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Mechanical Properties of Self-Compacting Geopolymer Concrete Using Fly Ash and GGBS

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Abstract **- Cement is the core content for the concrete mix. Manufacturing of cement causes CO_2 emission which leads to the pollution, health and environmental problems like global warming to control over the adverse effect we can prefer geopolymer concrete which is not a cement concrete. Factory wastes such as fly ash, ground granulated blast furnace slag (GGBS), silica fume and Metakaolin can be used as alternate for cement. This study mainly focus on the ratio of fly ash and ground granulated blast furnace slag (GGBS) for optimum levels which nearly matches the cement concrete properties. This study involves the various tests like slump flow, compression testing, split tensile strength and flexural strength of self-compacting geopolymer concrete. Self-compacting concrete is a highly flowable concrete that spreads into the form without the need of mechanical vibration. Self-compacting concrete is a non-segregating concrete that is placed by means of its own weight. The advantages include improved constructability, Labour reduction, bond to steel, Flow into complex forms, reduced equipment wear etc. The aim of this study is to achieve an optimum self-compacting concrete geopolymer concrete mix proportion using fly ash and ground granulated blast furnace slag (GGBS). Then the study will be further extended by investigating the durability properties of self-compacting geopolymer concrete.**
Keywords: **Geopolymer Concrete, Fly Ash, Compressive Strength, Split Tensile Strength, Flexural Strength**

I. INTRODUCTION

Geopolymer concrete is a substantial element for conventional concrete which reduce 80% of co_2 emission and control the global warming and green house effects. For curing purpose, heat is generally applied ranging from 60^0C to 100^0Cto the geopolymer specimens for about 24–48 h and then can be left at room temperature for use. NaOH also known as caustic soda and it is low cost and wide availability. It has a specific gravity nearly 2.13.The viscosity of NaOH increases with increase in concentration and decrease slightly with temperature. NaOH is more commonly used than KOH because of cost difference. Using potassium hydroxide could be more effective and the reaction could be even faster. The self-compacting concrete maintains all concrete's durability and characteristics, meeting expected performance requirements. In certain instances the addition of super plasticizers and viscosity modifier are added to the mix, reducing bleeding and segregation. Concrete that segregates loses strength and results in honeycombed areas next to the formwork.

SCC is defined by two primary properties: Deformability and Segregation resistance. Deformability or flowability is the ability of SCC to flow or deform under its own weight (with or without obstructions). Segregation resistance or stability is the ability to remain homogeneous while doing so. High range water reducing admixtures are utilized to develop sufficient deformability. At the same time, segregation resistance is ensured, which is accomplished either by introducing a chemical VMA or by increasing the amount of fines in the concrete. Self-compacting concrete produces resistance to segregation by using mineral fillers or fines, and using special admixtures. Self-consolidating concrete is required to flow and fill special forms under its own weight, it shall be flowable enough to pass through highly reinforced areas, and must be able to avoid aggregate segregation. This type of concrete must meet special project requirements in terms of placement and flow. Self-compacting concrete with a similar water cement or cement binder ratio will usually have a slightly higher strength compared with traditional vibrated concrete, due to the lack of vibration giving an improved interface between the aggregate and hardened paste. To obtain the optimum mix proportion of Self-compacting geopolymer concrete that gives the maximum serviceability and improves the safety against environmental impacts and to reduce the cost of construction by optimizing the cement content.

A. Material Properties

1. Fly Ash

Fly ash (or) pulverized fly ash is a residue from the combustion of pulverized coal collected by mechanical separators, from the fuel gases of thermal plants. The composition varies with type of fuel burnt, load on the boiler and type of separation. The fly ash consists of spherical glassy particles ranging from 1 to 150 micron in diameter and also passes through a 45-micron sieve.

The constituents of fly ash are mentioned below.

Silicon dioxide	- SiO_2 - 30 – 60 %
Aluminum oxide	- Al_2O_3 - 15 -30 %
Unburnt fuel	- Carbon - up to 30 %
Calcium oxide	- CaO - 1-7%
Magnesium oxide	- (MgO) - small amounts
Sulphur trioxide	- (SO_3) - small amounts

2. Ground Granulated Blast Furnace Slag (GGBS)

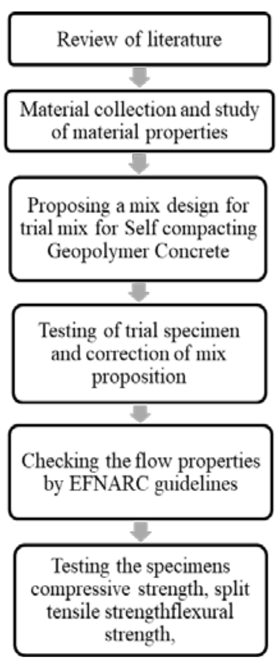
Ground granulated blast-furnace slag is a non-metallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water to form glassy sand like material. The granulated material when further ground to less than 45 micron will have specific surface about 400 to 600 m^2/kg. The chemical composition of blast furnace slag is similar to that of cement clinker.

Cao	30-45%
Sio_2	17-38%
Al_2O_3	15-25%
Fe_2O_3	0.5-2.0%
MgO	4.0-17.0%
MnO_2	1.0-5.0%
Glass	85-98%
Specific gravity	2.9

3. Super Plastisizer

The job of Super Plastisizer is to impart a high degree of flow ability and deformability, however the high dosages generally associate with SCC can lead to a high degree of segregation.In this paper Auromix300 (mixture of Super Plastisizer and VMA) is used as an admixture which improves the workability of the concrete. Super plasticizer acts as a lubricant among the materials. Generally in order to increase the workability the water content is to be increased provided a corresponding quantity of cement is also added to keep the water cement ratio constant, so that the strength remains the same.

II. METHODOLOGY



A. Tests on Self-Compacting Geopolymer Concrete FlowTest

The slump flow test is used to assess the horizontal free flow of SCC in the absence of obstructions. When the slump cone filled with concrete is lifted the concrete flows freely. The average diameter of the concrete circle is a measure for the filling ability of the concrete. The test is shown in Fig. 1. The time T_{50} cm is a secondary indication of flow. It measures the time taken in seconds from the instant the cone is lifted to the instant when horizontal flow reaches diameter of 530mm.

Fig. 1 Flow Test on Geopolymer Concrete

1. L Box Test

The passing ability is determined using the L- box test. Here the vertical section of the L-Box is filled with concrete, and then the gate lifted to let the concrete flow into the horizontal section. The height of the concrete at the end of the horizontal section is expressed as a proportion of which remains in the vertical section (H_2/H_1). This is an indication of the passing ability. The apparatus for L BOX test is shown in Fig. 2.

Fig.2 Apparatus for L BOX Test

2. V Funnel Test

The flow ability of the fresh concrete can be tested with the help of V-funnel test, where the flow time is measured, the funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus is measured. Further, T_5 min is also measured with V-funnel, which indicates the tendency for segregation, wherein the funnel can be refilled with concrete and left for 5 minutes to settle. The apparatus for V Funnel test is shown in Fig. 3 and Table 1 gives the guidelines for self-compacting concrete.

TABLE I EFNARC GUIDELINES

S.No	Property	Range
1	Slump flow by Abrams cone	530 mm
2	T50 slump flow	3sec
3	V funnel test	10 sec
4	L box test	0.85

III. MIX DESIGN

The w/c ratio of 0.45 is adoptedd for M50 grade Self-compacting geopolymer concrete. Table 2 presents concrete mix proportioning for concrete grades and for all concrete mixes respectively.

Fig. 3 Experimental setup of V Funnel Test

TABLE II MIX DESIGN VALUES

Design compressive strength MPa	50
Target mean strength MPa	58.25
coarse aggregates kg/cu.m	774.4
Fine aggregate kg/cu.m	1043.35
Fly ash (kg/cu.m)	370.67
GGBS (kg/cu.m)	158.8
Water content (kg/cu.m)	238.3
SP %	1.2
VMA%	0.2

IV. CASTING OF GEOPOLYMER CONCRETE

Nine cubes of size 150 * 150 mm were casted with different proportion of fly ash and GGBS content as a trail mix in the laboratory as shown in Fig. 4.

Fig. 4Casting of Cubes

A. Compressive Strength Results

The results of the experiments conducted for the 3 days, 7 days and 28 days cube specimens under different mix ratio of fly ash and ground granulated blast furnace slag (GGBS) is shown in Fig. 5. The cubes compressive strength was found using the compression testing machine. The average compressive strength of geopolymer concrete under various mix ratios were calculated numerically.

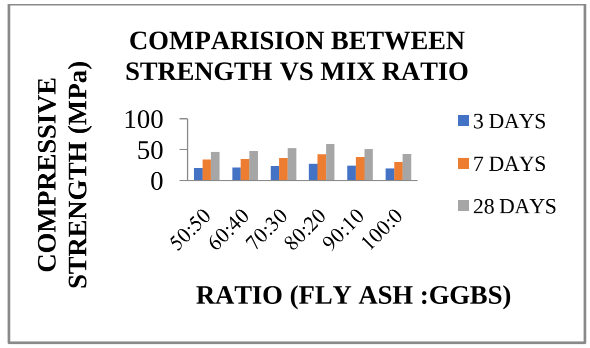


Fig. 5 Compressive Strength Values of Different Ratios

From the above experimental graph it is found that for the ratio of 80:20 (fly ash: GGBS) , M50 grade has achieved the highest compressive strength. For the above ratio (80:20), Self-compacting geopolymer specimens are casted and their mechanical properties viz. compressive strength, split tensile strength and flexural strength are calculated below.

V. MECHANICAL PROPERTIES OF SELF-COMPACTING CONCRETE

A. Compressive Strength

The compressive strength of any material is defined as the resistance to failure under the action of compressive forces. Especially for concrete, compressive strength is an important parameter to determine the performance of the material during service conditions. Fig. 6 shows the testing of cube in compression testing machine. Fig. 7 shows the compressive strength of concrete with and without gypsum.

Fig. 6 Compression Testing Machine

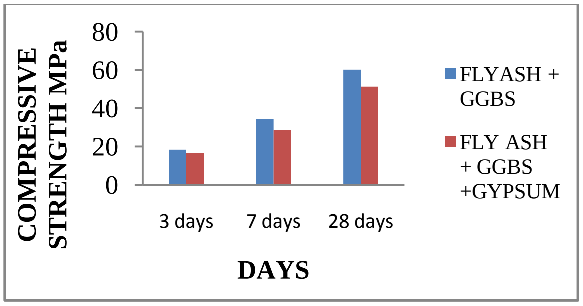


Fig. 7Compressive Strength of Concrete with and without Gypsum

B. Split Tensile Strength

Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Fig. 8 shows the testing of specimen for the tensile strength of geopolymer concrete. Fig. 9 Shows the Split tensile strength of Self Compacting Geopolymer concrete with and without gypsum.

Fig. 8 Split Tensile Test of Cylinder

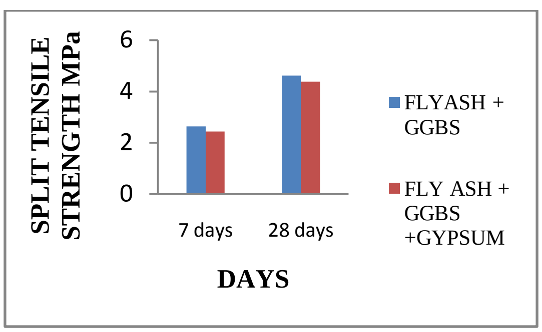


Fig. 9 Split Tensile Strength of Self Compacting Geopolymer Concrete with and without Gypsum

C. Flexural Strength

Flexure strength is the ability of a beam or slab to resist failure in bending. It is measured by loading unreinforced 150x150 mm concrete beams with a span three times the depth (usually 450mm). The flexural strength is expressed "Modulus of Rupture" (MR) in MPa. Fig. 10. represents the experimental setup for calculating the Flexural strength of prism using two point loading. Fig. 11 shows the Flexural strength of Self Compacting Geopolymer concrete with and without gypsum.

Fig. 10 Flexural Strength of Prism using Two Point Loading

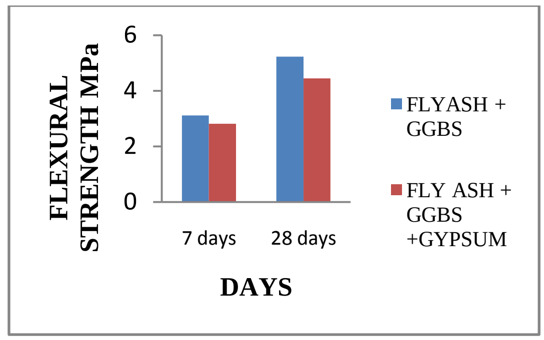
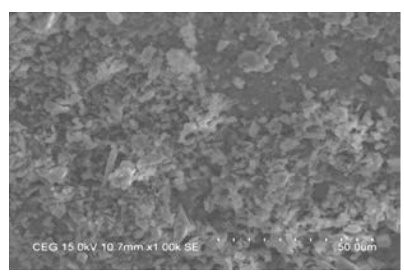


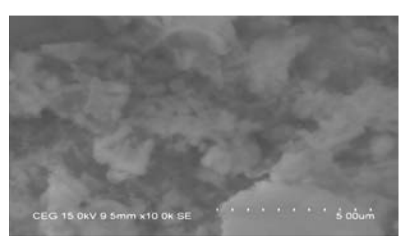
Fig. 11 Flexural strength of Self Compacting Geopolymer Concrete with and without Gypsum

VI. SCANNING ELECTRON MICROSCOPY

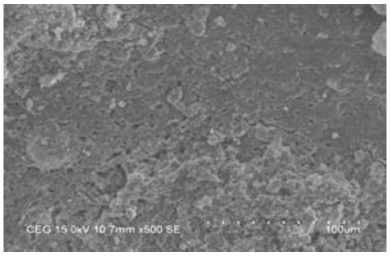
A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electron. In this self-compacting geo-polymer concrete NASH gel is formed. The scannedresults for SEM analysis is shown below in Fig. 12.



(a)



(b)



(c)

Fig. 12 SEM Analysis

VII. CONCLUSION

The segregation and bleeding of self-compacting geo-polymer concrete were checked using L-box test, V-funnel test and slump flow test are according to the guidelines of EFNARC. The results are within the limits specified by EFNARC. The mix design for M50 self-compacting geo-polymer concrete is tabulated in table 2 and also from figure 5 for fly-ash GGBS mix of 80:20 ratio gives maximum compressive strength. Gypsum is added to reduce the initial setting time of concrete. The compressive strength, split tensile strength, flexural strength of self-compacting geo-polymer concrete is calculated with and without addition of gypsum.

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