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Experimental Behavior of Reinforced Concrete with Partial Replacement of Cement with Ground Granulated Blast furnace Slag

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***Abstract*— GGBS a byproduct in pig iron manufacture has been found to be an ideal material to replace ordinary Portland cement used in concrete and it improves the durability of concrete. GGBS slag is obtained by quenching molten iron slag from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. In this project it is proposed to study the Experimental Behavior of Reinforced Concrete with Partial Replacement of Cement with GGBS.**

Mix design has been arrived for M25 concrete with replaced by the different ratios of 50%, 60%, 70% & 80% of GGBS slag. Fineness modulus, specific gravity, sieve analysis and bulk density of fine aggregate and coarse aggregate are also found out.Five set experiments were conducted the compressive strength on cube with and without GGBS. Five set experiments were conducted the compressive strength on cube with and without GGBS.

Totally forty five cube specimens were casted. Out of the first set, nine cubes casted with conventional concrete 0% replacement. The second set of nine cubes casted with 50% replacement of GGBS, the third set of nine cubes casted with 60% replacement of GGBS,The fourth set of nine cubes casted with 70% replacement of GGBS, The fifth set of nine cubes casted with 80% replacement of GGBS. Each set three cubes were tested with 7days, 14 days and 28 days respectively. Thus 50% GGBS as replacement for cement can be used in Cubes as it showed maximum compressive strength at 28% days.

Three experiments were conducted on beam-column with and without GGBS. Out of the three specimens. two control specimens were cast without GGBS and the other specimens were cast with 50% GGBS. The specimens were tested under a constant axial load and reverse lateral loading. Lateral load carrying capacity of the specimens with and without GGBS are studied.Trail mix has been carried out to qualify the mix, afterwards cubes were cast and compressive strength test to be conducted on the concrete with different ratios to satisfy the property of selected density.

I. INTRODUCTION

Concrete is typically the most massive individual material element in the built environment. If the embodied energy of concrete can be reduced without decreasing the performance or increasing the cost, significant environmental and economic benefits may be realized. Concrete is primarily comprised of Portland cement, aggregates, and water. Although Portland cement typically comprises only 12% of the concrete mass, it accounts for approximately 93% of the total embodied energy of concrete and 6% to 7% of the worldwide CO2 emissions. If concrete is mixed with ground granulated blast furnace slag as a partial replacement for Portland cement, it would provide environmental and economic benefits and the required workability, durability, and strength necessary for the design of the structures. Some of the recent studies in various parts of the world have revealed that

Ground granulated blast furnace slag concrete can protect the steel reinforcement more efficiently, so that it can resist corrosion, and thus the structure as a whole. GGBS concrete is a type of concrete in which a part of the cement is replaced by ground granulated blast furnace slag, which is an industrial waste. Thus the implementation of GGBS concrete can minimize corrosion in an effective way. Moreover it can lead to much durable structure without considerable increase in cost.

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

A. *APPLICATIONS*

GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. Two major uses of GGBS are in the production of quality-improved slag cement, namely Portland Blast furnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBS content ranging typically from 30 to 70%; and in the production of ready-mixed or site-batched durable concrete.

Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.

B. ADVANTAGES OF USING GGBS

From structural point of view, GGBS replacement enhances lower heat of hydration, higher durability and higher resistance to sulphate and chloride attack when compared with normal ordinary concrete. On the other hand, it also contributes to environmental protection because it minimizes the use of cement during the production of concrete.

On the other hand, designers have to be cautious of the potential bleeding problem of GGBS concrete. Another major hurdle of extensive use of GGBS concrete lies in the little source of supply of GGBS. As Hong Kong is not a major producer of steel, GGBS as a by-product of steel has to be imported overseas and this introduces higher material cost due to transportation and the supply of GGBS is unstable and unsteady.

- Reduce heat of hydration
- Refinement of pore structures
- Reduce permeability to the external agencies
- Increase resistance to chemical attack
- Better workability, making placing and compaction easier.
- Lower early-age temperature rise, reducing the risk of thermal cracking in large pours.
- Elimination of the risk of damaging internal reactions such as ASR high resistance to chloride ingress, risk of reinforcement corrosion.

C. SCOPE

This locally available material is used for strengthening of beam column and the experimental work is carried out with the main scopes as,

- To prove that the industrial waste from Steel industries can be a replacement for Cement.
- To study the physical and chemical properties of industrial waste and are the ingredients in concrete.
- To arrive the mix proportion for M25 grade concrete for of 50%, 60%, 70%, and 80% replacement GGBS.
- To arrive optimum percentage of w/c ratio and super plasticisers to get proper workability.
- To determine the compressive strength of concrete cubes at 7 days, 14 days and 28days curing with and without GGBS.
- To perform and compare the compressive strength of concrete with and without various replacement of GGBS.
- To design the beam- column.
- To determine Lateral load capacity and displacement and Strength carrying capacity of beam-column with and without GGBS concrete at 28 days.
- To compare the cost analysis of conventional concrete and without various replacement of GGBS.

II. EXPERIMENTAL WORKS AND METHODOLOGY

A. Methodology

The experimental work is carried out with the following methodologies are followed as

- Literature Review of construction waste.
- Identify the source of materials and collect the materials
- Testing of materials
- Design and mix proportion of concrete.
- Experimental work
- Testing of cubes and beam-columns
- Compare the compressive strength of conventional concrete with
  Partial replacement of GGBS concrete cubes
- Calculate the lateral load and displacement of beam-column with
  50% GGBS and without GGBS.
- Compare the cost analysis of conventional concrete and GGBS Concrete

Fig 1.1Manufacture of GGBS

Table 2.1 Shows the Physical properties of cement (OPC 53 grade)

Sl.No	Properties	Value
1	Specific gravity	3.08
2	Initial setting time(minutes)	150
3	Final setting time(minutes)	270
4	Soundness	
	Lechatelier Expansion(mm)	1
	Autoclave Expansion (%)	0.06
5	Compressive strength (N/mm2)	
	1 days	20
	3 days	39
	7 days	49
	28 days	70
6	Temperature during testing	28
7	Humidity (%)	65
8	Fineness : Specific surface (m2/Kg)	282

2.3 Table 2.2 Shows the Chemical properties of cement (OPC 53 grade)

S.NO	Properties	Test results
1	Lime Saturation factor	0.92
2	Alumina Iron Ratio	1.23
3	Insoluble residue (%)	0.25
4	Magnesia Mgo(%)	1.1
5	Sulphuric anhydride SO3 (%)	1.5
6	Loss on ignition LOI (%)	0.8
7	Chloride (%)	0.04
8	C3A Content	5
9	Alkalies (%)	0.46%

B. Ground granulated blast furnace slag

Ecocem GGBS comprises mainly of Cao, Sio2, Al2O3 ,Mgo, it contains less than 1% crystalline silica, and contains less than 1 ppm water soluble chromium IV. It has the same main chemical constituents as ordinary Portland cement, but in different proportions. It has a higher proportion of the strength-enhancing calcium silicate hydrates (CSH) than concrete made with Portland cement only, and a reduced content of free lime, which does not contribute to concrete strength.

Table 2.3 Shows the Comparison of chemical properties

Sl.No	Chemical constituent	Portland cement	GGBS
1	Cao	65%	40%
	Sio2	20%	35%
3	Al2O3	5%	10%
4	Mgo	2%	8%

Because of these chemical constituents, ecocem GGBS can be replaced for Portland cement in concrete mixes by as much as upto 95%.

C. Table 2.4 Shows the Physical properties of GGBS

Sl.No	Particulars	Property
1	Colour	Off white powder
2	Bulk density loose	1.0-1.1 tonnes/m³
3	Bulk density vibrated	1.2-1.3 tonnes/m³
4	Relative density	2.85-2.95
5	Surface area	400-600 m³/kg blaine

Ground cement powder in white in colour and is hydraulic cement, that is has property of setting and hardening through chemical reaction with water.

Table 2.5 Shows the Chemical properties for granulated slag

Sl.No	Particulars	Property
1	(Cao+Mgo/3Al2O3)/(Sio2+ 2/3Al2O3)	0.8
2	MgO %	15
3	MnO %	4
4	Sulphide sulphur %	1.5
5	Insoluble Residue %	4.5
6	Glass content %	78

D. Fine and Coarse Aggregate

- Fine Aggregate

In this study it was used the sand of Zone-II, known from the sieve analysis usingdifferent sieve sizes (10mm, 4.75mm, 2.36mm, 1.18mm, 600μ, 300μ, 150μ) adopting IS 83:1963.Local river sand was used as fine aggregate in the concrete. Aggregate comply with the requirements. Aggregate comprises about 55 per cent of the volume of mortar and about 85 per cent volume of mass concrete. Mortar contains aggregate of size of 4.75 mm and concrete contains aggregate up to a maximum size of 150 mm. Thus it is not surprising that the way particles of aggregate fit together in the mix, as influenced by the gradation, shape, and surface texture, has an important effect on the workability and finishing characteristic of fresh concrete, consequently on the properties of hardened concrete.

Table 2.6 Shows the Physical properties of Fine aggregate

Sl.No	Properties	Value
1	Specific Gravity	2.71
2	Fineness Modulus	3.41
3	Water Absorption	1 %
4	Surface Texture	Smooth
5	Bulk density	1.627 kg/m3

- Coarse Aggregate

The coarse aggregate used here with having maximum size is 20mm. We used the IS 383:1970 to find out the proportion of mix of coarse aggregate, with 60% 10mm size and 40% 20mmCrushed stones of 20 mm down were used as coarse aggregate. Aggregate comply with the requirements of IS 383.

The 20mm coarse aggregate free from silt and other deleterious impurities were collected from approved quarry. The physical, chemical, mechanical properties of coarse and fine aggregate for the same were evaluated by conducting standard test.

Table 2.7 Shows the Physical Properties of Coarse Aggregate

Sl.No	Properties	Value
1	Specific Gravity	2.75
2	Fineness Modulus	3.01
3	Water Absorption	0.5 %
4	Particle Shape	Angular
5	Impact Value	15.2
6	Crushing Value	18.6
7	Flakiness indices	28%
8	elongation indices	17%

- Admixture

In the present investigation, GLENIUM B1-233 (BASF) Super plasticizer was used. It is used for commercial type high range water reducing agent suitable for fly ash concrete. GLENIUM B1-233 is free of chloride & low alkali. It is compatible with all types of cements. Optimum dosage of GLENIUM B1-233 (BASF) should be determined with trial mixes. As a guide,a dosage range of 500 ml to 1500ml per 100kg of cementitious material is normally recommended.Because of variations in concrete materials, job site conditions, and/or applications, dosages outside of the recommended range may be required. In such cases, contact your local BASF representative. super plasticizers are used, (a) to increase the workability without changing the mixture composition, (b) to reduce the amount of mixing water, in order to reduce the w/c ratio which results in increase of strength and durability, and (c) to reduce both water and cement in order to cut cost and incidentally to reduce creep, shrinkage, and heat of hydration. One of the most important drawbacks of traditional super plasticizers such as SMF or SNF or MLS, is the slump loss. Slump loss with time presents a serious limitation on the advantages of super plasticizers.

Table 2.8 Shows the Physical and chemical properties of admixtures

Sl.No	Particulars	Property
1	Colour	Light brown liquid
2	Odour	Characteristics Change in physical state
3	Boiling point	> 100oC
4	Form	Liquid
5	Specific gravity (25oC)	≈ 1.2
6	Ph	6 – 9
7	Viscosity (25oC)	≈ 50- 150 cps
8	Relative density	1.08 (+/-) 0.01 at 25°C
9	Chloride ion content	< 0.2%
10	Solubility in water	Soluble

- Water

Water drawn from underground source of Padur premises is tested. A popular yard-stick to the suitability of water for mixing concrete is that, if water is fit for drinking it is fit for making concrete. This does not appear to be a true statement for all conditions. Some waters containing a small amount of sugar would be suitable for drinking but not for mixing concrete and conversely water suitable for making concrete may not necessarily be fit for drinking. Some specification also accept water for making concrete if the pH value of water lies between 6 and 8 and the water is free from organic matter. the source of water may be accepted. This criteria may be safely adopted in places like coastal area of marshy area or in other places where the available water is brackish in nature and of doubtful quality. However, it is logical to know what harm the impurities in water do to the concrete.

III. Results and Discussions

A. *Experimental Investigation On Testing Of Cubes*

The experimental programme comprises of, conducting trail mix for designing the grade of concrete, investigate about the consistency, preparation of specimen, curing and testing of the same. The stages mentioned above are explained individually. Trial mixes were conducted at, Padur

B. *Mix Design M 25 Grade conventional concrete*

This chapter deals with the mix design of concrete with and without GGBS.

Concrete mix design (Grade –M 25)

The grade of concrete used in the present study is M25. The following clauses explains briefly about the mix design of the concrete which is carried as per the specific code IS 10262 – 2009.

Ordinary Portland cement concrete (OPCC)

Ordinary Portland cement concrete (OPCC)

I) Design Stipulations for Proportioning

Grade designation : M 25
Type of cement : OPC 53 grade
Maximum nominal size of aggregate: 20mm
Minimum cement content : 300 Kg / m3
Maximum W/C Ratio : 0.5
Exposure condition : Moderate(For reinforced concrete)
Type of aggregate : Crushed angular aggregate
Degree of supervision : Good
Maximum cement content : 450 Kg / m3
Type of chemical admixture: Super plasticizer (Glenium B233)

II)Test Data for Materials

(a)Specific gravity ofCement : 3.08
Admixture : 1.09
Fine aggregate : 2.71
Coarse aggregate : 2.75
Water : 1
(b)Water absorbtion of Fine aggregate: 1% by mass
Coarse aggregate : 0.5% by mass
(c)Free surface moisture
Fine aggregate : Nil
Coarse aggregate : Nil

(d)Sieve analysis of
Fine aggregat :
Confirming to Zone II Grading of table 4 of IS 383 – 1970.
Coarse aggregate : Confirming to table 2 as perIS 383 – 1970 (% passing for graded aggregate of nominal

III) Design Calculation

(a) Target mean Strength of concrete for Mix Proportioning
Charactoristic compressive strength fck = 25 N/ mm2
f 'ck= fck + t s
t = Tolerance factor which not more than 5% (t = 1.65)
s = Standard deviation IS 10262 -2009 table – 1(s = 4 N/mm2)
f 'ck= fck + 1.65 s
= 25 + 1.65 * 4
= 31.60 N/ mm2

(b) Selection of Water – Cement Ratio
From Page 20, Table 5 of IS 456, maximum- water cement ratio = 0.50
Based on experience, Adopt water- cement ratio as 0.45
0.45 < 0.50, hence OK.

(c) Selection of Water Content
From Table 2 of IS 10262,
Maximum water content for 20 mm aggregate
= 186 Kg (for 25 – 50 mm slump)
From Page 2 of IS10262 Estimated water content for 100 mm slump
=186 + (6*186/100)
= 197 kg
As super plasticizer is used, the water content can be reduced up to 20 %.
Based on trials with super plasticizer, water content reduction of 21%
Has been achieved. Hence, the arrived water content
= 197 * 0.79 = 155.63liters
Say = 156 Litres

(d)Calculation of Cement Content
Water-Cement ratio= 0.45
Cementitious material content= 156 litres / 0.45,
= 346.66 Kg /m3
Say = 347 Kg /m3
From Table 5 of IS 456, minimum cement content for 'moderate' exposure
conditions is 300 kg /m3
347 Kg /m3 >300 Kg/m3 Hence OK

(e) Proportion of Volume of Coarse and Fine Aggregate Content
From table 3 as per IS 10262 - 2009, Page no.6
volume of coarse aggregate corresponding to 20 mm
size aggregate = 0.62 +0.02 = 0.64
For pumpable concrete these values should be reduced by 10% by volume
Volume of coarse aggregate = 0.64 X 0.90
= 0.58 m3 by mass
Volume of fine aggregate = 1 – 0.58
= 0.42 m3 by mass
based on the trials (Zone II)

(f) Mix Calculation

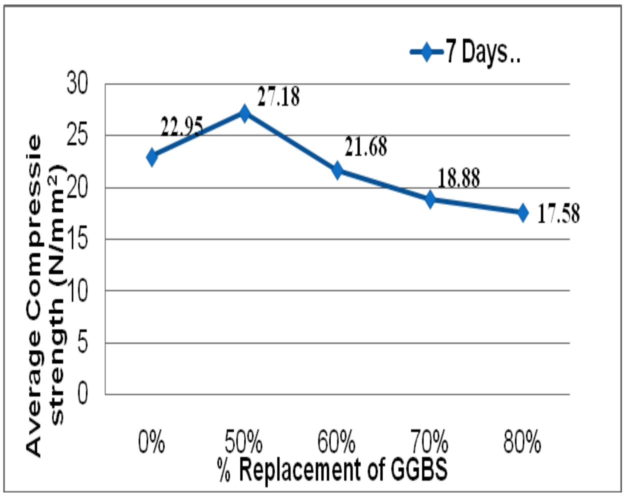
Volume of concrete (a) = 1 m3

Volume of cement= (Mass of cement/Specific gravity of cement) * (1/1000)
(b = (173.50 / 3.08*(1/1000) = 0.056 m3
Volume of GGBS (c) = (Mass of GGBS/ Specific gravity of GGBS) * (1/1000)
= (173.50/ 2.89)*(1/1000) =0.060 m3
Volume of water (d) = (Mass of water/ Sg. of water) * (1/1000)
= (156/1)*(1/1000) = 0.156 m3
Volume of chemical admixture
(at 700ml for 100Kg of cement)
=0.7% by weight of cementitious material)
= (Mass of admixture / Sg. of admixture)
= (347*0.007/1.09)*(1/1000)
Volume of admixture (e) =0.0022m3
Volume of all in aggregates = a-(b+c+d+e)
= (1-(0.056+0.06+0.156+0.0022)
Volume of all aggregate = 0.725 m3
Mass of coarse aggregates =
Volume of all aggregate X Volume of Coarse aggregate X Specific gravity of fine aggregate X 100
= 0.725*0.58*2.75*1000
= 1156 Kg/ m3
Mass of fine aggregate = 0.725 *0.42*2.71*1000 = 825 Kg /m3
Mass of super plasticizer = 2 Lit/m3

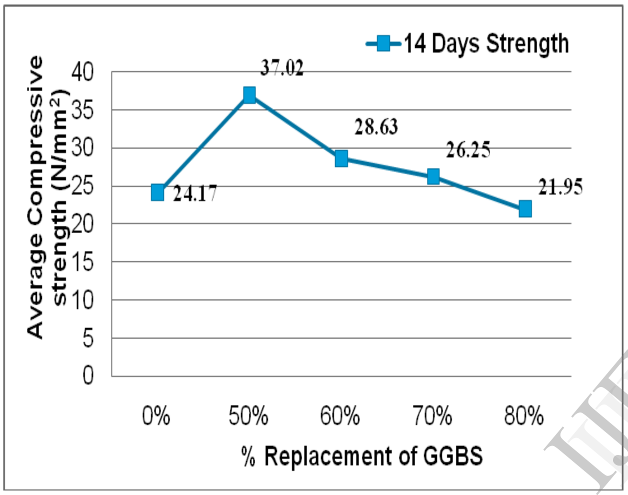
SI No	% of Replace ment	Cement Kg/m3	GGBS Kg/m3	Fine aggregate Kg/m3	Coarse aggregate Kg/m3	Water (Litre/ m3)
1	0 %	347	0	825	1156	156
2	50%	173.5	173.5	825	1156	156
3	60%	139	208	825	1156	156
4	70%	104	243	825	1156	156
5	80%	69	278	825	1156	156

Table 3.1 Shows the Average Cube Strength Test Result

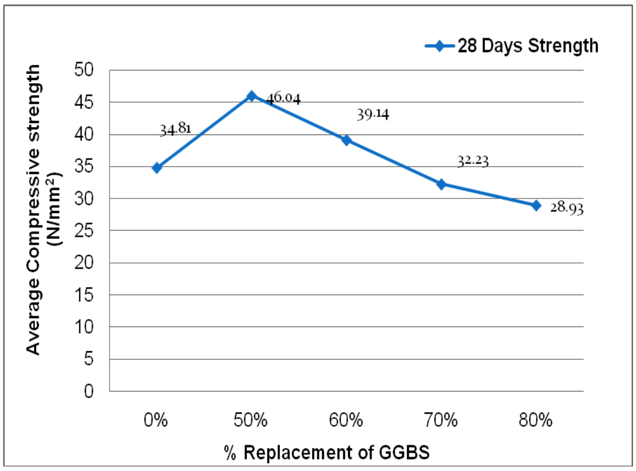
Sl. no	Cem ent%	GGB S%	Average Compressive strength (N/mm2)		
			7 days	14 days	28 days
1.	100 %	0%	22.95	24.17	34.81
2.	50%	50%	27.18	37.02	46.04
3.	40%	60%	21.68	28.63	39.14
4.	30%	70%	18.88	26.25	32.23
5.	20%	80%	17.58	21.95	28.93



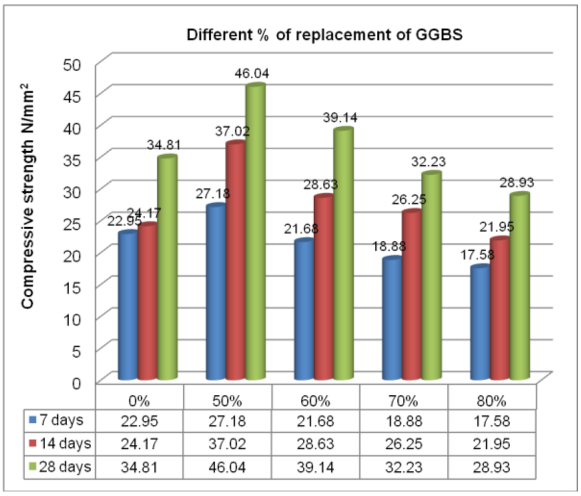
Graph 3.1 Shows the Cube Strength Test Result at 7 Days



Graph 3.2 Shows the cube strength test result at 14 Days



Graph 3.3 Shows the cube strength test result at 28 Days



Graph 3.4 shows the average cube strength test result

C. Experimental Investigation on Testing Of Beams And Column

- Design of column

The column is designed as per IS 456-2000 and detailed as per IS 13920.

Calculation of Slenderness Ratio

Length (L) = 1000mm

Breadth (B) = 150mm

Depth (d) = 150mm

L/d =

1000/150 = 6.66<12

Hence it can be designed as a short column 2. Traverse Reinforcement

Diameter of the main reinforcement= 12mm

Traverse reinforcement = 12/4

= 3

Minimum 6mm diameter bars should be provided as per IS 456-2000,

8mm dia bars provided.

(c) Spacing of Lateral Ties

(i) Dimension of column = 150mm

(ii) 16 times of longitudinal bar = 16*12

= 192mm

(iii) 300mm

8mm dia bar @ 150mm c/c spacing is provided.

(d) Confined Reinforcement

(i) Lateral dimension of column = 150mm

(ii) (1/6)th of clear span = 1000/6

= 450mm

(iii) 450mm Length of confined reinforcement provided (Lo) = 450mm

(e) Spacing of Confined Reinforcement

(i) (¼)th of the minimum dimension of column

= (¼)*150

= 37.5mm

(ii) Not less than 75mm

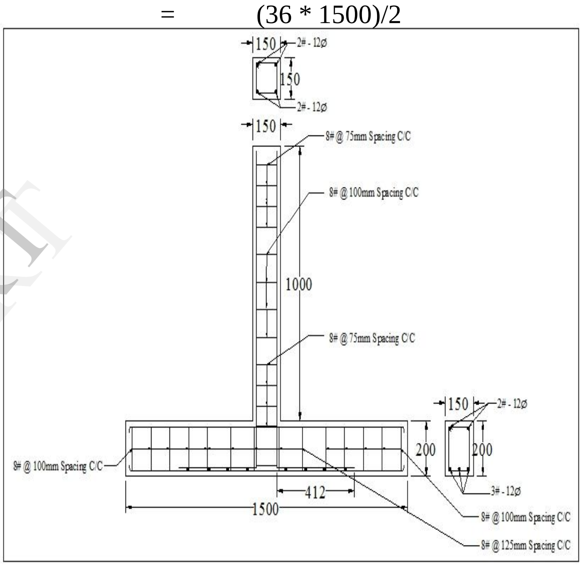
(iii) Not more than 100mm

Lateral ties @ 75mm spacing are provided.

Development Length Ld =(φσs/4τbd) + 10db
=(12*(230/4)*1.5) + (10*12)
=580mm
Where
db = diameter of longitudinal ba
σs = stress in the bar at the section considered at design
φ = nominal diameter of the bar
τbd = design of bond stress

(f) Calculation of Axial Load
Axial load (P) = 0.4fck Ac + 0.6 fyAsc
= (0.4*25*150*150) + (0.67*415*4*(π/4)*122)
= 350.78*103
= 351KN
30% axial load acting vertically
Vertical load= 30% Axial load
=(30/100)*351
pu = 105KN

(g) Non Dimensional Parameters
Fck = 25 N/mm2
(pu/fck*b*d)
= 105*103/25*150*150 = 0.187
Assume pt = 2%
p/fck =2/25
=0.08
Adopting effective cover 30mm
d/D = 30/150
= 0.2
From SP16 (chart 46)
p/fck = 0.08
(pu/fck*b*d) = 0.186
We get
(Mu/fck*b*d2) = 0.08
Mu = 0.08*25*150*1502
= 6.75KNmm
Area of reinforcement Ast = 2% of cross sectional area
= (2/100)*150*150
= 450mm2
Lateral Load
P*L = Mu
P*1000 = 6.75*106
Lateral load (P) = 6.75KN
3.7.2 Design of beam
(a) Dimensions
Breadth (b) = 150mm
Overall depth (D) = 200mm
Cover = 25mm
Effective depth (d) =200-25-(12/2)
= 170mm
Span (L) = 1500mm
Calculation of Reinforcement (Ast)
Xu/d= 0.87 FyAst / 0.36 Fck b d0.48
=0.87*415*Ast / 0.36*25*150*200
Ast = 359mm²
3#12mm dia bars provided @ tension side
2#12mm dia bars are provided @ compression side
Moment Calculation
RA X 1.5 X 103 = 6.75 X 106
RA = 4.5 KN
M = RA X (1500/2) + 6.75 X 106
= 4.5 x 103X (1500/2) + 6.75 X 106
M = 10.125 KN .mm
(d) Depth Calculation
Mu = 0.138 fckbd2
10.125*106 = 0.138*25*150*d
D = 139.87mm
Adopt d = 140mm
Shear Stress Calculation
Bending moment M
M = $(WL^2/8)$
10.125 * 106 = W *(1500)2/8
W = 36 N
Load W = 36 N
Vu = WL/2
= (36 * 1500)/2



Drawing 3.1 Shows the reinforcement details of the test specimen

D. Test specimen details

This chapter presents the experimental study on the behaviour of beam-column with GGBS concrete under reversed lateral loading. The specimens tested were of reinforced concrete with and without GGBS. This chapter gives a brief overview of the casting of specimens, test set-up and testing procedures.

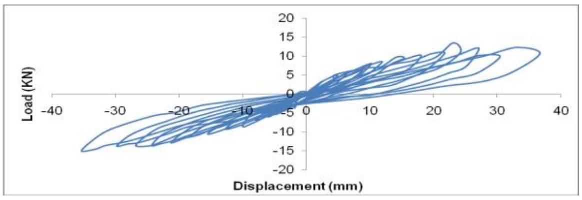
Three numbers of Reinforced concrete columns with and without GGBS were tested in the reversed lateral load testing frame. The reversed lateral loads have to be established so that the frames experience substantial inelastic deformations in tension and compression in the presence of axial compressive loads, similar to those during earthquake.

GGBS concrete with 50% cement was used in the investigation. The height of the column was 1000mm and of 150mm x 150mm size. Reinforcement details for the column are shown in Figure and the details of the specimens tested are given.

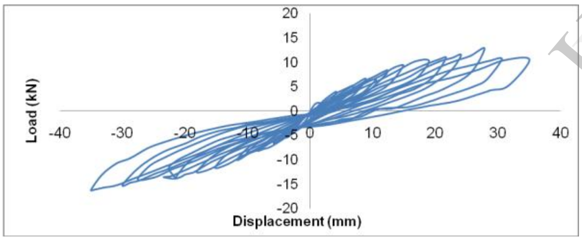
Columns and beams were made with M25 grade concrete and Fe- 415 grade steel was used for was used for lateral ties and stirrups. Out of the three specimens, there were one controlled specimens and the other two were cast with 50% of replacement of cement with GGBS. The specimens were designed and detailed as per IS 456:2000 and detailed as per IS 13920:1993. longitudinal reinforcement and Fe-415 grade steel .

Table 3.2 Lateral load versus lateral displacement

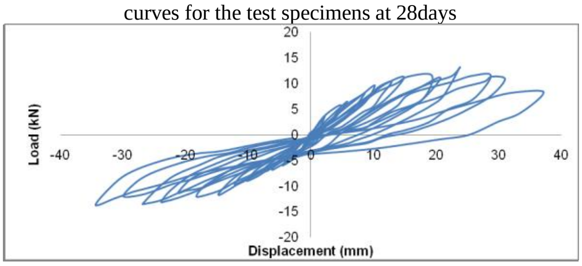
Specimen	Average ultimate load (KN)	Lateral displacement (mm)
A1	12.1	27.1
A2-1	12.9	25.2
A2-2		



Graph 3.3 Shows the Specimen A1 (without GGBS) Load Displacement curves for the test specimens at 28days



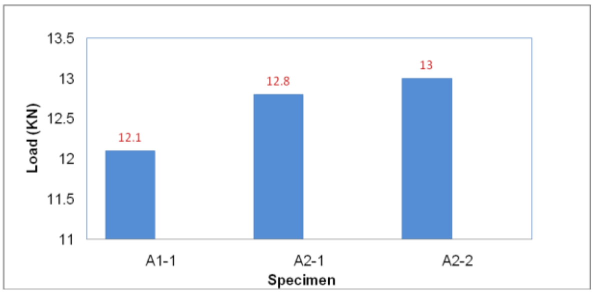
Graph 3.4 Shows the Specimen A2-1 (with GGBS 50%) Load Displacement curves for the test specimens at 28days



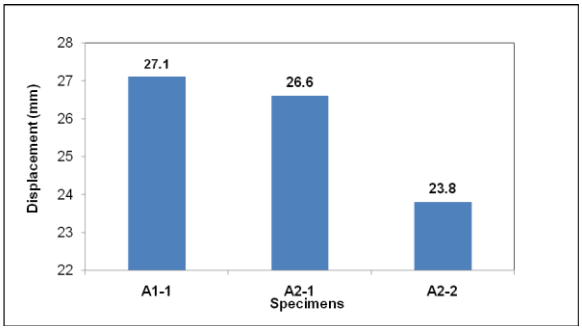
Graph 3.5 Shows the Specimen A2-2 (with GGBS 50%) Load Displacement curves for the test specimens at 28days

Table 3.3 Comparison on lateral load capacity and displacement

Specimen	Load (KN)	Average load (KN)	Displacement (mm)	Average Displacement (mm)
A1-1	**12.1**	**12.1**	**27.1**	**27.1**
A2-1	**12.8**	**12.9**	**26.6**	**25.2**
A2-2	**13**		**23.8**	



Graph 3.6 Shows the Comparison on maximum lateral load capacity of the specimens



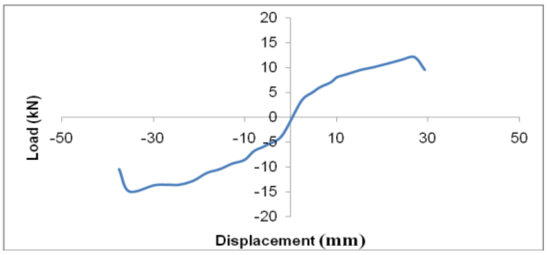
Graph 3.7 Shows the Comparison on maximum displacement of the specimens

Strength capacity of the specimens

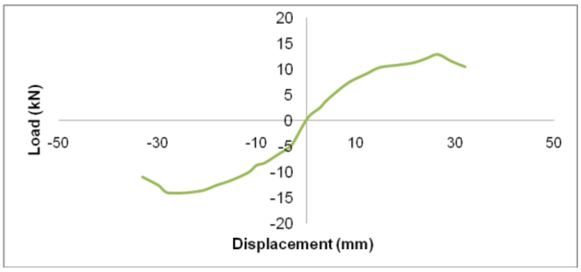
The trajectory of load displacement of all the specimen with and without GGBS such as A1-1, A2-1 and A2-2 respectively.

The specimens without GGBS A1 failed at an average lateral load of 12.1 kN with a lateral displacement of 27.1 mm. The other specimens with GGBS A2-1& A2-2 (with GGBS and tested at 28days) failed at an average loads of 12.9 kN with the lateral displacement of 25.2 mm.

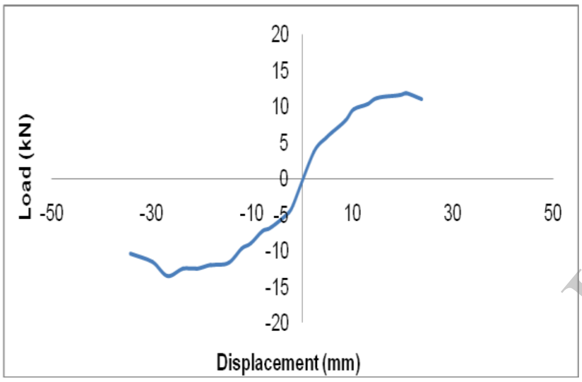
Thus there is 6.6% increase in the strength capacity of the specimens A2-1& A2-2 compared to the specimens A1-1



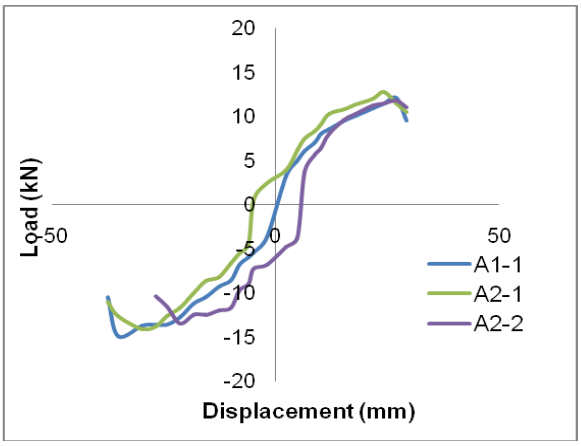
Graph 3.8 Shows the Peak lateral loads versus lateral displacement of the Specimen A1 (without GGBS)



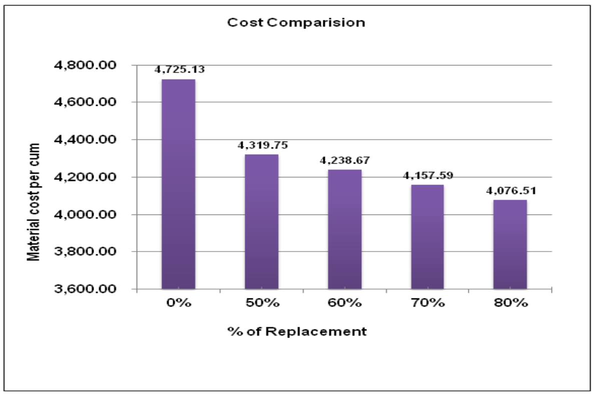
Graph 3.9 Shows the Peak lateral loads versus lateral displacement of the Specimen A2-1 (witGGBS 50%)



Graph 3.10 Shows the Peak lateral loads versus lateral displacement of the Specimen A2-2 (with GGBS 50%)



Graph 3.11 Shows the Comparison of Peak lateral loads-lateral displacement



Graph 3.12 Shows the Cost Comparison with different % replacement of concrete

IV. SUMMARY AND CONCLUSION

This study was primarily concerned with the evaluation the efficiency of GGBS in concretes containing normal Portland cements from the results of the investigation sported in recent years. The replacement levels in the concrete studied varied from 50% to 80% and the strength efficiencies at the 7 days, 14 days and 28 days were calculated. The primary conclusions can be listed as follows

Slag replacement by weight decreases the strength of concretes in short term when compared to control Portland cement concrete. However, in long term, concrete containing slag exhibits an equivalent or a greater final strength than that of control normal Portland cement concrete.

The strength loss caused by increasing slag replacement level is more evident at early ages. However, the strength loss disappears in long term and, concrete containing slag develops equivalent or higher strength than that of control normal Portland cement concrete.

When compared to control normal Portland cement concrete, the increase in the water–cementitious material ratio decreases more the strength of concrete having particularly high percentages of slag.

Thus 50% GGBS as replacement for cement can be used in Cubes as it showed maximum compressive strength at 28% days.

Three experiments were conducted on beam-column with and without GGBS.Out of the three specimens, one control specimens were cast without GGBS and the other two specimens were cast with 50% GGBS. The specimens were tested under constant axial load and varying lateral load.

The load carrying capacity of the specimens with GGBS and tested at 28 days increases by 6.6% when compared with specimens without GGBS.

Thus 50% GGBS as replacement for cement can be used in RC specimens as it showed good strength.

GGBS can achieve adequate early-age compressive strength, while maintaining a long-term strength higher than conventional concrete.

V. REFERENCES

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