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Geopolymer Concrete by Using Zeolite and Waste Tyre Rubber

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Abstract:
In this present study, geopolymer rubber concrete is prepared based on natural zeolite in which treated rubber powder is replaced in fine aggregate with various percentages such as 5,10,15 and 20 by weight. The control geopolymer are prepared with river sand for comparison purpose. Two binder contents fly ash and ggbs contents are used with 2:3 ratio, sodium silicate to sodium hydroxide ratio is 1.5 and fly ash is replaced with 5% of zeolite. After casting the cubes, beams and 28days ambient curing, mechanical properties, durability properties and NDT test was done. A compressive strength and impact resistance was increased by treating the rubber with 1M NaOH solution. Control geopolymer concrete shows better resistances to durability properties than rubber concrete. Control and treated rubber concrete shows good concrete quality in ultrasonic pulse velocity test.

***Keywords*:** Fly ash, GGBS, Zeolite, rubber treatment with 1M NaOH solution, rubber chips and rubber powder

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I. INTRODUCTION

Disposal of waste tire rubber has turned into a noteworthy environmental issue all around the world. Consistently a huge number of tires are disposed of, thrown away or buried throughout the world, a very serious danger to the environment [1]. It is estimated that every year almost thousand million tires end their service life and out of that, over half are disposed to landfills or waste, with no treatment. The disposed of tires are discarded in different ways like land filling, burning, use as fuel, pyrolysis, to produce carbon black etc. Stored tires likewise present numerous kinds of health, environmental and economic risks through the air, water, and soil pollution [2]. For the past few years, the construction field industry is responding to the challenge of incorporating sustainability in the production processes, this was done through the utilization of solid waste materials as aggregates in concrete or via searching for more environmentally friendly raw materials [3]. One of the possible solutions for the utilization of disposed of tire rubber is to be incorporated into concrete as a replacement of the natural aggregates. This approach could be environmentally friendly as it helps to prevent the environmental pollution impact through the disposal of the waste tires. Application of discarded tires in concrete besides improving some of the properties of concrete causes economical save, environmental cleaning and reducing use of aggregate resources [4].

However, CRCs have lower compressive strength, elastic modulus, tensile strength, workability, and durability performance compared to the original normal concrete which limits use of CRCs to non-structural elements such as paving blocks, roadside barriers, pervious concrete, rigid pavements, composite beams, metal deck composite slabs, concrete column in seismic zone and external building cladding [5]. It is worth noting that the constituents of scraped waste tires include natural rubber, poly butadiene rubber and styrene butadiene rubber that are hydrophobic and non-polar. This causes an inappropriate bond between rubber and cement in the concrete, which probably is the main reason of degradation of CRC mechanical properties. Therefore, it is seemed that surface modification of rubber to improve rubber-cement bond is inevitable [6].

To improve rubber-cement bond, water washing of rubber, rubber coating with cement or limestone, using saline coupling agent, adding silica fume into the mix design, pre-treatment with chemicals such as NaOH or CCl4 solution have been investigated. Replacing part of the cement with cheap and available natural pozzolans, is one of the ways to optimize cement production. Pozzolans are natural or artificial material containing active silica. In the presence of moisture, pozzolans react with calcium hydroxide and exhibits adhesion and improve mechanical properties of concrete such as compressive strength, and resistance to melting and freezing cycles. Zeolites are the most often used natural SCM. Zeolite is a natural pozzolan which has crystal structure, ion exchange and adsorption properties [7]. In this investigation coarse and fine aggregate is replaced with rubber chips and treated rubber powder. Fly is replaced with 5% zeolite. Mechanical, durability and NDT test were done after casting and curing the specimens.

1.1 Materials:

Fly ash used in this study was a byproduct of coal combustion from thermal power plant. Specific gravity and surface area of fly ash is 2.2 and 420 m^2/kg. GGBS is obtained from blast furnace used in iron. Surface area of ggbs is 407m^2/kg and specific gravity is 2.9. Zeolite is a good supplement cementitious material with three-dimensional framework structure. Zeolite is obtained from bethamcherla in Kurnool district with specific gravity of 2.47. Chemical composition of natural zeolite is as shown in table 1. 20mm and 12.5mm size coarse aggregate was used which has the specific gravity of 2.77. The maximum size of fine aggregate is 4.75mm; specific gravity of fine aggregate is 2.2. For Alkaline activation sodium hydroxide and sodium silicate is used. Rubber powder and rubber chips are taken from waste tyre. The specific gravity of rubber powder and rubber chips is 0.52 and 1.10. Polycarboxylic ether based 1B233 Glenium is the super plasticizer used. The specific gravity of super plasticizer is 1.06.

1.2. Rubber treatment:

The surface of rubber particles is modified with 1M of NaOH solution before 24hrs of mix. By doing this modification the rubber loses its hydrophobic nature, and it gains hydrophilic nature which leads to better adhesion between rubber surface and binder content.

Table.1 Chemical composition of natural zeolite

Chemical composition	Zeolite powder
SiO_2 (%)	67.79
Al_2O_3 (%)	13.66
Fe_2O_3 (%)	1.44
CaO (%)	1.68
Na_2O (%)	2.04
MgO (%)	1.20

II. MIX DESIGN

P. Pavitra and M. Srinivasula reddy proposed a new mix design for geopolymer concrete. Using the concept of them a mix design for geopolymer concrete done with alkaline liquid to binder ratio is 0.40, sodium silicate to sodium hydroxide ratio is 2.5, and molarity of sodium hydroxide is 12M. The mix proportion of geopolymer rubber concrete is shown in table 2. G1 to G4 represents untreated rubber; G5 to G8 represents Treated rubber where G0 represents control mix.

Table.2 Mix design proportions.

S.No	Binder Content (kg/m^3)			Alkaline solution (kg/m^3)		C.A (kg/m^3)		F. A (kg/m^3)		S. P
	Fly-Ash	Zeolite	GGBS	NaOH	Na_2SiO_3	C.A	Rubber Chips	F. A	Rubber powder	
G0	200	0	300	80	120	1404	0	338	0	1%
G1	190	10	300	80	120	1368	35.1	321	16.9	1%
G2	190	10	300	80	120	1368	35.1	304	33.8	1%
G3	190	10	300	80	120	1368	35.1	287	50.7	1%
G4	190	10	300	80	120	1368	35.1	270	67.6	1%
G5	190	10	300	80	120	1368	35.1	321	16.9	1%
G6	190	10	300	80	120	1368	35.1	304	33.8	1%
G7	190	10	300	80	120	1368	35.1	287	50.7	1%
G8	190	10	300	80	120	1368	35.1	270	67.6	1%

III. RESULTS AND DISCUSSION

3.1 Compressive strength:

Hydrophobic nature of rubber leads to decrease in strength from G1 to G4. Compression strength was increased by treating the rubber with 1M NaOH solution from G5 to G8 because formation of strong bond between the rubber and binder content. By modifying the rubber surface rubber will gain hydrophilic nature. Similar pattern was found in both 28, 56 days compressive strength as shown in figure 1 and figure 2.

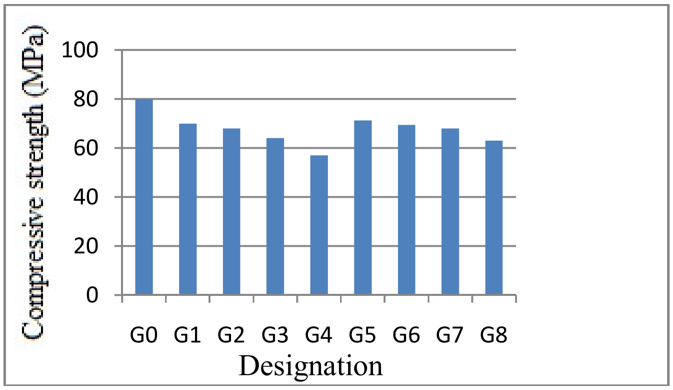

Figure 1: 28days compressive strength

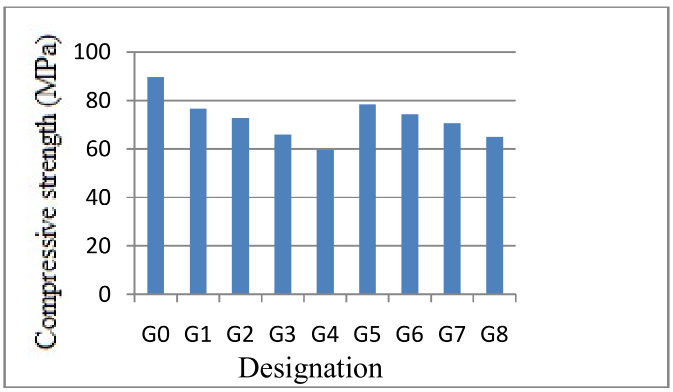

Figure 2: 56 days compressive strength

3.2 Impact Resistances test:

It was measured at 28days, by increasing rubber content the impact resistances also increased in untreated and treated rubber as show in fig 3. Highest impact resistances were seen at treated rubber concrete with 67 blows and lowest at control mix with 11 blows. Due to elastic nature of rubber impact resistances was increased.

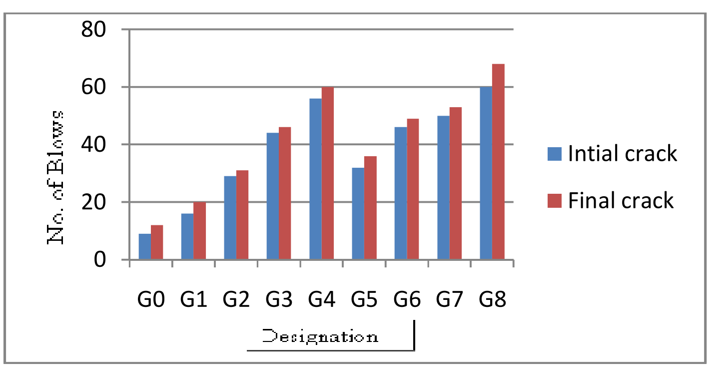

Figure 3: 28 days impact resistances test

3.3 Acid attack:

Acid test was measured at 28days after immersion of cubes in sulphuric acid. From below table 4 it was clearly shown that G0 (control geopolymer concrete) has good acid resistance. Rubberized concrete shows somewhat less strength compared with control mix. Test results shown in following table 3. Figure 4 shows the acid attack test.

Table 3: Acid attack test results

Mix designation	Weight before exposure (Kg)	Weight after exposure (Kg)	%weight loss	Compressive strength before exposure (N/mm2)	Compressive strength after exposure (N/mm2)	% Reduction in compressive strength
G0	2.604	2.582	0.84	80	32	60
G5	2.471	2.46	0.44	71.3	31.75	55.46

Figure 4: Acid attack test

3.4. Ultrasonic pulse velocity:

Figure 5 shows the equipment of ultrasonic pulse velocity. Ultrasonic pulse velocity test was conducted for cubes after 28days ambient curing of specimens. It was observed both control and rubber concrete shows excellent concrete quality. Both specimens are within limits. The test results are shown in table 4 and limits are as follows table 5.

Table 4: Ultrasonic pulse velocity test results

Designation	Velocity(km/sec)
G0	4.876
G5	4.543

Table 5: As per IS 13311(Part 1): 1992.Quality of concrete.

S.NO	Pulse Velocity by No. Cross Probing km/sec	Concrete Quality Grading
1	Above 4.5	Excellent
2	3.5 to 4.5	Good
3	3.0to 3.5	Medium
4	Below 3.0	doubtful

Figure 5: Ultrasonic pulse velocity

IV. CONCLUSIONS

It was observed that, by increasing waste rubber particles from 5 to 20%, the compressive strength decreased at all the stages. To increase the adhesion between binder content and rubber particle, the rubber particles are treated with 1M NaOH solution. After modifying the rubber surface the strength was slightly increased in both 28days and 56 days. Due to flexible nature of rubber by increasing rubber content, the impact resistances also increased in both untreated and treated rubber. It was observed that control concrete shows better acid resistances than rubberized concrete. In ultrasonic pulse velocity it was observed both control and rubber concrete shows excellent concrete quality. Both specimens are within limits i.e., Above 4.5.

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