Experimental Study on Mechanical Properties of Concrete Using Chipped Rubber Aggregate And Silica Fume

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Abstract- *Environmental concerns caused by the extraction of raw materials and CO2 emissions in the production of Portland cement led to pressures to reduce the consumption of this constituent of concrete, combined with the need to increase its durability. The cement is the costliest and energy intensive component of concrete. The unit cost of concrete can be reduced as much as possible by partial replacement of cement with other waste pozzolanic materials. Certain materials of mineral origin are also added to concrete to enhance their strength and durability properties of concrete materials such as Chipped rubber aggregate and other by product like Silica flume. Chipped rubber aggregate and Silica flume can be used in a combination as supplementary cementitious material as partial replacement of cement and Fine aggregate. 3% of chipped rubber aggregate with 15% Silica flume (K3) gives 32% increase in compressive strength which is 31.65N/mm2 of this newly modified concrete in comparison with conventional concrete of M25 grade which is optimum amongst other combinations within 7 Days. 3% Chipped rubber aggregate with 15% Silica flume (K3) gives 34% increase in compressive strength which is 38.45 N/mm2 of this newly modified concrete in comparison with conventional concrete of M25 grade which is optimum amongst other combinations within 14 Days. 3% Chipped rubber aggregate with 15% Silica flume (K3) gives 42% increase in compressive strength which is 48.07 N/mm2 of this newly modified concrete in comparison with conventional concrete of M25 grade which is optimum amongst other combinations within 28 Days. 3% Chipped rubber aggregate with 15% Silica flume (K3) gives increase in Tensile strength which is 2.76N/mm2, 3.23N/mm2 and 3.89N/mm2 within 7 Days, 14 Days and 28 Days alternatively. 3% Chipped rubber aggregate with 15% Silica flume (K3) gives increase in Flexural strength which is 8.6N/mm2, 9.1N/mm2 and 10.5N/mm2 within 7 Days, 14 Days and 28 Days alternatively. Percentage increase in Silica flume results in decrease of strength parameters i.e. combination having 20%, 25%, 30% of Granite Powder gives less increase in results for this mix proportion.*

Keywords- Silica flume, Chipped rubber aggregate, Compressive strength, Tensile Strength, Flexural Strength, Specific gravity, Concrete, Cement.

I. INTRODUCTION

Concrete is a composite material that consists of a binding medium within which are embedded particles of aggregate, usually a combination of fine aggregate and coarse aggregate. Concrete has been the leading construction material for a century and its strength is a frequently investigated property because it gives a good indication of the overall quality of concrete.

Fire is the severe environment condition which a concrete structure may be subjected. Since the work of the research pioneers, Lea and Starling was the first who in the 1920s investigated the influence of high temperatures on concrete strength. In the event of accidental fire when concrete is subjected to higher temperature level its chemical composition, physical structure and mechanical properties change considerably. In the 21st century of vast infrastructure development fire hazards are very common due to several reasons.

II. MATERIALS USED

Chipped rubber aggregate

Type rubber aggregate. About 30 cm long waste tyre rubber pieces are obtained from local market; the pieces were cleaned with soap water and rinse with clean water. After drying under sun at open place, both faces of the tyre pieces were rubbed with hard wire brush to make surfaces as rough as can be done by hand. The source of the rubber aggregate is recycled tyres which were collected from the local market. For uniformity of the concrete production and convenience, all the tires collected are from medium truck tire. The reason for choosing medium truck tires is that they can give the required shape and size which is similar to the common natural gravel.

This study has concentrated on the performance of a single gradation of rubber prepared by manual cutting. The maximum size of the rubber aggregate was 20 mm as shown in Figure 1. Specific gravity test was conducted on the rubber aggregate chips and found to be 1.123. The rubber aggregates used in the present investigation are made by manually cutting the tire in to the required sizes. It is very laborious, time consuming and is not easy to handle at the initial stages. However, all this complication can be easily sorted out if a large scale production is devised and proper cutting tools and machineries are made for this particular usage

Figure 1.1 Chipped Rubbers

Table No. 1.1 Physical and chemical properties of chipped rubber aggregate

S. No.	Test Properties	Technical indexes	Test Results
1	Bulk Density (kg/m$^{3)}$	260 – 460	302.5
2	Moisture content (%)	< 1	0.0
3	Metal Content (%)	< 0.03	0.009
4	Fiber Content (%)	< 1	0.065
5	Ash Content (%)	≤ 8	7.3
6	Acetone Extract (%)	≤ 22	7.2
7	Carbon Black Content (%)	≥ 28	30

Silica Fume

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 pozzolanic. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and, when specified, is simply added during concrete production. Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor.

Silicon metal and alloys are produced in electric furnaces as shown in this photo. The raw materials are quartz, coal, and woodchips. The smoke that results from furnace operation is collected and sold as silica fume, rather than being landfilled. Perhaps the most important use of this material is as a mineral admixture in concrete. Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide (SiO2). The individual particles are extremely small, approximately 1/100th the size of an average cement particle. Because of its fine particles, large surface area, and the high SiO2 content, silica fume is a very reactive pozzolanic when used in concrete. The quality of silica fume is specified by ASTM C 1240 and AASHTO M 307.

1.2 Physical and Chemical properties of Silica Fume and cement

S. No.	Properties	Cement	Silica Fume
1	Specific Gravity	3.15	2.2
2	Surface Area (m^2/kg)	320	20,000
3	Size, Micron	-	0.1
4	Bulk Density, kg/m	-	576
5	Initial setting Time (min)	45	-
6	Final Setting time (min)	375	-
Chemical Properties (%)			
1	SiO_2	90 – 96	20 – 25
2	Al_2O_3	0.5 – 0.8	4 - 8

Figure 1.2 Silica fume

III. EXPERIMENTATION

Compressive Strength Test

The compressive strength of cubes of different grades i.e. control mix M25 for 7, 14 and 28 days were tested. The testing was done using universal testing machine. The capacity of machine is 1000kN. The figure 3.8 shows the testing of cubes.

Compressive Strength Test

The compressive strength of cubes for 7days, 14 days and 28 days were determined and their values were compared.

Tensile Test

Tensile testing is a destructive test process that provides information about the tensile strength, yield strength, and ductility of the metallic material. It measures the force required to break a composite or plastic specimen and the extent to which the specimen stretches or elongates to that breaking point. Tensile testing of composites is generally in the form of basic tension or flat- sandwich tension testing in accordance with standards such as ISO 527-4, ISO 527-5, ASTM D 638, ASTM D 3039, and ASTM C 297. Such tests produce stress-strain diagrams used to determine tensile modulus.

Tensile Test

Tensile testing also provides tensile strength (at yield and at break), tensile modulus, tensile strain, elongation, and percent elongation at yield. In-plane tensile testing of plain composite laminates is the most common test. Tensile tests are also performed on resin-impregnated bundles of fibers (“tows”), through thickness specimens (cut from thick sections of laminates), and sections of sandwich core materials. Alignment is critical for composite testing applications because composites are anisotropic and generally brittle, as the anisotropy means that the properties and strength of the material differ depending on the direction of the applied force or load. Thus, the tensile strength of a composite material is very high in the direction parallel to the fiber orientation, while the tensile strength is much lower if tested in any other direction. Interestingly, to determine maximum tensile strength in the direction parallel to the fiber direction, the tensile test must have superior axial-load-string alignment, primarily critical in the aerospace industry, where composites are often applied in high-tensile-stress structures. Currently, a range of proven gripping mechanisms including manual, pneumatic, and hydraulic actuation is available for ambient, sub ambient and high-temperature testing, ranging between −269 and 600°C. Obtained test data specify the optimal materials, design parts to withstand application forces, and provide key quality control checks for materials.

Flexural Test

Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending. The results of flexural test on concrete expressed as a modulus of rupture which denotes as (MR) in MPa or psi. The flexural test on concrete can be conducted using either three-point load test (ASTM C78) or center point load test (ASTM C293). Test method described in this article is according to ASTM C78.

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Flexural Test

It should be noticed that, the modulus of rupture value obtained by center point load test arrangement is smaller than three-point load test configuration by around 15 percent. Moreover, it is observed that low modulus of rupture is achieved when larger size concrete specimen is considered. Furthermore, modulus of rupture is about 10 to 15 percent of compressive strength of concrete. It is influenced by mixture proportions, size and coarse aggregate volume used for specimen construction.

Specific Gravity

Specific gravity may be defined as a ratio of density of a substance to the density of a reference substance. The reference substance is nearly always water but sometimes we use other substance like kerosene. Kerosene is used as a reference substance for determining the specific gravity of cement and water is used as a reference substance for determining the specific gravity of sand and coarse aggregates.

Specific Gravity

S. No.	Materials	Specific Gravity
1	Granite Powder	2.73
2	Cement	3.15
3	Sand	2.6
4	Coarse aggregate	2.74

Sieve Analysis of Fine Aggregates

Here sand is allowed to pass through the different sieves size varying from 4.75mm to 75µmm and their particle size distribution is determined. The sand used confirms to table 4 of IS 383 and it belongs to zone 1.

Sieve Size Analysis of Fine Aggregates

IS sieve size	Weight retained	% Weight retained	Cumulative % weight retained	Cumulative % Passing
4.75mm	8.7	0.87	0.87	99
2.36mm	35	3.5	4.37	95
1.18mm	275	27.50	31.87	68
300µm	235	23.50	95.57	4.43
150µm	40	4	99.57	0.43
75µm	0.5	0.05	99.62	0.38
Pan	3.8	0.38	99.65	0.35

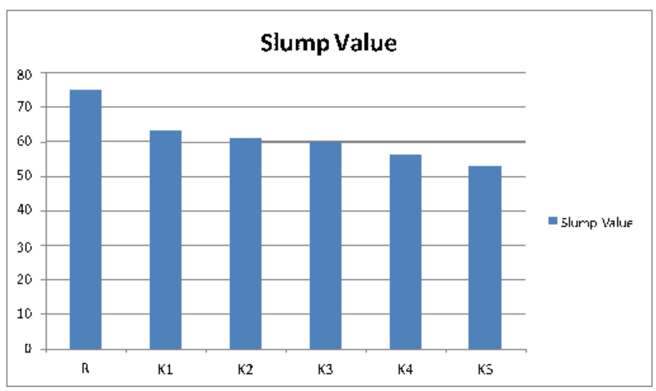
Fineness Modulus = 295/100 = 2.95

Effect on Workability

The consistency of concrete for each mix group has been determined using the slump test in accordance to IS: 1199-1959. The test results for workability of Chipped rubber at a varying percentage of 1%, 2%, 3%, 4% and 5%) and Silica fume by replacing of cement in varying percentage of 5%, 10%, 15%, 20% and 25% (by total weight of cement)

Slump Values of Concrete Mix

Mix Group	Chipped rubber (%)	Silica fume (%)	Slump (mm)
R	0	0	75
K_1	1	5	63
K_2	2	10	61
K_3	3	15	60
K_4	4	20	56
K_5	5	25	53



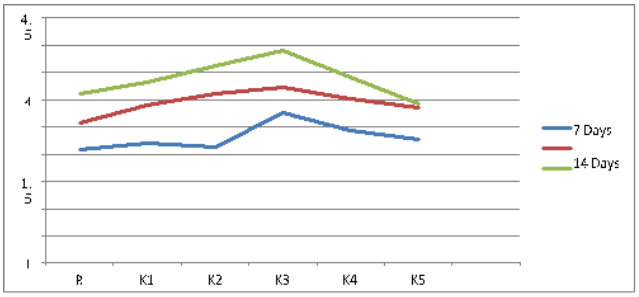
Slump Value

Comparison of Tensile Strength

The Tensile strength of 7 days, 14days and 28 days increased by 2.76N/mm^2, 3.23N/mm^2 and 3.89N/mm^2 respectively than that of control mix M25. The Tensile strength of Chipped rubber and silica fume for 28 days is 3.89N/mm^2

Comparison of Tensile Strength

Mix groups	7 Days	14 Days	28 Days
R	2.08	2.58	3.10
K_1	2.19	2.89	3.32
K_2	2.12	3.10	3.61
K_3	2.76	3.23	3.89
K_4	2.42	3.02	3.42
K_5	2.26	2.86	2.93



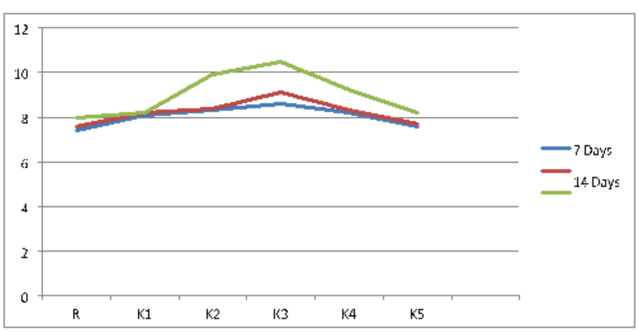
Comparison of Tensile Strength

Comparison of Flexural Strength

The Flexural strength of 7 days, 14days and 28 days increased by 2.76N/mm^2, 3.23N/mm^2 and 3.89N/mm^2 respectively than that of control mix M25. The Flexural strength with addition of Chipped rubber and silica fume 28 days is 3.89N/mm^2.

Comparison of Flexural Strength

Mix groups	7 Days	14 Days	28 Days
R	7.4	7.6	8.0
K_1	8.1	8.2	8.2
K_2	8.3	8.4	9.9
K_3	8.6	9.1	10.5
K_4	8.2	8.3	9.2
K_5	7.6	7.7	8.2



\Mix Group
Compression of Flexural Strength

IV. CONCLUSIONS

1. Chipped Rubber aggregate and silica fume can be used in a combination as supplementary cementitious material as partial replacement of cement and Fine aggregate
2. 3% Chipped rubber with 15% Silica fume (K3) gives 32% increase in compressive strength which is 31.6N/mm2 of this newly modified concrete in comparison with conventional concrete of M35 grade which is optimum amongst other combinations within 7 Days.
3. 3% Chipped rubber with 15% Silica fume (K3) gives 34% increase in compressive strength which is 39.6 N/mm2 of this newly modified concrete in comparison with conventional concrete of M35 grade which is optimum amongst other combinations within 14 Days.
4. 3% Chipped rubber with 15% Silica fume (K3) gives 42% increase in compressive strength which is 49.08 N/mm2 of this newly modified concrete in comparison with conventional concrete of M35 grade which is optimum amongst other combinations within 28 Days.
5. 3% Chipped rubber with 15% Silica fume (K3) gives increase in Tensile strength which is 2.76N/mm2, 3.23N/mm2 and 3.89N/mm2 within 7 Days, 14 Days and 28 Days alternatively.
6. 3% Chipped rubber with 15% Silica fume (K3) gives increase in Flexural strength which is 8.6N/mm2, 9.1N/mm2 and 10.5N/mm2 within 7 Days, 14 Days and 28 Days alternatively.
7. Percentage increase in Silica fume results in decrease of strength parameters i.e. combination having 20%, 25%, 30% of Silica fume gives less increase in results for this mix proportion.

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