MECHANICAL PROPERTIES OF M 25 GRADE CONCRETE WITH PARTIALLY REPLACEMENT OF WASTE RUBBER AS COARSE AGGREGATE

R Rajesh Kumar[1], K Silpha [2], P V Swetha[3], D Sabhapathi[4], G Oormi Prasad[5]

[1]Assistant Professor of Civil Engineering Department, Siddharth Institute of Engineering & Technology, Puttur A.P, India

[2,3,4,5] Under Graduate Student, Civil Engineering Department, Siddharth Institute of Engineering & Technology, Puttur A.P, India

ABSTRACT

At present disposal of waste tyres is becoming a one of the major problem in the world. It is anticipated that almost 1.2 Billions of waste tyre rubber is produced globally per year. It is estimated 11% of postconsumer tyres 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 tyres in civil engineering projects.

In this research, a study was carried out on the use of rubber tyre 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 IS method and a total of 4 mixes were prepared consisting of concrete grade (M 25). The specimens were produced with percentage replacements of the coarse aggregate by 5, 10, and 15% 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, compressive strength and split tensile strength. The data collection is mainly based upon the prepared specimens in the laboratory.

The test results were compared with the respective usual concrete properties and show that there is a decrease in compressive strength of the concrete due to the insertion of rubber aggregates.

KEYWORDS

Aggregate, Compressive strength, Concrete, Recycled tyres, Rubberized concrete, Splitting tensile strength, Workability.

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.

Concrete has been a major construction material for centuries. Moreover, it would even be of high application with the increase in industrialization and the growth of urbanization. Yet concrete construction so far is mainly based on the use of virgin normal resources. Meanwhile the conservation concepts of natural resources are worth identification and it is very essential to have a look at the dissimilar alternatives. Among them lies the recycling mechanism. This is a double advantage. One is that it can prevent the depletion of the scarce natural resources and the other will be the anticipation of different used materials from their severe intimidation to the environment.

It has been well reported that about 1 billion of used automobile tyres are produced each year globally. Specifically, 275 million of used rubber tyres gather in the United States and about 180 million in European Union. In Ethiopia, the amount of waste tyres is estimated to increase with the increase of vehicles. In addition to that, the usual ways of recycling tyres in our country like as a shoe making material and other tools is decreasing nowadays. This is consider as one of the main environmental challenges facing municipalities around the world because waste rubber is not easily biodegradable even after a long period of landfill treatment. The best management plan for scrap tyres that are worn out beyond hope for reuse is recycling. Utilization of scrap tyres should minimize environmental impact and maximize protection of natural resources. The regulatory practices consist of landfill bans and scrap tyres fees. Because rubber waste does not biodegrade eagerly, even after long periods of landfill treatment, there is changed concentration in developing alternatives to disposal. One possible clarification for this problem is to incorporate rubber particles into cement-based materials. Scrap tyres know how to be shredded into raw materials for use in hundreds of crumb rubber products.

The other part of the problem is that aggregate production for construction purpose is continuously leading to the reduction of natural resources. Moreover, some countries are depending on imported aggregate and it is definitely very costly. For example, the Netherlands does not have its own aggregate and has to import. This concern leads to a highly growing interest for the use of substitute materials that can restore the natural aggregates.

2. LITERATURE REVIEW

The replacement of natural aggregates with rubber aggregates tends to reduce the density of the concrete. This reduction is attributable to the lower unit weight of rubber aggregate compared to ordinary aggregate. The unit weight of rubberized concrete mixtures decreases as the percentage of rubber aggregate increases. The unit weight (density) of concrete varies, depending on the amount and density of the aggregate, the amount of air that is entrapped or purposely entrained, and the water and cement contents, which in turn are influenced by the maximum size of the aggregate.

Because of low specific gravity of rubber particles, unit weight of mixtures containing rubber decreases with the increases in the percentage of rubber content. Moreover, increase in rubber content increases the air content, which in turn reduces the unit weight of the mixtures. At 30% rubber content, the dry density diminished to about 95 % of the normal concrete. However, the decrease in dry density of rubber is negligible when rubber content is lower than 10-20 % of the total aggregate volume. The reduction in the unit weight of the rubberized concrete mix increases as the percentage crumb rubber added increases.

Compressive strength tests are widely accepted as the most convenient means of quality control of the concrete produced. Tests conducted by Kumaran S.G. et al on rubberized concrete behavior, using tyre chips and crumb rubber as aggregate substitute of sizes 38, 25 and 19 mm exhibited 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.

Kaloush K.E. et al also noted that the compressive strength decreased as the rubber content increased. Part of the strength reduction was contributed by the entrapped air, which increases as the rubber content increases. Investigative efforts showed that the strength reduction could be substantially reduced by adding a de-airing agent into the mixing truck just prior to the placement of the concrete.

In another study by Ling T.C. and Hasanan M.N, test results have shown that there was a systematic reduction in the compressive strength with the increase in rubber content from 0 % to 30 %. According to Felipe J.A. and Jeannette Santos, a maximum strength reduction of 50% was noted for a mix with 14% substitution in their studies. Nevertheless, in a very different approach, Hanson aggregates achieved higher compressive strength in crumb rubber concrete by reducing entrapped air in the mix.

In most of the previous studies, a reduction in compressive strength was noted with the addition of rubber aggregate in the concrete mix but there is still a possibility of greatly improving the compressive strength by using de-airing agents.

The tensile strength of rubber containing concrete is affected by the size, shape, and surface textures of the aggregate along with the volume being used indicating that the strength of concretes decreases as the volume of rubber aggregate increases. As the rubber content increased, the tensile strength decreased, but the strain at failure also increased. Higher tensile strain at failure is indicative of more energy absorbent mixes. Tests conducted on rubberized concrete behavior, using tyre chips and crumb rubber as aggregate substitute of sizes 38, 25 and 19 mm exhibited reduction in splitting tensile strength by 50% but showed the ability to absorb a large amount of plastic energy under tensile loads.

3. EXPERIMENTAL PROGRAMME

3.1 Cement

Ordinary Portland Cement 53 grade was used corresponding to IS 12269 (1987). The physical properties of the cement as obtained by the manufacturer are presented in the Table 3.1.

Table 3.1 Physical Properties of Cement

Physical properties	Test result
Specific gravity	3.15
Fineness (m^2/Kg)	311.5
Normal consistency	30%
Initial setting time (min)	90
Final setting time (min)	220
Soundness Lechatelier Expansion (mm) Autoclave Expansion (%)	 0.8 0.01
Compressive strength (MPa) 3 days 7 days 28 days	 25 39 57

3.2 Rubber Aggregate

For uniformity of the concrete production and convenience, all the tyres collected were from those which were originally produced from Matador Addis Tyre factory and the type was a medium truck tyre as shown in figure 3.1. The reason for this is that the factory is the only tyre producing company in the country as the other tyres in the market are imported ones and the reason for choosing medium truck tyres is that they can give the required shape and size which is similar to the common natural gravel.

The maximum size of the rubber aggregate was 20 mm as shown in figure 4.4. Specific gravity test was conducted on the rubber aggregate chips and found to be 1.123. The rubber aggregates used in the present investigation were made by manually cutting the tyre in to the required sizes. It was very laborious, time consuming and was not easy to handle at the initial stages. However, all this complications can be easily sorted out if a large scale production is devised and proper cutting tools and machineries are made for this particular usage.

Fig.3.1 20 mm size Rubber aggregate

3.3 Coarse aggregate

Crushed granite stones of size 20 mm used as coarse aggregate. The bulk specific gravity in oven dry condition and water absorption of the coarse aggregate 20 mm per IS 2386 (Part III, 1963) are 2.6 and 0.3% respectively. The bulk density, impact strength and crushing strength values of 20 mm aggregate are 1580 kg/m3, 17.9% and 22.8% respectively.

3.4 Fine aggregate

Natural river sand is used as fine aggregate. The bulk specific gravity in oven dry condition and water absorption of the sand as per IS 2386 (Part III, 1963) are 2.6 and 1% respectively. Fineness modulus of sand is 2.26.

3.5 Water

Generally, water that is suitable for drinking is satisfactory for use in concrete. When it is suspected that water may contain sewage, mine water, or wastes from industrial plants or canneries, it should not be used in concrete unless tests indicate that it is satisfactory. Water from such sources should be avoided.

3.6 Test Methods

This section describes the test methods that are used for testing the fresh and hardened properties of concrete.

3.6.1 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. For instance, a load of aggregate may be wetter or drier than what is expected or there may be variations in the amount of water added to the mix

Fig. 3.2 Slump Test

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 3.2.

3.6.2 Compressive strength test

Compressive strength test was conducted on the cubical specimens for all the mixes at different curing periods as per IS 516 (1991) shown in fig 3.3. Three cubical specimens of size 150 mm x 150 mm were cast and tested for each age and each mix. The compressive strength (f'c) of the specimen was calculated by dividing the maximum load applied to the specimen by the cross-sectional area of the specimen.

Fig.3.3 compressive strength of cubes

3.6.3 Splitting tensile strength Test

Splitting tensile strength (STS) test was conducted on the specimens for all the mixes at different curing periods as per IS 5816 (1999). The load was applied gradually till the failure of the specimen occurs. The maximum load applied was then noted. Length and cross-section of the specimen was measured. The splitting tensile strength (fct) was calculated as follows:

$$fct = 2P/ (\Pi\ l\ d)$$

Where,

fct = Splitting tensile strength of concrete (N/mm^2)

P = Maximum load applied to the specimen (in Newton)

l = Length of the specimen (in mm)

d = cross-sectional diameter of the specimen (in mm)

4. RESULTS AND DISCUSSIONS

4.1 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, compressive strength, splitting tensile strength tests are presented. Analysis and discussions are also made on the findings.

4.2 Fresh Concrete Properties

4.2.1 Workability Test

Table 4.1 shows the results of the slump test for the control concretes and the rubberized concretes.

Table 4.1 Slump Test Results

No.	Specimen	% rubber	Slump (mm)
1	A1	0.00	21
2	A2	5.00	27
3	A3	10.00	30
4	A4	15.00	36

The introduction of recycled rubber tyres to concrete significantly increased the slump and workability. All concrete mixes were designed to have a slump of 25-50 mm. As can be seen from the results above, the control concretes A1 had a less slump which is below the designed value whereas the result for A1 (21 mm) is close to the designed range. It was noted that the slump has increased as the percentage of rubber aggregate was increased in all samples. In the low strength category (A1, A2, A3 and A4) the observed slump is between 21mm and 36 mm. This shows that the workability decreases as the strength of the concrete increases for a given amount of w/c ratio in rubberized concrete. But in the literature review it was noted that different researchers reported a reduction in slump in rubberized concrete mixes.

4.3 Hardened Concrete Properties

4.3.1 Compressive strength Test

The compressive strengths of concrete specimens were determined after 3, 7 and 28 days of standard curing shown in Table 4.2. 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 with increasing percentage of rubber aggregate.

The reason for the compressive strength reductions the lack of adhesion at the boundaries of the rubber aggregate. Soft rubber particles behave as voids in the concrete matrix. It is well known that the presence of voids in concrete greatly reduces its strength. The existence of 5 % of voids can lower strength by as much as 30 % and even 2 % voids can result in a drop of strength of more than 10%.

Table 4.2 Compressive strength test results

			Compressive strength (MPa)			% strength loss		
No	Mix	% rubber	3 days	7 days	28 days	3 days	7 days	28 days
1	A1	0	20.21	27.15	33.14	0.00	0.00	0.00
2	A2	5	17.86	21.63	29.01	11.62	20.33	12.46
3	A3	10	12.76	17.74	20.06	36.86	35.76	39.46
4	A4	15	10.36	14.30	19.70	48.73	47.32	40.55

4.3.2 Splitting tensile strength Test

Table 4.3 shows the splitting tensile strength test results. The relative percentage of strength loss with respect to the control mixes are also tabulated together.

Table 4.3 Splitting Tensile Strength Test Results

No.	Spec.	% Rubber	Splitting Strength (MPa)	% Strength Loss
1	A1	0	3.6	0.00
2	A2	5	2.9	17.09
3	A3	10	2.2	28.95
4	A4	15	1.86	42.16

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.

Losses of up to 17.09% (A2), were observed when 5% of the coarse aggregate was replaced by rubber aggregate. The observed losses of strength when 10 % of coarse aggregate was replaced by rubber aggregate were 28.95% (A3) were noticed. Likewise, for rubberized concrete containing 15% by volume of rubber aggregate, losses of 42.16 % (A4), were observed.

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 tyre particles is poor. Besides, pore structures in rubberized concretes are much more than traditional concrete.

5. CONCLUSION

1. The introduction of recycled rubber tyres into concrete significantly increased the slump and workability. It was noted that the slump has increased as the percentage of rubber was increased in all samples by using 5% replacement of rubber aggregates for the natural coarse aggregates.

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. Losses in compressive strength ranging from 12.46% to 40.55% were observed.

3. The reason for the strength reduction could be attributed both to a reduction of quantity of the solid load carrying material and lack of adhesion at the boundaries of the rubber aggregate, soft rubber particles behave as voids in the concrete matrix. Therefore, rubber aggregate tends to behave like weak inclusions or voids in the concrete resulting in a reduction in compressive strength.
4. Although the compressive strength values have considerably decreased with the addition of waste tyre pieces, their values are still in the reasonable range for a 5 and 10% replacement values because the intended compressive strengths of 25 MPa were achieved in this category.
6. 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.
7. 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 tyre particles is poor. Besides, pore structures in rubberized concretes are much more than conventional concrete.

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