.

Figure 1: Slump Test

The mould for the slump test is in the form of a frustum of a cone, which is placed on top of a metal plate. The mould is filled in three equal layers and each layer is tamped 25 times with a tamping rod. Surplus concrete above the top edge of the mould is struck off with the tamping rod. The cone is immediately lifted vertically and the amount by which the concrete sample slumps is measured. The value of the slump is obtained from the distance between the underside of the round tamping bar and the highest point on the surface of the slumped concrete sample. The types of slump i.e. zero, true, shear or collapsed are then recorded. Table 1 shows the results of the slump test for the control concretes and the rubberized concretes.

Table 1: Slump Test Results

No.	*Specimen*	*Grade*	*% rubber*	*w/c ratio*	*Slump (mm)*
1	A1	M15	0.00	0.75	32
2	A2	M15	10.00	0.75	38
3	A3	M15	25.00	0.75	41
4	A4	M15	50.00	0.75	49
5	B1	M25	0.00	0.60	7
6	B2	M25	10.00	0.60	14
7	B3	M25	25.00	0.60	21
8	B4	M25	50.00	0.60	42

The introduction of recycled rubber tires to concrete significantly increased the slump and workability. As seen fromtable it shows that the workability decreases as the strength of the concrete increases for a given amount of w/c ratio in rubberized concrete.

3.3 Hardened Concrete Properties

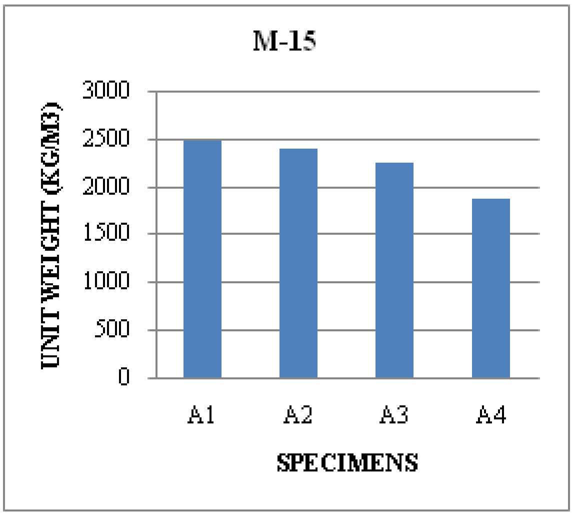
The different tests that have been carried out to establish the hardened properties of the concrete samples produced were; determination of unit weight, compressive strength, splitting tensile strength tests.

3.4 Determination of Unit weight

The unit weight values used for the analysis of this section are measured from the concrete cube samples after 28 days of standard curing. The results for the unit weight are presented in Table 2 below and Figure 2 demonstrates the comparative decrease in unit weight of the rubberized concrete in contrast with the respective control concrete.

Table 2: Unit weights of the control concretes and rubberized concrete

No.	*Specimen*	*Grade*	*% rubber*	*Unit wt.(kg/m3)*	*% Reduction*
1	A1	M15	0.00	2468.82	0.00
2	A2	M15	10.00	2385.21	3.39
3	A3	M15	25.00	2234.90	9.48
4	A4	M15	50.00	1874.45	24.08
5	B1	M25	0.00	2508.78	0.00
6	B2	M25	10.00	2419.33	3.57
7	B3	M25	25.00	2314.99	7.72
8	B4	M25	50.00	2041.75	18.62



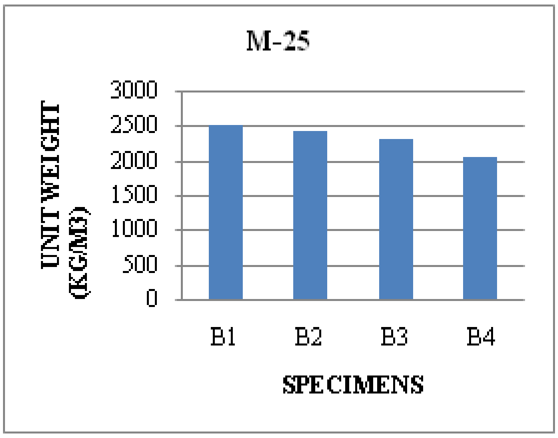


Figure 2: Graphical comparison of unit weight values

Table 3: Compressive Strength Test Results

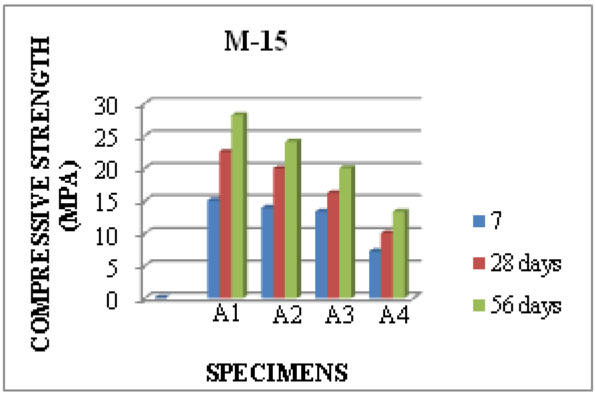
				Compressive strength (mpa)			% strength loss		
No	Specimen	Grade	% rubber	7 Days	28 days	56 days	7 Days	28 days	56 days
1	A1	M15	0	15.07	22.50	28.19	0.00	0.00	0.00
2	A2	M15	10	13.93	19.94	24.07	7.57	11.38	14.64
3	A3	M15	25	13.35	16.15	19.97	11.39	28.19	29.18
4	A4	M15	50	7.20	10.00	13.32	52.23	55.55	52.74
5	B1	M25	0	29.33	41.09	46.62	0.00	0.00	0.00
6	B2	M25	10	24.30	34.39	40.17	17.15	16.30	13.84
7	B3	M25	25	23.55	28.92	31.08	19.69	29.62	33.34
8	B4	M25	50	12.17	14.78	18.00	58.51	64.02	61.39

with increasing percentage of rubber aggregate. Table 3 below shows the results of the 7th, 28th and 56th day compressive strength tests.

Using concrete with a lower density can result in significant benefits in terms of load bearing elements of smaller cross-section and a corresponding reduction in the size of foundations. Occasionally, the use of concrete with a lower density permits construction on ground with a low load-bearing capacity. Concrete that has a lower density also gives better thermal insulation than ordinary concrete.

3.5 Compressive strength Test

The compressive strengths of concrete specimens were determined after 7, 28 and 56 days of standard curing. For rubberized concrete, the results show that the addition of rubber aggregate resulted in a significant reduction in concrete compressive strength compared with the control concrete. This reduction increased. Figure 3 below illustrates the trend of strength development in the different concrete specimens prepared and Figure 4 shows the comparison of the strength achieved in contrast with the control concrete.



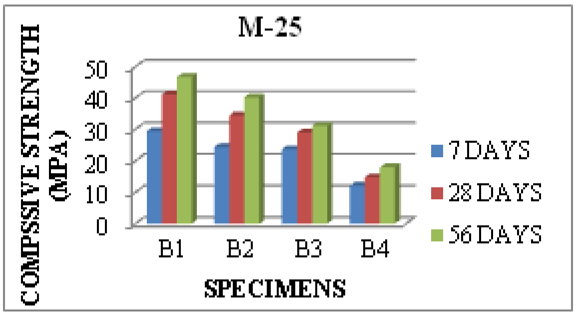
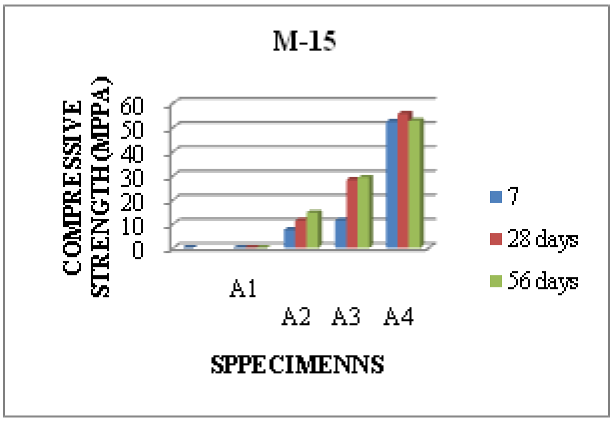


Figure 3: Compressive strength development



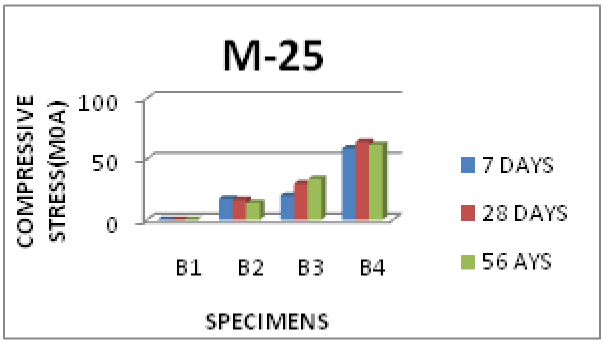


Figure 4: Percentage Loss of Compressive Strength

The reason for the compressive strength reductions could be attributed both to a reduction of quantity of the solid load carrying material and to the lack of adhesion at the boundaries of the rubber aggregate. Soft rubber particles behave as voids in the concrete matrix.

3.6 Splitting Tensile Strength Test

The common method of estimating the tensile strength of concrete is through an indirect tension test. The splitting tensile test is carried out on a standard cylinder tested on its side in diametral compression. The horizontal stress to which the element is subjected is given by the following equation.

Horizontal tension $\sigma_t = 2P/\pi LD$ …[14]

The test is carried out on cylindrical specimens using a bearing strip of 3 mm plywood that is free of imperfections and is about 25 mm wide.

The specimen is aligned in the machine and the load is then applied. Figure 5 below shows the testing method for splitting tensile strength test and Table 4 shows the splitting tensile strength test results. The relative percentage of strength loss with respect to the control mixes are also tabulated together.

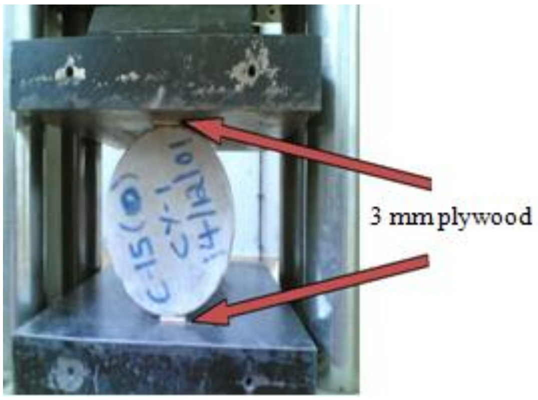
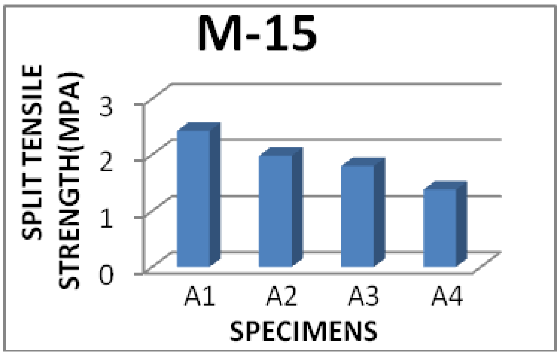


Figure 5: Splitting tensile strength Test

Table 4 Splitting Tensile Strength Test Results

No.	Spec.	Grade	% Rubber	Splitting Load(kN)	Splitting Streng.(MPa)	%Strength Loss
1	A1	M20	0	172	2.43	0.00
2	A2	M20	10	139.95	1.98	18.63
3	A3	M20	25	126.9	1.80	26.22
4	A4	M20	50	97.5	1.38	43.31
5	B1	M30	0	242.9	3.44	0.00
6	B2	M30	10	189.8	2.69	21.86
7	B3	M30	25	168.95	2.39	30.44
8	B4	M30	50	110.95	1.57	54.32

For rubberized concrete, the results show that the splitting tensile strength decreased with increasing rubber aggregate content in a similar manner to that observed in the compressive strength tests. However, there was a relatively smaller reduction in splitting tensile strength as compared to the reduction in the compressive strength. The comparison of the results with the control concretes are shown graphically in Figure 6 below



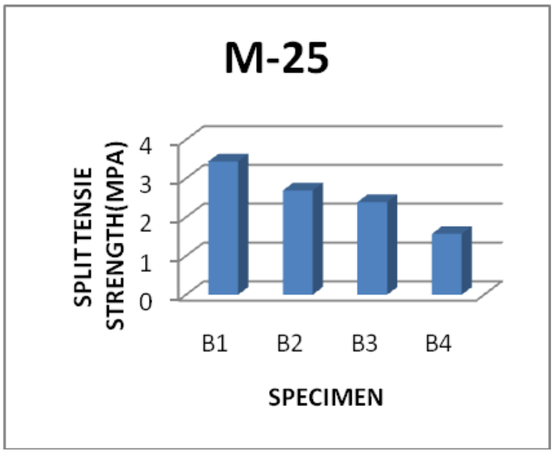


Figure 6: Comparison of splitting tensile strength test results

One of the reasons that splitting tensile strength of the rubberized concrete is lower than the conventional concrete is that bond strength between cement paste and rubber tire particles is poor. Besides, pore structures in rubberized concretes are much more than traditional concrete. The splitting tensile strength test samples for control and rubberized concrete are shown after testing in Figure 7. It can be observed that the rubberized concrete does not exhibit typical compression failure behavior. The control concrete shows a clean split of the sample into two halves, whereas concrete with the rubber aggregate tends to produce a less well-defined failure.

Control concrete at failure

Control concrete after test

Rubberized concrete after test

Figure 7: Failure patterns of Specimen during and after Splitting tensile strength tests

4. Conclusions

1) The introduction of recycled rubber tires into concrete significantly increased the slump and workability. It was noted that the slump has increased as the percentage of rubber was increased.
2) For rubberized concrete, the test results show that the addition of rubber aggregate resulted in a significant reduction in concrete compressive strength compared with the control concrete. This reduction increased with increasing percentage of rubber aggregate.
3) The results of the splitting tensile strength tests show that, there is a decrease in strength with increasing rubber aggregate content like the reduction observed in the compressive strength tests. However, there was a smaller reduction in splitting tensile strength as compared to the reduction in the compressive strength.
4) The overall results of this study show that it is possible to use recycled rubber tires in concrete construction as a partial replacement for coarse aggregates. However, the percentage replacement should be limited to specified amounts as discussed above and the application should be restricted to particular cases where the improved properties due to the rubber aggregates outweigh the corresponding demerits that may occur due to them.

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