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Experimental Investigation of Mechanical and Durability Properties of Concrete by Partial Replacement of Sand with Multi Staged Surface Treated and Surface Coated Crumb Rubber

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Abstract: ***Production of vehicle tires increases rapidly worldwide due to growth in automobile industry so it becomes worldwide problem to dispose of waste tires. Available procedures adopted for disposing the tires are not environment friendly. For the concern of environmental sustainability it is essential to reuse waste tires in different industries. Crumb rubber obtained from industries has wide application as partial replacement of aggregates and asphalt. In this research, strength and durability of normal concrete is compared experimentally with surface treated and surface coated crumb rubber concrete. Crumb rubber is surface coated in multiple steps in which to clean the crumb rubber; it is soaked in sodium hydroxide (NaOH). Secondly crumb rubber is oxidized with oxidant potassium permanganate (KMnO4), and then soaked in saturated sodium bisulphate solution (NaHSO3). Lastly silica fume coating is applied on crumb rubber. This multi staged surface treated crumb rubber is used as replacement of sand in varying proportions of 10%, 20%, and 30% by the weight of sand in concrete to carry out mechanical and durability investigation of prepared concrete with and without replacement of cement with silica fume powder.***

Keywords: Crumb rubber, mechanical properties, surface treatment, durability performance, multi-staged surface treatment.

I. INTRODUCTION

In construction industry concrete plays vital role as it is the heart of construction industry. But for production of concrete and its ingredients like cement, aagregates lots of natural resources are depleted and more energy is spent for its production. The demand of these materials is increasing day by day. So it is needful to find alternatives. Utilization of industrial and agricultural waste is widely accepted because of their ability to improve the strength and durability properties of concrete. So it is desirable to use industrial and agricultural waste as replacement in construction industry after considering its impacting cost and material property. Rapid growth in automobile industry leads to huge scrap tires generation worldwide. This resulted in the big problem of disposing the waste tires. Many attempt made to reuse the waste tires in the form of crumb rubber which is obtained by ambient grinding in mills in the form of partial replacement of aggregates and asphalt. Ground rubber is used as fuel in industry boilers, cement kilns, sports ground surfacing, sub-grade of roads, landfills construction, septic tank construction, embankment construction but is not assured environment friendly disposal. In past researches while using crumb rubber directly as replacement without any surface coating did not give expected increase in compressive, tensile and flexural strength, only impact strength is achieved. In this research it is aimed that crumb rubber surface is treated in such a way that it does not create any chemical reaction and other possible problems. Crumb rubber is surface coated in multiple steps in which to clean the crumb rubber; it is soaked in sodium hydroxide (NaOH). Secondly crumb rubber is oxidized with oxidant potassium permanganate ($KMnO_4$), and then soaked in saturated bisulphate solution. Lastly silica fume coating is applied on crumb rubber. This multi staged surface treated crumb rubber is used as replacement of sand in varying proportions of 10%, 20%, and 30% by the weight of sand in concrete to carry out mechanical and durability investigation of prepared concrete with and without replacement of cement with silica fume powder. Alireza Kashani et al. (2018) performed compressive strength testing, workability, density test by coating the crumb rubber with five different coating agents i.e. surface cement coating, surface silica fume coating, surface potassium permanganate coating, surface sodium hydroxide coating and surface sulphuric acid coating. Surface silica fume coating provides an economically feasible solution with less safety and environmental risks associated compared to the chemical treatments. But chemical coating gives clean, stable, oxidized rubber. So it is preferred to use silica fume coating after multi-staged chemical coatings. Trilok Gupta et al. (2016) investigated Mechanical and durability properties of waste crumb rubber fibre concrete with and without silica fume. They observed that it is better to use 5% replacement of cement with silica fume.

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II. MATERIAL AND METHODS

A. *Materials*

1) *Crumb Rubber:* Crumb rubber is obtained from local suppliers. The crumb rubber is in the form of single graded 2.36-4.75 mm. The specific weight of crumb rubber is 1100 kg/m^3. The variation of crumb rubber as the replacement of sand is kept as 10%, 20% and 30% weight of sand.

2) *Silica Fume Powder:* Silica fume powder is obtained from Guru Corporation, Ahmadabad, Gujarat. The specific gravity of silica fume powder is 2.22. The colour of silica fume powder is light grey blue. Silica fume powder is used in two parts, firstly it is used as surface coating agent and secondly it is used as replacement of cement.

Fig. 1 Actual photo of crumb rubber and silica fume powder.

3) *Chemicals*

a) Sodium hydroxide (NaOH): For cleaning crumb rubber.

b) Potassium permanganate ($KMnO_4$): As oxidant.

c) Saturated sodium bisulfate ($NaHSO_3$): For sulphonation reaction.

4) *Concrete:* The concrete of designed M-30 grade were used for casting of cubes, cylinders and beams specimen as per IS 10262:2009 and 456:2000 design specifications and procedure were followed for design of concrete mix.

a) *Cement:* Ordinary Portland Cement (OPC) –Birla Super 53 Grade cement.

b) *Fine Aggregates:* Crush Sand (Specific Gravity 1500 Kg/m^3), Coarse Aggregates: 20mm (Specific Gravity1500 Kg/m^3).

c) *Type of Admixture:* No admixture was used.

d) *Mix Proportion:* 1: 1.70:2.50 (Cement: Fine Aggregates: Coarse Aggregates: 20mm)

e) *Water/Cement Ratio:* 0.45

B. *Mixture proportion and multi-staged treatments.*

Figure 2: Flowchart of the multi-staged rubber modification process

The mixture design is as shown in table 1

Table no I: Mixture Design and different replacement ratios

Mix ID	Crumb Rubber %	Coarse aggregate (Kg/m^3)	Fine aggregate (Kg/m^3)	Cement (Kg/m^3)	Silica fume powder percentage
A0	0	1065	750	417.60	0
A10	10	1065	675	417.60	0
A20	20	1065	600	417.60	0
A30	30	1065	525	417.60	0
B10	10	1065	675	396.72	5
B20	20	1065	600	396.72	5
B30	30	1065	525	396.72	5

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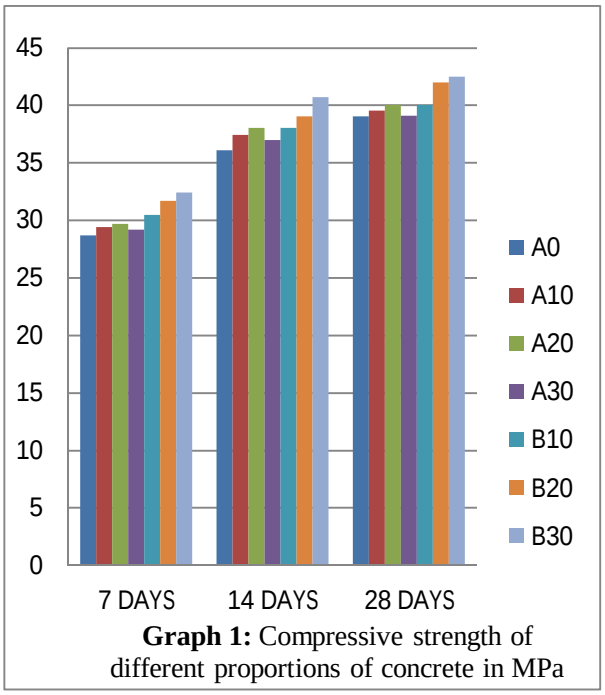
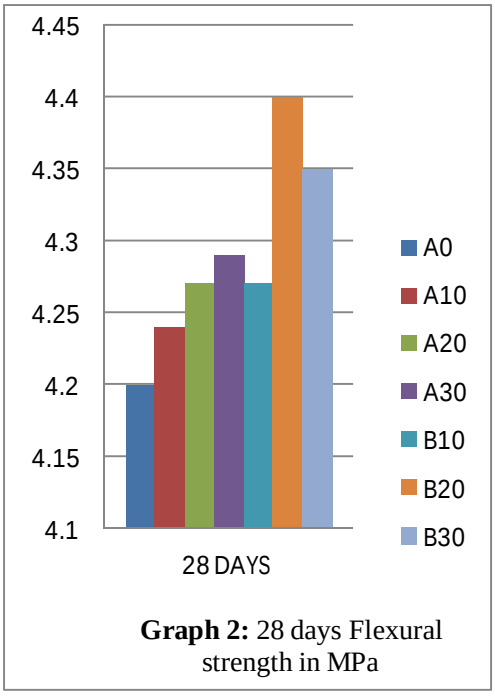
III. RESULTS

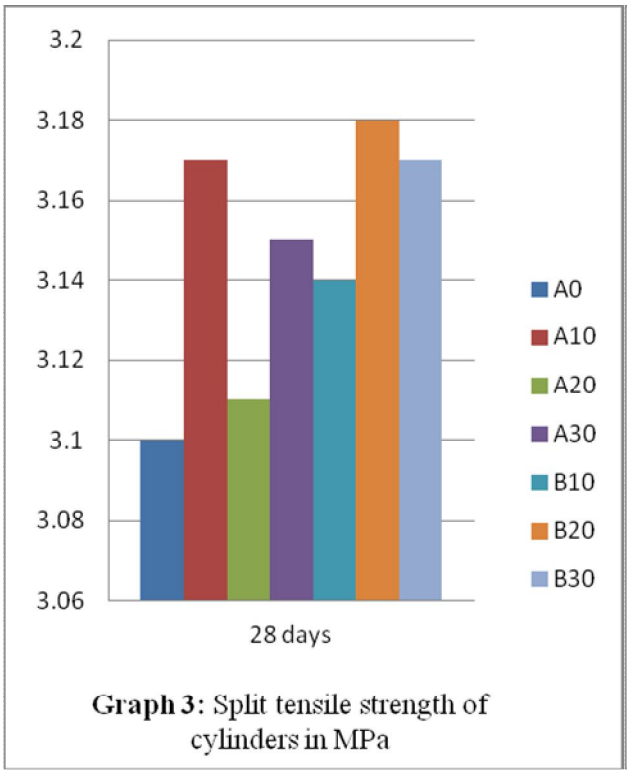
The variation in test results is as shown in following graphs



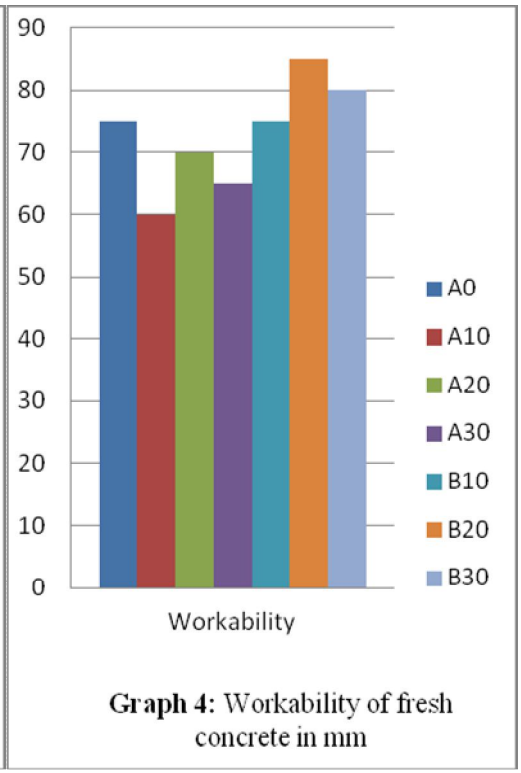
Graph 1: Compressive strength of different proportions of concrete in MPa



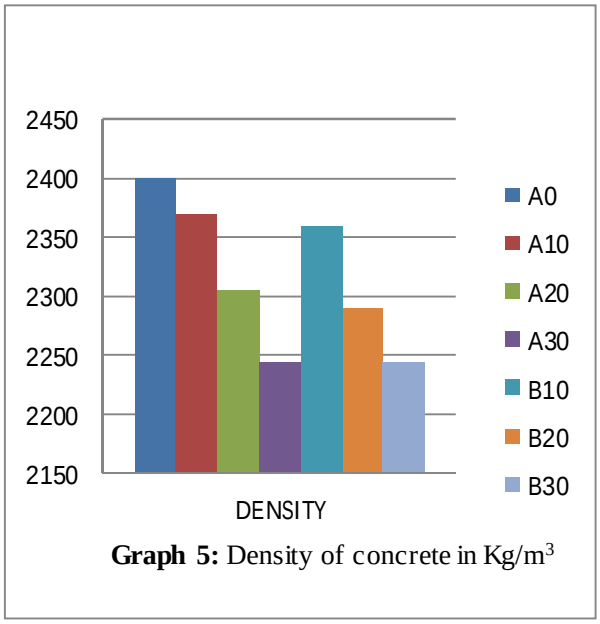
Graph 2: 28 days Flexural strength in MPa



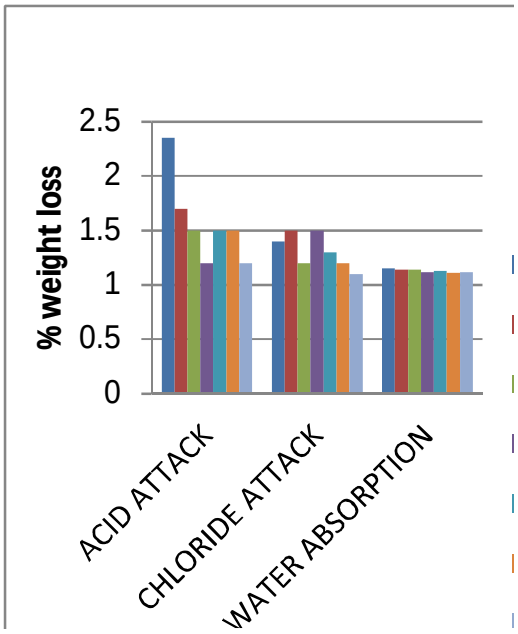
Graph 3: Split tensile strength of cylinders in MPa



Graph 4: Workability of fresh concrete in mm



Graph 5: Density of concrete in Kg/m^3



IV. CONCLUSIONS

It is observed that by replacing the cement with silica fume partially provides firm bond to the silica fume coated crumb rubber. The compressive strength of crumb rubber concrete increases upto 20% and decreases at 30% with increase in replacement proportions and it is maximum when cement is also replaced with silica fume. The flexural and split tensile strength of crumb rubber concrete increases upto 20% and decreases at 30% with increase in replacement proportions and it is maximum when cement is also replaced with silica fume. Increased strength was because of the void filling and better adhesion between crumb rubber and cement. In addition, less safety and environmental risks associated with this method and possibility of any negative effects on durability of concrete would be negligible. It can be used as light weight concrete foam as density decreases with increasing crumb rubber content. So it is concluded that it is desirable to use 20% crumb rubber with multi-staged surface treatments and 5% cement replacement with silica fume is most feasible method for improvement in properties of concrete.

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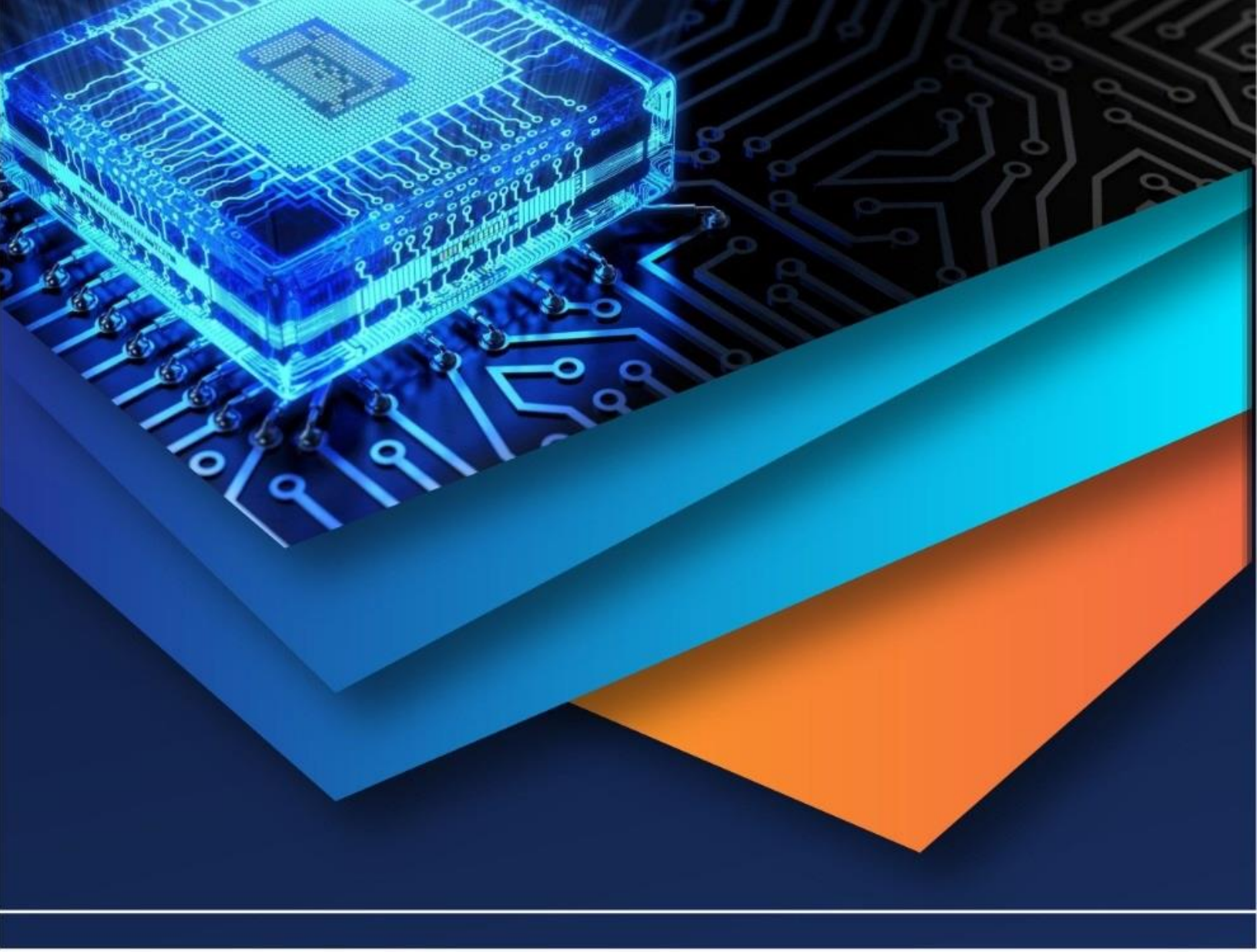

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