A Major Project II Report On

"PARTIAL REPLACEMENT OF CEMENT BY GGBS IN CEMENT CONCRETE"

submitted in partial fulfillment of the requirements

for the award of degree of

MASTER OF TECHNOLOGY

in

ENVIRONMENTAL ENGINEERING

submitted by

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DECLARATION

I, Ashwini Kumar Singh, Roll No. 2K18/ENE/04 student of M.Tech (Environmental Engineering), hereby declare that the project Dissertation titled "Partial Replacement of Cement by GGBS in Cement Concrete" which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of and Degree, Diploma Associate ship, Fellowship or other similar title or recognition.

Place: **Delhi** **Ashwini Kumar Singh**

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CERTIFICATE

I hereby certify that the Project Dissertation titled "**Partial Replacement of Cement by GGBS in Cement Concrete**" which is submitted by **Ashwini Kumar Singh**, 2K18/ENE/04, Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

Ground Granulated Blast Furnace Slag is a by-product waste generated while producing iron. It is off white in colour and has similar cementitious properties like cement. Thus use of supplement materials is good for environment as manufacturing cement liberates a lot of carbon-dioxide. Hence, there is a constant search for supplement material. This article is all about study of compressive strength of M30 concrete (Design mix) prepared from Ordinary Portland cement (Dalmia) 53 garde, partially replaced by GGBS in 0%, 10%, 20%, 30% proportions and further comparisons will be done.

Keywords : GGBS, OPC, Mix-Design, compressive strength.

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1. INTRODUCTION

1.1. GENERAL

Save environment! We often listen or read these words in our day to day life. But the main question is that any steps are taken by us in favour to save environment. We all must join hands to save our beloved environment, and thus many such initiatives were taken like Cauvery Calling etc. As we know that concrete is the most used material on Earth after water. Thus it possesses a vital role in developing civilization, concrete-mix is used from classical civilizations till now only difference is the binding agent . Some used Gypsum, some lime later volcanic ash or old brick and tiles were added to improve setting parameters of cement. Later we used Portland cement. Cement production or manufacturing is an exhaustive energy process, which emits a lot of greenhouse gases which we know harms our environment. Also the raw materials used for the cement production is depleting thus the cost of cement is increasing year after year.

Thus the use of waste material in the most used material that is concrete has significant good impacts on environment but the material should be such type of waste which has cementitious properties like cement which can be partially replaced and not much difference is encountered in the properties. So many researches are done in order to save the environment as lot of emissions would be reduced and further the waste is also utilized properly. Here comes ground granulated blast furnace slag (which is often called GGBS) in picture which has very similar chemical composition of cement and also is a waste which is generated from iron making industry.

As we know that one tonne of cement manufacturing liberates 0.95 tonne of carbon dioxide equivalent whereas GGBS is just a by-product which is considered as a waste. GGBS is obtained in blast furnace of iron making industry in which molten iron slag is quenched in water to produce GGBS. Most of the ground granulated blast furnace slag (GGBS) is land filled, and rest is mostly used in road bases, asphalt paving, track ballast. A lot of slag is generated annually from the iron and steel industries in India which can be seen from the above table provided.

Table 1: Plant wise capacity of slag in the country.

STEEL PLANT	CAPACITY ('000 tpy)
Bhilai Steel Plant, Durg, Chattisgarh	2675
Bokaro Steel Plant, Bokaro, Jharkhand	7884
Rourkela Steel Plant, Rourkela, Odissa	1570
Durgapur Steel Plant. Durgapur, West Bengal	566
Rashtriya Ispat Nigam Ltd, Andhra Pradesh	1440
IDCOL Kalinga Iron Works Ltd, Odisha	53
Tata Steel Ltd, Jamshedpur, Jharkhand	2100
Visa Steel Ltd, Kalinganagar, Odisha	175

Hence from the table we can conclude that a lot of waste by-product is generated which should be handled carefully and cement concrete can be a good medium to incorporate these wastes as it will reduce carbon emission too. Moreover it has economical aspect too as it is waste hence when added to the cement as a partial replacement then it lowers the cost. It looks as if it will reduce a little cost but by seeing a whole project which uses GGBS incorporated cement in its concrete production it will reduce overall cost of the project significantly. Also there is growing demand in the market as we are heading towards sustainable development and trying to reduce carbon emission, the imports and exports are significantly increasing year by year as more and more interests is shown by the leading manufacturers of cement, but until the local population gets awaked of the uses and application of these, the major decrease is extended till that date.

In the study, an attempt has been made to study the properties of concrete after incorporating GGBS partially for M30 grade of concrete cubes.

1.2. MATERIAL PROPERTIES

When molten iron slag from blast furnace is quenched from water then Glassy granular product is obtained and then it is dried and grounded in the form of fine powder which we know as Ground Granulated Blast Furnace Slag. GGBS is typically off white in color and are fine in nature. It is very cementious in nature and contains good amount of CSH (Calcium silicate hydrates) which increases the strength, durability and appealing appearance. Its chemical composition varies as it depends on the raw stuff used in the iron production process. Ore and coke have contaminations like silicate and aluminate which gets merged in the blast furnace with a flux and hence lowers the viscosity of slag. To acquire good slag hydraulicity, the slag need to be quickly cooled underneath 800 degree Celsius. To cool off either jet stream can be applied or can be subjected to pressurized air. On the other hand, in pelletization operation the liquid slag is not wholly cooled with water and then projected into the air by a spinning drum. For suitable reactivity it is then ground as uniform fineness of Portland cement or OPC. The chemical composition of Slag are Cao(30-50%), SiO2(28-38%), Al2O3(8-24%), and MgO(1-18%). The growing CaO content develops an increase in slag basicity and also increase in compressive strength. The chemical composition of blast furnace slag produced in different plants in India are shown in table and also the chemical composition of cement is shown in next table from where we can clearly deduce different aspects that why we can use it which we will discuss later.

Table 2: Composition of slag generated in Steel Plants.

NAME OF STEEL-PLANT	COMPOSITION (%)							
	SiO_2	Al_2O_3	CaO	MgO	MnO	FeO	S	Basicity (CaO/SiO_2)
Bhilai Steel Plant, Durg, Chattisgarh	34.52	20.66	32.43	10.09	0.23	0.57	0.77	-
Bokaro Steel Plant, Bokaro, Jharkhand	30.06 to 31.85	21.12 to 22.71	32.48 to 34.17	10.12 to 10.39	-	0.260 to 0.370	-	-
Rourkela Steel Plant, Rourkela, Odisha	34.38 to 34.85	17.82 to 20.91	32.99 to 34.26	9.290 to 9.680	0.070 to 0.120	0.460 to 0.580	0.470 to 0.610	0.96 to 0.98

Durgapur Steel Plant, Durgapur, West Bengal	32.68	21.23	32.14	-	-	-	-	-
Tata Steel Ltd, Jamshedpur, Jharkhand	34.5	20.8	34.3	7.3	0.052	0.6	-	-

Table 3: Chemical composition of cement

OXIDE	COMPOSTION (%)
Lime (Cao)	60-65
Silica (SiO_2)	17-25
Alumina (Al_2O_3)	3-8
Iron Oxide (Fe_2O_3)	0.5-6
Magnesia (MgO)	0.5-4
Soda and Potash (Na_2O and K_2O)	0.5-1
Sulphur Trioxide (SO_3)	1-2

Hence we can clearly see from the two tables (Chemical compostion of slag from different industries and Chemical composition of cement) that the contents are almost similar and thus the percentages of the constituents are only varying thus we can incorporate ground granulated blast furnace slag in the cement concrete which will reduce the carbon emission and also the waste will be handled efficiently.

1.3. BENEFITS OF USING IT

- GGBS in cement concrete sets slowly as compared to concrete made with only OPC. But also continue to increase its strength potency over a long span of time.

- GGBS substitution cut the heat of hydration and lower the temperature rises thus prevents cracking. (But where quick setting is required there it will delay the schedule).
- Reduces the risk of alkali-silica reaction – It is often called as alkali-aggregate reaction as it is the reaction between silica in aggregate and alkali in cement. This reaction absorbs water as it produces a gel like substance and thus concrete vol increases hence cracking and disintegration occurs. Here GGBS incorporated cement concrete is useful as it is resistant towards this reaction as it decreases the total alkali content in cementitious material.

Figure 1: Alkali Silica reaction in Concrete

- Protection against sulphate attack – almost all soil types have sulphates in them in the form of magnesium, calcium, sodium, potassium etc. when concrete structures are built on these soil the sulphates specially liquid type passes inside the voids of the concrete-block and reacts with the hydrated cement products. Generally these attacks the calcium hydroxide and hydrated calcium aluminates which are in the concrete and changes the vol of cement paste in concrete thus results in deterioration. Further Magnesium sulphate reacts with hydrated calcium silicate and converts concrete into powder. Hence here GGBS incorporated cement concrete plays a vital role as it has resistance towards sulphate attack as it is due to reduction in C3A level and reduction in permeability.

Figure 2: Sulphate attack in concrete

- Protection against chloride attack – It is a vital aspect of durability of concrete as it attacks on the reinforcement used in the concrete and causes corrosion. Chloride can be added to the concrete-mix by admixtures or water used in the preparation or in case of after construction it may be placed in sea water or salty water is used. The alkaline protected layer around the bar reinforcement used in concrete is removed or destroyed by the chloride in the presence of H_2O and O_2. Hence GGBS incorporated concrete is helpful here as it chemically binds the chlorides with slag hydrates effectively decreasing the mobility of chlorides therefore reduction in corrosion risk.

Figure 3: Chloride attack in concrete

- Durability is high – Durability of concrete increases when there is decrease in permeability or diffusion to liquids and gases and its resistance to penetration of ions like SO3+ or Cl-. And the concrete is properly cured. GGBS incorporated concrete generally are more durable than same concrete prepared by OPC.
- High ultimate strength in comparison to normal, also tensile strength and elastic modulus is higher for a given compressive strength.
- Use of GGBS is recognised by LEED (Leadership in Energy and Environmental Design) and points are added for its certification.
- Improves workability.
- Good surface finish – as colour is lighter than the concrete prepared by only OPC hence it achieves a good surface finish.
- GGBS is more consistent than fly-ash as it is factory made with latest technologies introduced.

2. LITERATURE REVIEW

A.H.L Swaroop, K. Venkateshwararao and P. Kodandaramarao (2013) experimental results showed that GGBS offers more resistance than fly ash in case of weight loss. They evaluated the alteration in compressive strength and weight diminution reduction in 5 odd mixes of M30 grade and in different proportions of partial replacement by fly ash and GGBS for 7, 28, and 60 days. From this study they found that the initial or early age strength is less in fly ash and GGBS concrete w.r.t concrete which were used long back and results of fly ash and Ground granulated blast furnace slag concretes is more than conventional concrete at end of 28 days.

Arivalagan. S (2014) incorporated GGBS with cement with 20%, 30%, 40% partial replacement of OPC with GGBS for a mix design of M35 for 7 days and 28 days and concluded that 20% replacement is optimum and cost-effective as it is waste.
Yogendra O Patil, P. N. Patil, Arun Kumar incorporated the slag from blast furnace which is waste product generated from iron industry in making different things. They used it as partial substitution of cement and concrete which has cementititous property. They prepared several proportions from 0% to 40% partial substitution by GGBS. It is observed 20% replacement of cement is optimum without compromising much the compressive strength at 90 days.

Reshma Rughooputh and Jaylina Rana (2014) investigated the effects of GGBS partially replaced with cement on concrete cubes including tensile strength, flexure and splitting strength and most important compressive strength. The percentage dry shrinkage was a slight increase with GGBS and also those cubes were unsuccessful as the initial surface absorption test confirming the decrease in the permeability of GGBS incorporated concrete. Also they found that workability improves but plastic density decrease with partial replacement by GGBS. Based on results the optimum and best mix was one with 50% OPC and 50% GGBS.
K.V. Pratap and M. Bhaskar (2014) noticed the threefold blending of the cement concrete with fly ash and GGBS (ground granulated blast furnace slag). They conducted compressive strength and flexural strength on M60 grade with partial replacement of cement with GGBS and fly ash. They concluded increase in the compressive strength and split tensile strength at 28days with (4+16)% replacement.

3. MATERIALS

Concrete is a composite material which generally consists of aggregates and a binder. Basically binder is cement and other materials are aggregates, admixtures, water. Cement is widely used because of its quality and quick setting property and it also gives considerable strength. India is producer of cement after China. The modern day cement was invented by Joseph Aspidium and M. Vicat which we know as Ordinary Portland Cement (OPC). It is named as Ordinary Portland Cement because after hardening it resembles Portland stone. For Ordinary Portland Cement basic raw materials are categories into calcareous material (i.e. lime stone, chalk etc.) and argillaceous material (i.e. clay, marl etc.). After burning these basic compound together forms complex compounds. These complex compounds are mainly responsible for properties of cement. These complex compound are called bogue compound as it found by R.H. Bogue. These complex compounds are Tricalcium Aluminate (C_3A), Tetracalcium Alumino Ferrite (C_4AF), Tricalcium Silicate (C_3S) and Dicalcium Silicate (C_2S). Tricalcium Aluminate (C_3A) has 5-15% proportion in cement which provides flash setting property to the cement. Its rate of hydration is very high i.e. it hydrate within 24 hours. Due to high rate of hydration it causes shrinkage and develop cracks in hard concrete. Tetracalcium Alumino Ferrite (C_4AF) has 8-15% proportion in cement . It also provide flash setting property and hydrate within 24 hours. This compound is less significant than the Tricalcium Aluminate (C_3A). Both Tricalcium Aluminate (C_3A) and Tetracalcium Alumino Ferrite (C_4AF) have less tendancy of sulphate attack. Tricalcium Silicate (C_3S) has 40-60% proportion. This compound is mainly responsible for the early strength of cement and it is having best cementing action. It hydrates within a week and increase in proportion results in early strength. Higher proportion of C_3S, increases the frost resistance of the cement because of early strength. Dicalcium Silicate (C_2S) has 20-40% proportion in cement. It hydrate very slowly i.e. it take more than year to hydrate. This compound have least heat of hydration and responsible for ultimate strength of cement. By increasing the proportion C_2S in cement can make cement chemical resistant and its proportion is also increased for mass concreting. Silica in cement acts as pozzolanic material. These material are called Pozzolanas. Pozzolanas are the biproduct material of industry which intially do not show any binding property but when they are mixed with cement they start behaving like a binding materials. Some of chemical reaction involve in cement are:-

C_3S + H_2O $\xrightarrow{\text{hydration}}$ C-S-H gel + $Ca(OH)_2$ + Heat

C_2S + H_2O $\xrightarrow{\text{hydration}}$ C-S-H gel + $Ca(OH)_2$ + Heat $\uparrow$

$Ca(OH)_2$ +. Pozzolana Siliceous $\longrightarrow$ C-S-H gel

Cement acts binding material in concrete mix. It is made up of bogue compound. Property of cement can be changed by changing its chemical composition. The property of concrete can also change by addition of admixture. These admixture are added to the cement to enhance the specific property of cement. There are about 15 types of admixture. Cement constituents with its functions can be seen in the above table.

Table 4: Composition of cement functions

OXIDE	COMPOSTION (%)	FUNCTIONS
Lime (Cao)	60-65	If less then reduces the strength and setting time
Silica(SiO_2)	17-25	Excess of it causes slow setting
Alumina (Al_2O_3)	3-8	Responsible for quick setting, If more then lowers the strength
Iron Oxide(Fe_2O_3)	0.5-6	Gives color and helps in fusion of all ingredients.
Magnesia(MgO)	0.5 - 4	Colour and Hardness
Soda and Potash(Na_2O and K_2O)	0.5 - 1	If in excess causes efflorescence
Sulphur Trioxide (SO_3)	1-2	Makes cement sound

Here aggregates can be of two types – first one can be fine aggregates which we know as sand and the other can be coarse aggregate which are crushed stone. Almost 70% of the concrete consists of Aggregate and quality of aggregate impacts the property of concrete. For better workability less surface area of aggregates is required along with more cement paste but for more strength more surfaced area of aggregates is required because of more inter-particle bonding, thus we should use proper amount of fine aggregates and coarse aggregates. Sands or Fine aggregates are classified as 3 types on the basis of their fineness modulus, these are - Fineness modulus for fine sand, medium sand and course sand are 2.2 to 2.6, 2.6 to 2.9 and 2.9 to 3.2 respectively. For Coarse aggregates – Angular aggregates will give strong mix as better inter particle locking, but Round aggregates will give better workability, moreover Flaky aggregates will give neither strength nor workability thus flaky aggregates should be avoided. There are several tests conducted for coarse aggregates like for hardness Los Angeles abrasion test is conducted and for toughness impact test is conducted and for checking strength crushing strength test is conducted.

Table 5:- Composition of sand

Compound	**Percentage**
Alumina(Al_2O_3)	13.86
Silica(SiO_2)	79.98
Potassium and Sodium (K and Na)	1.67
Calcium (Ca)	0.87
Titanium (Ti)	0.15
Iron (Fe)	1.89
Manganese (Mn)	1.44

Water is used to make paste of concrete which should be free from harmful content like acid, salt, organic matter, oil & grease, sugar and other vegetative matter. The water in concrete should not be in excess amount because it leads formation of voids inside the body of concrete after evaporation due to which strength reduces. Deficiency of water which also not desirable because it may loss in workability, improper compaction due to which again voids can form and strength can reduce. Water used for concrete should be free from algae, organic component, alkalinity should be within limit etc. Water used in this experiment is potable water. Water used in the construction should comply these values –

Table 6:- Permissible limits as per IS456:2000	
pH	less than 6
Organic matter	200ppm
Inorganic matter	3000ppm
Sulphate	400ppm
Chloride	500ppm for RCC & 2000ppm for PCC
Suspended matter	2000ppm

Concrete has a low tensile strength and high compressive strength, just because of that we use reinforcement where the design says that the structure will also go through tension.

Figure 4: Construction materials

A. Cement

In the present work Dalmia cement of 53 grade Ordinary Portland Cement (OPC) is used for making cubes for every odd mixes. Cement used is uniform in colour and with-out any lumps. The properties of OPC used are below in Table 1

Table 7: Cement Properties

Particulars	Experimental Results	IS limits (IS : 8112-2013)
Specific Gravity	3.15	-
Initial-Setting Time	75min	Should not be less than 30

		minutes
Final-Setting Time	330min	Should not be more than 600 minutes

Figure 5: Cement

B. Fine Aggregates (F.A.)

The sand is locally procured and conformed to Zone II of grading as per IS383-2016. The specific gravity of sand used is 2.64. And the water absorption is found to be 1.26%.

Table 8: F.A. Properties

Properties of F.A.	Results
Specific Gravity	2.64
Grading Zone	II
Water absorption	1.26%

Figure 6: Fine Aggregate

C. Coarse Aggregate (C.A.)

Locally available coarse aggregate is used and the maximum size used is 20mm. Aggregates are angular in shape and no flaky or elongated aggregates were used in the process. For Coarse aggregates – Angular aggregates will give strong mix as better inter particle locking, but Round aggregates will give better workability, moreover Flaky aggregates will give neither strength nor workability thus flaky aggregates should be avoided. The specific gravity of C.A. is 2.7. And the water absorption is 0.58%.

Table 9: C.A. Properties

Properties of C.A.	Results
Specific Gravity	2.70
Maximum Size	20mm
Water absorption	0.58%

Figure 7: Coarse Aggregate

D. Ground Granulated Blast Furnace Slag (GGBS)

GGBS is acquired from Bokaro Steel Plant which is located in Bokaro District of Jharkhand. It is off- white in colour as shown in figure.

Figure 8: GGBS

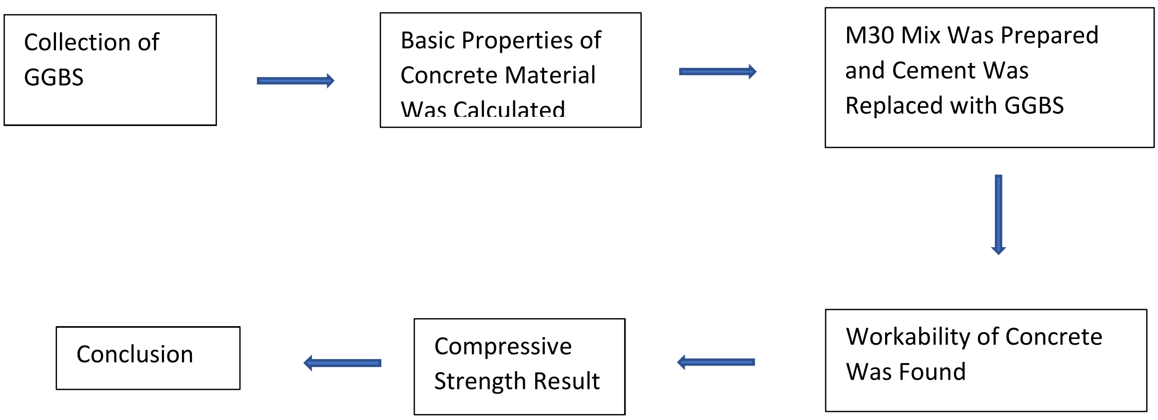
E. Water

Potable tap water is used.

4. EXPERIMENTAL PROGRAMME

4.1. METHODOLOGY

Waste GGBS was collected. The collected material was kept for replacement of cement. This GGBS powder was used to partially replace the cement with 0%, 10%, 20% and 30%. For each replacement, three cube were casted and each time workability was calculated. For calculation of compressive strength average of three cubes were taken and these value should not varies +/- 15. Workability test was conducted to test ease of placement of concrete. Concrete was filled in frustum in three layer and each layer 25 number of blow was given and workability is checked.



4.1.1. COMPESSIVE STRENGTH

Compressive strength of concrete is destructive test which can be determined using cubical, cylindrical, prismoidal mould. The strength obtained from cylindrical mould is 0.8 times the strength of cubical mould, it due to restraining effect in central portion. Strength of concrete depends upon quality of ingredients used, exposure condition, admixture used, degree of compaction and skill of the working man. In casting of if the size of aggregate is less than 20 mm than 15 cm X 15 cm X 15 cm size cube mould will be used and if the size of course aggregate is less than 10 mm than 10 cm X10 cm X10 cm size cube mould will be used. After filling of mould, it is kept at 27+/-2 degree Celsius then demoulded after 24 hours. After 28 days of curing, it is kept in open air for drying. Then gradual loading of 14 N/mm^2/ minute is applied and minimum averages of three cubes are taken. The compressive strength of these three cube should not varies more than 15% of average vale of cube. The strength of should not be less than characteristic strength of cube although it is designed for target mean strength.

This test gives compressive strength cube .This test check the quality control of mix. This test also check, whether desired strength of mix is achieved.

APPARATUS REQUIRED:-

- 150mm X 150mm X 150mm moulds
- Temping Rod (600mm&16mm)
- Universal testing machine
- Wrench
- Trowel
- Lubricant(Grease)
- Cloth

PROCEDURE:-

- A mix of 1 : 1.6136 : 2.8099 was prepared.
- Inner dimension of mould was measured and after that grease was applied on inner surface of cube.
- Prepared concrete was filled in cube in three layer i.e. 50 mm each layer.
- Each layer was tamped with the help of temping rod 35 times so, that rod should not penetrate on another.
- After filling the mould, cubes were taken to vibrator so that air taped inside cube can be removed which will further create honeycomb.
- Above procedure was repeated for different percentage of glass powder.
- After 24 hours, the mould was kept in curing chamber for 7 day and 28 day.

- After 7 day and 28 day, compressive test was conducted.

4.1.2. WORKABILITY TEST

Workability is property by which concrete can be placed, compacted, mixed and transported easily or it can be defined as amount of internal work done by concrete. If concrete having higher workability than amount of external energy required will be reduced. Workability of concrete depends upon shape of concrete, surface texture of concrete, grading of aggregate, water content, admixture and mix proportion etc. Workability can be tested by slump cone test, Compaction factor test, Flow table test, Vee-Bee Consistometer test. There range of utility are:-

Table 10:- Range of workability for different test

Degree of workability	Slump	Compaction factor	Vee-Bee time	Use
Very low	-	0.75-0.8	10- 20 sec	Road work
Low	25-75 mm	0.8-0.85	5-10 sec	Shallow section, Mass concreting of light reinforcement
Medium	50-100 mm	0.85-0.92	2-5sec	Heavily reinforced section, pumpable concrete
High	100-150 mm	0.92 above	-	Piling
very high	-	0.92 above	-	Trmie pile

Slump value calculated by slump cone test. The shape of slump can be of three type True slump, Sheared slump and Collapse slump.

APPARATUS REQIRED

- Conical frustum
- Tamping rod
- Wrench
- Trowel

PROCEDURE:-

- Clean the Frustum such that it is free from moisture.
- Place the mould (cone) on the steel plate.
- Fill the frustum in 3 or 4 layer.
- Tamp each layer 25 times such that it should not penetrate other layer.
- Lift the frustum slowly.

4.2. EXPERIMENT

The ambition of testing was to comprehend the concrete behaviour with replacement of cement with ground granulated blast furnace slag at room temperature. Concrete is term which is used to indicate the paste prepared by addition of water in specified proportion in the mixture of binding material i.e. course aggregate, fine aggregate ,cement, and admixture if required. The process of measuring the ingredient required for the preparation of concrete is termed as batching. It is of two type, weight batching and volume batching. In volume batching proportion of aggregates are done by volumetry basis, this type of mix are generally used for minor engineering work because its accuracy is low.

Table 11:- Nominal Mix proportion (IS456:2000)	
Nominal mix	Ratio
M5	1:05:10
M7.5	1:04:08
M10	1:03:06
M15	1:02:04
M20	01:05.5

In weight batching proportion of aggregate is done on the weight basis which more accurate than the volumetry batching. It is used in precision work and therefore it increase the cost production. If any structure require concrete strength more than 20 N/mm^2 then Mix design concrete is used. In this project weight batching is used for accurate result.

The prime parameter of study was compressive strength. The construction materials used here for casting concrete samples along with tested results are explained.

The design mix of cement concrete is done as per the procedure mentioned in the IS 10262:2009. Cubes are prepared in the proper proportions varying from 0% to 30% GGBS and compared with plain cement concrete cubes. The partial replacement is done on weight basis. And the mix proportion is 1:1.6136:2.8099 and w-c ratio is taken as 0.45 for all the mixes. The result of the ,mix design of the concrete (for 1 m^3) is shown in the table 4.1.

a. Grade of design = M30

b. Type of cement used = OPC53 (Dalmia)

c. Max nominal size of aggregate = 20mm

d. Min cement content = 300Kg/m^3 (IS456:2000)

e. Max water to cement ratio = .5(IS456:2000)

f. Exposure circumstances = Moderate

g. Approach of concrete placing = non pumping

h. Degree of supervision= Good

i. Type of aggregate used = Crushed angular aggregate

j. Workability = 75 (IS456:2000)

k. Maximum cement content = 450 Kg/m^3(IS456:2000)

l. Chemical admixture used = None

m. The Specific-gravity of binder (cement) = 3.15

n. The Specific-gravity of river sand = 2.64

o. The Specific-gravity of course aggregate = 2.7

Table 12: Mix For Compressive Strength

Particulars	Plain Cement Concrete	10%	20%	30%
Cement (kg/m^3)	413.33	372	330.67	289.34
Sand (kg/m^3)	666.96	666.96	666.96	666.96
Coarse Aggregate (kg/m^3)	1161.44	1161.44	1161.44	1161.44
GGBS (kg/m^3)	0	41.33	82.66	123.99
Water (kg/m^3)	186	186	186	186

Here 24 cubes are tested. The cubes having dimension of 150mm x 150mm x 150mm are prepared compressive strength of the concrete-mix is calculated for 7, 28 days of curing. All the cubes are tested as per IS specifications and norms. Testing is done in Hand operated Compression Testing Machine (CTM). Here a lever is attached to the machine and the lever is pulled and pushed regularly to increase the load also gradual increase of load is generated and thus a point comes when the concrete cubes fails and the particular load on which the cube failed is recorded in the dial as it has two hands, one of which strucks onto the load on which the cubes casted fails.

Figure 9: Cubes For Testing

Design Mix Calculation (As per IS Code 10262:2009) –

A1 –

1. Grade Specification – M30
2. Form of cement – OPC 53 grade
3. Max nominal size of aggregate – 20mm
4. Min cement content – 300kg/cubic metre
5. Max water-cement ratio – 0.5
6. Workability – 25 to 75 mm slump
7. Exposure Circumstances – Moderate
8. Type of aggregate – Crushed angular aggregate

9. Max cement content – 450 kg/m3

A2 -

1. Cement used – OPC 53 grade
2. Specific gravity – 3.15
3. No admixture was used
4. Specific Gravity of – a) FA – 2.64 , b)CA – 2.7
5. Water Adsorption – a)fa – 1.26 , b)ca – 0.58
6. Sieve Analysis – Zone II

A3 –

fck' = fck + 1.65s, here s= 5 as per table 1, IS10262

fck' = 25 + 1.65x5 = 38.25

A4 –

From Table 5 , IS 456,

Max w-c ratio= 0.5

Let us take 0.45 w-c ratio

A5 –

Max water content = 186 L

A6 –

Cal. of cement capacity –

w-c ratio = 0.45

Cement Content = 186/0.45 = 413.33 kg/m3

Thus 413.33 > 300 and 450 < 413 , hence passed.

A7 –

From table-3 (IS10262:2009), volume of CA referring to 20mm size aggregate and FA (zone II), for water content 0.5 = 0.62

In the present case water cement ratio is 0.45, therefore the corrected proportion of volume of coarse aggregate for w-c ratio 0.45 =0.63

Volume of Fine aggregate = 1-0.63 = 0.37

A8 –

a) Vol of concrete-mix = 1 cubic metre

b) Volume of cement to be used = (413.33/3.15)x(1/1000) = 0.1312 cubic metre

c) Volume of water to be used = (186/1)x(1/1000) = 0.186 cubic metre

d) Volume of all aggregates = {a – (b+c)} = 1-0.1312-0.186 = 0.6828 m^3

e) Mass of fine aggregate = 0.6828x0.37x2.64x1000 = 666.959 kg/m^3

f) Mass of CA = 0.6828x0.63x2.7x1000 = 1161.44 kg/m^3

Designed Mix proportion obtained is 1 : 1.6136 : 2.8099

5. RESULTS

5.1. SIEVE ANALYSIS OF SAND

Fineness modulus is an index number which indicate the average size of the sample of aggregate. With the increase in fineness modulus, the average size of aggregate also increases. If the sand have fineness modulus greater than 3.2 than it should not be used in concreting. Fineness modulus for fine sand, medium sand and course sand are 2.2 to 2.6, 2.6 to 2.9 and 2.9 to 3.2 respectively.

The fine aggregate used in this experiment have fineness modulus of 2.981 which is less than 3.2 and course type of sand was used.

Table 13:- Fineness modulus

% PASSING OF SAND	IS CODE 383 LIMIT
100	100
91.60	90 - 100
84.64	75 - 100
63.30	55 - 90
43.82	35 - 59
14.23	8. - 10
4.12	0 - 10
0.00	
2.981	FINENESS MODULUS

5.2. SLUMP CONE TEST

Slump cone test used for concrete having workability between low to high i.e. settlement of slump from 25 mm to 150 mm. The shape of slump can be of three type True slump, Sheared slump and Collapse slump. This test can be performed in field as well as in lab. With increase in water content, workability also increases and if water is increased gradually then slump shape can be attained from true to collapse slump but if the water content is very high than it will reduce the strength of concrete and initial setting time also increases.

In this experiment, concrete is designed for workability of 75 mm which have low workability. The workability obtained is increasing with increase in proportion of glass powder. Slump obtained in all the sample are true slump.

Table 14:- Slump value	
% REPLACEMENT OF SAND	SLUMP VALUE OF M30
0	34
10	37

5.3. COMPRESSIVE STRENGTH

The compressive strength of the design mix concrete cubes of various proportions of partial replacement of cement by GGBS at the age of 7 & 28 days with M30 grade of concrete with Dalmia OPC 53 grade given in table 5.1.

Table 15: Compressive Strength Of Mix

Concrete Types	Compressive Strength of Mix	
	7 Days (N/mm2)	28 Days (N/mm2)
100% OPC , 0%GGBS	26.05	42.21
90% OPC , 10%GGBS	21.81	38.03
80% OPC , 20%GGBS	22.44	40.58
70% OPC , 30%GGBS	22.24	39.16

Figure 10: Testing Of Cubes On CTM

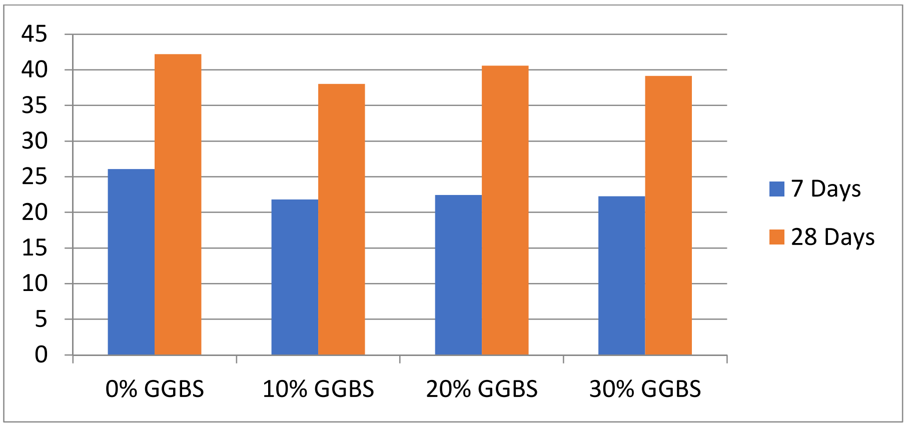


Figure 11: Graph of Compressive Strength At 7Days and 28Days

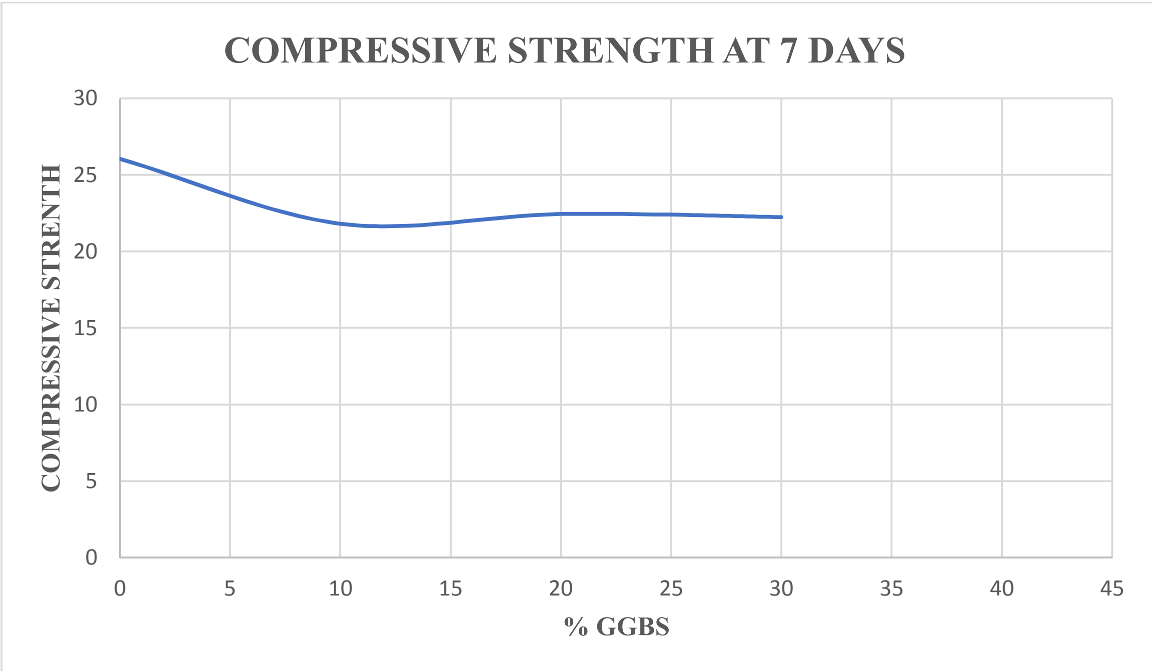


Figure 12: Chart of Compressive Strength at 7 days

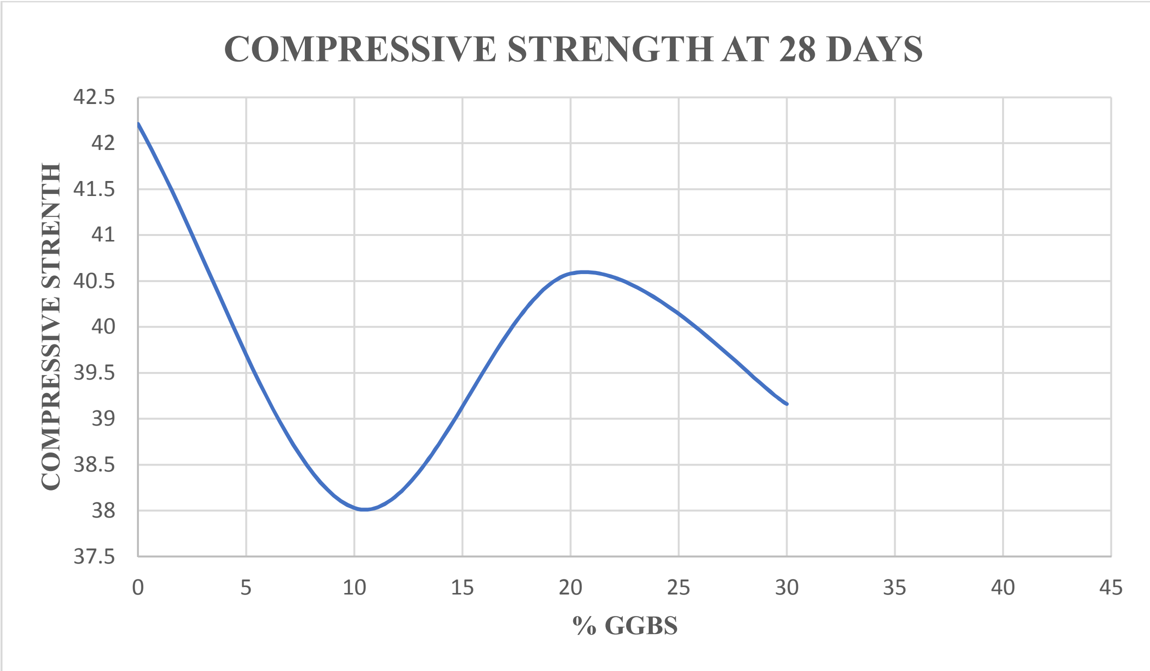


Figure 13: Chart of Compressive Strength at 7 days

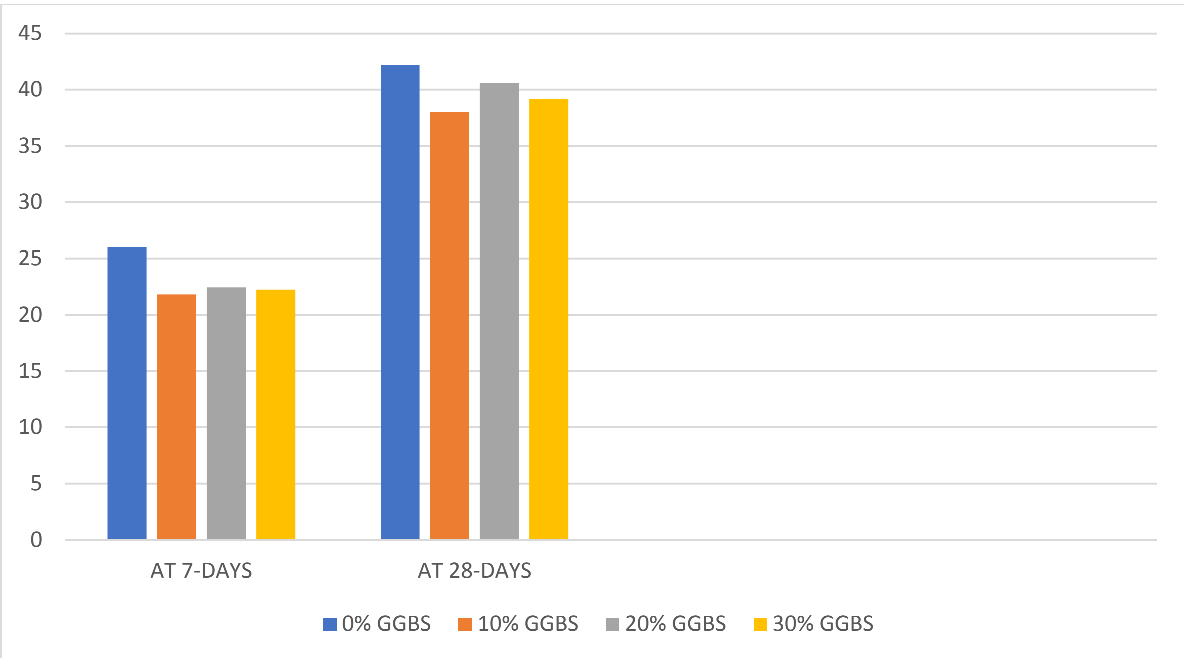


Figure 14: Compressive Strength vs. Replacement by GGBS at different ages.

6. DISCUSSION

This study is done to get the best suitable partial replacement of cement by GGBS and have several proportions is made from 0%, 10%, 20%, 30% and there compressive strength is calculated after 7 days and 28 days and the results can be seen with the help of column chart, the results shows maximum suitability for the aim is 20% partial replacment of cement by GGBS withour much impacting the compressive strength in comparison to the 100% OPC (0% GGBS). Hence the optimum replacement as per study is 20% without changing much the compressive strength in M30 grade concrete mix.

7. CONCLUSION

The increase of the GGBS content in mix-concrete decreases the compressive strength of concrete but partial replacement of 20% can be considered as the compressive strength value is near to plain cement concrete.

The application of GGBS in concrete is economical as this is considered as a waste which comes from the iron industry. And thus reduction in cost, environmental friendly and resistant to chemical attack

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