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A RESEARCH ON PARTIAL REPLACEMENT OF CEMENT BY GROUND GRANULATED BLAST FURNACE SLAG (GGBS) AND ADDITION OF CARBON FIBER

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Abstract - Concrete is a composite material consisting of a hard inert particulate substance known as aggregates and bonded together by cement and water. Brittleness and crack formation are weaknesses of concrete related to its durability. The present research trend in concrete technology is towards increasing the strength and durability of concrete to meet the demands of the modern construction. The manufacturing process of cement emits considerable amount of carbon dioxide (CO2). Therefore, is an urgent need to reduce the usage of cement. Ground Granulated Blast Furnace Slag (GGBS) is a byproduct from steel industry. It has good structural and durable properties with less environmental effects. The concrete in which the cement is replaced 35-40% by GGBS have advanced durability properties such as increased resistance to sulphate attack, increased resistance to alkali silica reaction, reduced chloride ion ingress which enhances corrosion resistance. Carbon fibers also offer an economical benefit as they are readily available as a waste product from the aerospace industry and offers 2 to 5 times more rigidity than the other fibers. Carbon fibers possess many potential benefits over other fibers, including a higher strength, higher modulus, and increased durability. It has higher strength than steel with quarter of its weight. The main objective of this research is to design M30 grade concrete and perform strength tests and durability studies by adding 0%, 0.50%, 1.00% and 1.50% of carbon fibers by volume of concrete and constant adding percentage of GGBS is 40%. The strength and durability characteristics are studied. The mechanical properties studied are compressive, split tensile and flexural strengths. The test specimens were also subjected to acid and sulphate attacks and tested for their durability. The results show that there is an increase in compressive, split tensile and flexural strengths of carbon fiber reinforced concrete.

Key Words: Carbon fiber, GGBS, High Strength, Increased Durability.

1 INTRODUCTION

1.1 General

Concrete is the most commonly used constructional material in the world, which can be attributed largely to the fact that its characteristics can be altered to meet the needs of a wide variety of applications. However concrete has some deficiencies such as low tensile strength, low post cracking capacity, brittleness and low ductility, limited fatigue life, not capable of accommodating large deformations, low impact strength. The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cementitious material, aggregate and water and by adding some special ingredients. Hence concrete is very well suited for a wide range of applications.

1.2 OBJECTIVES

The main objective of this study is to determine the high strength and increased durability by partial replacement of cement by GGBS and addition of Carbon fiber to the mixes and also to compare the results of mixes.

1.3 SCOPE

To determine the properties of the materials. To examine the mechanical properties of hardened concrete. To determine the permeability range.

2 LITERATURE REVIEW

2.1 Nada Mahdi Fawzi Aljalawi, Haider M.K. Al-Jelawy - This work focuses on studying the mechanical characteristics of carbon fibre reinforced concrete, containing a different percentage of fibre. This work was carried out using several tests. These tests were hardened density, compressive strength, flexural strength . Tests were performed for specimens at ages of (7,28,60) days. The test results indicated that the inclusion of fibre in the reference concrete mixes did not affect the compressive strength significantly, while the flexural strength was improved. Test results indicated that the flexural strength of (0.75%) carbon fibre concrete specimens are twice that of the reference specimens in age of 28 days . The percentage of increasing the flexural strength for carbon mixes containing fibre by volume fraction of (0.5%,

0.75%) were (23%, 27%) respectively at age of 28 days.

2.2 Robert Bohm, Mike Thieme, Daniel Wohlfahrt, Daniel Sebastian Wolz, Benjamin Richter and Hubert Jager - Carbon concrete polyacrylonitrile (PAN)/lignin-based carbon fiber (CF) composites are a new promising material class for the building industry. The replacement of the traditional heavy and corroding steel reinforcement by carbon fiber (CF)-based reinforcements offers many significant advantages: a higher protection of environmental resources because of lower CO2 consumption during cement production, a longer lifecycle and thus, much less damage to structural components and a higher degree of design freedom because lightweight solutions can be realized. However, due to cost pressure in civil engineering, completely new process chains are required to manufacture CF-based reinforcement structures for concrete. This article describes the necessary process steps in order to develop CF reinforcement: (1) the production of cost-effective CF using novel carbon fiber lines, and (2) the fabrication of CF rebars with different geometry profiles. It was found that PAN/lignin-based CF is currently the promising material with the most promise to meet future market demands. However, significant research needs to be undertaken in order to improve the properties of lignin-based and PAN/lignin-based CF, respectively. The CF can be manufactured to CF-based rebars using different manufacturing technologies which are developed at a prototype level in this study.

2.3 Shanmuganathan.N, Akbar Basha. S , Sheik Ibrahim.K, Mohammed Fahad.A.S - Cement is the most important material of the concrete which produced by natural raw material like silica and lime over consumption of lime may lead to the condition there will be no lime production of cement for concrete. The effect of cementitious waste material (GGBS) as cement in concrete give more compressive strength and flexural strength 0-80% replacement of GGBS in different grade of concrete. The GGBS give more strength in 40% of replacement and attains more than 9% strength in 7 days and increasing of 6% strength with 30% replacement attains in 28 days . The large replacement of GGBS cause reduction in flexural & compressive strength in adding 30% of GGBS compressive strength lower than the plain cement concrete addition. Concrete achieve adequate strength in GGBS. The compressive & flexural strength will be high in adding 15%-45%.it will identical to achieve mechanical Properties.

2.4 P. Saranya , Praveen Nagarajan, A P Shashikala - Concrete is the most commonly used material in the construction industry in which cement is its vital ingredient. Although the advantages of concrete are many, there are side effects leading to environmental issues. The manufacturing process of cement emits considerable amount of carbon dioxide (CO2). Therefore is an urgent need to reduce the usage of cement. Ground Granulated Blast furnace Slag (GGBS) is a by-product from steel industry. It has good structural and durable properties with less environmental effects. This paper critically reviews the literatures available on GGBS used in cement concrete. In this paper, the literature available on GGBS are grouped into engineering properties of GGBS concrete, hydraulic action of GGBS in concrete, durability properties of GGBS concrete, self compacting GGBS concrete and ultrafine GGBS are highlighted. From the review of literature, it was found that the use of GGBS in concrete construction will be eco-friendly and economical. The optimum percentage of replacement of cement by GGBS lies between 40 – 45 % by weight. New materials that can be added in addition to GGBS for getting better strength and durability also highlighted.

2.5 Aneesh V Bhat, Dr. Sunil Kumar Tengli - At present, the usage of concrete is increasing day by day. In future days cement may find its scarcity due to over usage. After water, cement is the second most consumed product in the world. This scarcity may affect the construction industry. The rapid production of cement may create several environmental issues also, for which solution is to be found out. In the production process of cement, CO2 emission takes place. One ton of CO2 gets emitted for one ton of OPC manufacture. And cement production requires the availability of lime which will be soon in the list of limited resource available. Hence it is necessary to find a replacement to cement in concrete as a substitute to it.. Ground Granulated Blast Furnace Slag (GGBS) is been continuously used as a replacement material for cement. But a very little knowledge about GGBS concrete behaviour in marine environment is available. Nowadays due to a

revolutionary improvement in marine structure and due to which the present study holds importance.

3 MATERIALS TO BE USED

- Cement
- M-Sand
- Coarse Aggregate
- GGBS
- Carbon Fiber

Table 3.1 Physical properties of Fine Aggregate and Coarse Aggregate

Physical properties	Fine Aggregate	Coarse Aggregate
Bulk Density (kg/m3)	1630	1386
Fineness modulus	3.99	7.53
Specific gravity	2.68	2.76

4 CONCRETE MIX DESIGN AND MIX PROPORTION

Mix Proportions: M40 grade concrete was designed as per IS 10262-2009. Quantity of materials per cubic meter of concrete and dosages of carbon fibers used are listed in Table. A constant water cement ratio of 0.36 was used.

Contents	Values (kg/m3)
Cement	439
Fine Aggregeate	662
Coarse Aggregate	1256
GGBS	175.6
Water Cement Ratio	0.36
Carbon Fiber	0.5%, 0.75% and 1 % (by volume of concrete)

4.1 MIX PROPORTIONS

Table 4.1 Designation of Specimens

MIX DESIGNATION	PROPORTION OF CEMENT AND SILICA FUME
40%GGBS + 0%CF	60% Cement +40%GGBS+ 0% Carbon Fiber
40%GGBS + 0.5%CF	60% Cement +40%GGBS+ 0.5% Carbon Fiber
40%GGBS + 0.75%CF	60% Cement +40%GGBS+ 0.75% Carbon Fiber
40%GGBS + 1.0%CF	60% Cement +40%GGBS+ 1.0% Carbon Fiber

Table 4.2 Mix Proportion

MIX DESIGNATION	CEMENT	GGBS	FINE AGGREGATE	COARSE AGGREGATE	CARBON FIBER	W/C RATIO
PROPORTION I	263	176	662	1256	0	0.36
PROPORTION II	263	176	662	1256	0.5	0.36
PROPORTION III	263	176	662	1256	0.75	0.36
PROPORTION IV	263	176	662	1256	1.0	0.36

5 TEST ON CONCRETE

5.1 COMPRESSIVE STRENGTH TEST

Compressive strength test is a mechanical test measuring the maximum amount of compressive load a material can bear before fracturing. The strength of concrete is found and determined by the crushing strength of 150mm x 150mm x 150mm, at an age of 7 and 28 days. The moulds and its base rigidly clamped together so as to reduce leakages during casting. The sides of the moulds and base plates were oiled before casting to prevent bonding between the moulds and concrete. The cube was then stored for 24 hours undisturbed.

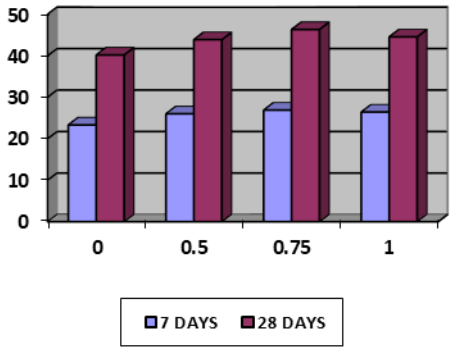
$$f_c = (P/A)\ N/mm^2$$

where,

P = Load at which the specimen fails in Newton (N)
A = Area over which the load is applied in mm
F_c = Compressive stress in N/mm^2

Table 6.1 Compressive Strength Obtained By GGBS Replacement & Addition of Carbon Fiber

CARBON FIBER	7 DAYS (N/mm^2)	28 DAYS (N/mm^2)
CF 0%	23.33	40.20
CF 0.5%	26	43.88
CF 0.75%	26.89	46.33
CF 1.0%	26.44	44.55



5.2 SPLIT TENSILE STRENGTH TEST

The determination of tensile strength of concrete is necessary to determine the load at which the concrete member cracks. In this test, cylindrical specimens of dimension 150 mm diameter and 300 mm length were cast. The specimens are tested after 7 days and 28 days. The split tension test was conducted by using digital compression machine having 2000 kN capacity.

$f_t = 2P / \pi DL\ (N/mm^2)$
where, P = Maximum Load (kN)
D = Diameter of Specimen (150 mm)
L = Length of Specimen (300 mm)
f_t = Tensile strength N/mm^2

Table 5.2 Split Tensile Strength Obtained By GGBS Replacement & Addition of Carbon Fiber

CARBON FIBER	7 DAYS (N/mm^2)	28 DAYS (N/mm^2)
CF 0%	1.98	4.01
CF 0.5%	2.35	4.35
CF 0.75%	2.65	4.82
CF 1.0%	2.45	4.62

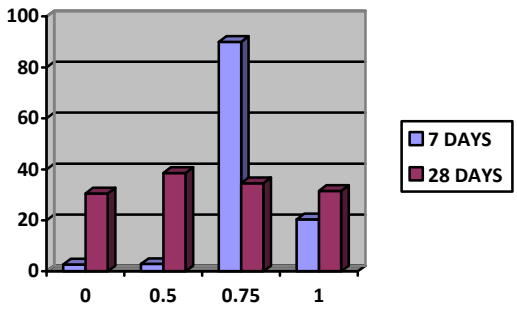


FIG 5.2 Split Tensile Strength Obtained By GGBS Replacement & Addition of Carbon Fiber

6. CONCLUSION

a. Compressive strength for 40 grade of concrete for different dosages of carbon fibers at 0.5%, 0.75% and 1.0%. The maximum percentage increase in compressive strength was achieved at 0.75% of fibre dosage and was found to reduce for 1.0% of fibre content.

b. Split tensile strength for 40 grade of concrete for different dosages of carbon fibers at 0.5%, 0.75% and 1.0%. The maximum percentage increase in split tensile strength was achieved at 0.75% of fibre dosage and was found to reduce for 1.0% of fibre content.

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