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An Experimental Study on Properties of High Strength Concrete by Using Ggbs and Metakaolin

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ABSTRACT— Due to exponential growing in urbanization and industrialization, by product from industries is becoming an increasing concern for recycling and waste management. Ground granulated blast furnace slag (GGBS) is by product from blast furnace of iron and steel industries. GGBS is very useful in design and development of high quality cement paste. It effects on strength and durability properties. Concrete occupies unique position among the modern construction materials & is widely used 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. High strength concrete is defined as concrete with considered characteristic cube strength above 40 Mpa. Environmental concerns both in terms of damage caused by the extraction of raw material and carbon dioxide emission during cement manufacturing also reduce cement consumption by the use of supplementary materials. Applications of high strength concrete are bridges, aqueducts, high rise buildings, off shore structures, dams etc. The study involves the replacement of cement with ground granulated blast furnace slag, replacement of cement with metakaolin and also replacement of cement with ground granulated blast furnace slag & metakaolin .using different percentages of supplementary materials. A 15% replacement of the cement by metakaolin resulted in satisfactory mean target compressive strength and workability and durability, GGBS 40% replacement in cement is satisfactory target strength is achieved, for M-60 grade concrete with glenieum B233 as super plasticizer and the strength properties were studied after 7 days, 28 days.

INTRODUCTION

1.1 GENERAL

High strength concrete is defined as concrete with considered characteristic cube strength above 40 Mpa. Generally, now a day's importance of high strength concrete is increased. To make a high strength concrete used as a supplementary cementineous materials in partially replaced by weigh of cement and also Environmental concerns both in terms of damage caused by the extraction of raw material and carbon dioxide emission during cement manufacturing also reduce cement consumption by the use of supplementary materials. In case of cement production, it contributes significant amount of green house gas, because the production of one ton of Portland cement also releases about one ton of CO_2 gas in to the atmosphere. Admixtures are used as ingredients of concrete and added to the batch immediately before or during mixing.

In view of the global sustainable development, it is imperative that supplementary cementing materials should be used to replace large proportions of cement in the construction industry. In such cases alternatively utilization of supplementary cementation materials is well accepted & these materials replace the by weight of cement, it useful for to change properties of normal concrete and affects it produces high strength as well as high durability. Ground granulated blast furnace slag is obtained by quenching molten iron slag (a by-product of iron and steel making) from a blast furnace in water (or) stream , to produce a glassy , granular product that is then dried and ground into a fine powder. The metakaolin (MK) or calcined Metakaolin, other type of pozzolan, produced by calcination has the capacity to replace silicafume as an alternative material.

1.2 Ground Granulated blast furnace slag (GGBS)

It is a granular product with very limited crystal formation, is highly cementitious in nature and, ground to cement fineness, and hydrates like port land cement. The specific gravity of GGBS is 2.85.

Fig 1.0

Table 1.1 Properties of GGBS

Calcium Oxide(CaO)	40-52

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Silicon Dioxide(SiO2)	10-19
Iron Oxide(FeO)	10-40 70-80% FeO2,20-30%Fe2O3
Manganese Oxide(MnO)	5-8
Magnesium Oxide(MgO)	5-10
Aluminium Oxide(Al2O3)	1-3
Phosphorous Pent Oxide	0.5-1
Sulphur(S)	<0.1
Metallic Fe	0.5-10

1.3 Metakaolin(MK)

Metakaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous aluminosilicate that is reactive in concrete. metakaolin reacts with the calcium hydroxide (lime) byproducts produced during cement hydration. specific gravity of metakaolin 2.5

Fig 1.1

Table1. 2 Properties of Metakaolin

SIO2+AL2O3+Fe2O3	96.88%
CaO	0.39%
MgO	0.08%
TiO2	1.35%

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Na_2O	0.56%
K_2O	0.06%
Li_2O	NIL

1.4 ADVATAGES OF MINERAL ADMIXTURES

- ✓ Densification
- ✓ Improve durability
- ✓ Reduce thermal cracking
- ✓ Improve workability and cohesiveness
- ✓ Reduce bleeding and segregation
- ✓ high compressive strength
- ✓ low heat of hydration
- ✓ resistance to chemical attack
- ✓ good durability and cost-effectiveness

1.5 APPLICATIONS

- ➢ Bridges
- ➢ Aqueducts
- ➢ high rise buildings
- ➢ off shore structures
- ➢ dams etc

Fig 1.3

Fig 1.4

2.LITERATURE REVIEW

1. P. Dinakar, Pradosh K.

Effect of Metakaolin Content on the Properties of High Strength Concrete

This study presents the effect of incorporating metakaolin (MK) on the mechanical and durability properties of high strength concrete for a constant water/binder ratio of 0.3. MKmixtures with cement replacement of 5, 10 and 15 %were designed for target strength and slump of 90 MPa and 100 ± 25 mm. From the results, it was observed that 10 % replacement level was the optimum level in terms of compressive strength.

Beyond 10 %replacement levels, the strengthwas decreased but remained higher than the controlmixture. Compressive strength of 106 MPa was achieved at 10 %replacement Splitting tensile strength and elasticmodulus values have also followed the same trend. In durability tests MKconcretes have exhibited high resistance compared to control and the resistance increases as theMKpercentage increases. This investigation has shown that the local MK has the potential to produce high strength and high performance concretes.

2 S. Arivalagan

He studied on the Sustainable Studies on Concrete with GGBS As a Replacement Material in Cement

This research evaluates the strength and strength efficiency factors of hardened concrete, by partially replacing cement by various percentages of ground granulated blast furnace slag for M35 grade of concrete at different ages. From this study, it can be concluded that, since the grain size of GGBS is less than that of ordinary Portland cement, its strength at early ages is low, but it continues to gain strength over a long period.

The degree of workability of concrete was normal with the addition of GGBS up to 40% replacement level for M35 grade concrete. From the above experimental results, it is proved that GGBS can be used as an alternative material for cement, reducing cement consumption and reducing the cost of construction. Use of industrial waste products saves the environment and conserves natural resources

3. B. Patil, P. D. Kumbhar

Strength and Durability Properties of High Performance Concrete incorporating High Reactivity Metakaolin

Concrete is probably the most extensively used construction material in the world. The addition of mineral admixture in cement has dramatically increased along with the development of concrete industry, due to the consideration of cost saving, energy saving, environmental protection and conservation of resources. The 7.5% addition of high reactivity metakaolin in cement is enhanced the resistance to chloride attack.

The compressive strength of concrete incorporated with 7.5% HRM is reduced only by 3.85% as compared with the reduction of strength of control mix specimen is by 4.88%. The 7.5% addition of high reactivity metakaolin in cement is also enhanced the resistance to sulfate attack. The compressive strength of concrete incorporated with 7.5% HRM is reduced only by 6.01% as compared with the reduction of strength of control mix specimen by 9.29%.

4.K. Suvarna Latha, M V Seshagiri Rao

Estimation of GGBS and HVFA Strength Efficiencies in Concrete with Age

The utilization of supplementary cementitious materials is well accepted because of the several improvements possible in the concrete composites, and due to the overall economy. This paper is an effort to quantify the strength of ground granulated blast furnace slag (GGBS) and high volume fly ash (HVFA) at the various replacement levels and evaluates their efficiencies in concrete. In recent years GGBS when replaced with cement has emerged as a major alternative to conventional concrete and has rapidly drawn the concrete industry attention due to its cement savings, energy savings, and cost savings, environmental and socio-economic benefits.

The strength efficiency factor „k" of GGBS in concrete mixes of all grades at 90and 180 days was found to be between 1.2 to 2.85 and for HVFA „k" is between 1.45 to 2.14 which shows the strength efficiency factors for GGBS are higher than HVFA replaced concrete. It is observed that there is an increase in the compressive strength for different concrete mixes made with GGBS and HVFA replacement mixes. The increase is due to high reactivity of GGBS and HVFA.

5.Dr. P.Muthupriya

An Experimental Investigation On Effect Of Ggbs And Glass Fibre In High Perfomance Concrete

The present paper focuses on investigating characteristics of M75 concrete with partial replacement of cement with Ground Granulated Blastfurnace Slag (GGBS) and glass fibre. High Performance Concrete (HPC) is a concrete meeting special combinations of performance and uniformity requirements that cannot be always achieved routinely by using conventional constituents and normal mixing.

Ten mixes were studied with GGBS & Glass Fibre using a water binder ratio of 0.26 and super plasticizer CONPLAST SP-430. The cubes and cylinders were tested for both compressive and tensile strengths GGBS can enhance the durability aspects of HPC compared to control mix. Among the mixes the mix with replacement level as 7.5% GGBS and 0.3% glass fibre is better with respect to strength and durability. It is observed that the

GGBS based HPC can have higher strengths. From the above experimental results it is proved that, GGBS can be used as alternative material for the cement. Based on the results the compressive and split tensile strengths are increased as the percentage of ggbs increased.

It is observed that the GGBS based HPC can have higher strengths. From the above experimental results it is proved that, GGBS can be used as alternative material for the cement. Based on the results the compressive and split tensile strengths are increased as the percentage of ggbs increased. The addition of super plasticizer also tends to reduce strength of concrete remarkably due to the chemical action between the super plasticizer and GGBS.

6. M. Adams Joe , A. Maria Rajesh

An Experimental Investigation on the Effect of Ggbs & Steel Fibre in High Performance Concrete

The present paper focuses on investigating characteristics of M40 concrete with Various propotional of replacement of cement with Ground Granulated Blast furnace Slag (GGBS) and adding 1% of steelfibre. High Performance Concrete (HPC) is a concrete meeting special combinations of performance and uniformity requirements that cannot be always achieved routinely by using conventional constituent sand normal mixing. Ten mixes were studied with GGBS & Steel Fibre using a water binder ratio of 0.35 and super plasticizer CONPLAST SP-430. The cubes, cylinders and prisms were tested for both Compressive, Split tensile, Flexural and Pull out strengths GGBS can enhance the durability aspects of HPC compared to control mix. Among the mixes the mix with replacement level as 0%,10%,20%,30%,40% & 50% of GGBS and 1% steel fibre is better with respect to strength and durability. It is observed that the Optimum Compressive Strength of High Performance Concrete is obtained replacement of 40 % Cement by GGBS

7. Sanjay N. Patil , Anil K

Metakaolin- Pozzolanic Material For Cement in High Strength Concrete

The infrastructure development is an important aspect for the overall development of country. India is developing as a major hub for service industry, automobile industry and for which the infrastructure development plays an important role. In case of infrastructure development construction of bridges, aqueducts, high rise buildings, off shore structures, nuclear power stations, dams, high strength concrete above M55 is commonly adopted. The necessity of high strength concrete is increasing because of demands in the construction industry

Literature Review shows that optimal performance is achieved by replacing 7% to 15% of the cement with metakaolin. While it is possible to use less, the benefits are not fully realized until at least 10% metakaolin is used. Values of compressive strength of concrete with metakaolin after 28 days can be higher by 20%. Dosage of 15% of metakaolin causes decrease of workability of suspension in time. Increasing amount of percentual proportion of metakaolin in concrete mix seems to require higher dosage of superplasticizer to ensure longer period of workability

8. Ashok Kumar , S.K. Agarwal

Comparative Hydration Behavior of Metakaolin-Microfine System

In the present study comparative hydration behaviour of cement with metakaolin and-microfine (ultra fine slag) system has been investigated. Various properties like pozzolanic activity, compressive strength, heat of hydration, XRD of control, hydrated and blended metakaolin/microfine-cement compositions has been compared. With 5%, 7.5% and 10% replacement of cement by metakaolin and microfine, pozzolanic activity increases about 22%, 27%,13% for metakaolin and 23%,35%,20% for microfine compare to control However with the use of superplasticizer the activity is 35%, 41% for 5% MF and MK and 44% for 7.5% MF and MK both. Compressive strength of cement paste in cement-metakaolin system shows gain of approx. 12% and 10% and 15% for microfine-cement system over control. Non-evaporable water content increases with the age in both 5% &10% metakaolin and microfine blend systems and at 28 days it is comparable to control. The results of compressive strength data also indicate the same trend

It can be concluded from the present study that metakaolin which is being propagated as replacement of silica fume in the Indian concrete industry has all the properties of being good pozzolana and can be a substitute of silica fume which is being imported. Further, properties of microfine are comparable to metakaolin. A detailed long term study of microfine is required.

9. Dr. P. Srinivasa Rao, P.Sravana

Cracking Behaviour Of Metakaolin Blended High Strength Concrete In Flexure By Using Crimped Steel Fibers

An experimental investigation was carried out to study the post cracking behaviour by replacing the cement with Metakaolin at various percentages as 5 %, 10 %, 15 % and 20 % along with addition of crimped steel fibres at

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various percentages as 0 %, 0.5 %, 1 % and 1.5 % by volume of concrete. The concrete was designed to have a compressive strength of 50MPa. Number of sets of fibre Reinforced concrete prisms (without conventional reinforcement) with different percentages of Metakaolin and different percentages of fibres were cast, cured and tested in flexure under two point load. 10 % replacement of cement with Metakaolin and 1 % addition of fibres is the optimum value for the property of hardened concrete like cube compressive strength. There is a 23 % increase in cube compressive strength when compared to plain concrete. The onset of first crack has occurred when the stresses induced in the bottom most layer of the test specimen becomes equal to the cracking stress of the composite.

10. Beulah M & Prahallada M

Effect Of Replacement Of Cement By Metakalion On The Properties Of High Performance Concrete Subjected To Hydrochloric Acid Attack

This paper presents an experimental investigation on the effect of partial replacement of cement by metakalion by various percentages viz 0%, 10%, 20%, and 30% on the properties of high performance concrete, when it is subjected to hydrochloric acid attack. An aggregate binder ratio of 2 and different water binder ratios viz 0.3, 0.35, 0.40 and 0.45 was used in this investigation. The various results which indicate the effect of replacement of cement by metakalion on HPC

Type	Ploycorboxylic ether
Colour	Light brown
Specific gravity	1.06
Dosage	500 – 1500 ml per 100kg of cement
Standard confirming	ASTM C494 Type-F

are presented in this paper to draw useful conclusions.The results were compared with reference mix. Test results indicate that use of replacement cement by metakalion in HPC has improved performance of concrete up to 10%. It can be concluded that the residual Compressive strength after 30, 60 and 90 days of acid immersion decreases with increasing water binder ratio. This may be due to porous transition zone leading to the formation of ettringite at higher water levels. It can be concluded that the addition of metakaolin increases the resistance to acid attack of HPC.

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Optimum results obtained were at 10% replacement of cement by metakaolin.

EXPERIMENTAL INVESTIGATIONS

3.1 Materials

Portland cement

Opc of 53 grade was used for making a HSC, used a fresh and free from lumps and it satisfies the requirements of IS: 12269-1987 specifications.

Coarse Aggregate

It was collected from local quarry of crushed granite and coarse aggregate was used in the experimental investigation of 20mm and 12.5mm as per IS: 2386-1963(I, II, III) specifications

Fine Aggregate

Locally available river sand was used as fine aggregate and confirmed to grading zone –II as per IS-383-1970 specifications

3.2 GLENIUM B233

BASF glenium B233 is a super plasticizing admixture. Glenium B233 is an admixture of a new generation based on modified polycarboxylic ether. The product has been primarily developed for applications in high performance concrete where the highest durability and performance is required. Glenium B233 is free of chloride & low alkali and compatible with all types of cements.

Table 3.1 Properties of GLENIUM B233

It is confirming to "Type F" means water reducing, high range and retarding agent. In this experimental work, the amount of SP used is of 0.3% by cement weight.

3.3 Advantages of Glenium B233

- Elimination of vibration and reduced labour cost in placing. Marked increase in early & ultimate strengths.
- Higher Young's modulus.
- Improved adhesion to reinforcing steel.
- Better resistance to carbonation and other aggressive atmospheric conditions.
- Increased durability.
- Reduced shrinkage and creep.

The material s used in making high strength concrete mixes along with their various properties have been give in table

Table 3.2

Materials	Specific gravity	Fineness modulus	Grade/type	Compressive strength(N/mm2)	Source
cement	3.15	-	53(opc)		KCP
F.A	2.70	3.2	Zone-ll		Krishna river(local spot)
C.A	2.78	5.6	60%-20mm 40%-12.5mm	22.2%	Locally available
MK	2.50				20 microns Ind. Lid Mumbai
GGBS	2.85				
SP	1.09		Glenium B233(Polycarboxylic ether polymer)		BASF chemical company Ltd. Mumbai

EXPERIMENTAL PROGRAM

4.1 Mix Proportions

Mix proportions of M-60 grade HSC mix was obtained by making certain modifications in the mix proportion arrived by using a guidelines of ACI 211.1-91 code method. The mix proportion was without considering any replacement of mineral admixture are GGBS, MK. after several trials, a cement content of 520kg/m3 and water/cement ratio of 0.30 were used along with optimum contents of high reactivity metakaolin and GGBS used as mineral admixture after carrying out several preliminary mix trails, the optimum contents of metakaolin at 15% and GGBS at 40%,and a super plasticizer dose at 0.34% both by weight of cement, were found to give desired workability and strength properties and also durability . The final mix proportion was arrived at by altering ratio is expressed as parts of cement: fine aggregate: coarse aggregate: water (1:1.384:2.026:0.3).

4.2 Preparation of HSC Mix

The required quantities of all the ingredients were taken by weight batching. a reference mix was prepared using a water/cement ratio 0.30 and sp (Glenium B233) content (by weigth of cement) in order to get desired workability. The workability of the concrete was studied by conducting slump test (IS: 1199:1959).

Considered all HSC mixes were prepared using same mix proportion, W/C ratio and glenium dose .workability, strength and durability properties are studied.

MIX DESIGN

5.1 GENERAL

Mix design is an essential part in manufacturing of concrete. Proper Mix design method gives better properties to the concrete. In this experimental work, the mix design method used is of ACI 211.1 – 1991.

5.2 ACI METHOD

The American Concrete Institute was adopted a successful mix design method in 1944 by ACI Committee 613. Various mix design methods are prepared and implemented by this Institute. Recently ACI committee 211 has updated and revised the mix design method in 1991. The revised mix design method is ACI 211.1 – 1991.

5.3 MIX DESIGN DATA

The following data is required for the mix design for ACI method

Specific gravity of coarse and fine aggregates

Rodded Bulk density of coarse aggregates

Fineness modulus of fine aggregate

Specific gravity of cement

Maximum size of coarse aggregate

Standard deviation of compressive strength of concrete

5.4 MIX DESIGN PROCEDURE (As Per ACI 211.1 – 91)

5.4.1 TARGET MEAN STRENGTH OF CONCRETE

Target mean strength is calculated by the formula

$f'_{ck} = f_{ck} + ks$

Here f_{ck} = characteristic compressive strength

k = a statistic factor

S = standard deviation

5.4.2 SELECTION OF WATER CONTENT

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The first step in selecting water content is the selection of Slump range. The range of slump was selected from the Table A 1.5.3.1 of ACI 211.1 – 91.

By deciding the maximum size of coarse aggregate and range of slump select the required water content from the Table A 1.5.3.3 of ACI 211.1 – 91

5.4.3 SELECTION OF W/C RATIO

The water cement ratio can be selected from the Table A 1.5.3.4 (a) and Table A 1.5.3.4 (b) of ACI 211.1 – 91

5.4.4 CALCULATION OF CEMENT CONTENT

To calculate cement content, use selected water cement ratio from the tables

Cement content will be obtained by dividing Required water content with W/C ratio

Here the calculated cement content is of maximum cement content

Cement content = required water / water cement ratio

5.4.5 CALCULATION OF COARSE AGGREGATE

To calculate the amount of coarse aggregate we need two important properties they are

Rodded Bulk density of Coarse aggregate

Volume of coarse aggregate

Bulk density is obtained from the test results.

To calculate the volume of coarse aggregate, re require maximum size of coarse aggregates and Fineness modulus of fine aggregate

Form Table A 1.5.3.6 by comparing fineness modulus of FA and size of CA, the volume of CA can be calculated.

Now the amount of Coarse aggregate will be calculated by the formula

CA content = Rodded bulk density x volume of CA

5.4.6 CALCULATION OF FINE AGGREGATE CONTENT

Calculate the first estimate density of Fresh concrete from Table A 1.5.3.7.1

By subtracting the amount of water, cement and coarse aggregates from the fresh density the Fine aggregate content will be obtained.

5.5 MIX DESIGN FOR M60 GRADE

- This mix design is adopted after conducting several conventional trails.
- The final mix
- design procedure is tabulated as follows
- Target mean strength (f'ck) = fck + k(s)
  = 60 + 1.65(5)
  = 69.9 Mpa
- Water cement ratio = 0.30 [from Table A 1.5.3.4 (a) and Table A 1.5.3.4 (b) of ACI 211.1-91]
- Range of slump = 25 – 50mm [from Table A 1.5.3.1 of ACI 211.1-91]

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- Actual water content = 156 lit/m3 [from Table A 1.5.3.3 of ACI 211.1-91]
- Cementitious materials = 156/0.30
  = 520 kg/m3
- Cementitious materials includes cement, GGBS, Metkaolin
- Bulk density of coarse aggregate = 1700 kg/m3
- Volume of coarse aggregate required = 0.62 (from Table A 1.5.3.6 of

ACI211.1-91)

- Weight of Coarse aggregate = 1700x0.62
  = 1054 kg/m3
- First estimate density of fresh concrete = 2450 kg/m3
- Required water content:
- Cement = 520 kg/m3
- Water = 520x0.30 = 156 lit/m3
- Weight of fine aggregate required:
- Fine aggregate content = estimate density – (cement + water + CA)
  = 2450 – (520 + 156 + 1054)
- FA = 720 kg/m3
- Ratio of materials:
- Cement: fine aggregate: coarse aggregate: water
- 520: 720: 1054: 156
- 1: 1.384: 2.02: 0.30
- Super plasticizer dosage = 0.3% by cement weight
- No of trails for M -60 Grade

TESTING OF SPECIMENS

6.1 GENERAL

Calculation of Fresh and Hardened properties is the main era in concrete testing. The well cured specimens in curing tank are tested for compressive strength, split tensile strength and modulus of rupture. By taking out the specimens from the curing tank, the specimens were exposed to sun light for surface drying. After the drying process, the specimens are processed for testing. The specimens are tested for 7 days and 28 days strengths. In this chapter the testing procedures and formulations are discussed and presented as follows.

6.2 FRESH PROPERTIES

Fresh properties of concrete are observed at the time of concreting. To measure the fresh properties of concrete workability test is very important. Concrete good in workability will shows better properties in its life time. Before pouring concrete into the moulds we need to check the workability by slump cone method. The workability test for concrete is confirms to IS 1199 – 1959.

6.2.1 SLUMP CONE METHOD

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Slump cone method consist a cone of 300mm height, 200mm bottom diameter and 100mm top diameter. For doing slump test concrete is poured into the cone in 3 layers and tamped at 24 times for each layer with a tamping bar. After total compaction the cone will removed and height of cone will measured. The difference between actual height and formed cone height will give slump value.

6.3 MECHANICAL PROPERTIES

Mechanical properties of concrete are mainly related to the calculation of its strength. The calculation of mechanical properties includes the testing of concrete for its performance in Compressive strength, Split tensile strength and modulus of rupture. The procedures and calculations of these three tests are confirmed by the standard specification IS 516 – 1959.

6.3.1 COMPRESSIVE STRENGTH

Compressive strength or crushing strength is the main property observed in testing the cubes. Cubes are tested to calculate compressive strength by applying gradual loading in Compression Testing Machine. The reading of the failure load is occurred on the top of the machine in the indicator.

The compressive strength has been calculated by the formula

Compressive strength (f_{ck}) = applied load/cross sectional area

$(f_{ck}) = P/A$

$= \text{load/area} \quad N/mm^2$

6.3.2 CASTING OF CUBES:

For each trail 6 cube specimens were casted for calculating 7 days and 28 days strengths. The dimensions of specimen for cube are of 150mm x 150mm x 150mm.

Fig 6.0

6.3.3 SPLIT TENSILE STRENGTH

Split tensile strength is the most important property of concrete. Concrete generally weak in tension. So to improve tensile behavior of concrete, split tensile strength is important. It is also important in reducing formation of cracks in concrete. Cylinders are casted for calculating split tensile strength. The cylindrical specimens are also tested in compression testing machine. The cylinders are placed in axial direction by facing cylindrical face to the loading surface. Here the cylinder split into the two parts and reading observed on the top of the machine.

The split tensile strength has been calculated by the formula

Split tensile strength (f_{spt}) = 2P / Πld

P = failure load (applied load)

L = height of the cylinder specimen

D = diameter of mould

6.3.4 CASTING OF CYLINDERS:

For each trail 6 cylinder specimens were casted for calculating 7 days and 28 days strengths. The dimensions of the cylindrical specimen are of

Height = 300mm

Diameter = 150mm

Fig 6.1

6.3.6 FLEXURAL STRENGTH

Most of the beam failures are occurred due to their failure in flexural strength. It is important that prediction of flexural strength by calculating modulus of rupture for reducing failure problems in beams. The calculation of modulus of Rupture in terms of Flexural strength is the main aim in casting beam specimens. In this modulus of rupture is calculated by testing specimens in the universal testing machine. In this line of facture is the main important property in formulating the modulus of rupture.

The modulus of rupture is denoted by "f_{cr}".

The 'f' value is mainly based on the shortest distance of line fracture 'a'

If 110mm < a < 133mm, $f_{cr} = 3PL/bd^2$

If a > 133mm, $f_{cr} = PL/bd^2$

If a < 110mm, the test shall be discarded.

6.3.7 CASTING OF BEAMS:

For each trail 6 beam specimens were casted for calculating 7 days and 28 days strengths. The dimensions of the beam specimen are of

500mm x 100mm x 100mm

Fig 6.2

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Fig 6.3

6.3.8 Durability Tests

The durability of concrete in this experimental work was carried out by measuring acid resistance at different ages of curing. The concrete acid resistance was observed by two types of tests named as Acid attack factor test and Acid durability factor test. The concentrations of acids in water are 5% HCL and 5% H_2SO_4.

6.3.9 Acid Attack Factor:

In acid attack factor test, cubes after 28 days of acid curing were taken out of acid. The faces of cube should be cleaned properly. The mass of the cube and diagonal dimensions are measured for each two cubes. The difference between initial and final mass are calculated. The dimension loss at each diagonal face is calculated. The extent of deterioration at each corner of the struck face and the opposite face is measured in terms of the solid diagonals (in m). Then the Acid attack factor was calculated by the formula

Acid attack factor = (loss in mm on 8 corners) / 4

6.4 Acid Durability Factor:

Durability of concrete reduces when the concrete exposed to severe environment and aggressive chemical attack. To improve the concrete durability in acid durability factors are necessary. The acid durability factor was calculated by the formula

Acid durability factor = $S_r(N/M)$

Here S_r = relative strength at N days (%)

N = Number of days at which acid durability factor is needed

M = Number of days at which the acid durability factor is terminated

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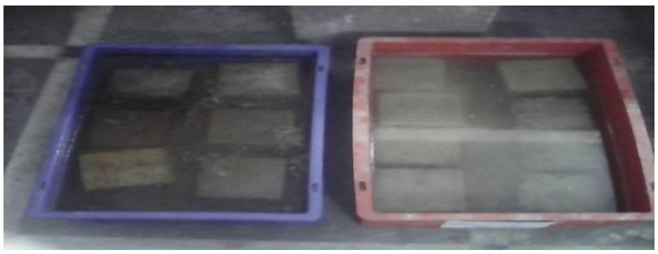
If the cube had removed from acid for 28 days, then M equals to 28in this case

Fig 6.4 Cubes in acid curing of 5% HCL

Fig 6.5 Cubes in acid curing of 5% H_2SO_4

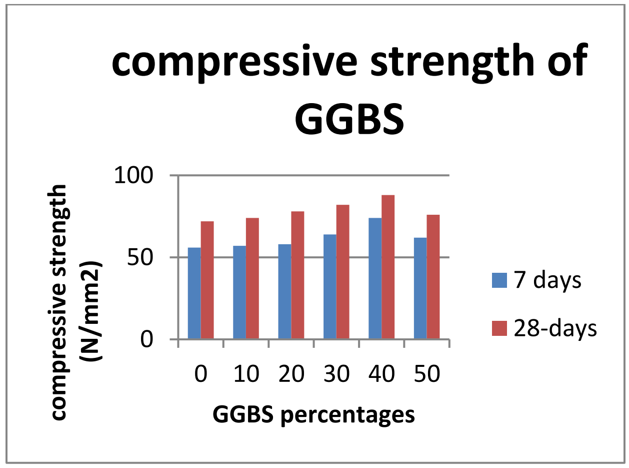


RESULTS AND CONCLUSIONS

Test results for workability & compressive strength of GGBS

Table.6.0

GGBS (%)	SLUMP(mm)	SP(%)	COMPRESSIVE STRENGTH (N/mm2)	
			7-days	28-days
0	45	0.32	56	72
10	45	0.32	57	74
20	50	0.34	58	74
30	50	0.34	64	82
40	50	0.34	74	88
50	50	0.34	62	76



Test results for workability & compressive strength of MK

MK (%)	SLUMP(mm)	SP (%)	COMPRESSIVE STRENGTH (N/mm2)	
			7-days	28-days
0	45	0.32	56	72
5	50	034	58	74
10	50	034	64	84
15	50	0.34	76	90
20	50	0.34	62	80

Table.6.1

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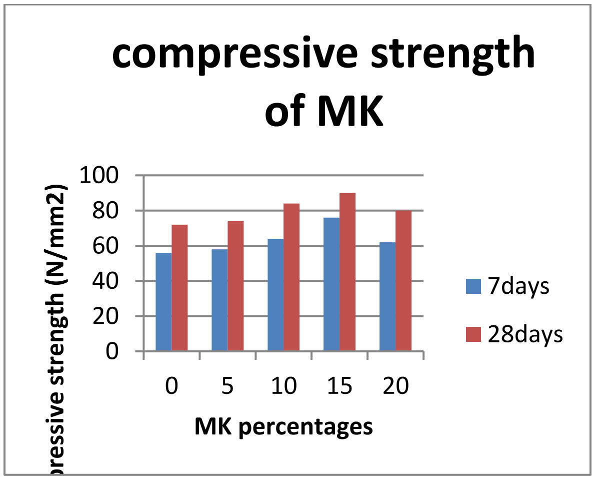
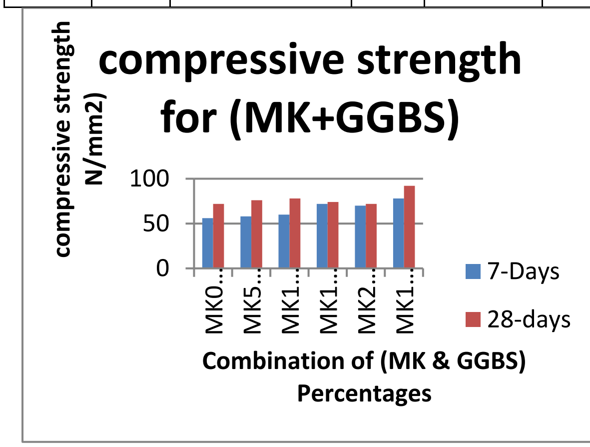


Test results for workability &compressive strength combination of (MK+GGBS)

Table.6.2

MK+GGBS (%)		**SLUMP(mm)**	**SP (%)**	**COMPRESSIVE STRENGTH (N/mm2)**	
				7-days	28-days
0	0	45	0.32	56	72
5	10	50	0.34	58	76
10	20	50	0.34	60	78
15	30	50	0.34	72	74
20	40	50	0.34	70	72
15	40	50	0.34	78	92



Test results for split tensile strength of MK

Table.6.3

MK (%)	**SP (%)**	**SPLIT TENSILE STRENGTH(N/mm2)**	
		7-days	28-days
0	0.34	4.6	5.94
5	0.34	4.8	6.02
10	0.34	5.09	6.41
15	0.34	6.08	6.64
20	0.34	5.23	6.26

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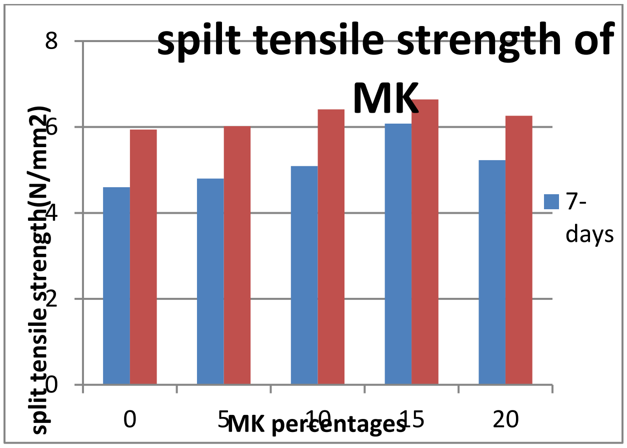

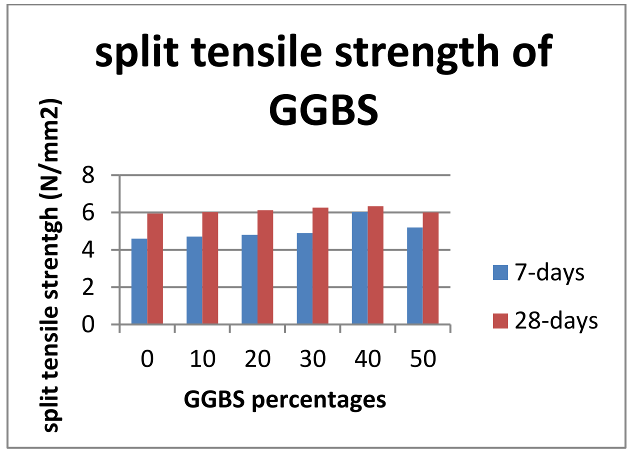

Test results for split tensile strength of GGBS

Table.6.4

GGBS (%)	SP (%)	SPLIT TENSILE STRENGTH (N/mm2)	
		7-days	28-days
0	0.34	4.6	5.94
10	0.34	4.71	6.02
20	0.34	4.8	6.12
30	0.34	4.90	6.26
40	0.34	6.03	6.34
50	0.34	5.2	6.0

Test results for split tensile strength combination of (GGBS+MK)

Table.6.5

(GGBS+MK) (%)	SP (%)	SPLIT TENSILE STRENGTH(N/mm2)	
		7-days	28-days
0%+0%	0.34	4.6	5.94
5%+10%	0.34	4.84	6.1
10%+20%	0.34	4.92	6.20
15%+30%	0.34	4.94	6.20
20%+40%	0.34	5.84	6.24
15%+40%	0.34	6.07	6.32

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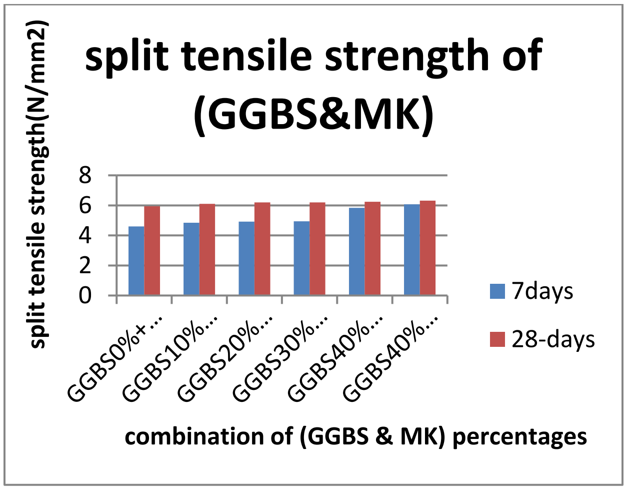

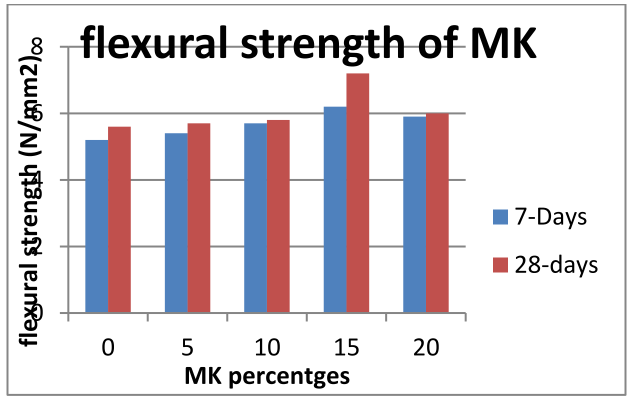

Test results for flexural strength of (MK)

Table.6.6

MK (%)	SP (%)	FLEXURAL STRENGTH(N/mm2)	
		7-days	28-days
0	0.34	5.2	5.6
5	0.34	5.4	5.7
10	0.34	5.7	5.8
15	0.34	6.20	7.2
20	0.34	5.9	6.0

Test results for flexural strength of (GGBS)

Table.6.7

GGBS (%)	SP (%)	FLEXURAL STRENGTH(N/mm2)	
		7-days	28-days
0	0.34	5.2	5.6
10	0.34	5.3	5.8
20	0.34	5.6	5.9
30	0.34	5.7	6.10
40	0.34	6.8	7.10
50	0.34	5.8	6.0

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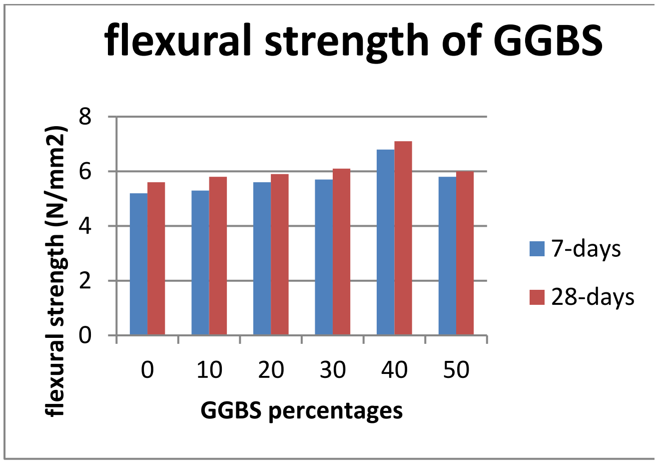
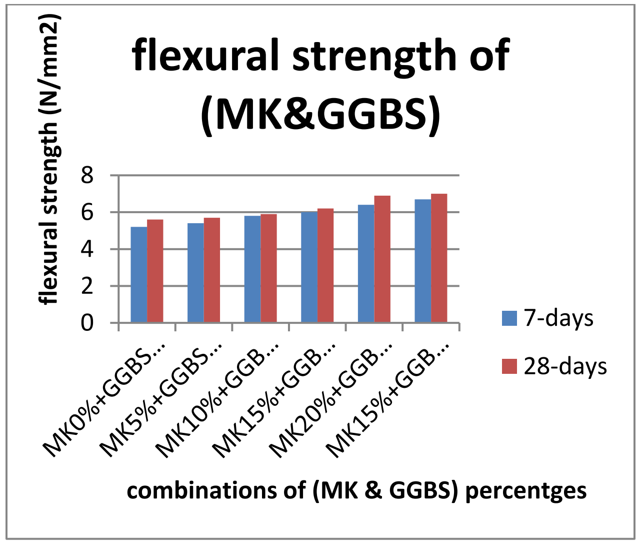


Test results for flexural strength combination of (MK&GGBS)

Table.6.8

(MK+GGBS)(%)	**SP (%)**	**FLEXURAL STRENGTH (N/mm2)**	
		7-days	28-days
0%+0%	0.34	5.2	5.6
5%+10%	0.34	5.4	5.7
10%+20%	0.34	5.8	5.9
15%+30%	0.34	6.0	6.20
20%+40%	0.34	6.40	6.90
15%+40%	0.34	6.70	7.00



The specimens are immersed in HCL solution to study durability

Table.6.9

Mineral admixtures	Specimen weight(kgs)		Compressive strength(N/mm2)	
	Before immersing	After immersing 60-days	Before immersing	After immersing 60-days
MK	2.59	2.48	86	78

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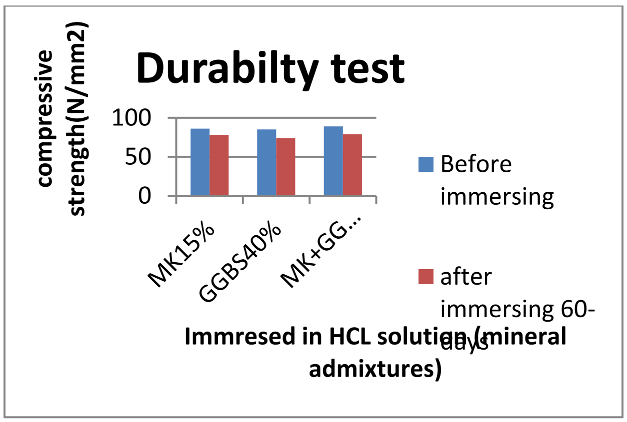
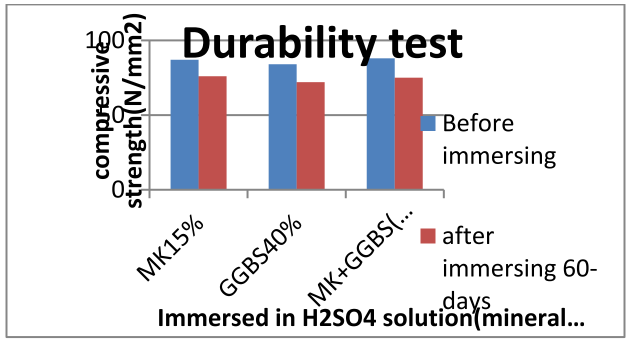
(15%)				
GGBS (40%)	2.50	2.39	85	74
MK+GGBS (15%+40%)	2.61	2.50	89	79



The durability test was conducted by using H_2SO4 solution

Table.7.0

Mineral admixtures	Specimen weight(kgs)		Compressive strength(N/mm2)	
	Before immersing	After immersing 60-days	Before immersing	After immersing 60-days
MK (15%)	2.60	2.52	87	76
GGBS (40%)	2.59	2.40	84	72
MK+GGBS (15%+40%)	2.65	2.52	88	75



It was observed that met kaolin (MK) has been achieved optimum strength at 15% and GGBS at 40%.The maximum increase in compressive strength for M-60 grade is 25%for metakaolin, GGBS is 23%.and by combination of Metakaolin (15%) &GGBS (40%) is 28%.

Added Glenium B233 increased the workability of concrete by reducing the water content

The increase in compressive strength for met kaolin is 3%greater than GGBS and combination of met kaolin and GGBS is getting 3% more strength compared with metakaolin

- From the above results it was proved that combination of GGBS and metakaolin can be used as an alternate material for cement and safe to environment.

- Excessive usage of admixtures above the specified optimum percentages results in strength reduction. Comparative researches can be carried out with using different admixtures with combinations.

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