International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 11 Issue 11, November-2022, Impact Factor: 7.957

Investigation on the use of Waste Type Rubber piece in The Prodection of Light Weight Concrete

Y. Venkata Sai[1], T. Greeshma[2], C. Ashok Kumar[3]

[1]Professor & Principal, Department of Civil Engineering, Sree Rama Engineering College, Tirupati, Andhra Pradesh, India
[2]Assistant Professor, Department of Civil Engineering, Sree Rama Engineering College, Tirupati, Andhra Pradesh, India
[3]PG Scholar, Department of Civil Engineering, Sree Rama Engineering College, Tirupati, Andhra Pradesh, 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 post consumer 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 DOE method and a total of 8 mixes were prepared consisting of two concrete grades (M20, M30). 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.

Nevertheless, the percentage of replacement should be limited to a specified amount and the application should be restricted to particular cases where the improved properties due to the rubber aggregates are desirable and when the corresponding demerits of the rubber aggregates don't affect the use of the structure.

Key Words: Aggregate, Compressive strength, Concrete, Recycled tyres, Rubberized concrete, Splitting tensile strength, Unit weight, Workability.

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 strength is greatly affected by the properties of its constituents and the mix design parameters. Because aggregates are the major constituents of the bulk of a concrete mixture, its properties affect the properties of the final product. An aggregate has been normally treated as inert filler in concrete. However, due to the increasing awareness of the role played by aggregates in determining many important properties of concrete, the traditional view of the aggregate as an inert filler is being seriously questioned. Aggregate was initially viewed as a material dispersed throughout the cement paste largely for economic reasons. It is possible, however, to take an opposite view and to look on aggregate as a building material connected into a cohesive whole by means of the cement paste, in a manner similar to masonry construction. In fact aggregate is not truly inert and its physical, thermal, and sometimes chemical properties influence the performance of concrete.

Aggregate is cheaper than cement and it is, consequently, economical to put into the mix much of the former and as little of the soon as possible. Nevertheless, economy is not the only reason for using aggregate: it confers considerable technical advantages on concrete, which has a higher volume stability and better durability than hydrated cement paste alone.

According toward Kumaran S.G. et al, the goal of sustainability is that life on the planet can be sustained for the foreseeable future and there are three components of sustainability: environment, economy, and society. To meet its goal, sustainable development must ensure that these three components remain healthy and balanced. Moreover, it must do so simultaneously and right through the entire planet, both now and in the future. At the moment, the environment is most likely the most important factor and an engineer or architect uses sustainability to mean having no net unhelpful impact on the environment

Among the many threats that affect the environment are the wastes which are generated in the production process or discarded after a specific material ends its life time or the intended use. The wastages are divided as solid waste, liquid waste and gaseous wastes. There are many ways for disposal of liquid and gaseous waste materials. Some solid waste materials such as plastic bottles, papers, steel, etc can be recycled without affecting the environment. However, studies on how to dispose some solid wastes such as waste tyres in the most beneficial ways are not yet fully exhausted.

Tyre is a thermo set material that contains cross-linked molecules of sulphur and supplementary chemicals. The process of mixing rubber with supplementary chemicals to form this thermo set material is generally known as vulcanization. This makes post consumer tyres very stable and nearly not possible to degrade under ambient conditions. Consequently, it has resulted in a growing disposal problem that has led to changes in legislation and significant researches worldwide. On the other hand, disposal of the waste tyres all around the world is becoming higher and higher through time. This keeps on increasing every year with the number of vehicles, as do the future problems relating to the crucial environmental issues.

Kumaran S.G. et al stated that the increasing piles of waste tyres will create the accumulation of used tyres at landfill sites and presents the threat of uncontrolled fires, producing a complex mixture of chemicals harming the environment and contaminating soil and vegetation. It was estimated that in the UK alone, 37 million car and truck tyres are being discarded annually and this number is set to increase. This is considered as one of the main environmental challenges the World is facing because waste rubber is not easily biodegradable even after a long period of landfill healing. One of the solutions suggested was the use of tyre rubber as partial substitution of coarse aggregate in cement-based materials.

If the tyre is burned, the toxic product from the tyre will damage the environment and thus creating air pollution. Since it is not a biodegradable material, this may influence the fertility of the soil and vegetation. Sometimes it may generate uncontrolled fire. Similarly, the other test to the human society is in the form of carbon dioxide secretion and green house secretion. These emissions are considered as highly aggressive wastes to the universe.

Since 1990, it has been the policy of the State of Arizona that the recycling and reuse of waste tyres are given the highest priority. The Arizona Department of Transportation (ADOT) has lengthy support to the use of recycled waste tyre rubber in asphalt rubber hot mi2 A Co-operative work between ADOT and Arizona State University (ASU) was conducted to extend the use of crumb rubber in Portland cement concrete mixes. The intent was to use such mixes on urban improvement related projects. A list of reasonable projects was identified. Examples are roadways or else road intersections, sidewalks, recreational courts and pathways, and wheel chair ramps for improved skid resistance. This collaboration has also extended to include members from industry associations, concrete suppliers and consultants. Several crumb rubber in concrete test sections were built right through the state of Arizona and are being monitored for performance. Figure 1.1 below shows the stockpiles of waste tyres.

Fig. 1.1 Stockpiles of Waste tyres

Concrete strength is greatly affected by the properties of its constituents and the mix design parameters. Because aggregates are the major constituents of the bulk of a concrete mixture, its properties affect the properties of the final product. An aggregate has been normally treated as inert filler in concrete. However, due to the increasing awareness of the role played by aggregates in determining many important properties of Fig. 1.1 Stockpiles of Waste tyres

MATERIAL PROPERTIES AND MIX DESIGN

General

Concrete mixtures with and without rubber aggregates for different compressive strength values were prepared in this research work. The materials used to develop the concrete mixes in this study were fine aggregate, coarse aggregate, rubber aggregate, cement, water and admixture. A total of 8 mixes were prepared consisting of two types of concrete grades (M20,M30) with partial replacements of the coarse aggregate by 10, 25 and 50% of the rubber aggregate. Moreover, a control mix with no replacement of the coarse aggregate was produced to make a comparative analysis. In the subsequent parts, the different materials used in this study are discussed.

Cement

The cement type used in this research was OPC grade 53 cement manufactured in India. The main reason for using Ordinary Portland Cement (Type I) in this study is that, this is by far the most common cement in use and is highly suitable for use in general concrete construction when there is no exposure to sulphates in the soil or groundwater. The choice of OPC from PPC also avoids any uncertainties in the results of the test.

Aggregates

The relevant tests to identify the properties of the aggregates that were intended to be used in this research were carried out. After that, corrective measures were taken in advance before proceeding to the mix proportioning. In general, aggregates should be hard and strong, free of undesirable impurities, and chemically stable. Soft, porous rock can limit strength and wear resistance; it may also break down during mixing and adversely affect workability by increasing the amount of fines. Aggregates should also be free from impurities: silt, clay, dirt or organic matter. If these materials coat the surfaces of the aggregate, they will isolate the aggregate particles from the surrounding concrete, causing a reduction in strength. Silt, clay, and other fine materials will also increase the water requirements of the concrete, and organic matter may interfere with cement hydration. To proportion suitable concrete mixes, certain properties of the aggregate must be known. These are; shape and texture, size gradation, moisture content, specific gravity and bulk unit weight.

Properties of the Fine Aggregate

The fine aggregate sample used in this experiment was purchased from local sand suppliers at Addis Ababa around 'Legehar area'. To investigate its properties and suitability for the intended application, the following tests were carried out.

- sieve analysis for fine aggregate and fineness modulus
- Specific gravity and absorption capacity for fine aggregate
- Moisture content for fine aggregate
- Silt content for fine aggregate
- Unit weight of fine aggregate

Sieve Analysis for Fine Aggregate and Fineness Modulus

Sieve analysis is a procedure for the determination of the particle size distribution of aggregates using a series of square or round meshes starting with the largest. It is used to determine the grading, fineness modulus, an index to the fineness, coarseness and uniformity of aggregates. The quality of concrete to be produced is very much influenced by the properties of its aggregates. Aggregate grain size distribution or gradation is one among these properties and should be given due consideration.

The original test sample was not meeting the graduation requirement and therefore blending of the fine aggregate passing the 1.18 mm sieve was done with the original sample in a proportion of 60%:40%. Table 1 below shows the percentage passing each sieve size and Figure 1 shows the corresponding graph.

Table 1: sieve Analysis Test is Test for Fine Aggregate

Sieve Size (mm)	Wt. of Sieve (gm)	Wt. of Sieve and Retained (gm)	Wt. Retained (gm)	% age Retained	Cumul. Retained	% passing	Lower Limit	Upper Limit
9.5	586	586	0	0.00	0.00	100.00	100.00	100
4.75	567	576	9	1.80	1.80	98.20	95.00	100.00
2.36	521	535	14	2.80	4.60	95.40	80.00	100.00
1.18	529	584	55	11.00	15.60	84.40	50.00	85.00
0.06	506	719	213	42.60	58.20	41.80	25.00	60.00
0.03	478	627	149	29.80	88.00	12.00	10.00	30.00
0.015	462	512	50	10.00	98.00	2.00	2.00	10.00
Pan	423	431	8	1.60	99.60	0.40		

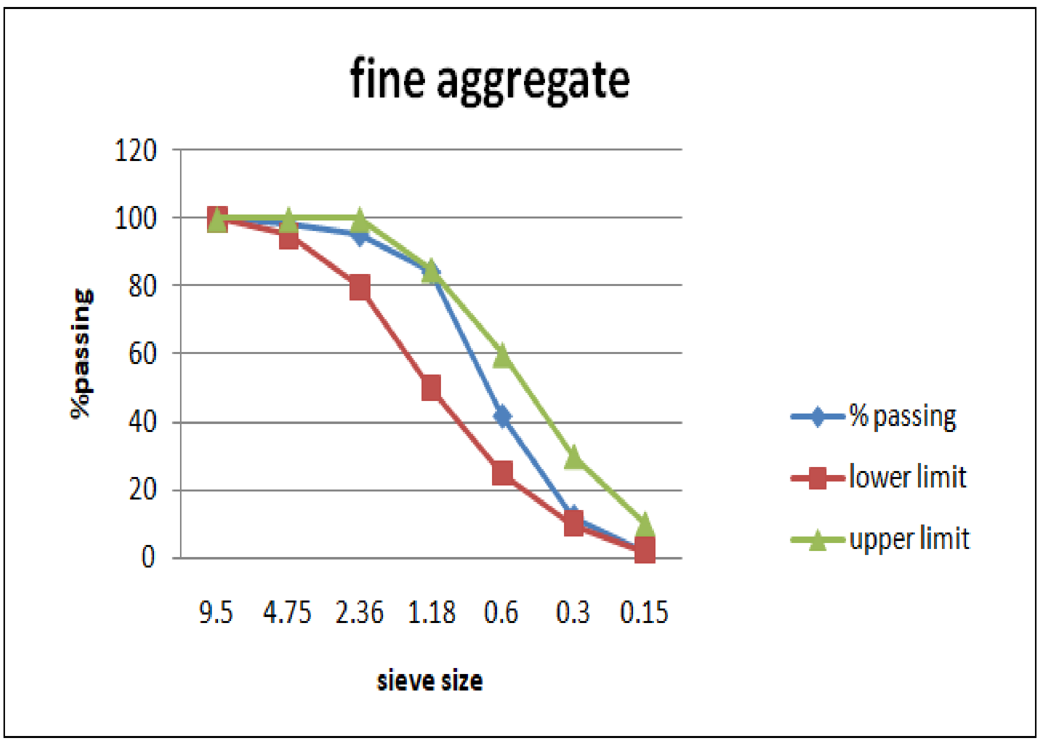


Fig. 1 Graph for Sieve analysis of Fine aggregate

Fineness modulus (F.M) = ∑ cumulative coarser (%) ....[38] 100

F.M. = 266.2/100 =2.66

Specific gravity and absorption capacity of fine aggregate

The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. The specific gravity of a substance is the ratio between the weight of the substance and that of the same volume of water. This definition assumes that the substance is solid throughout. Aggregates, however, have pores that are both permeable and impermeable. The structure of the aggregate (size, number, and continuity pattern) affects water absorption, permeability, and specific gravity.

The following results were found for the fine aggregate sample.

Bulk Specific gravity=2.41
Bulk Specific gravity (SSD basis)=2.51
Apparent specific gravity=2.69
Absorption capacity =4.38 %

Moisture content of fine aggregate

A design water cement ratio is usually specified based on the assumption that aggregates are inert (neither absorb nor give water to the mixture). But in most cases aggregates from different sources do not comply with this i.e. wet aggregates give water to the mix and drier aggregates take water from the mix affecting in both cases, the design water cement ratio and therefore workability and strength of the mix. In order to correct for these discrepancies, the moisture content of aggregates has to be determined.

The moisture content of the fine aggregate sample used in this study was tested at different times prior to mixing and it was found to be in the range of 2.04 %.

Silt content of fine aggregate

Sand is a product of natural or artificial disintegration of rocks and minerals. Sand is obtained from glacial, river, lake, marine, residual and wind-blown deposits. These deposits however do not provide pure sand. They often contain other materials such as dust, loam and clay that are finer than sand. The presence of such materials in sand used to make concrete or mortar decreases the bond between the materials to be bound together and hence the strength of the mixture. The finer particles do not only decrease the strength but also the quality of the mixture produced resulting in fast deterioration. Therefore, it is necessary that one make a test on the silt content and check against permissible limits.

From the silt content test performed on the sand, it was found that the original silt content was 11%. According to the Ethiopian standard, it is recommended to wash the sand or reject if the silt content exceeds a value of 6 %. Therefore, it was necessary to wash the sand to improve the property. Finally, the silt content reached 2% that is within the acceptable range.

Unit weight of fine aggregate

Unit weight can be defined as the weight of a given volume of graded aggregate. It is thus a density measurement and is also known as bulk density. But this alternative term is similar to bulk specific gravity, which is quite a different quantity, and perhaps is not a good choice. The unit weight effectively measures the volume that the graded aggregate will occupy in concrete and includes both the solid aggregate particles and the voids between them. The unit weight is simply measured by filling a container of known volume and weighing it. Clearly, however, the degree of compaction will change the amount of void space, and hence the value of the unit weight. Since the weight of the aggregate is dependent on the moisture content of the aggregate, a constant moisture content is required. Oven dried aggregate sample is used in this test. The unit weight of the fine aggregate sample used was found to be 1520 kg/m^3

Properties of coarse the aggregate

Coarse aggregate for concrete shall consist of natural gravel or crushed rock or a mixture of natural gravel and crushed rock. Coarse aggregate used in this research was purchased from Tikur Abay Construction Company.

In a similar manner like the fine aggregate, laboratory tests were carried out to identify the physical properties of the coarse aggregate and the results are shown in Table 2 below. Table 3 shows the sieve analysis test results and figure 2 shows the corresponding graph.

Table 2 Physical Properties of the Coarse Aggregate.

Description	Test Result
Moisture content	1.37 %
Unit weight of coarse aggregate	1533.25 kg/m^3
Bulk Specific gravity	2.79
Bulk specific gravity(SSD basis)	2.84
Apparent specific gravity	2.93
Absorption capacity	1.72 %
Crushing value of aggregate	17.83 %
Los Angeles Abrasion Test	14.9 %

Table 3: for Sieve Analysis for the Coarse Aggregate.

Sieve Size (mm)	Wt. of Sieve (gm)	Wt. of Sieve and Retained (gm)	Wt. of Retained (gm)	% Retain.	Cum. Retain.	% Pass.	Lower Limit	Upper Limit
37.5	1188	1188	0	0.00	0.00	100.00	100.00	
19	1419	1419	0	0.00	0.00	100.00	90.00	100.00
12.5	1166	3645	2479	48.36	48.36	51.64	40.00	80.00
9.5	1171	2682	1511	29.48	77.84	22.16	20.00	55.00
4.75	1194	2222	1028	20.05	97.89	0.35	0.00	10.00
Pan	1060	1150	90	1.76	99.65	0.35	0.00	5.00

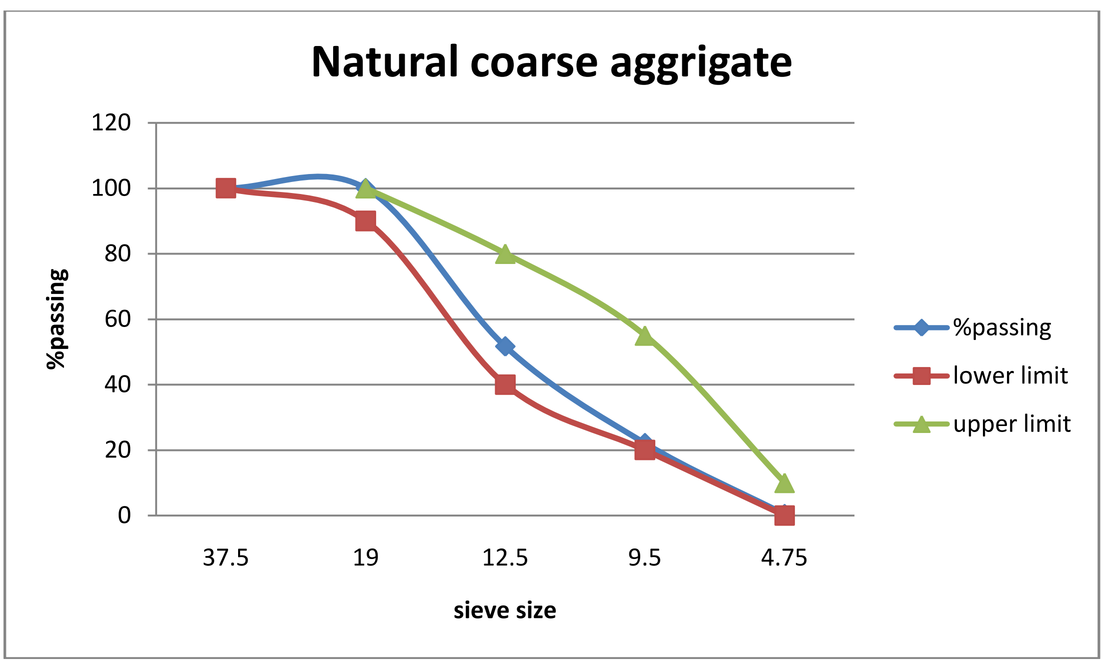


Fig 2. Graph for Sieve analysis of Coarse aggregate

TEST RESULTS AND DISCUSSIONS

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 tests are presented. Analysis and discussions are also made on the findings.

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. 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. These all necessitate a check on the workability and strength of concrete after producing. Slump test is the simplest test for workability and are most widely used on construction sites. 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 below.

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

Table for Slump Test Results

No.	Specimen	Grade	% rubber	w/c ratio	Slump (mm)
1	AM1	M20	0.00	0.65	21
2	AM2	M20	10.00	0.65	27
3	AM3	M20	25.00	0.65	32
4	AM4	M20	50.00	0.65	38
5	BM1	M30	0.00	0.53	9
6	BM2	M30	10.00	0.53	17
7	BM3	M30	25.00	0.53	22
8	BM4	M30	50.00	0.53	30

The introduction of recycled rubber tyres to concrete significantly increased the slump and workability. All concrete mixes were designed to have a slump of 10-30 mm. As can be seen from the results above, the control concretes BM1 had a slump of less than 10 mm which is below the designed value whereas the result for AM1 (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 (AM1, AM2, AM3 and AM4) the observed slump is between 21 mm and 38 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. The possible reason for the differences between the previous studies and this research can be the use of admixtures.Super plasticizing admixtures greatly increase the workability of the concrete and the improvement to the workability of the rubberized concrete can be attributed to the admixture. In most of the earlier studies, the use of admixtures to improve the workability of the concrete was not explained. Nevertheless, in a research by Kumaran S.G. et al, an admixture was used in rubberized concrete mix design but its effect on the workability of the rubberized concrete mix was not clearly explained.

A different observation which was noticed while casting the rubberized concrete was that the rubber aggregates mixes did not pose any difficulties in terms of finishing, casting, or placement and can be finished to the same standard as plain concrete.have a high tendency to come out to the top surface when vibrated by a table vibrator. This is due to the low specific gravity of the rubber aggregate. In general, rubberized concrete

Hardened Concrete Properties

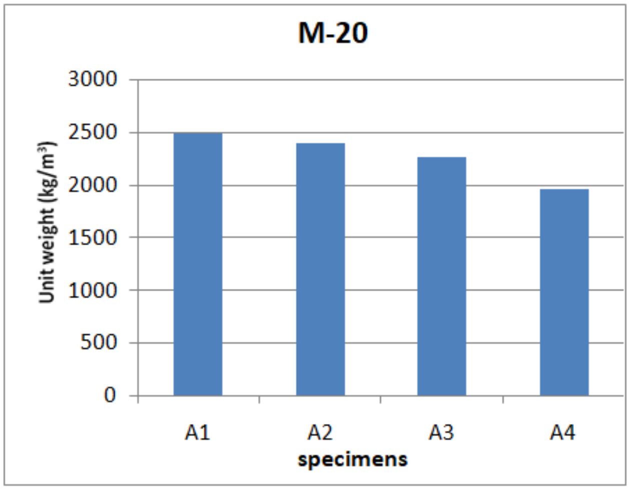
The different tests that have been carried out to establish the hardened properties of the concrete samples produced were; determination of unit weight, compressive strength, splitting tensile strength, impact resistance and flexural strength tests.

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. From the results, it was found out that a reduction of unit weight up to 21% was observed when 50 % by volume of the coarse aggregate was replaced by rubber aggregate in sample AM4. Whereas 3.53 and 9.13% reductions were observed for 10 and 25 % rubber aggregate replacement in samples AM2 and AM3 respectively. In the second category (B group) a reduction in unit weight of 3.76%,

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

No.	Specimen	Grade	% rubber	Unit wt. (kg/m^3)	% Reduction
1	A1	M20	0.00	2479.85	0.00
2	A2	M20	10.00	2392.29	3.53
3	A3	M20	25.00	2253.34	9.13
4	A4	M20	50.00	1959.57	20.98
5	B1	M30	0.00	2485.93	0.00
6	B2	M30	10.00	2392.27	3.76
7	B3	M30	25.00	2335.21	6.06
8	B4	M30	50.00	2078.53	16.38



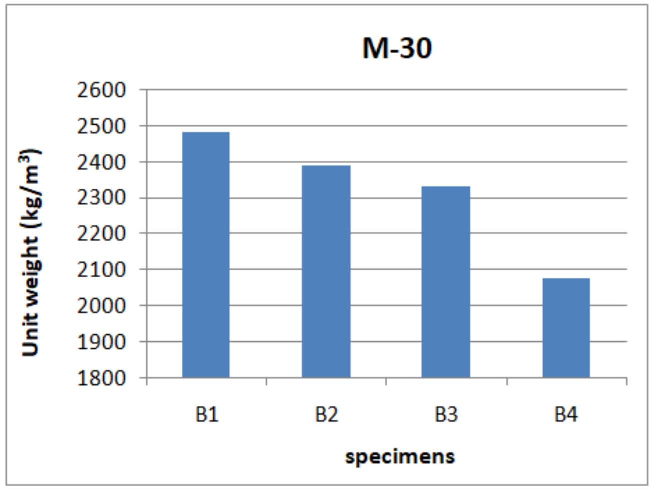


Fig: Graphical comparison values of unit weight

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. Furthermore, with lighter concrete, the formwork need withstand a lower pressure than would be in case with normal weight concrete, and also the total mass of materials to be handled is reduced with a consequent increase in productivity. Concrete that has a lower density also gives better thermal insulation than ordinary concrete. Therefore, the reduced density of concrete containing rubbers aggregates can provide with all the benefits mentioned which are associated with a lower density.

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 with increasing percentage of rubber aggregate. Losses in compressive strength of 5.70% (AM2), 17.91% (BM2) were observed when 10% of the coarse aggregate was replaced by an equivalent volume of rubber aggregate. The observed losses of strength when 25 % of the coarse aggregate was replaced by rubber aggregate were 17.86% (AM3), 29.34 % (BM3). For rubberized concrete containing 50% by volume of rubber aggregate replacement, losses of 47.32% (AM4), 43.93% (BM4) were noticed. Table below shows the results of the 7th, 28th and 56th day compressive strength tests

Table: 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	M20	0	20.21	27.15	33.14	0.00	0.00	0.00
2	A2	M20	10	19.3	25.60	28.75	4.50	5.70	13.24
3	A3	M20	25	17.50	22.30	25.63	13.40	17.86	22.66
4	A4	M20	50	10.43	14.30	19.70	48.39	47.32	40.55
5	B1	M30	0	33.70	44.28	52.72	0.00	0.00	0.00
6	B2	M30	10	31.50	36.28	48.36	6.52	17.91	8.27
7	B3	M30	25	20.78	31.23	37.29	38.33	29.34	29.26
8	B4	M30	50	15.60	24.78	22.54	53.70	43.93	57.24

International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 11 Issue 11, November-2022, Impact Factor: 7.957

Figure below illustrates the trend of strength development in the different concrete specimens prepared and Figure shows the comparison of the strength achieved in contrast with the control concrete

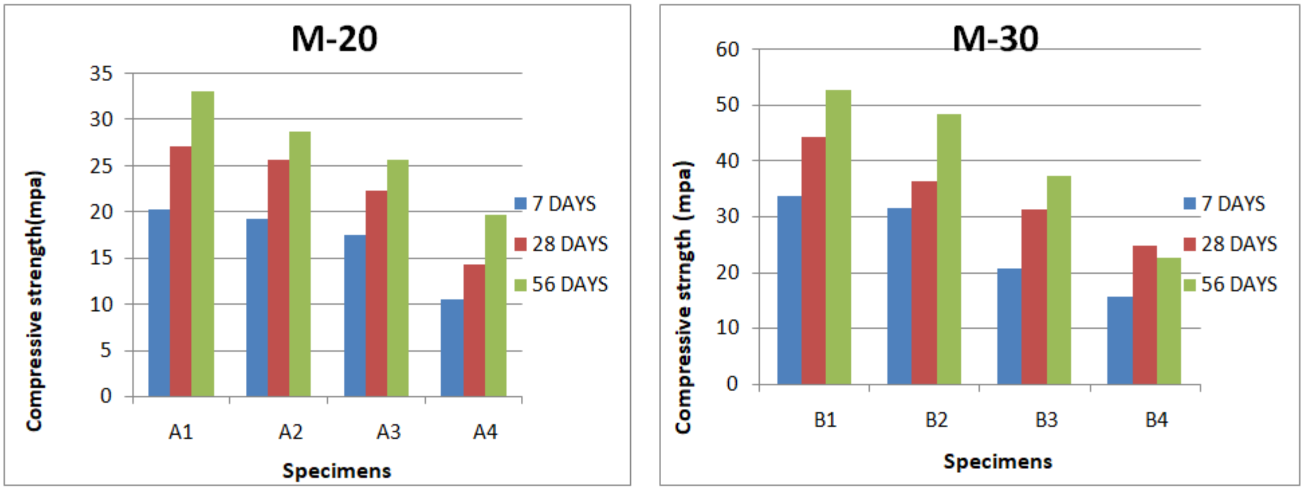


FIG: Compressive strength development

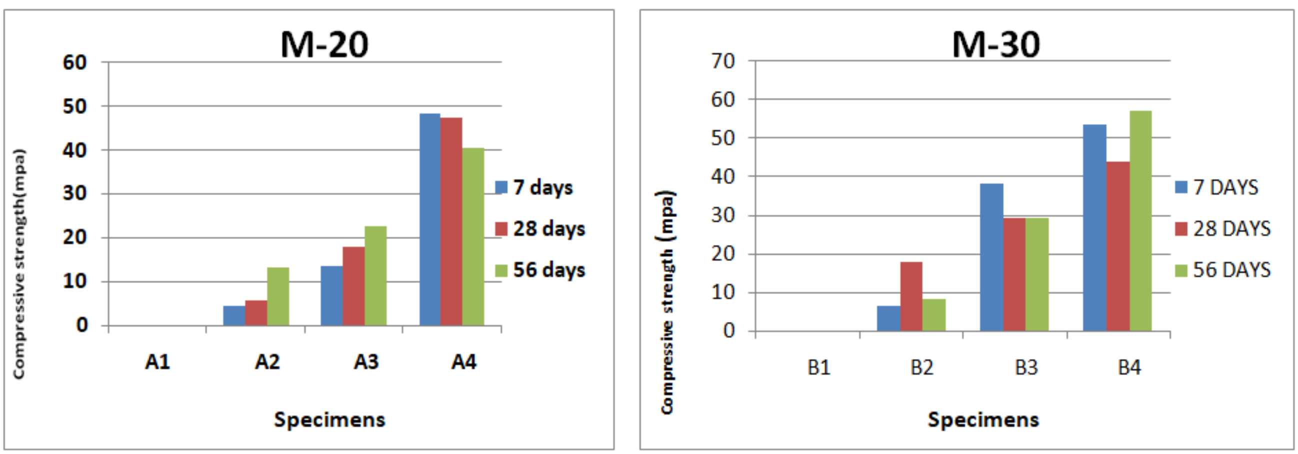


Fig.: percentage loss of compressive strength

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. Considering the very different mechanical properties of mineral aggregates and rubber aggregates, mineral aggregates usually have high crushing strength and they are relatively incompressible, whereas rubber aggregates are ductile, compressible and resilient. Rubber has a very low modulus of elasticity of about 7MPa and a Poisson's ratio of 0.5. Therefore, rubber aggregates tend to behave like weak inclusions or voids in the concrete, resulting in a reduction in compressive strength. 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%.

Another observation while carrying out the compressive strength test was the nature of crack formation. In rubberized concrete, crack formation is different from plain concrete because bond strength between rubber and cement paste is poor than that of between aggregate and cement paste. Therefore, initial cracks were formed around rubber aggregates and cement paste in rubberized concrete.

Although the compressive strength values have considerably decreased with the addition of waste tyre pieces as seen in Table, their values are still in a reasonable range for a 10 and 25 % replacement values because the intended compressive strength of 15, 25, 30, and 40 mpa respectively were achieved in these categories.

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]

Where: P - the applied compressive load

L- the cylinder length, and D- the cylinder diameter

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 below shows the testing method for splitting tensile strength test and Table shows the splitting tensile strength test results. The relative percentage of strength loss with respect to the control mixes are also tabulated together.

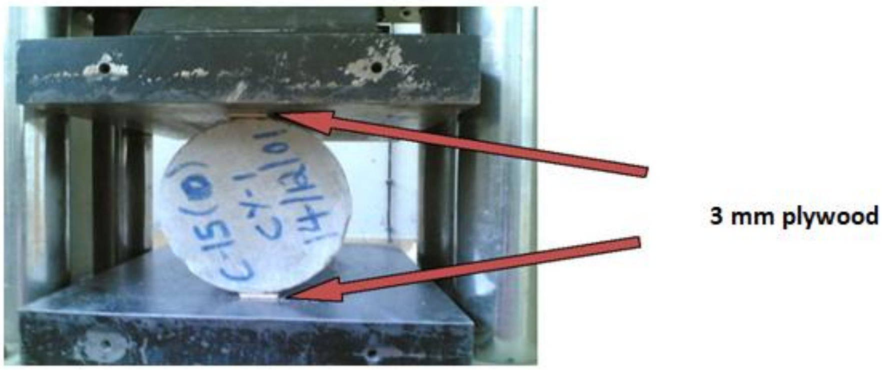


Fig. Splitting tensile strength Test

Table: Splitting Tensile Strength Test Results

No.	Spec.	Grade	% Rubber	Splitting Load(KN)	Splitting Strength (MPA)	% Strength Loss
1	A1	M20	0	215.25	3.03	0.00
2	A2	M20	10	178.46	2.52	17.09
3	A3	M20	25	152.93	2.16	28.95
4	A4	M20	50	124.5	1.76	42.16
5	B1	M30	0	270.45	3.82	0.00
6	B2	M30	10	235.23	3.33	13.00
7	B3	M30	25	157.64	2.23	41.71
8	B4	M30	50	130.76	1.84	51.65

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% (AM2), 13.00% (BM2) were observed when 10% of the coarse aggregate was replaced by rubber aggregate. The observed losses of strength when 25 % of coarse aggregate was replaced by rubber aggregate were 28.95% (AM3), 47.71 % (BM3) were noticed. Likewise, for rubberized concrete containing 50% by volume of rubber aggregate, losses of 42.16 % (AM4), 51.65% (BM4) were observed. The comparison of the results with the control concretes are shown graphically in Figure below.

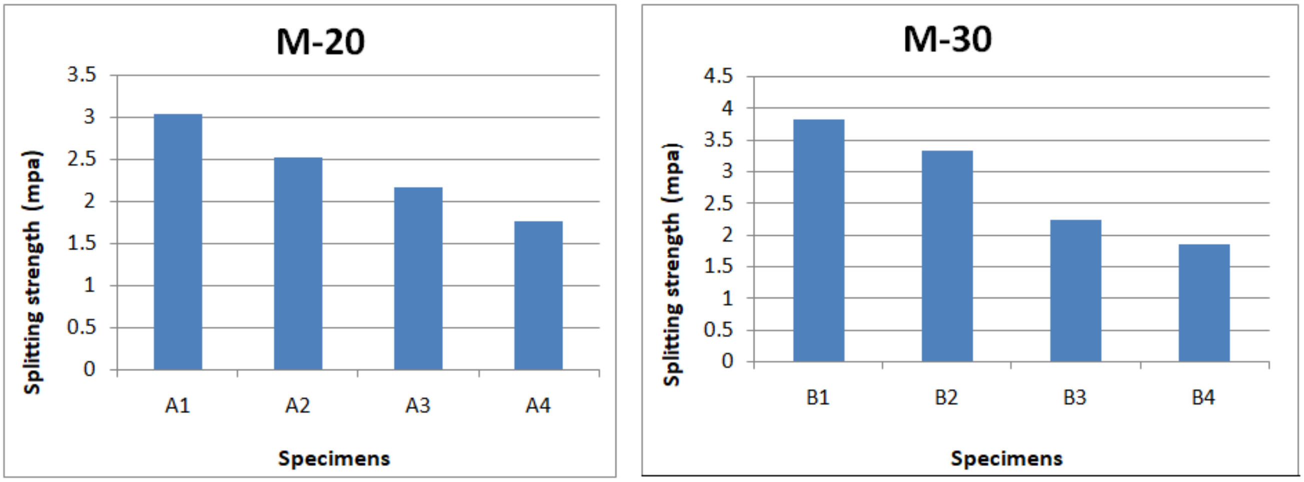


Fig. Comparison of splitting tensile strength test results

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 tyre 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 . 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.

(a) Control concrete at failure

(b) Control concrete after test

(c) Rubberized concrete at failure

(d) Rubberized concrete after test

Fig. Failure patterns of Specimen during and after Splitting tensile strength tests

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 50% replacement of rubber aggregates for the natural coarse aggregates.

2. A reduction in unit weight of up to 21% was observed when 50% by volume of the coarse aggregate was replaced by rubber aggregate in sample AM4 which is with a targeted compressive strength of 20 MPa. A much similar trend of reduction in unit weight of the rubberized concrete was observed in all the other samples containing rubber aggregates. The low specific gravity of the rubber chips as compared to the mineral coarse aggregates produced a decrease in the unit weight of the rubberized concrete. Crumb rubber is nearly two and half times lighter than the conventional mineral coarse aggregate and hence it can be expected that the mass density of the mix would be relatively lower.

3. Rubberized concrete can be used in non load bearing members such as lightweight concrete walls, building facades, or other light architectural units, thus the rubberized concrete mixes could give a viable alternative to the normal weight concrete.

4. 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 5.70% to 47.32% were observed. 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. 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 10 % and 25 % replacement values because the intended compressive strengths of 20 and 30 MPa were achieved in this categories.

ACKNOWLEDGMENT

I am thankful to our chairman Sri. Mannem Rami Reddy & the Principal Prof.K.JayachandraM.Tech &Ph.D, for permitting us to use facilities available in the college toaccomplish the project.I express my deep sense of gratitude to Dr.G.Veera Swamy Ph.D, Head of Civil Engineering Department, for his support and suggestions during this Project.I would like to express my deep sense of gratitude and heartfelt thanks to, Mr. T.Venkata Sai M.Tech, Department of Civil Engineering, for his constant encouragement innovative ideas and guidance throughout this project.I am extremely thankful to all my friends and well-wishers for their never-ending supportand encouragement.

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