Partial Replacement of Natural Aggregates with Reclaimed Rubber in Cement Concrete

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Abstract

Concrete is one of the utmost extensively used construction materials in the world. Cement and aggregate, which are the most essentialingredients used in concrete making, are the vital materials needed for the construction business. Parallel to the need for the utilization of the natural resources emerges a growing concern for protecting the environment and a need to realm natural resources (such as aggregate) by using unconventional materials which are recycled or discarded materials. In this investigation, a study was carried out on the use of recycled rubber tires as a limited substitution for coarse aggregates in concrete manufacture using locally obtainable waste tires. In the first part of this proposal, the contextual of the study and the extent of the problem were discussed. A review of relevant writings was done to study previous works in the subject problem. The research was carried out by performing tests on the raw materials to determine their properties and appropriateness for the experiment. The specimens were produced with percentage replacements of the coarse aggregate by 10, 20 and 30 % of rubber aggregate. Moreover, a control mix with no replacement of the coarse aggregate was formed to make a comparative investigation. The prepared samples consist of concrete cubes.

Keywords— *Recycled rubber tires, Natural coarse aggregate, Waste tires, Rubber aggregate.*

I. INTRODUCTION

Aggregate is low-priced than cement and it is, therefore, cost-effective to put into the mix much of the former and as little of the latter 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 to 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. Furthermore, it must do so concurrently and all the way throughthe entire planet, both now and in the future. At the moment, the environment is undoubtedly the most imperative element and an engineer or architect uses sustainability to ensure that there’s no net negative impact on the environment**.** Tire is a thermoset material that contains cross-linked molecules of sulphur and other chemicals. The process of mixing rubber with other chemicals to form this thermoset material is commonly known as vulcanization. This makes postconsumer tires very stable and nearly impossible to degrade under ambient conditions. Consequently, it has resulted in a rising dumping problem that has led to changes in legislation and significant researches worldwide. On the other hand, disposal of the waste tires all around the world is becoming higher and higher through time. This keeps on snowballing every year with the number of automobiles, as do the forthcoming problems relating to the crucial environmental issues.

II. LITERATURE REVIEW

M. Turki, I. Ben Naceur, M. Makni, J. Rouis, K. Saihave presented a research on ‘Mechanical and damage behavior of mortar-rubber aggregates mixtures: Experiments and Simulations’ published in Material and Structures Magazine (2009).

The reuse of rubber waste of torn tires in aggregates form, to serve as a building material, is cherished to realmthe environment. This study aims to examine the mechanical behavior of a mortar-rubber aggregates material. A multi-phase model called 2M2C (2 mechanism 2 criteria) which take the volume fraction substitution of rubber into interpretation is examined with the assistance of stress-strain curves. The proposed model is based on the localization of the stress on the phase’s level (rubber and mortar, respectively) and the homogenization of the local plastic strains. The modal has also incorporated an isotropic damage variable to describe the loss of compressive strength. The investigational tests are well replicated by the model. Also, the simulations provide local information such as damage evolution and local plastic strains. The purpose of this experiment is to test the capabilities of a multi-mechanism model to represent the mechanical behavior of the mortar-rubber aggregate composites with different rubber percentage (0%, 10%, 30%, 50%).The comparison between investigational data and simulated results shows good accordance. The local contribution of the plastic strain at each level are then correctly estimated.

III. OBJECTIVE

- By conducting different laboratory tests on prepared specimens, it is intended to analyse the results. Furthermore, from the properties of the concrete the benefits and shortcomings of using it will be reckoned.
- Solicitation of used tires in concrete construction is a new expertise and a well -established mix design for material proportioning is not available. Through this study, it is intended to arrive at a suitable mix proportion and percent replacement by means of locally accessible materials by fractional replacement of the usual coarse aggregates with reprocessed coarse rubber aggregates. Hence the probability of using discarded tires as an unconventional construction material will be investigated.

IV. ISCOPE

- This study concentrated on the performance of a single progression of crumb rubber. The discarded tires are collected from native sources and physically cut into pieces to achieve a uniform size of 20 mm, which is the maximum aggregate size in the mix design.
- The influence of different degrees of the rubber aggregate on concrete properties was not evaluated in this study but it should be considered in future researches.
- The study was done on M_{20} Grade of concrete. The influence of using recycled tires in high strength concrete was not covered in the present study. The percentage replacements were limited to three categories i.e. 10, 20 and 30% replacement of the natural coarse aggregate. The different effects, which can be observed in alteredproportions of replacements, were not included in the present study.

V. MATERIAL TESTING

Cement

Pozzolana Portland cement was used in casting the specimens. Specific Gravity of the cement was 2.56. Tested the material properties as per IS 383-1980 procedures.

Fine Aggregates

The fine aggregate (Sand) used was clean and dry river sand. The sand was strained to get rid of all thestones. The result of the sieve analysis particulars and the details of Specific Gravity test of the fine aggregate were tabulated. The material properties were tested as per IS 383-1980.

Coarse Aggregate

Hard Granite broken stones of 20mm size were used as coarse aggregate. The results of the sieve analysis for the coarse aggregate have been tabulated and the material properties were tested as per IS 383-1980.

Reclaimed Rubber

Reclaimed Rubber was purchased from ELGI RUBBER COMPANY Pvt. Ltd, Chengalpattu.

Water

Potable tap water available in laboratory with pH value of 7±1 and conforming to the requisite of IS 456-2000 was used for mixing concrete and curing the specimen as well.

Admixtures

According to IS 10262-2009 the chemical admixtures are used for water reducing purpose. Plaster of Paris is used as an admixture for coating the rubber.

A. Properties of Cement

1) Specific Gravity

A cylindrical bottle of inside diameter 150mm and height 170mm was used for specific gravity test. The empty weight of the bottle was taken as M_1. Some amount of cement was placed in the bottle and weighed as M_2. Then sufficient water is added to make it saturated. The sample was thoroughly stirred for removing the entrapped air. The bottle was filled completely with water and weighed as M_3. It was then emptied, cleaned well, filled with water alone and weighed as M_4.

Specific Gravity of Cement (G) $=\frac{M2-M1}{[(M2-M1)-(M3-M4)]}$

2) Consistency

500 grams of cement was taken and made into paste with a weighed quantity of water (24% weight of cement) for the first trial. The paste was formulatedin a standard routine and packed into the Vicatmould plunger, 10mm diameter, 50mm long and was appended and brought down to touch the surface of the paste by its own weight. The depth of penetration of the plunger wasrecorded. Likewise trials were conducted with greater water cement ratios till such time the needle penetrates for a depth of 33-35mm from the top. That exactproportion of water which allows the plunger to penetrate only to a depth of 33-35mm from the top is known as percentage of water necessary to produce a cement paste of standard consistency.

3) Initial Setting Time

The needle of the Vicat apparatus was lowed gently and brought in contact with the exterior of the test block and swiftly released. It was permitted to infiltrate into the test block. In the beginning, the needle wholly pierced through the test block. But after sometime when the paste starts loosing its plasticity, the needle penetrates only to a depth of 33-35mm from the top. The period elapsing between the time when water is added to the cement and the time at which the needle pierces the test block to a depth equal to 33-35mm from the top was procured as the initial setting time.

B. Properties of Coarse Aggregate

1) Specific Gravity

A cylindrical mould of inside diameter 150mm and inside height 170mm was used for specific gravity test. The empty weight of the mould was taken M1. Some amount of coarse aggregate was placed in the mould and weighed as M2. Sufficient water was added to make it saturated. The sample was stirred thoroughly for removing the entrapped air. The mould was filled with water and weighed as M3. It was emptied, cleaned well, filled with water and weighed as M4.

Specific Gravity of Coarse Aggregate (G) $=\frac{M2-M1}{[(M2-M1)-(M3-M4)]}$

Where,

M1 = Mass of empty pycnometer in gm.

M2 = Mass of the pycnometer& coarse aggregate in gm.

M3 = Mass of the pycnometer& coarse aggregate& water in gm.

M4 = Mass of the pycnometer filled with water in gm.

2) Bulk Density

Bulk density is the heaviness of a material in a given volume. It is expressed in kg/m3. A cylindrical measure of measure of nominal diameter 150mm and height 300mm was used. The cylindrical measure was jam-packed about 1/3 each time with meticulously mixed aggregate and tamped with 25 strokes. The measure was cautiously struck off level using tamping rod as a straight edge. The grossweight of aggregate in the measure wasfinalized. Bulk density was calculated as follows:

Bulk density = (Net weight of sand in Kg)/(Volume)

3) Surface Moisture

100g of coarse aggregate is taken and their weight is determined, say w1. The sample is then kept in the oven for 24 hours. It is then taken out and the dry weight is determined, sayw2. The difference between w1 and w2 gives the surface moisture of the sample.

4) Water Absorption

100g of coarse aggregate is taken and their weight is determined, say w1. The sample is then immersed in water for 24hours. It is then abstractedout, drained and its weight is determined, say w2. The difference between w1 and w2 gives the water absorption of the sample.

Fig. 1 Water Absorption Test for Coarse Aggregate

5) Fineness Modulus

The sample was gottento an air – dry situation by dehydrating at room temperature. The requisiteportion of the sample was taken (3kg). The sieves were placed in the order of size, with larger sieve on the top, in a mechanical sieve shaker. Sieving was done for 10 minutes. The material retained on each sieve after shaking, epitomizes the segment of the aggregate coarser than the sieve deliberated and tinierthan the sieve above. The weight of aggregate recollected in each sieve was evaluatedand transformed to a total sample. Fineness modulus was establishedas the ratio of sum totalof cumulative percentage weight retained (F) to 100.

Percentage of material on ant sieve Pn = (Mn/M)×100

C. Properties of Fine Aggregate

1) Specific Gravity

A cylindrical mould of inside diameter 150mm and inside height 170mm was used for specific gravity test. The empty weight of the mould was taken as M1. Some amount of fine aggregate was placed in the mould and weighed as M2. Sufficient water was added to make it saturated. The sample was stirred thoroughly for removing the entrapped air. The mould was filled with water and weighed as M3. It was emptied, cleaned well, filled with water and weighted as M4.

Specific Gravity of Fine Aggregate (G) $=\frac{M2-M1}{[(M2-M1)-(M3-M4)]}$

2) Fineness Modulus

The sample was brought to air air-dry condition by drying at room temperature. The required quantity of the sample was taken (3kg). The sieves were placed in the order of size, size with larger sieve on the top, in a mechanical sieve shaker. Sieving was done for 10 minutes. The quantifiable retained on each sieve after shaking, characterizes the segment of the aggregate coarser than the sieve take into accountand finer than the sieve directly above. The weight of aggregate heldin each sieve was quantifiedand transformed to a total sample. Fineness modulus was establishedas the ratio of grand totalof cumulative percentage weight retained (f) to 100.

Percentage of material retained on any sieve Pn = (Mn/M)×100

Fig. 2 Fineness Modulus Test for Fine Aggregate

D. Properties of Reclaimed Rubber

1) Tensile Strength

The tensile strength of rubber containing concrete is affected by the size, shape, and surface textures of the aggregate alongside with the volume being consumed designating that the strength of concrete decreases as the volume of rubber aggregate increases. As the rubber content increased, the tensile strength decreased, but the strain at failure also amplified. Elevatedtensile strain at failure is symbolic of more energy absorbent mixes. Tests conducted on reclaimed rubber behaviour, using tire chips and crumb rubber as aggregate substitute of sizes 38,25 and 19mm exhibited reduction in splitting tensile strength by 50% but showed the ability to absorb a large amount of plastic energy under tensile loads.

2) Unit Weight (Density)

The replacement of natural aggregates with rubber aggregates tends to reduce the density of the concrete. This lessening is attributable to the smallerunit weight of rubber aggregate equatedto regular aggregate. The unit weight of rubberized concrete blends decreases as the fraction of rubber aggregate upsurges. The unit weight (density) of concrete fluctuates, depending on the amount and density of aggregate, the amount of air that is entrapped or purposely entertained, 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 encompassing rubber diminutions with the increase in the percentage of rubber content.

VI. TEST RESULTS AND DISCUSSION

Table I : Details of Test Specimens and The Type of Mechanical Tests

PROPORTIONS	COMPRESSIVE STRENGTH IN N/mm^2	
	AFTER 7 DAYS	AFTER 28 DAYS
A	22.96	27.78
B	8.14	11.63
C	15.25	21.79
D	4.45	6.36
E	15.11	21.59
F	19.55	27.93
G	8.74	12.49

Table II

Type of test	Test specimen	Size (in mm)	No of specimens	Testing machine
Compressive Strength	Cube	150	54	CTM

Table III : Percentage Variation In Compressive Strength Of Varying Proportions Of Coated Rubber Aggregate And Rubber Aggregate Concrete From Conventional Concrete

Proportions	% Varying In Compressive Strength			
	After 7 days		After 28 days	
	Increase	Decrease	Increase	Decrease
B (10% CRA)	-	64.54	-	58.13
C (20% CRA)	-	33.58	-	21.5
D (30% CRA)	-	80.60	-	77.10
E (10% RA)	-	34.18	-	22.28
F (20% RA)	-	14.85	0.5	-
G (30% RA)	-	61.93	-	55.03

Table IV : Slump Test Results

Water Ratio	Flow Index						
	A	B	C	D	E	F	G
0.4	45	88.3	75.5	84.6	30.7	65.7	47.5
0.5	80.6	49.7	34.3	37.7	88.6	59.7	57.3
0.55	110.6	99.2	55.2	45.8	122.4	61.5	48
0.6	116.9	104.3	77	75.3	121.3	72.4	77.7

Table V : Tests Results of Flow Percentage

S. No	Proportions	Slump Value	Workability
1	A	100	HIGH
2	B	105	HIGH
3	C	95	MODERATE
4	D	90	MODERATE
5	E	185	VERY HIGH
6	F	180	VERY HIGH
7	G	160	HIGH

VII. CONCLUSION

- The test results show that the compressive strength increases with increase in curing period.
- It also shows that as the proportions of coated Rubber Aggregate and Rubber Aggregate increase in natural coarse aggregate simultaneously decreasing the strength of concrete. But, replacing 20% coarse aggregate with rubber aggregategives equivalent strength of conventional concrete strength.
- The test shows that rubber aggregate produced good strength than coated rubber aggregate.
- The test results shows that the slump value of CRA and RA concrete are very high compared to conventional concrete.
- Test results show that coated rubber aggregate and rubber aggregate give high workability of concrete.
- According to the workability of concrete the CRA and RA concrete are suitable for reinforced concrete without giving vibration.

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