Behaviour of Ground Granulated Blast Furnace Slag Infilled Concrete Column with Different End Conditions

Prof. Bharitkar Dipali[1] Prof. Mehetre Sagar[2]
Assistant Professor[1,2] Department of Civil Engineering,
JCOE Kuran(4084)
Savitribai Phule Pune University, Pune
Maharashtra, Pune
bharitkar.dipali7@gmail.com[1] ,sagarmehetre12@gmail.com[2]

Prof. Maid Nilesh[3] Prof. Supekar G. S.[4]
Assistant Professor[3,4] Department of Civil Engineering,
JCOE Kuran(4084)
Savitribai Phule Pune University, Pune
Maharashtra, Pune
nilesh.maid01@gmail.com[3] , supekae01@gmail.com[4]

Abstract- The production of cement results in emission of many green house gases in atmosphere, which are responsible for global warming. Hence, the researches are currently focussed on use of waste material having cementing properties, which can be added in cement concrete as partial replacement of cement, without compromising on its strength and durability, which will result in decrease of cement production thus reduction in emission in green house gases, in addition to sustainable management of the waste. The concrete industry is constantly looking for supplementary cementitious material with the objective of reducing the solid waste disposal problem which may be used as partial replacement of cement in concrete like GGBS. Due to its cementing properties This article represents an study of compressive strength of concrete prepared with Ordinary Portland Cement (Ultratech) 53 grade, partially replaced by ground granulated blast furnace slag (GGBS).

In this study, GGBS partially replaced at varying percentage of 0 to 75 %, at an interval of 25% and tested for its Compressive strength up to 28 days and those results were compared with conventional concrete. The overall test results shows that GGBS could be utilized in concrete as a partial replacement of cement which improves the mechanical properties of concrete.

Keywords–*GGBS, concrete column, compressive strength, End conditions*

I. INTRODUCTION

Concrete is one of the world's most used construction material due to its availability, durability and economy. India uses about 7.25 million cubic meters of ready-mixed concrete every year. It finds applications in highways, tunnels, bridges, high-rise buildings, dams etc. Greenhouse gas like CO_2 causes global warming and it leads to about 65% of global warming. The global cement industry emits about 7% of greenhouse gas to the earth's atmosphere. To minimize this environmental impact alternative binding material are introduced to make concrete.

GGBS, a by-product of iron manufacture, is a glassy, non-metallic granular material which exhibits cementitious properties on its own while others do so in the presence of Portland cement and calcium sulphate which are activators. Thus, GGBS acts as pozzolans and is therefore combined with Portland cement; resulting in a hardened cement of GGBS combined with Portland cement, which has more of smaller gel pores and fewer larger capillary pores than that of normal Portland cement which consequently results in lower permeability and hence greater durability. Moreover, it contains less free lime, which in its presence forms efflorescence and makes the resulting hardened cement more chemically stable. In addition, GGBS has a lower content of C3A than normal cement, thus decreasing the reactivity with sulphate.

II. OBJECTIVES OF INVESTIGATION

Experiment was conducted on concrete prepared by partial replacement of cement by GGBS ranging from 0 to 75% with an increment of 25%. The main objective of this investigation was to find out the effect of GGBS on the compressive strength with different end conditions as well as to evaluate the possibility of using GGBS in concrete as a partial replacement for cement without sacrificing the its strength. Following are the main objectives of the investigation:

1) To investigate partial substitute for ordinary Portland cement.
2) To determine the percentage of GGBS which gives maximum strength when it was compared to the control mix concrete at different end conditions

There are three end condition given below

- Column with both the ends fixed
- Column with both the ends pin
- Column with one end is fixed and other end is pin

Assembly for testing of column is prepared from steel material. This is a plate and nut combination assembly which can achieve end condition of testing.

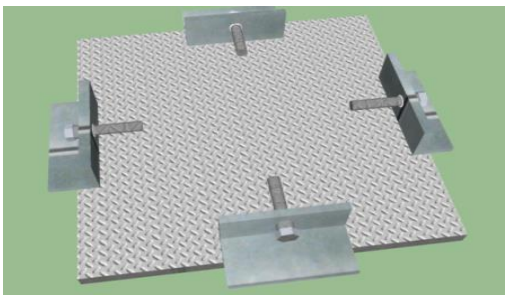

Fig. 1 Assembly for testing

III. MIX MATERIALS

A. *Cement*

The cement used in this experimental work is "Ulttratech 53 grade Ordinary Portland Cement". All properties of cement are tested by referring IS 12269 - 1987 Specification for 53 Grade Ordinary Portland Cement.

B. *Fine Aggregate*

River sand confirming to IS 383-1970 is used. Various tests such as specific gravity, water absorption, sieve analysis etc. have been conducted on C.A. to know their quality & grading.

C. *Coarse Aggregate*

About 20 mm size of coarse aggregate is used for concrete preparation. tests such as specific gravity, water absorption, impact strength, crushing strength, etc.have been conducted on C.A. to know their quality.

D. *Water*

In ferrocrete, the water used for mixing cement mortar should be fresh, clean and fit for construction purposes; the water of pH equal or greater than 7 and free from organic matter such as silt, oil, sugar, chloride and acidic material

E. *GGBS*

Ground Granulated Blast Furnace Slag (GGBS) is a byproduct of the steel industry. GGBS is produced when molten slag is quenched rapidly using water jets, which produces a granular glassy aggregate. Thus Ground Granulated Blast Furnace Slag is advantageous over various other cementing materials. Normally, silica, calcium, aluminum, magnesium, and oxygen are more than 95% in the composition of the blast-furnace slag.

TABLE I - PHYSICAL PROPERTIESOF GGBS

Sr.no	Physical Propertiesof GGBS	Value
1	Colour	off white
2	Specific gravity	2.9
3	Bulk density	1200 Kg/m^3
4	Fineness	350 m^2/kg

TABLE II- CHEMICAL COMPOSITION OF GGBS

Constituents	%
SiO2	34.4
Al2O3	21.5
Fe2O3	0.2
CaO	33.2
MgO	9.5
K2O	0.39
Na2O	0.34
SO3	0.66

IV EXPERIMENTAL WORK AND TEST

A. *Mix Design*

The grade of concrete used in the present study is M25. The mix design of the concrete is carried as per the specific code IS 10262 – 2009..The partial replacement of cement by 0 % to 75% at an increment of 25% each. Chemical admixtures are not used in the work.

B. *Compressive Strength:*

The concrete columns were removed from curing period of 28 days. Columns were tested for Compressive strength under universal testing machine with different end conditions. The compressive strength of concrete column with diff percentage of GGBS is found out.

V. TEST RESULTS

A. *Compressive Strength of Cubes:*

Three cubes of size 150x150x150mm were casted to work out the 7thand 28th day's compressive strength of all the proportions.

TABLE III- COMPRESSIVE STRENGTH OF CUBES FOR 7 DAYS

Mix Notation	% replacement of cement by GGBS	Avg. Compressive Strength In Mpa (7 Days)
C1	0%	19.71
C2	25%	20.97
C3	50%	21.65
C4	75%	20.12

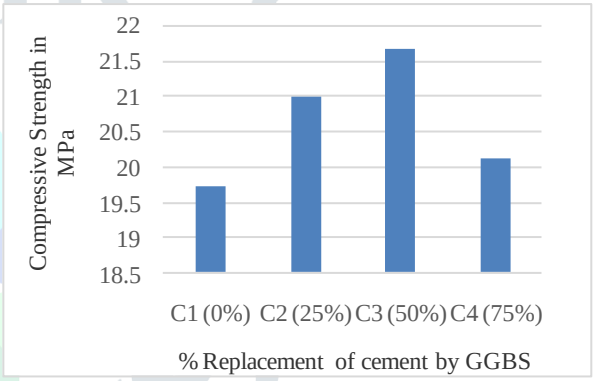

FIG.2 COMPARATIVE COMPRESSIVE STRENGTH OF CONCRETE CUBES WITH GGBS FOR 7 DAYS.

TABLE IV- COMPRESSIVE STRENGTH OF CUBES FOR 28DAYS

Mix Notation	% replacement of cement by GGBS	Avg. Compressive Strength In Mpa (28 Days)
C1	0%	31.86
C2	25%	33.10
C3	50%	34.92
C4	75%	32.31

Mix Notation	% replacement of cement by GGBS	Load taken by specimen	Comp. Strength In Mpa (7 Days)	Avg. Comp. Strength In Mpa (7 Days)
C1	0%	233	10.35	10.45
C1	0%	235	10.44	
C1	0%	238	10.57	
C2	25%	240	10.66	10.76
C2	25%	243	10.80	
C2	25%	244	10.84	
C3	50%	248	11.02	11.03
C3	50%	245	10.88	
C3	50%	250	11.11	
C4	75%	235	10.44	10.53
C4	75%	237	10.53	
C4	75%	239	10.62	

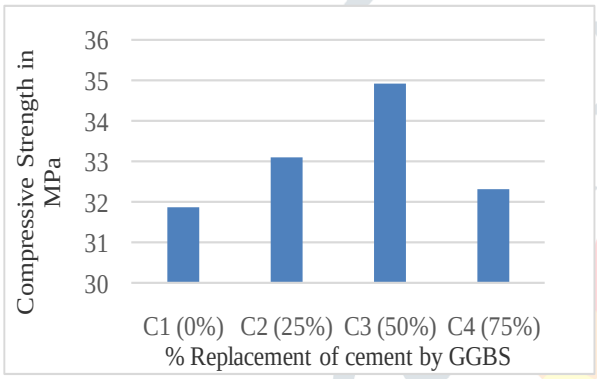

FIG.3 COMPARATIVE COMPRESSIVE STRENGTH OF CONCRETE CUBES WITH GGBS FOR 28 DAYS.

B. Compressive Strength of Columns:

C. Columns of size were tested for Compressive strength under universal testing machine with different end conditions. The compressive strength of concrete column with diff percentage of GGBS is found out.

FIG.4 COMPRESSIVE TEST TAKEN ON COLUMN

TABLE V-COMPRESSIVE STRENGTH OF COLUMNS FOR 7 DAYS (BOTH ENDS ARE FIXED)

Mix Notation	% replacement of cement by GGBS	Load taken by specimen	Compressive Strength In Mpa (7 Days)	Avg. Compressive Strength In Mpa (7 Days)
C1	0%	241	10.71	10.76
C1	0%	244	10.84	
C1	0%	242	10.75	
C2	25%	249	11.06	11.076
C2	25%	251	11.15	
C2	25%	248	11.02	
C3	50%	255	11.33	11.37
C3	50%	260	11.55	
C3	50%	253	11.24	
C4	75%	248	11.02	11.03
C4	75%	250	11.11	
C4	75%	247	10.97	

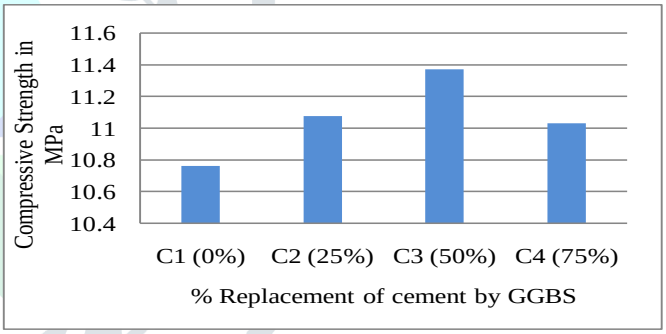

FIG.5 COMPARATIVE COMPRESSIVE STRENGTH OF CONCRETE COLUMNS WITH GGBS FOR 7 DAYS.
(BOTH ENDS ARE FIXED)

TABLE VI COMPRESSIVE STRENGTH OF COLUMNS FOR 7 DAYS (ONE END FIXED AND ONE END PINNED)

Mix Notation	% replacement of cement by GGBS	Load taken by specimen	Comp. Strength In Mpa (7 Days)	Avg. Comp. Strength In Mpa (7 Days)
C1	0%	233	10.35	10.45
C1	0%	235	10.44	
C1	0%	238	10.57	
C2	25%	240	10.66	10.76
C2	25%	243	10.80	
C2	25%	244	10.84	
C3	50%	248	11.02	11.03
C3	50%	245	10.88	
C3	50%	250	11.11	
C4	75%	235	10.44	10.53
C4	75%	237	10.53	
C4	75%	239	10.62	

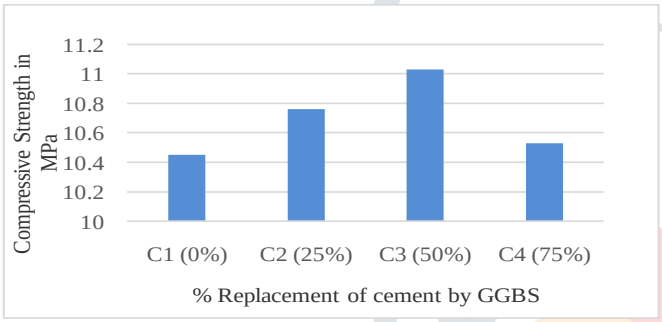

FIG.6 COMPARATIVE COMPRESSIVE STRENGTH OF CONCRETE COLUMNS WITH GGBS FOR 7 DAYS.(ONE END FIXED AND ONE END PINNED)

TABLE VII COMPRESSIVE STRENGTH OF COLUMNS FOR 7 DAYS (BOTH ENDS ARE PINNED)

Mix Notation	% replacement of cement by GGBS	Load taken by specimen	Comp. Strength In Mpa (7 Days)	Avg. Comp. Strength In Mpa (7 Days)
C1	0%	224	9.95	9.92
C1	0%	220	9.77	
C1	0%	226	10.04	
C2	25%	234	10.4	10.36
C2	25%	230	10.22	
C2	25%	236	10.48	
C3	50%	240	10.66	10.83
C3	50%	245	10.88	
C3	50%	247	10.97	
C4	75%	229	10.17	10.28
C4	75%	232	10.31	
C4	75%	233	10.35	

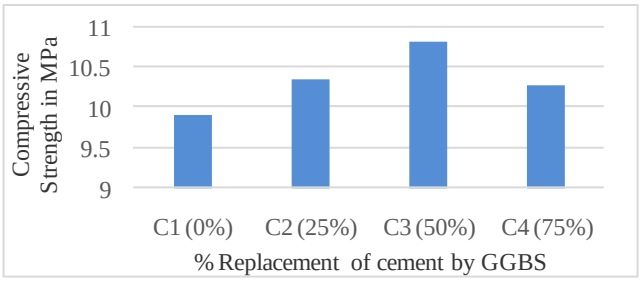

FIG.7 COMPARATIVE COMPRESSIVE STRENGTH OF CONCRETE COLUMNS WITH GGBS FOR 7 DAYS.(BOTH ENDS ARE PINNED)

TABLE VIII COMPRESSIVE STRENGTH OF COLUMNS FOR 28 DAYS (BOTH ENDS ARE FIXED)

Mix Notation	% replacement of cement by GGBS	Load taken by specimen	Comp. Strength In Mpa (28 Days)	Avg. Comp. Strength In Mpa (28 Days)
C1	0%	365	16.22	16.19
C1	0%	360	16.01	
C1	0%	368	16.36	
C2	25%	372	16.53	16.73
C2	25%	381	16.93	
C2	25%	377	16.75	
C3	50%	378	16.80	17.18
C3	50%	394	17.51	
C3	50%	388	17.24	
C4	75%	376	16.71	16.65
C4	75%	367	16.31	
C4	75%	381	16.93	

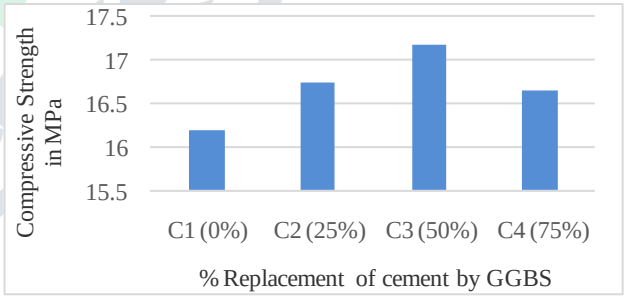

FIG.8 COMPARATIVE COMPRESSIVE STRENGTH OF CONCRETE COLUMNS WITH GGBS FOR 28 DAYS.

TABLE IX COMPRESSIVE STRENGTH OF COLUMNS FOR 28 DAYS (ONE END FIXED AND ONE END PINNED

Mix Notation	% replacement of cement by GGBS	Load taken by specimen	Compressive Strength In Mpa (7 Days)	Avg. Compressive Strength In Mpa (7 Days)
C1	0%	357	15.86	15.68
C1	0%	354	15.73	
C1	0%	348	15.46	
C2	25%	362	16.08	16.30
C2	25%	368	16.35	
C2	25%	371	16.48	
C3	50%	374	16.62	16.66
C3	50%	379	16.84	
C3	50%	372	16.53	
C4	75%	356	15.82	15.95
C4	75%	359	15.95	
C4	75%	362	16.08	

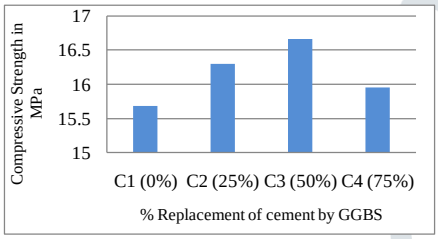

FIG.9 COMPARATIVE COMPRESSIVE STRENGTH OF CONCRETE COLUMNS WITH GGBS FOR 28 DAYS.

VI. RESULTS AND DISCUSSION

The influence of GGBS on the Properties of concrete such as the compressive strengthstudied. An appreciable increase in the compressive strength is observed with the increase in the percentage replacement of cement by GGBS from 0 % to 75 %. With 25% replacement.

Considering the strength criteria, the replacement of cement by GGBS is feasible up to 50%. Usage of GGBS in concrete can prove to be economical as it is having less cost than cement.

VII. CONCLUSION

Based on experimental observations, following conclusions can be established:

1) GGBS concrete increases the compressive strength as compared with the conventional concrete.
2) Use of GGBS in concrete will minimize the disposal problem of GGBS and prove to be eco-friendly.
3) From strength point of view, partial replacement of cement by GGBS shows positive results.

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