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Experimental Study on Effect of Silica Fume on Properties of Crumb Rubber Concrete

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Abstract: ***Concrete is a widely used construction material for various types of structures due to its structural stability and strength. Basically it consists of aggregates which are bonded together by cement and water. Use of these conventional materials in concrete causes depletion of resources unless there is a suitable substitute. Rubber which is generated in large quantities as waste does not have useful disposal till now. Hence in this study crumb rubber is used as a partial substitute for fine aggregate. The main parameter investigated in this study is M30 grade concrete as per IS 10262-2009 with partial replacement of fine aggregate by crumb rubber by 0%, 5%, 10%,15% and by 20%.In this mix, by replacing fine aggregate by 0%, 5%, 10%, 15% and 20% crumb rubber optimum percentage of crumb rubber is find out. Then silica fume is added at 5%, 10%, 15% and 20% at the optimum % of crumb rubber. The silica fume is used to regain the reduced strength of concrete due to the use of waste tyre crumb rubber particle. This paper presents a detailed experimental study on compressive strength, split tensile strength, flexural strength at age of 7 and28 days. The mechanical and durability properties are determined and are compared with the corresponding values of the conventional concrete. The present investigation has been aimed at to bring awareness amongst the practicing civil engineers regarding advantages of these new concrete mixes.***

Keywords: Crumb rubber, Silica fume, Fine aggregate

1. Introduction

Concrete strength is greatly affected by the properties of its constituents and the mix design parameters. Because aggregates represent the major constituents of the bulk of a concrete mixture, its properties affect the properties of final product. An aggregate has been customarily treated as inert filler in the 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 inert filler is being seriously questioned. Aggregate was originally viewed as a material dispersed throughout the cement paste largely for economic reasons. It is possible, 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.

Among the many threats that affects 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 wastes are divided as solid waste, liquid waste and gaseous wastes. There are many disposal ways for liquid and gaseous waste materials. Some solid waste materials such as plastic bottles, papers, steel etc can be recycled without significant effect on 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.

Crumb rubber (CR) is a commodity made by re-processing (shredding) disposed automobile tires. Shredding waste tires and removing steel debris found in steel-belted tires generates crumb rubber. CR is fine rubber particles ranging in size from 0.075 mm to no more than 4.75 mm. In the concrete mix, CR constitutes a portion of the aggregate in the concrete mix. Crumb rubber is the name given to any material derived by reducing scrap tires or other rubber into uniform granules with the inherent reinforcing materials such as steel and fiber removed along with any other type of inert contaminants such as dust, glass, or rock.

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan.

2. Literature Survey

Previous researches that have done to rubberized concrete found that the strength of the rubberized concrete was lower than conventional concrete. Eldin et al., (1993) [1] conducted a study on rubber tyre particles as concrete aggregate. They concluded that the particle size and the amount of crumb rubber in concrete mixture must be investigated to obtain relevant strength of concrete.

Khatib and Bayomy, (1999) [3] investigated the properties of rubberized portland cement concrete. Results showed that rubberized PCC mixes can be made and are workable to a certain degree with the tire rubber content being as much as 57% of the total aggregate volume. However, strength results showed that large reductions in strength would prohibit the use of such a high rubber content. It is suggested that rubber contents should not exceed 20% of the total aggregate volume.

Pierce and Blackwell, (2013)[2]conducted research on potential of scrap tire rubber as lightweight aggregate in flowable fill. Crumb rubber can be used as a complete replacement for concrete sand in flowable fill. Crumb rubber contents as high as 38% by weight (57% by volume) can be mixed in flowable fill without noticeable segregation of the rubber, although there is measurable bleeding in some cases. Crumb rubber offers other benefits when used in flowable fill, such as improved ductility and higher thermal insulation. These and other technical benefits need to be explored further.

Najim and Hall, (2010) [5] investigated that the reutilization of waste rubber from scrap vehicle tires in the construction industry has a direct limiting impact on environmental pollution . As well, the low density of rubber aggregate compared with a conventional aggregate can significantly contribute to developing semi lightweight and lightweight concrete that can help in more economical building design.
Fattuhi et al., (1996) [4] proposed that the cement paste, mortar, and concrete (containing OPC) mixes were prepared using various proportions of either rubber crumb or low-grade rubber obtained from shredding scrap tyres. Results showed that density and compressive strength of various mixes were reduced by the addition of rubber. Density varied between about 1300 and 2300 kg/m^3. Compressive strength reduced by 70% when the proportion of rubber to total solid content by mass of concrete reached about 13%.

3. Experimental Programme

In this research the strength and durability characteristics of concrete in which fine aggregate replaced with crumb rubber and studied the structural properties of silica fume at optimum percentage of replacement. The test program includes the determination of strength properties by cube compressive strength, modulus of elasticity, spilt tensile strength, flexural strength, and durability properties by carbonation test, sulphate resistance test, bulk diffusion test. The properties of materials used in this study were tested in the laboratory as per IS specifications and by using the test results mix design was done. This study limited to the preparation of 10 different types of mixes. The first mix is a control mix and the next 4 mixes were prepared by replacing fine aggregate by weight with crumb rubber in 5%, 10%, 15%, 20%. After that at optimum percentage of replacement of fine aggregate is added with 0%, 5%, 10%, 15% and 20% of silica fume by weight. For all mixes the grade of cement used was M30.

3.1 Preparation of test specimens

Mixing was done in a laboratory type pan mixer shown in Fig 4.4. Pan mixers with revolving star of blades were used. While preparation of concrete specimens, aggregates, cement and mineral admixtures were mixed in the revolving pan. After proper mixing, mixture of water and plasticizer were added. The mixing was continued until a uniform mix was obtained. The concrete was then placed into the moulds which were properly oiled. After placing of concrete in moulds proper compaction was given using the table vibrator. Standard moulds were used for casting 100 mm cube specimen, 150 mm diameter and 300 mm height cylinders, 100 mm diameter and 200 mm height cylinders, 150 mm diameter and 50 mm height discs and 100 mm x 100 mm x 500 mm beam specimens. A total of 360 specimens were casted.

3.2 Curing of specimens

The specimens were demoulded after 24 hours of casting and were kept in a curing tank for curing till the age of the test. The preparation of specimens by pan mixer are shown in Fig 1. The prepared specimens were then cured in water for 28 days and the curing of specimens are shown in Fig 2.

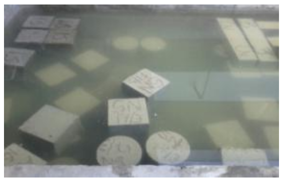



Figure 1: Concrete mixing **Figure 2:** Curing of Speciens

3.3 Mix proportion

Mix design is the process of selection of suitable ingredients of concrete and to determine their properties with object of producing concrete of certain maximum strength and durability, as economical as possible. The mix proportion for the M30 grade of concrete was arrived through trial mixes. The mix proportion for M30 grade of concrete are shown in Table 1.

Table 1: Quantity of materials per cubic meter of concrete

Sl No	*Materials*	*Quantity*
1	Cement	394 kg/m^3
2	Fine aggregate oarse aggrege	670.660 kg/m^3
3	Coarse aggregate	1215.184 kg/m^3
4	Water	157kg/m^3
5	Water cement ratio	0.39

Table 2 : Mix designation

Mix	*Fine aggregate %*	*Crumb rubber %*	*Sillica fume %*
M30	100	0	0
M30+R5%	95	5	0
M30+R10%	90	10	0
M30+R15%	85	15	0
M30+R20%	80	20	0
M30 + R10% +S0%	90	10	0
M30+ R10%+S5%	90	10	5
M30+ R10%+S10%	90	10	10
M30+ R10%+S10%	90	10	15
M30+ R10%+S10%	90	10	20

4. Results

The fine aggregate in the concrete is replaced up to a certain percentage by crumb rubber in the concrete. The strength and durability studies were conducted on crumb rubber and crumb rubber silica fume admixed concrete mixes based on the experimental investigations. ('A' indicates M30 + R10%)

4.1 Slump Test

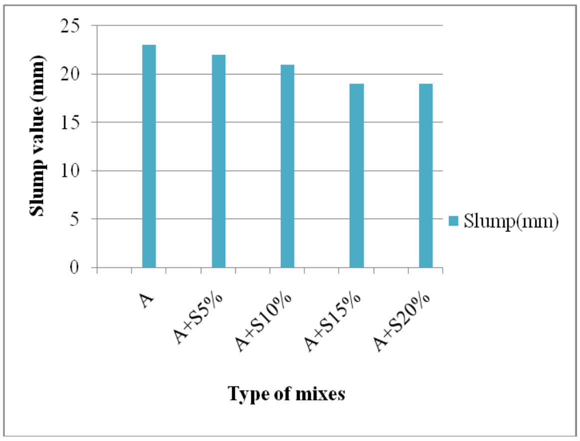


Figure 3: Slump value for different mixes

4.2 Compaction factor test

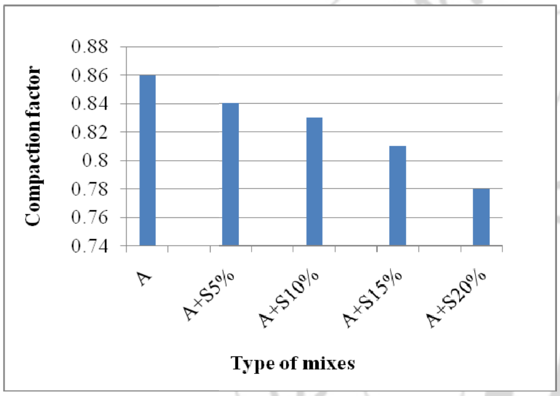


Figure 4: Compaction factor values for different mixes

4.3 Compressive strength test

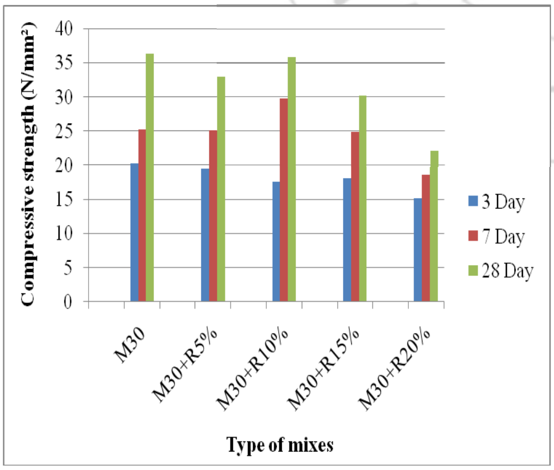


Figure 5: Compressive Strength of concrete for various combinations after 3,7 and 28-days of curing

The results showed that the compressive strength of the concrete is decreased when the addition of crumb rubber increases in the concrete. The strength parameter shows an inverse relation with the increase in replacement of fine aggregate. However, the target mean strength is achieved up to 10% of fine aggregate replacement in the concrete as per the Indian slandered code of mix design.

4.4 Flexural strength test

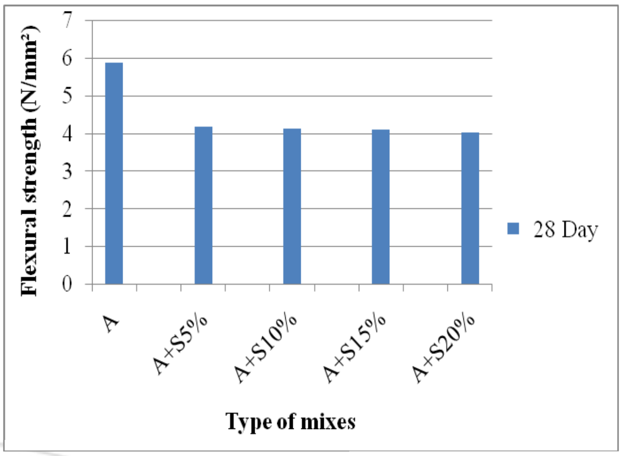


Figure 6 : Flexural strength for different mixes

4.5 Split tensile strength test

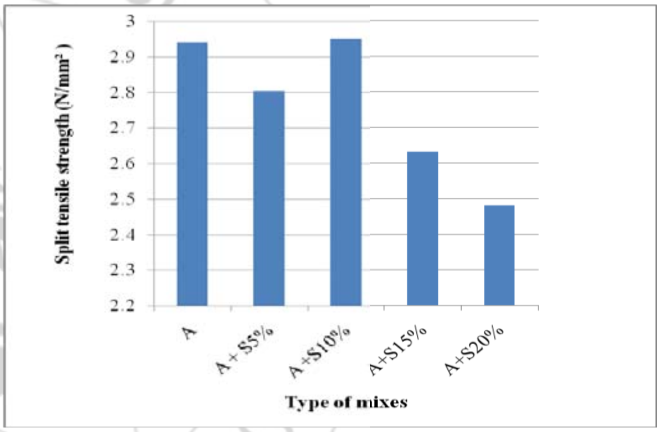


Figure 7: Split tensile strength for different mixes

The split tensile strength decreases with increase in the % of crumb rubber. Split tensile strength of 5% replaced concrete is less than, the normal concrete and the strength reduces with the increase of replacement.

4.6 Carbonation Study

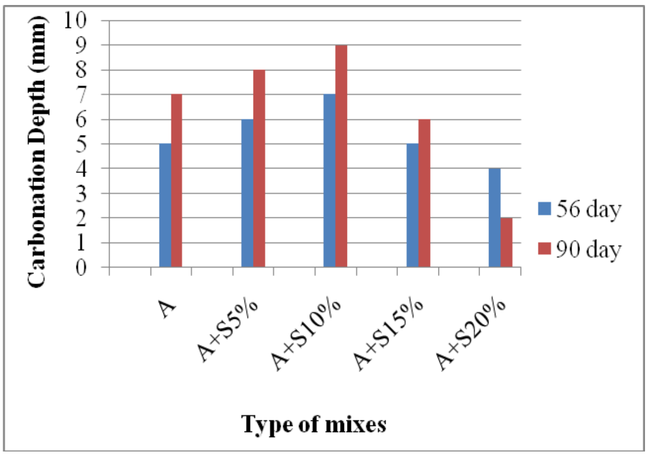
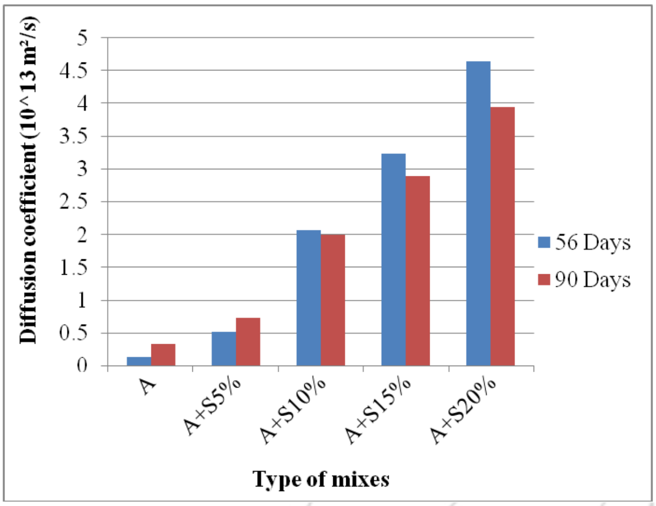


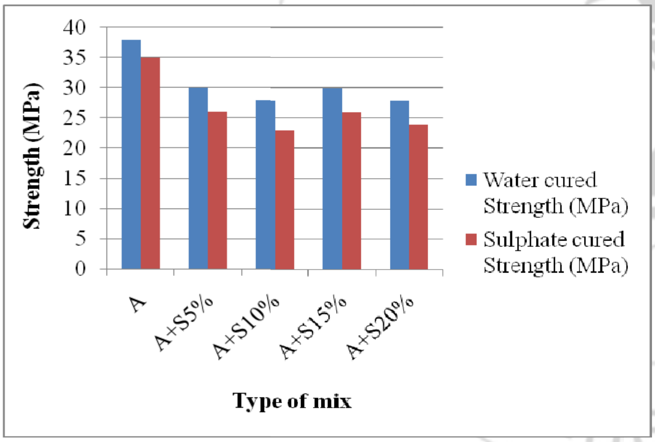
Figure 6: Carbonation Depth for different mixes

Figure 6 shows the carbonation depth variation for different mixes. Carbonation depth first just increases then decreases as the increase in replacement of fine aggregate. This may be due to any chemical reaction occurs. From the plot, it may be observed that the depth of carbonation goes on increasing with increase in silica fume content until the percentage of silica fume replacement reaches 10%.

4.7 Bulk Diffusion test



4.8 Sulphate Attack



5. Conclusions

Experimental investigations are carried out to study the replacement of fine aggregate by crumb rubber in concrete and silica fume is added at optimum percentage of replacement of fine aggregate to improve its mechanical properties. The properties such as compressive strength, flexural strength, split tensile strength ,modulus of elasticity, impact resistance and durability properties such as carbonation and chloride penetration were examined. The major conclusions drawn from this research are presented below.

- The use of crumb rubber in concrete mix is very much beneficial to environmental concern and to solve the problem related to disposal of waste tyre rubber throughout the world.
- For durability studies crumb rubber concrete admixed with silica fume showed better results.
- The test results indicated that there was a systematic reduction in the compressive and splitting tensile strengths, and modulus of elasticity with the increase in rubber content from 0% to 20%.
- The use of silica fume considerably enhanced the mechanical features of both plain and especially rubberized concretes and decreased the rate of strength loss accompanied by the addition of rubber.

6. Future Scope

- The study may be extended to evaluate the electrical resistivity of concrete which may be useful in assessing the hydration characteristics of the mixes
- It seems that there is still a need for future studies to optimize the size, shape, grading, density, amount, and methods of pre-treatment of rubber particles on the properties of rubber concrete.

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Author Profile

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