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EXPERIMENTAL STUDY ON PARTIAL CEMENT REPLACEMENT IN CONCRETE WITH METAKAOLIN AND GGBS

V.Akshana [1], P. Roshini[2], B.Aravinthan[3]

[12&3] Assistant Professor, Dept. of Civil Engineering, CMS College Of Engineering and technology, Coimbatore, Tamil Nadu

Abstract— **By product from industries is becoming an increasing concern for recycling and waste management because of the exponential growing in urbanization and industrialization. The product from blast furnace of iron and steel industries is by Ground granulated blast furnace slag (GGBS). GGBS is very useful in design and development of high quality cement paste. It effects on strength and durability properties. Concrete occupies a very important role in all types of constructions. It consists of a hard, chemically inert particulate substance. Due to increase in demand of concrete more &more new methods &materials are being developed. This paper presents the use of ground granulated blast furnace slag (GGBS) on strength development of concrete and the use of GGBS and mineral admixture metakaolin. Experimental investigation conducted by complete replacement of slag with cement and partial replacement of slag and mineral admixtures by weight in the form of 3cubes by using M30 grade. Results of GGBS with concrete are compared with the results of partial replacement of GGBS and mineral admixtures.**

A total of cubes were cast and compressive strength of the concrete specimens were determined at curing age of 3, 7, 28 days. Test results show that strength increases with the increase of slag up to optimum value and also the strength increases by adding of mineral admixture metakaolin. The study of workability of concrete with GGBS as a replacement material with and without adding of mineral admixture.

Keywords— ***ggbs , Metakaolin, compressive strength, split tensile strength, flexural strength.***

I. INTRODUCTION

Concrete is typically a massive individual material element to built environment. the energy of concrete can be used to reduce the performance or increasing the cost, significant environmental and economic benefits may be realized. Concrete is usually comprised of Portland cement, aggregates, and water. Although Portland cement typically comprises only 12% of the concrete mass, it accounts for approximately 93% of theand strength necessary for the design of the structures.

Some of the recent studies in various parts of the world have revealed that Ground granulated blast furnace slag concrete can protect the steel reinforcement more efficiently, so it can also resist corrosion. In the GGBS type of concrete the part of the

cement is replaced by ground granulated blast furnace slag that comes out as an industrial waste. Thus the implementation of GGBS can used to reduce corrosion in an effective way.

Ground granulated blast furnace slag from modern thermal power plants generally does not require processing prior to being incorporated into concrete and is therefore considered to be an environmentally free input material. When used in concrete, ground granulated blast furnace slag is a cementations 'material that can act as a partial substitution for Portland cement without significantly compromising the compressive strength. An attempt is made to study the suitability of Mineral

admixture as metakaolin and its effect on the properties of the concrete. Concrete mixes were made using Ordinary Portland cement alone as Control and also replacing cement by 10%, 20%, and 30% of metakaolin. The physical properties and compressive strength of Concrete were measured.

I. THE ADVANTAGES AND DISADVANTAGES OF CONCRETE ARE MENTIONED BELOW:

A. GGBS:

The GGBS which is an abbreviated form of "Ground Granulated Blast furnace Slag" is a by- product from the blast furnaces that are used in making iron. They are operated at a very high temperature of 1500 degrees and are mixed with iron ore, limestone and coke. The main motive of the present civil engineers is to find alternative construction materials and thus leading us to deal with GGBS. Although it is a by-product, the use of it in correct proportions to an extent serves as a great initiative to support green environment and on the contrary it also retains the strength of the concrete without degrading its properties.

B. METAKAOLIN:

It is a form de-hydroxylated aluminumsilicate. It is an amorphous non-crystallized material. Researchers have proved that using Metakaolin, which is a very effective pozzolanic material, enhances the strength properties of concrete. It also reduces the hardened cement permeability to liquids, gases. Replacing small quantities of Portland cement with Metakaolin reduces carbon dioxide emissions, but also increases the serviceability of buildings to a large extent. Thus it led us to the use of this chemical compound "metakaolin" as a replacement cementieous material in normal concrete.

II. LITERATURE REVIEW

However, wild and khatib reported results on strength development of concrete, where cement was partially replaced with MK (5% to 30%), while sabir el al (2006) carried out the review regarding the use of the claimed clays and metakaolin as Pozzolanas for concretes. Further the compressive tests on the GGBS and MK are not reported so far

Sabir B.B. et.al (2014) described the partial replacement of cement with the Metakaolin in concrete and mortar which cause great improvement in the pore structure and hence resistance of concrete to harmful solutions. This paper also demonstrated clearly that MK is very effective pozzolanas and result in enhanced early strength with no detriment to, and some improvement in the long term strength of mortar and concrete. It greatly improves the resistance to the transportation of water and diffusion ions which lead to degradation of matrix.

John N. (2013) investigates the effects of Metakaolin on strength of concrete. The inclusion of Metakaolin leads to faster early age strength development of concrete. For all Metakaolin admixed concrete overs the strength of OPC. Mixed with 15% Metakaolin is superior to all other mixes. The increase in Metakaolin content improves the compressive strength, Split Tensile Strength and Flexural Strength up to 15% replacement. Arunakanthi E. et.al (2013) described the effect of chemical environment on High performance concrete with Metakaolin in which Ordinary Portland cement is partially replaced by 20% of Metakaolin by weight and chemical environment is simulated by subjecting the concrete to different concentrations of Magnesium sulphate in de-ionized water during mixing and curing. The results indicate that the compressive strength and split tensile strength decrease with the decrease in concentration of Magnesium sulphate when compared with concrete without Magnesium sulphate in mixing and curing water.

D. Suresh and K. Nagaraju in a review concluded that the movement of moisture of GGBS mixes, probably due to the dense and strong microstructure of the interfacial aggregate/binder transition zone is probably responsible for the high resistance of GGBS mix to attack in aggressive environments such as silage pits. GGBS is a good replacement for cement in some cases and serves effectively but it can't replace cement completely. But even though it replaces partially it gives very good results and a greener approach to construction and sustainable development which we are engineers are keen about today. Dr. P. Muthupriya, "An experimental investigation on effect of GGBS and glass fiber in high performance concrete", International journal of civil engineering and technology (IJCIET), volume4, issue4 in 2013

S.Revathy et.al (2019) investigating characteristics of concrete with partial replacement of cement with Ground Granulated Blast furnace Slag (GGBS). This usage of GGBS serves as replacement to already depleting conventional building materials and the recent years and also as being a byproduct it serves as an Eco Friendly way of utilizing the product without dumping it on ground.Maximum compressive strength obtained for replacement of cement by 40% GGBS. Due to increase in compressive strength this replacement is used in the construction of prefabrication structures.

Suriya Mani et.al(2020) The replacement of cement byGround Granulated Blast-Furnace slag (GGBS) is investigated by compressive strength, flexural strength and Split Tensile strength to increase the strength parameter based on durability test. From the Compressive strength of concrete, 40% replacement of GGBS is higher than the normal concrete. From the flexural strength of concrete,40% replacement of GGBS is higher than the normal concrete. The natural sand demand also reduced by introducing theM-sand as it provides greater strength and being economical. Inhigh performance concrete also 40% replacement gives efficient strength. The strength will be reduced after40%replacement of GGBS

Poonelal (2006) studied the mechanical and durability properties of high performance MK concrete to silica fume concretes found that the performance of MK used in the study was superior to silica fume in terms of strength development.

III. MATERIALS USED:

In this project the materials used are 53 OPC Cement, M.sand, GGBS, Metakaolin, Coarse Aggregate and Water

A. Cement:

Cement is usually available in powder form and it turns into a paste when mixed with correct proportions of water. This forms the primary constituent of concrete.

TABLE 3.1

S.No	Chemical Composition	%
1	Cao	61-67
2	Sio_2	19-23
3	Ai_2O	2.5-6
4	Fe_2O_3	0-6
5	So_3	1.5-4.5

TABLE 3.2

S.No	Property	Results
1	Brand of cement	53 OPC grade
2	Initial setting time (in min)	30
3	Final setting time (in min)	600
4	Specific gravity	3.15

B. Fine aggregate:

Sand is the next main material used in concrete after cement. It is fine in nature and hence called as fine aggregate. The sand is collected at the nearby source and sieved through 4.75mm sieve.

TABLE 3.3

Properties	Results
Specific gravity	2.613
Fineness modulus	2.72

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C. *Coarse aggregate:*

The material which is used in the concrete which is of size 2/16" is called as the coarse aggregate

TABLE 3.4

Specific gravity	2.625
Fineness modulus	6.15

D. *GGBS*

GGBS is granular material formed when molten iron blast furnace slag is rapidly chilled by immersion of water. Water has a very limited crystal formation because it is granular product, is highly cementations in nature and, ground to cement fines, and hydrates like Portland cement.

TABLE 3.5

PROPERTIES	RESULTS
Specific gravity	2.55
Fineness of GGBS	0.29

E. *METAKAOLIN:*

Metakaolin (POZZOFILZ) is an SCM that conforms to ASTM C618 and Class N pozzolanic specifications.
POZZOFILZ HRM is derived from a naturally occurring mineral and is produced under carefully controlled conditions to refine its color, remove inert impurities, and tailor particle size such that much higher degree of purity And pozzolanic reactivity can be obtained. This range improves many properties of concrete while also reducing cement consumption.

TABLE 3.6

S.No	Chemicals	%
1	Sio2	33.77
2	Cao	33.77
3	Al2O3	13.24
4	Mgo	8.46
5	Fe2O3	0.65

IV. PREPARATION OF TESTING SPECIMEN:

i) CASTING OF THE SPECIMENS

The present experimental work includes casting and testing of specimens to know the compressive strength of cubes. These concrete cubes are casted and tested as per IS 516-1959 specifications.

The specimens are casted for the following:

1. M30 grade concrete.
2. M30 grade concrete with OPC (800gms) + 10% GGBS (100grms) +10% MK (100grms)
3. M30 grade concrete with OPC (600gms) + 20% GGBS (200grms) + 20% MK (200grms)
4. M30 grade concrete with OPC (400gms) + 30% GGBS (300grms) + 30% MK (300grms)

V. TEST RESULTS AND DISCUSSION:

The test is carried out on one concrete cube, cylinder and beam which are casted by the above mentioned raw materials and they are tested on 3rd, 7th and 28th days.

i) Compresssive Strength

Compressive strength test is done to check the load with holding capacity of the cube in other words it is the test done to check the strength of a cube by applying load on it until it cracks .The cube of 150x150x150mm dimensions is taken and kept in a compressive testing machine (CTM) where the cube is placed in between two surfaces.
Compressive strength in N/mm2

TABLE 5.1

S.NO	Mix Proportions	7th day	28th day
1	NM	2.6	2.86
2	MK & GGBS1	15.5	33.30
3	MK & GGBS2	16.7	34.31
4	MK & GGBS3	18.8	35.33
5	MK & GGBS4	17.6	34.32

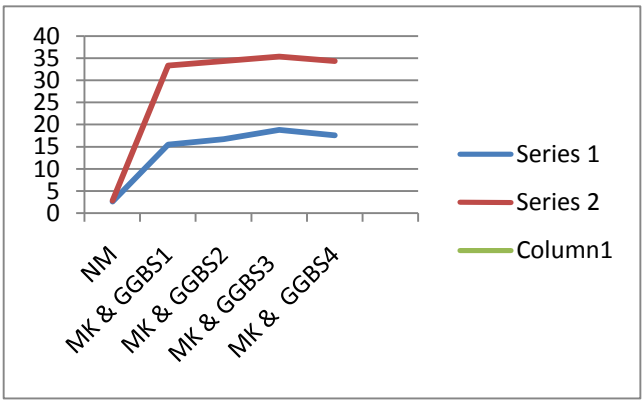

FIG 1:

ii) *Split Tensile Strength*:

After curing of Beam specimens they are placed in testing machine having a maximum capacity of 40 tonne. The load is applied on the beam specimens. The specimen is failed at ultimate load which is noted from dial gauge reading. From the result flexural strength is increased with respect to the grade of concrete when adding 30 % of MK and 30% of GGBS when compared to the conventional concrete. Flexural strength is property of the hardened concrete. The RCC Beams were casted, cured and tested accordance with the IS standard and 7,14 and 28 days

TABLE 5.2

S.No	Mix Proportions	7th day	28th day
1	NM	2.8	2.89
2	MK & GGBS1	3.33	3.52
3	MK & GGBS2	3.41	3.65
4	MK & GGBS3	3.48	3.76
5	MK & GGBS4	3.44	3.69

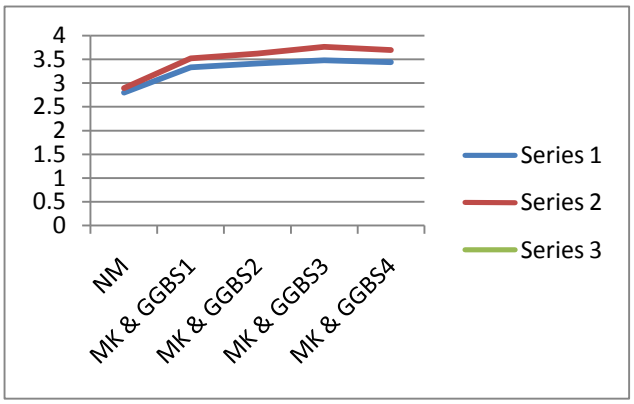

FIG 2:

iii) *Flexural Strength:*

After curing of Beam specimens they are placed in testing machine having a maximum capacity of 40 tonne. The load is applied on the beam specimens. The specimen is failed at ultimate load which is noted from dial gauge reading. From the result flexural strength is increased with respect to the grade of concrete when adding 30 % of MK and 30% of GGBS when compared to the conventional concrete.

TABLE 5.3

S.NO	Mix Proportions	7th day	28th day
1	NM	4.09	5.11
2	MK & GGBS1	4.31	5.24
3	MK & GGBS2	4.42	5.32
4	MK & GGBS3	4.56	5.46
5	MK & GGBS4	4.52	5.38

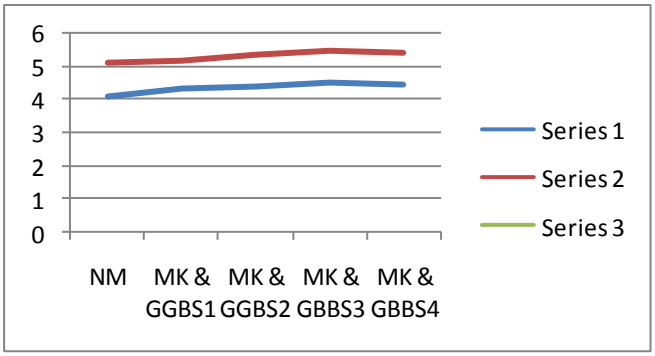

FIG 3:

CONCLUSIONS:

- The strengths achieved in concrete made with percentage use of GGBS and MK achieved high strengths when compared with cement.
- Super plasticizer named is used to attain workability and water cement ratio.
- At 28 days curing, the 30% replacement of cement with GGBS and MK gave very high strength.
- Thus the workability is improved by the partial replacement of the GGBS and Metakaolin with cement.
- As GGBS and Metkaolin is partially replaced with the cement, the consumption of the cement is reduced and also the cost of construction is reduced.

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