VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"Jnana Sangama", Belgaum-590014

A Dissertation Project Report on

"PARTIAL REPLACEMENT OF CEMENT WITH MINERAL ADMIXTURES FOR MECHANICAL PROPERTIES OF CONCRETE WITH MICROSTRUCTURAL ANALYSIS"

Submitted in partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING IN CIVIL ENGINEERING

BY

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CMR INSTITUTE OF TECHNOLOGY ITPL MAIN ROAD BENGALURU-560 037

2019-2020

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Department of Civil Engineering

Certificate

This is to certify that the project work entitled ***"PARTIAL REPLACEMENT OF CEMENT WITH MINERAL ADMIXTURES FOR MECHANICAL PROPERTIES OF CONCRETE WITH MICROSTRUCTURAL ANALYSIS"*** *has been successfully completed by Mr. RUDRESH K P (USN 1CR16CV051), Ms. SHALINI S (USN 1CR16CV058), Mr. SRINIVAS N EDARA (USN1CR16CV063), Mr. SUNDAR KANTH V (USN 1CR16CV065) bonafide students of CMR Institute of technology in partial fulfilment of the requirement for the award of degree of Bachelor of Engineering in Civil Engineering of the "VISVESVARAYA TECHNOLOGICAL UNIVERSITY", Belgaum during the academic year 2019-20. It is certified that all corrections indicated for internal assessment has been incorporated in the Report. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said Degree.*

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DECLARATION

We**, Mr. Rudresh K P, Ms. Shalini S , Mr. Srinivas N Edara , Mr. Sundar Kanth V** bonafide students of CMR Institute of Technology, Bangalore, hereby declare that dissertation entitled **"Partial Replacement Of Cement With Mineral Admixture For Mechanical Properties Of Concrete With Microstructural Analysis"** has been carried out by us under the guidance of Dr. Nagendra (HOD) Department of Civil Engineering**, CMR Institute of Technology, Bangalore**, in partial fulfilment of the requirement for the award of degree of Bachelor of Engineering in **Civil Engineering** of the Visvesvaraya Technological University, Belgaum during the academic year 2019-2020. The work done in this dissertation report is original and it has not been submitted for any other degree in any university.

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ABSTRACT

Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. Concrete plays a vital role in the development of infrastructure, buildings, industrial structures, bridges and highways etc. leading to utilization of large quantity of concrete. On the other side, cost of concrete is attributed to the cost of its ingredients which is scarce and expensive, this leading to usage of economically alternative materials in its production. This requirement is drawn the attention of investigators to explore new replacements of ingredients of concrete.

The construction industry plays a vital role in India's development and it contributes about 8-10 per cent to GDP on an average. Developing nations like India need to have faster construction with high quality, durability and a pollution-free environment, which can be achieved only with Ready mix concrete (RMC).

The present technical report focuses on investigating characteristics of concrete with partial replacement of cement with Ground Granulated Blast Furnace Slag (GGBS). The topic deals with the usage of GGBS and advantages as well as disadvantages in using it in concrete. This usage of GGBS serves as replacement to already depleting conventional building materials and the recent years and also as being a by-product it serves as an Eco Friendly way of utilizing the product without dumping it on ground.

The microstructure study of concrete is conducted with help of scanning electron microscopy (SEM) and energy dispersive spectrometer (EDS), to find the percentage of consumption of various elements before and after the reactions.

The investigation presents the effect of Ground Granulated Blast Furnace Slag (GGBS) and their proportion in concrete with particular size of particle passing through a set of sieves with different dosages. GGBS effect was studied as replacement to cement in varied proportions of 10, 20, 30 and 40%.

CONTENTS

1. INTRODUCTION:

Admixtures are the integral part of modern concrete. The advances in construction industry have contributed tremendously for the new developments in admixtures. The use of various admixtures in concrete alters the fresh properties (Workability) and hardened properties (Strength) and durability. Due to the vast construction activities, different grades of concrete with natural and artificial ingredients are in use. In the preparation of concrete, a number of mineral and chemical admixtures are used in addition to the standard ingredients. The dosage of these admixtures is comparatively more in READY MIX CONCRETE.

Usage of six components namely, coarse aggregate, fine aggregate, water, Ordinary Portland cement with mineral admixture/blended cement and plasticizer for production of engineered concrete, instead of non-engineered/semi-engineered concrete production with four components, can make concrete sustainable in India. Mineral admixture such as Alco fine, Micro silica, Rice husk ash, Fly ash, ground granulated blast furnace slag (GGBS), are commonly used in concrete to enhance the concrete properties.

Ground Granulated Blast Furnace Slag (GGBS) is a by-product from the blast furnaces used to make iron. These operate at a temperature of about 1500 degrees centigrade and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials from a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimises the cementitious properties and produces granules similar to coarse sand. This granulated slag is then dried and ground to a fine powder.

Granulated blast furnace slag is defined as a non-metallic product consisting essentially of glass containing silicates and alum inosilicates of lime and other bases which is developed simultaneously with iron in blast furnace. Granulated blast furnace slag is obtained by further processing the molten slag by rapidly chilling or quenching with water or steam.

GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. GGBS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years.

Uses of GGBS The major use of GGBS is in ready mixed concrete, and it is utilised in a third of all UK ready-mix deliveries. Specifiers are well aware of the technical benefits, which GGBS imparts to concrete, including.

- Better workability, making placing and compaction easier.
- Lower early age temperature rise, reducing the risk of thermal cracking in large pours.
- High resistance to chloride ingress, reducing the risk of reinforcement corrosion
- High resistance to attack by sulphate and other chemicals
- Considerable sustainability benefits.

The disadvantage of the higher replacement level is that early age strength development is somewhat slower. GGBS is also used in other forms of concrete, including site-batched and precast. Unfortunately, it is not available for smaller-scale concrete production because it can only be economically supplied in bulk. GGBS is not only used in concrete and other applications include the in-situ stabilisation of soil.

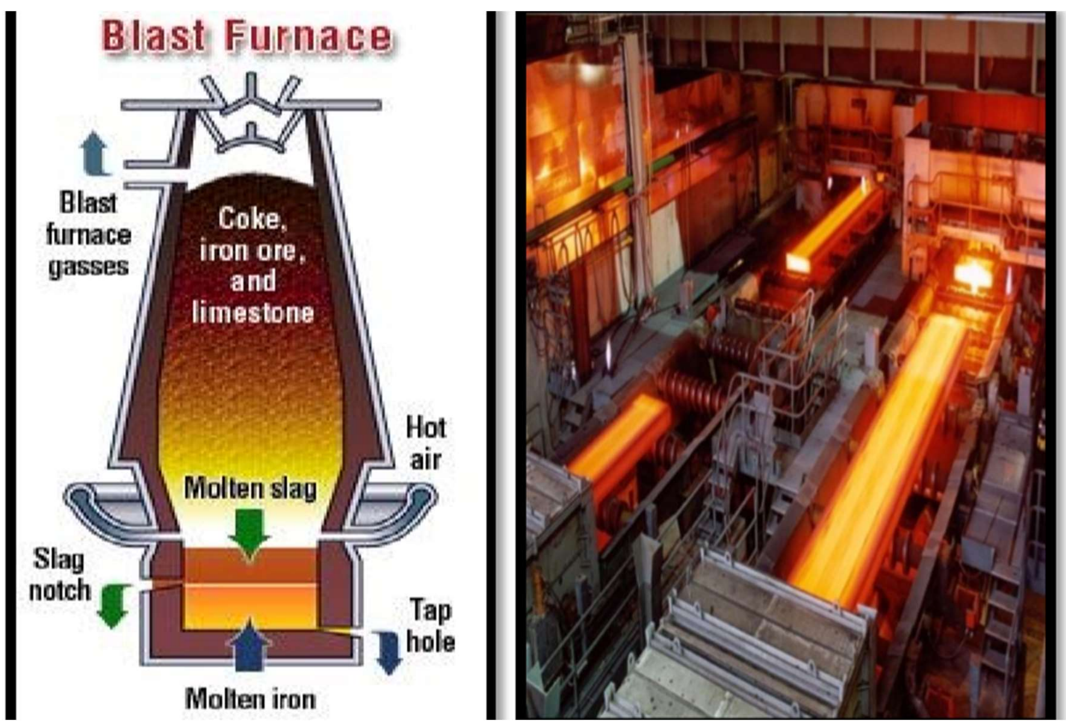


Fig.1 Sources of Ground Granulated Blast Slag

2. MATERIALS:

For this experimental investigations the following materials with their properties mentioned in the table are adopted.

Cement: Ordinary Portland cement (OPC) of grade 53 with physical and chemical properties, as presented in Table 1 and 2 are used. It has been certified with IS: 12269-1987, grade 53 which is known for its rich quality and high durability issued.

Specific gravity	2.15
Bulk Density	1870 kg/m^3
Surface Area	330 m^2/kg

Table 1 Physical Properties of cement

CaO	SiO_2	Al_{203}	Fe_{203}	MgO	SO_3	P_{205}	K_{20}	Na_{20}	TiO_2
60.54	16.64	6.55	5.78	2.52	1.79	1.87	2.53	1.40	0.38

Table 2 Chemical Properties of cement

Coarse Aggregate: Aggregate Maximum size of coarse aggregates which will be used of size 20mm and 12mm. well graded cubical aggregates are desirable. Aggregates should be uniform quality with respect to shape and grading. The properties of the coarse aggregate tested in accordance with IS 2386:1963.

M-sand: Fine aggregate used in the study is M-sand of grade II. Grading must be uniform throughout the work and must pass through 4.75mm sieve size which confirms to the code IS: 383-1970.

Water: Portable water available locally is used for mixing and curing of the specimens.

Ground Granulated Blast Furnace Slag (GGBS): The GGBS utilized in the experiments is obtained from JSW Steel, Dickenson Rd, Sivanchetti Gardens, Bengaluru, Karnataka, which is shown in Fig. 2. The properties of GGBS is presented in the Table 3 and 4.

Fig. 2 JSW GGBS

Specific gravity	2.65
Bulk Density	1250 kg/m³
Surface Area	415 m²/kg

Table 4 Physical Properties of GGBS

Binder	SiO_2	Cao	Al_2O_3	Mgo	Mno	Fe_2O_3	Sulphide sulphur	Sulphite sulphur	Total chlorides
GGBS	33.87	33.68	13.35	8.75	0.09	0.75	2.15	0.35	0.02

Table 3 Chemical Properties of GGBS

COMPRESSION TESTING MACHINE: Compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to which withstands loads tending to elongate. In other words, compressive strength resists being pushed together. (Cubes of 150X150X150mm are used).

SCANNING ELECTRON MICROSCOPE (SEM): It is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample. The electron beam is scanned in a raster scan pattern, and the position of the beam is combined with the intensity of the detected signal to produce an image.

ENERGY-DISPERSIVE SPECTROSCOPY (EDS): It is an analytical technique used for the elemental analysis or chemical characterization of a sample. It relies on an interaction of some source of X-ray excitation and a sample. Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing a unique set of peaks on its electromagnetic emission spectrum (which is the main principle of spectroscopy).

Fig 4 SEM and EDS Analytic Service

3. EXPERIMENTAL PROGRAM:

The mix proportioning was carried out as per IS 10262:2009 code. First preliminary tests are conducted in fine aggregate, coarse aggregate and cement. The tests include particle size distribution of fine aggregate and coarse aggregate, specific gravity of cement, fine aggregate, coarse aggregate.

Due to Covid 19 we could not able to complete the project and we could not able to check compression strength for 28 days. The consistency, initial and final setting time of cement is being recorded. The test data of the material is obtained, the concrete mix design for M40 grade is designed using IS 10262 -2019 and IS 456-2000 codes.

The first approach for 10%(1.36kg) of GGBS. volume of cement 12.48 kg with water cement ratio 0.45, 5.55 kg water, 20.35 kg cum crushed 20 mm aggregate, 13.54 kg of 12.5 mm aggregate, 18.74 kg of M sand and an admixture of 12.4 g.

The second approach for 20% (2.77kg) of GGBS. volume of cement 11.08 kg with water cement ratio 0.45, 5.55 kg water, 20.32 kg cum crushed 20 mm aggregate, 13.54 kg of 12.5 mm aggregate, 18.68 kg of M sand and an admixture of 10.9 g.

The third approach for 30%(4.15kg) of GGBS. volume of cement 9.69 kg with water cement ratio 0.45, 5.55 kg water, 20.32 kg cum crushed 20 mm aggregate, 13.54 kg of 12.5 mm aggregate, 18.68 kg of M sand and an admixture of 9.5g.

The fourth approach for 40%(5.54kg) of GGBS. volume of cement 8.31 kg with water cement ratio 0.45, 5.55 kg water, 20.32 kg cum crushed 20 mm aggregate, 13.54 kg of 12.5 mm aggregate, 18.68 kg of M sand and an admixture of 8.35g.

One set of cubes will be casted for M40 grade of concrete for nominal mix design and kept curing for 7,14,21,28 days totally 12 number of cubes are casted. By adding GGBS partially replacing cement with 10, 20,30 and 40 percentages will be casted and kept curing for 7,14,21 days.

These specimens are tested by compression testing machine after 7days ,14days, 21days.

GGBS is a fine powder that may cause mechanical irritation to the eyes and respiratory system, if appropriate dust control measures are not implemented. Manufacturers and suppliers of GGBS provide Safety Information Sheets to enable appropriate risk management measures to be identified and applied.

RESPIRATORY PROTECTION

Where practicable, dust exposure should be controlled by engineering methods. Otherwise, suitable respiratory protection should be worn to ensure that personal exposure is less than the WEL.

HAND PROTECTION

Waterproof gloves should be worn, particularly when handling any GGBS/water mixture, eg, concrete or mortar.

EYE PROTECTION

Dust-proof goggles should be worn wherever there is a risk of GGBS powder or any GGBS water mixture entering the eye.

SKIN PROTECTION

Protective clothing should be worn which ensures that GGBS or any GGBS/water mixture eg, concrete or mortar, does not come into contact with the skin. In some circumstances such as when laying concrete, waterproof trousers and Wellingtons may be necessary. Particular care should be taken to ensure that wet concrete does not enter the boots and persons do not kneel on the wet concrete so as to bring the wet concrete into contact with unprotected skin. Should wet mortar or wet concrete get inside boots, gloves or other protective clothing then this should be immediately removed and the skin Thoroughly washed as well as the protective clothing/footwear.

HAZARD IDENTIFICATION GGBS

It is a fine powder, which can cause mechanical irritation to the eyes and respiration system. When mixed with water, the resultant liquid will gradually become alkaline with a pH up to 12. GGBS may be hot when delivered in bulk.

4. RESULT AND DISCUSSION:

COMPRESSIVE STRENGTH FOR CONTROL MIX:

For M 40 grade concrete, the cubes were cast and tested after 7, 14 and 21 days without adding any admixtures, results of which are tabulated in the table 5.

Sl.No	Particulars	7 Days	14 Days	21 Days
1	Compression strength (N/mm^2)	25.1	34.2	38.9

Table 5 Compression strength of Control mix

EFFECT ON COMPRESSIVE STRENGTH AT DIFFERENT PERCENTAGE REPLACEMENT OF GGBS

The partial replacement of cement is conducted with mineral admixture as GGBS with percentage ranging from 10% to 40%.

EFFECT ON COMPRESSIVE STRENGTH AT 10% REPLACEMENT OF GGBS

The percentage increase in strength, when compared with control mix is slightly higher. The compressive strength for 3 different days is presented in the below table 6. From table 6 it is observed that the compressive strength was increased by adding 10% of GGBS. This was noticed for all the days of testing i.e. 7, 14 and 21 days. At 7 days the compressive strength is i.e. 28.4 N/mm² and at 14 and 21 days, the highest values of compressive strength were observed the values are 36.1 N/mm² and 40.1N/mm².

Sl.No	Particulars	7 Days	14 Days	21 Days
1	Compression strength (N/mm²) for 10% of GGBS	28.4	36.1	40.1

Table 6 compression strength of replacing cement with GGBS by 10%

EFFECT ON COMPRESSIVE STRENGTH AT 20% REPLACEMENT OF GGBS

The percentage increase in strength, when compared with control mix is slightly higher. The compressive strength for 3 different days is presented in the below table 7. From table 7 it is observed that the compressive strength was increased by adding 20% of GGBS. This was noticed for all the days of testing i.e. 7, 14 and 21 days. At 7 days the compressive strength is i.e. 31.1 N/mm² and at 14 and 21 days, the highest values of compressive strength were observed the values are 37 N/mm² and 42.1N/mm².

Sl.No	Particulars	7 Days	14 Days	21 Days
1	Compression strength (N/mm²) for 20% of GGBS	31.1	37	42.1

Table 7 compression strength of replacing cement with GGBS by 20%

EFFECT ON COMPRESSIVE STRENGTH AT 30% REPLACEMENT OF GGBS

The percentage increase in strength, when compared with control mix is slightly higher. The compressive strength for 3 different days is presented in the below table 8. From table 8 it is observed that the compressive strength was increased by adding 30% of GGBS. This was noticed for all the days of testing i.e. 7, 14 and 21 days. At 7 days the compressive strength is i.e. 32.2 N/mm² and at 14 and 21 days, the highest values of compressive strength were observed the values are 36.5 N/mm² and 41.1N/mm².

Sl.No	Particulars	7 Days	14 Days	21 Days
1	Compression strength (N/mm²) for 30% of GGBS	32.2	36.5	41.1

Table 8 compression strength of replacing cement with GGBS by 30%

EFFECT ON COMPRESSIVE STRENGTH AT 40% REPLACEMENT OF GGBS

The percentage increase in strength, when compared with control mix is slightly higher. The compressive strength for 3 different days is presented in the below table 9. From table 9 it is observed that the compressive strength was increased by adding 40% of GGBS. This was noticed for all the days of testing i.e. 7, 14 and 21 days. At 7 days the compressive strength is i.e. 30 N/mm² and at 14 and 21 days, the highest values of compressive strength were observed the values are 35.3 N/mm² and 40.1 N/mm².

Sl.No	Particulars	7 Days	14 Days	21 Days
1	Compression strength (N/mm²) for 40% of GGBS	30	35.3	40.1

Table 9 compression strength of replacing cement with GGBS by 40%

As we have seen from results GGBS is a good replacement to 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 in construction and sustainable development which we are engineers are keen about today.

Due to the GGBS we have observed minimal water demand and due to slower reaction rate of early hydration. The slower hydration rates help to lower early heat generation thereby reducing the incidences of early thermal cracking.

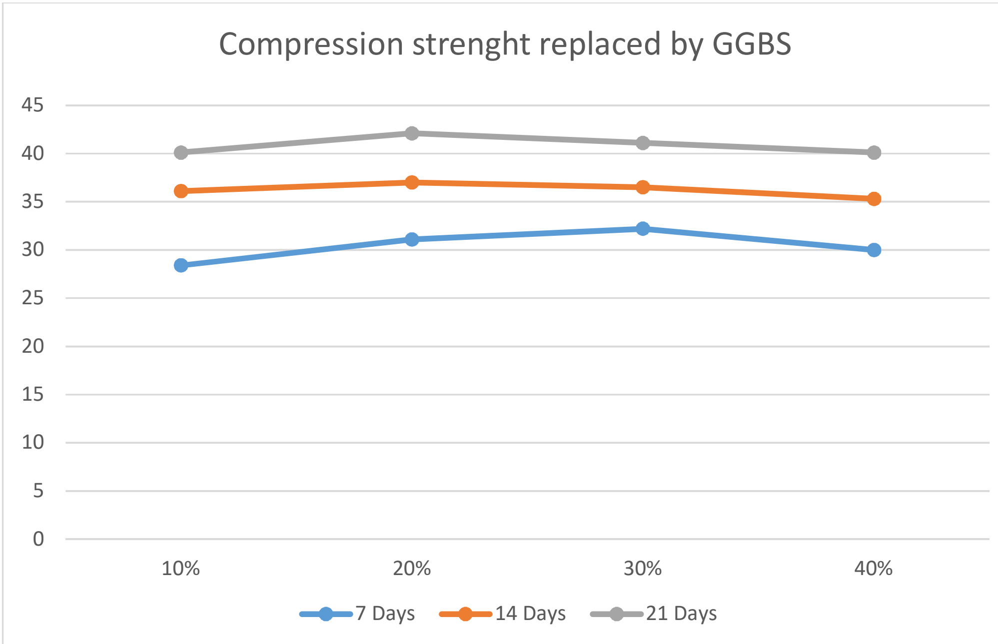
Higher replacement of GGBS increases the setting time of concrete but it does have some adverse effect on the final product. 20% to 40% GGBS may be best to ensure high early strength.

The compressive strength for M40 grade of concrete was found to maximum at 20% replacement of cement with GGBS when compared with 10%, 30% and 40 % replacement of cement with GGBS.

Total results of compression strength

Sl.No	Particulars	7 Days	14 Days	21 Days
1	Compression strength for control mix	25.1	34.2	38.9
Percentage of replacement of GGBS	Compression strength for Design mix			
10%		28.4	36.1	40.1
20%		31.1	37	42.1
30%		32.2	36.5	41.1
40%		30	35.3	40.1

Table 10 All result of compression strength



X-axis = percentage cement replacing with GGBS

Y-axis = N/mm²

Chart 1

From the investigations we also noted, the particle sizes, which is observed from the SEM (scanning electron microscope) and EDS (energy-dispersive spectroscopy) of GGBS, cement, M sand.

Fig. 5 shows the SEM image for cement, the particles are both spherical and non-spherical in appearance. Fig. 6 shows the EDS/EDXA for cement, the various elements and compounds present are detailed as percentage weight or atomic weight in the Table 11.

As shown in table, silica present in cement is 17.41% and calcium is 54.36% by weight, with these two elements as datum, the investigations is done to know the pozzolanic reactions that takes place before and after the replacement of admixture in concrete.

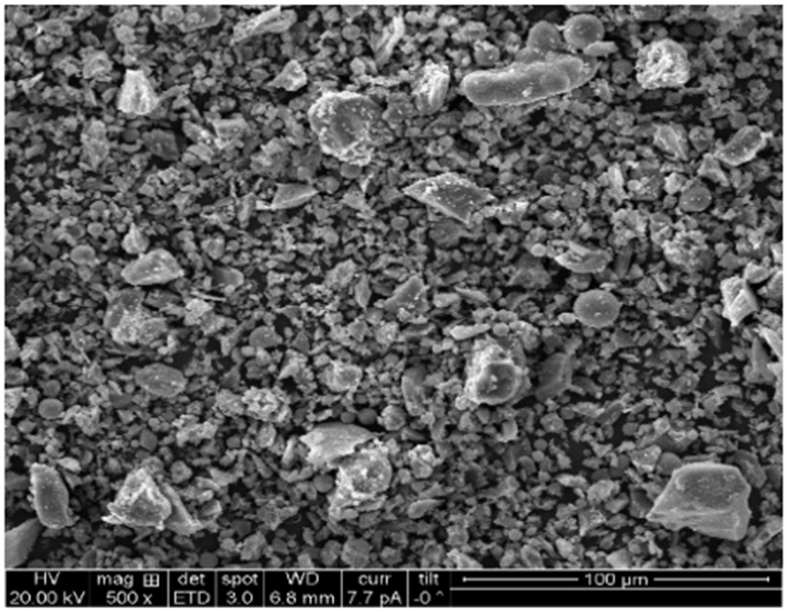


Fig. 5 SEM image of cement

Elem	Wt %	At %	K-Ratio	Z	A	F
O K	9.57	19.19	0.0144	1.0714	0.1404	1.0003
MgK	0.65	0.86	0.0040	1.0229	0.5971	1.0056
AlK	6.86	8.16	0.0498	0.9946	0.7232	1.0084
SiK	17.41	19.89	0.1393	1.0249	0.7759	1.0061
S K	3.63	3.63	0.0310	1.0106	0.8315	1.0158
K K	1.66	1.37	0.0163	0.9679	0.9432	1.0744
CaK	54.36	43.53	0.5165	0.9889	0.9593	1.0014
FeK	5.85	3.36	0.0505	0.8941	0.9663	1.0000
		Total	100.00	100.00		

Z, A and F are corrections applied; Z- Atomic number; A-Absorption number; F-Fluorescence

Table 11

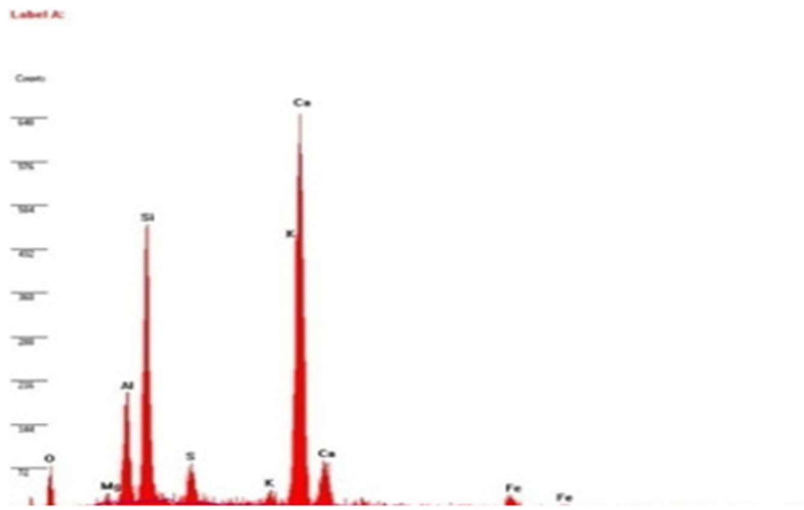


Fig. 6 EDS of cement

Fig. 7. Shows the particles appear angular in shape, which helps in better bonding of particles in the concrete mix. Fig. 8. Shows the EDS for M-sand, the peak for silica as the maximum content. The values (52.87%) can be observed in Table 12.

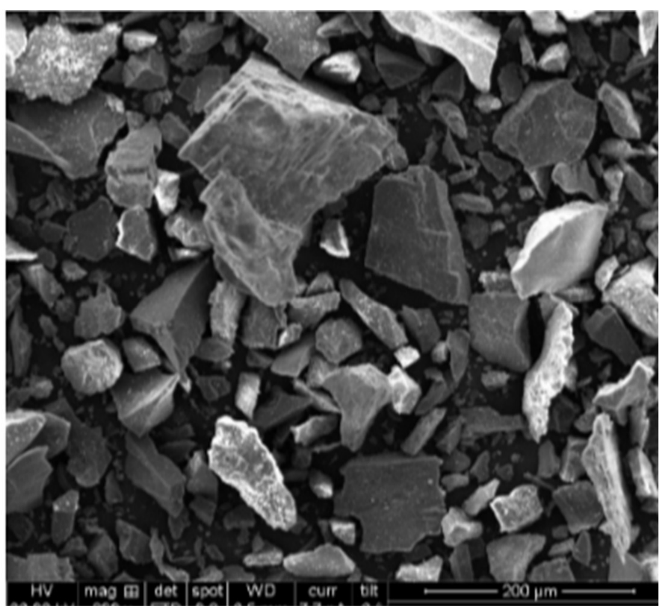


Fig.7 SEM of M sand

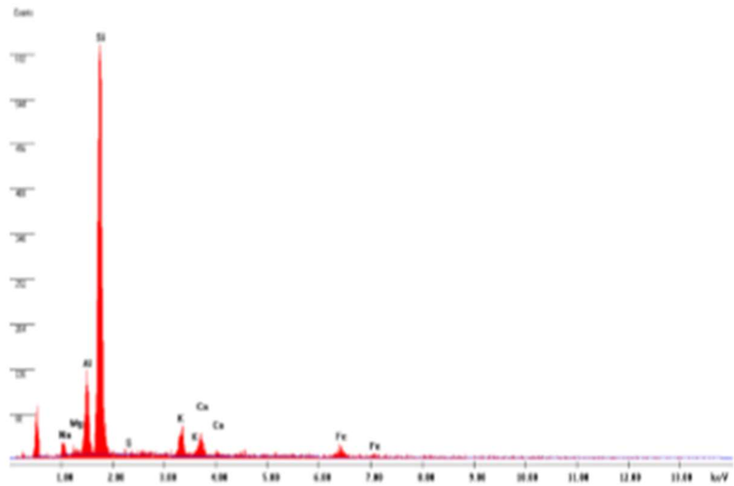


Fig. 8 EDS of M sand

Elem	Wt %	At %	K-Ratio	Z	A	F
O K	12.77	22.02	0.0350	1.0626	0.2578	1.0008
NaK	1.89	2.27	0.0104	0.9911	0.5495	1.0058
MgK	0.71	0.80	0.0050	1.0149	0.6809	1.0117
AlK	8.75	8.94	0.0695	0.9853	0.7916	1.0187
SiK	52.87	51.91	0.4342	1.0131	0.8097	1.0013
S K	0.34	0.29	0.0024	1.0004	0.7071	1.0031
K K	7.22	5.09	0.0621	0.9588	0.8911	1.0065
CaK	5.33	3.67	0.0474	0.9795	0.9053	1.0026
FeK	10.12	5.00	0.0884	0.8840	0.9880	1.0000
		Total	100.00	100.00		

Table 12

Fig. 8 and 9 shows the SEM and EDS for GGBS. Fig. 8 shows the SEM image for GGBS, the particles appear here are also angular in shape. EDS for GGBS is shown in Fig. 9 when analyzed in energy dispersive spectrometer (EDS), before mixing in concrete, shows the two peaks, they are silica 29.51% and calcium 44.74%.

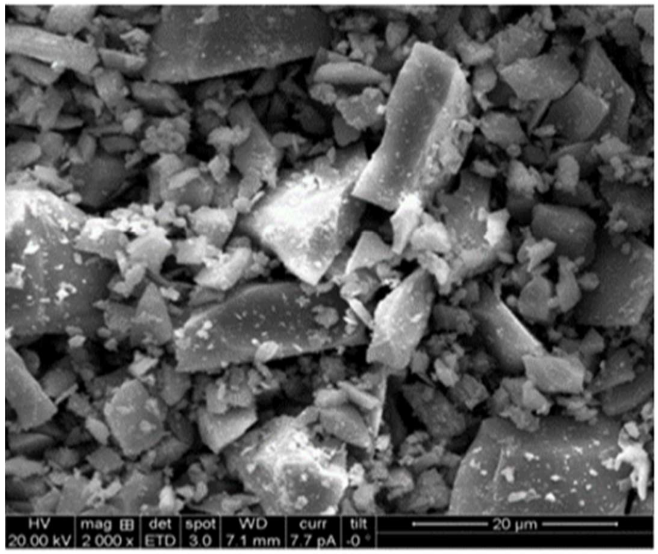


Fig. 8 SEM of GGBS

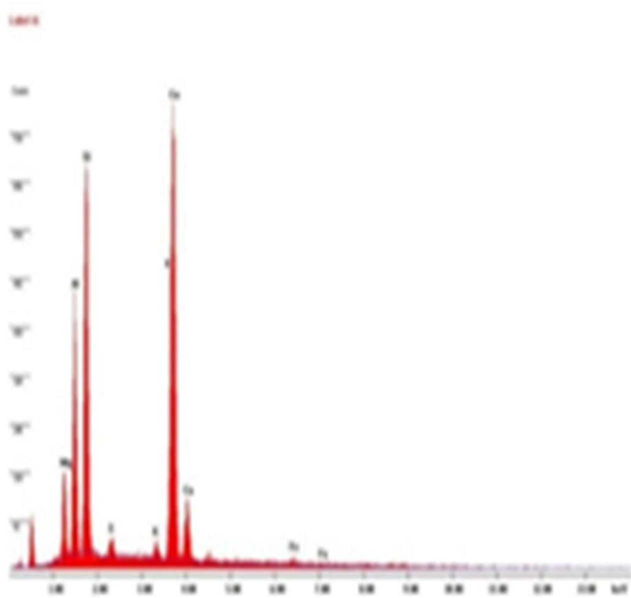


Fig. 9 EDS of GGBS

5. CONCLUSION:

- As we have seen from results GGBS is a good replacement to 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 in construction and sustainable development which we are engineers are keen about today.

- Due to the GGBS we have observed minimal water demand and due to slower reaction rate of early hydration. The slower hydration rates help to lower early heat generation thereby reducing the incidences of early thermal cracking.

- Higher replacement of GGBS increases the setting time of concrete but it does have some adverse effect on the final product. 20% to 40% GGBS may be best to ensure high early strength.

- The compressive strength for M40 grade of concrete was found to be maximum at 20% replacement of cement with GGBS when compared with 10%, 30% and 40 % replacement of cement with GGBS.

- Based on setting time test results, higher replacement of GGBS increases the setting time of concrete but it does not have any adverse effect on the final product. It is very important to select a good chemical admixture to achieve the required properties of concrete.

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  International Journal on Emerging Technologies 11(3): 1179-1184(2020)

7. APPENDIX:

DESIGN MIX:

C-1 STIPULATIONS FOR PROPORTIONING

a) Grade designation: M40

b) Type of cement: OPC 53 grade conforming to IS 269

c) Type of mineral admixture: GGBS conforming to IS 16714

d) Maximum nominal size of aggregate: 20mm

e) Minimum cement content and maximum water-cement ratio to be adopted and/or Exposure condition as per Table 3 and Table 5 of IS 456 Mild (for reinforced concrete)

f) Workability: 120 mm (slump)

g) Method of concrete placing: Pumping

h) Degree of supervision: Good

I) Type of aggregate: Crushed stone angular aggregate

j) Maximum cement (OPC content): As per IS 456

k) Chemical admixture type: Super plasticizer- normal

l) For 9 number of cubes its calculated.

C-2 TEST DATA FOR MATERIALS

a) Cement used: OPC 53 grade conforming to IS 269

b) Specific gravity of cement: 3.15

c) GGBS: Conforming to IS 16714

d) Specific gravity of GGBS: 3

e) Chemical admixture: Super plasticizer conforming to IS 9103

f) Specific gravity (at SSD condition)

1) Coarse aggregate: 2.75 (based on saturated surface dry condition)

2) Fine aggregate: 2.69 (based on saturated surface dry condition)

3) Chemical Admixture: 1.145

g) Water absorption 1) Coarse aggregate: 0.34 percent

2) Fine aggregate: 3.20 percent

C-3 TARGET STRENGTH FOR MIX PROPORTIONING

f'ck = fck + 1.65 S

or

f'ck = fck + X

whichever is higher where f'ck = target average compressive strength at 28 days, fck = characteristic compressive strength at 28 days, S = standard deviation, and from Table 2, standard deviation S = 5 N/mm2 from Table 1, X = 6.5. Therefore, target strength using both equations.

a) f'ck = fck +1.65 S = 40 + 1.65 x 5 = 48.25 N/mm2

b) f'ck = fck + 6.5 = 40 + 6.5 = 46.5 N/mm2

The higher value is to be adopted. Therefore, target strength will be 48.25 N/mm2 as 48.25 N/mm2 > 46.5N/mm2.

C-4 APPROXIMATE AIR CONTENT

From Table 3, the approximate amount of entrapped air to be expected in normal (non-air entrained) concrete is 1.0 percent for 20 mm nominal maximum size of aggregate.

C-5 SELECTION OF WATER-CEMENT RATIO

From Fig. 1 the free water-cement ratio required for the target strength of 48.25 N/mm2 is 0.35 for OPC 53 grade curve. This is lower than the maximum value of 0.55 prescribed for 'Mild' exposure for reinforced concrete as per Table 5 of IS 456.

0.35 < 0.55, hence O.K.

C-6 SELECTION OF WATER CONTENT

From Table 4, water content = 186 kg (for 50 mm slump) for 20 mm aggregate.

Estimated water content for 120 mm slump (increasing at the rate of 3 percent for every 25 mm slump) =186+9/100*186 = 202.74 kg

As super plasticizer is used, the water content may be reduced. Based on trial data, the water content reduction of 10 percent is considered while using super plasticizer at the rate of 1.0 percent by weight of cement. Hence the arrived water content = 209 × 0.9 = 182.47kg ≈ 183 kg

C-7 CALCULATION OF CEMENT CONTENT

Water-cement ratio = 0.4

Cement content = 183/0.4 = 456 kg/m3

From Table 5 of IS 456, minimum cement content for ‘mild’ exposure condition ‘mild’ exposure condition = 320 kg/m3 456 kg/m3> 320 kg/m3, hence O.K.

To proportion a mix containing GGBS the following steps are suggested.

a) Decide the percentage of GGBS to be used based on project requirement and quality of GGBS.

b) In certain situations increase in cementitious material content may be warranted. The decision on increase in cementitious material content and its percentage may be based on experience and trials.

GGBS @ 10 percent of total cementitious material content = 456 × 10 percent = 45.61 kg/m3 Cement (OPC) = 456 – 45.61 = 410.57 kg/m3

C-8 PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

From Table 5, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.50 = 0.62.

In the present case water-cementitious ratio is 0.4.

Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.14, the proportion of volume of coarse aggregate is increased by 0.028 (at the rate of 0.01m^3 for every ± 0.05 change in water-cement ratio).

Therefore, corrected volume of coarse aggregate for the water-cementitious ratio of 0.4 = 0.62 + 0.028 = 0.64 m^3. For pump able concrete these values may be reduced by up to 10 percent. (see 5.5.2).

Here, 10 percent reduction is considered. Therefore, volume of coarse aggregate = 0. 648 × 0.9 = 0.583 2 say 0.58 m^3 Volume of fine aggregate content = 1 – 0.64 = 0.36 m^3

C-9 MIX CALCULATION

The mix calculation per unit volume of concrete shall be as follows:

a) Total Volume = 1 m^3

b) Volume of entrapped air in wet concrete = 0.01 m^3

c) Volume of cement = (Mass of cement / Specific gravity of cement) *(1/1000) = (410.57 / 3.15) *(1/1000) = 0.130 m^3

d) Volume of GGBS = (Mass of GGBS / Specific gravity of GGBS) *(1/ 1000) = (45.61/ 3) *(1/1000) = 0.015 m^3

e) Volume of water = (Mass of water / Specific gravity of water) *(1/ 1000) = (182 / 1) *(1/ 1000) × = 0.182 m^3

f) Volume of chemical admixture (super plasticizer) @0.4 percent by mass of cementitious material) = (Mass of chemical admixture / Specific gravity of admixture) *(1/ 1000) = ((4.10x1.145) / 1.145) *(1/1000) = 0.00358

g) Volume of total aggregate = [(a-b)-(c+d+e+f)] = (1-0.01) - (0.130+0.015+0.182+0.00358) = 0.659m^3

h) Mass of coarse aggregate = g × Volume of coarse aggregate × Specific gravity of coarse aggregate × 1000 = 0.659 × 0.58 × 2.75 × 1000 = 1051 kg

i) Mass of fine aggregate = g × Volume of fine aggregate × Specific gravity of fine aggregate × 1000 = 0.659 × 0.42 × 2.69 × 1000 = 714.54 ≈ 744 kg

C-10 MIX PROPORTIONS FOR TRIAL NUMBER 1

1. Cement = 411 kg/m^3

2. GGBS = 46 kg/m^3

3. Water (Net mixing) = 183 kg/m^3

4. Fine aggregate (SSD) = 744 kg/m^3

5. Coarse aggregate (SSD) = 1051 kg/m^3

6. Chemical admixture = 1.37%

7. Free water-cementitious material ratio = 0.4