Investigation on Strength and Durability of Concrete by Partial Replacement of GGBS in Cement

Ms. K. Suseela[1] Sk. Alisha[2]
[1,2]Vishnu Institute of Technology, India

Abstract— The advancement of concrete technology can reduce the consumption of natural resources and energy sources and lessen the burden of pollutants on the environment. Presently, Industry inevitably generates wastes, irrespective of the improvements introduced in manufacturing processes. In the industries, about 15%-30% production goes as waste. These wastes pose a problem in present-day society. So, it is most essential to develop eco-friendly concrete from these wastes. This project reports the results of an experimental study on the partial replacement of (OPC) cement with GGBS waste powder of 0%, 10%, 20%, 30% and 40% by weight of cement. Concrete mixtures were produced, tested of compressive strength to the conventional concrete. These tests were carried out to evaluate the properties for 7, 14 & 28 days. The moulds prepared are as follows 150mm X 150mm X 150mm cubes and 300 X 150 mm cylinders for each concrete mix. The aim of the investigation is to study the behaviour of concrete while replacing the GGBS waste with different proportions in concrete. The results of this work have been presented in this dissertation. These tests were carried out to evaluate the properties for the test results of 7, 14, 28days for compressive strength and tensile strength in normal water and in HCL solution of 1%, 3% and 5%. Also, the durability aspect of GGBS with cement for HCL solution was tested.

Keywords: GGBS, M35 Design, Compressive Test, Split Tensile Test and Durability in HCL Solution

I. INTRODUCTION

Ground Granulated Blast Furnace Slag (GGBS) which is a by-product formed from the production of cast iron, also called pig iron, if the slag is cooled slowly in air, the chemical components of slag are usually present in the form of crystalline melilite (C2AS-C2MS2, solid solution), which does not react with water at ordinary temperature.

If it ground to very fine particles, the material will be weak cementitious and pozzolanic. However, when the liquid slag is rapidly quenched from high temperature by either water or a combination of air and water most of the lime, magnesia, silica and alumina are held in non-crystalline or glassy state. The water-quenched product is called granulated slag due to the sand-sized particles, while the slag quenched by air and a limited amount of water which is in the form of pellets is called palletized slag. It can develop satisfactory cementitious properties. Keeping the above in mind, an attempt has been made in the present study to investigate into potentialities of using GGBS admixture in cement concretes and compared to similar characteristics of concretes made with ordinary Portland cement alone without replacement.

II. MATERIALS AND METHODS

A. Cement

Cement is a material that has cohesive and adhesive properties in the presence of water. Such cements are called hydraulic cements.

These consist of primarily silicates and aluminates of lime obtained from limestone and clay. There are different types of cements, out of which OPC is used.

Ordinary Portland Cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. It is of three types 33 grade, 43 grade, and 53grade. One of the important benefits is the faster rate of development of strength.

Ordinary Portland Cement (OPC) available in the market conforming to IS 12269-1987 was used for casting the specimens. The cement using is 43 Grade.

1) Main Compounds of Portland Cement:

Name of the Compound	Oxide Composition	Abbreviation
Tri calcium silicate	$3CaOSiO_2$	C_3S
Di calcium silicate	$2CaOSiO_2$	C_2S
Tri calcium aluminate	$3CaO,Al_2O_3$	C_3A
Tetra calcium alumina ferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF

2) Chemical Composition of Ordinary Portland Cement:

Chemicals	Compositions
Lime (CaO)	60 - 67 %
Silica (Sio_2)	17 – 25 %
Alumina (Al_2O_3)	3 – 8 %
Iron oxide (Fe_2O_3)	0.5 – 6 %
Magnesia (MgO)	0.1 – 4 %
Sulphur trioxide (So_3)	1 – 3 %
Soda and /or potash ($Na_2O + k_2O$)	0.5 – 1.3 %

3) Physical Properties of Cement

S.NO	PROPERTY	VALUE
1	Normal Consistency	
2	Initial Setting	30mnts
3	Final Setting	10hrs
4	Specific Gravity	3.15
5	Fineness of cement	

B. Aggregates

Aggregate properties greatly influence the behaviour of concrete, since they occupy about 80% of the total volume of concrete. The aggregate are classified as

– Fine aggregate
– Coarse aggregate

1) Fine aggregate

Fine aggregate are materials passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as

coarse aggregate. From the main matrix of the concrete whereas fine aggregate form the filler matrix between the coarse aggregate. The most important function of the fine aggregate is to provide workability and uniformity in the mixture. The fine aggregate also helps the cement paste to hold the coarse-aggregate particles in suspension.

According to IS 383-1970 the fine aggregate is being classified in to four different zones, that is Zone-1, Zone-2, Zone-3 and Zone-4. The sand obtained from river beds or quarries is used as fine aggregate.

2) Coarse aggregate

The coarse aggregate are granular materials obtained from rocks and crushed stones. They may be also obtained from synthetic material like slag, shale, fly ash and clay for use in light weight concrete. Also, in case of coarse aggregate maximum 20mm sized coarse aggregate is suitable for concrete work. But where there is no restriction, 40mm or large size may be permitted.

3) Sand

Locally available river sand in dry condition is used for the preparation of concrete. The grading of sand confined to Zone II As per IS 383-1970, the specific gravity of sand is 2.67.

C. GGBS

Ground Granulated Blast Furnace Slag (GGBS) which is a by Product formed from the production of cast iron, also called pig iron, if the slag is cooled slowly in air, the chemical components of slag are usually present in the form of crystalline melilite (C2AS-C2MS2, solid solution), which does not react with water at ordinary temperature. If it ground to very fine particles, the material will be weak cementitious and pozzolanic. However, when the liquid slag is rapidly quenched from high temperature by either water or a combination of air and water most of the lime, magnesia, silica and alumina are held in non-crystalline or glassy state. The water-quenched product is called granulated slag due to the sand-sized particles, while the slag quenched by air and a limited amount of water which is in the form of pellets is called palletized slag. It develops satisfactory cementitious properties.

1) Physical Properties of GGBS

S.no	Property	Value
1	Normal Consistency	30%
2	Initial Setting	55mnts
3	Final Setting	9hrs
4	Specific Gravity	2.98
5	Fineness of GGBS	8%

2) Chemical Properties of GGBS

Chemicals	Percentage in GGBS
CaO	30 – 50 %
SiO_2	28 – 38 %
Al_2O_3	8 – 24 %
MgO	1 – 18 %
MnO	0.68 %
TiO_2	0.58 %
K_2O	0.37 %
N_2O	0.27 %

3) Water

Clean potable water is used for mixing concrete. Water used for mixing and curing should be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete and steel.

III. EXPERIMENT

Weigh is the correct method of measuring the material. Use of weight system is batching, facilities accuracy, flexibility and simplicity. Different types of weigh batches are available. In smaller works, the weighing arrangement consists of two weighing buckets, each connected through a system of levers to spring loaded dials which indicate the load. The weighing buckets are mounted on a central spindle about which they rotate. Thus, one can be loaded while the other is being discharged into the mixer skip. A simple spring and electronic balance or the common platform weighing machines also can be used for small job.

On large work sites, the weigh bucket types of weighing equipment are used. This is fed from a large overhead storage hopper and it discharges by gravity, straight in to mixer. The weighing is done through a lever arm system and two inter linked beam and jockey weights. The required quantity of say coarse aggregate is weighted, having only the lower beam in operation. After balancing, by turning the smaller lever, to left of the beam, the two beams are inter-linked and the fine aggregate is added until they both are balanced. The pointer indicates the final balance on the scale to the right of the beams. Discharge is through the swivel gate at the bottom.

A. Measurement of Water

When weigh batching is adopted, the measurement of water must be done accurately. Addition of water by graduated bucket in terms of litres will not be accurate enough for the reason of spillage of water etc. It is usual to have the water measured in a horizontal tank or a vertical tank fitted to the mixer. These tanks are filled up after every batch. The filling is so designed to have control so as to admit any desired quantity of water. Sometimes, water – meters are fitted in the main water supply to the mixer from which the exact quantity of water can be into the mixer.

B. Mixing

Thorough mixing of the material is essential for the production of uniform concrete. The mixing should ensure that the mass becomes homogenous, uniform in colour and consistency. Initially the coarse aggregates and fine aggregates are weighed. Later required quantities of cement and GGBS separately are mixed dry to a uniform colour. As per the mix design water is measured. All the ingredients are added to the concrete mixture and mixed for the required time period to achieve a homogeneous mix of uniform colour.

C. Hand Mixing

Hand mixing should be done over impervious concrete or brick floor of sufficiently large size to take one bag of cement. Spread out the measured quantity of coarse aggregate, fine aggregate in alternate layers. Pour the required quantities of cement and GGBS mixture on the top of it, and mix them dry by a shovel, turning the mixture over and over again until uniformity of colour is achieved. This uniform mixture is spread out in the thickness of about 20cm. Water is taken in

required quantity is taken and sprinkled over the mixture and simultaneously turned over. This operation is continued till such a time that good uniform homogenous concrete is obtained. It's a particular importance to see to that the water is not poured but it is only sprinkled. Water in small quantity should be added towards the end of the mixing to get the required consistency.

D. Compressive Strength Test

Compression test is the most common test conducted on hardened concrete, partly because it's an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

Test for compressive strength was conducted as the specimens of 150mm cubes are exposed to a specific temperature and duration were released from the furnace and tested for compressive strength after cooling down the specimens to normal room temperature condition. The specimen cubes were placed in compression testing machine such that the load was applied on the opposite sides of the cube the axis of the cube was aligned with the Centre of steel plate of the testing machine.

The load was gradually applied without any shock and increased continuously until the resistance of the specimen to the increasing load broke down and no greater load was sustained. The compressive strength of the specimen was computed by dividing the maximum load received by the specimen with the Cross-Sectional area. Average of three test results of the specimen was considered as the compressive strength by ensuring the individual variation is not more than 15% of the average value. A total of 45 conventional cubes was cast for strength testing to account for different ages of curing 7, 14 and 28 days.

E. Split Tensile Test

The split tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure. The test consists of applying a compressive live load along the opposite generators of a concrete cylinder placed with its axis horizontal between the compressive plates. Due to the compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter as obtained from an elastic analysis. Cylinder specimens of different percentages of GGBS waste were tested under compression testing machine in accordance with after a curing period of 7,14 & 28 days.

After required curing period the cylinder specimens are removed from the curing tubs and cleaned to wipe off the surface water. Draw diametrical lines on each end of the specimen using a suitable device that will ensure that they are in the same axial plane. Determine the diameter of the test specimen by averaging three diameters, Determine the length of the specimen by averaging at least two length measurements. Position the bearing strips, test cylinder, and supplementary bearing bar by means of the aligning jig and centre the jig so that the supplementary bearing bar and the centre of the specimen are directly beneath the centre of the thrust of the spherical bearing block. Apply the load continuously and without shock, splitting tensile stress until failure of the specimen, record the maximum applied load indicated by the testing machine at failure, note the type of failure and the appearance of the concrete.

The humiliating character of cement concrete begins on the surface of the concrete, slowly penetrating into the inner mass of the concrete and gets a reduction of strength. In order to make the durable structure with usage of GGBS, it is necessary to take all precautions which will be taken in normal weight concrete. There are different degradation agents available like soft water and some acid in solution containing soluble HCL. To evaluate the durability behaviour of concrete (cement replacement with GGBS), test has been performed in this study of concrete strength

The main objective of the present experimental investigations is to obtain specific experimental data, which helps to understand the Bacterial concrete and its characteristics (Strength and Durability)

Effect of HCl acid on pore structure Based on the previous research, damage impact of various de-icing chemicals and exposure conditions on concrete materials was studied and resulted that various de-icing chemicals penetrated at different rates into given paste and concrete, resulting different degree of damage. In present study, the percentage concentration of HCl is 1%,3%,5% concentration and its effect on GGBS is not so significant. As consider the strength of concrete specimens after 7, 14, 28 days variation was low even for replacement. The range of variation is 0% to 40% with respect to the reference concrete after 7, 14,28 days exposure to the HCl.

IV. Results and Discussion

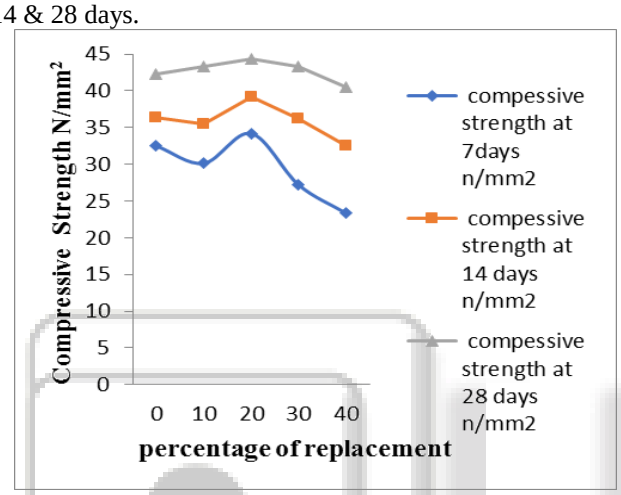
Above Tables shows the experimental results of the test samples made from partial replacement of cement using GGBFS. In the Table 3 the result of Slump values of various mix proportions of GGBFS concretes increased when replacement of GGBFS with cement increase 10-40%. Slump value Control mix concrete has Obtain less value than the 40% replacement GGBFS. Test result of Compressive strength(Table 4) of the mix lower with 10%, 20%, 30%, 40% GGBFS replacing with cement as compared to control mix at 7 days and 28 days due to slower rate of reaction. The compressive strength of the mix with 10%, 20%, 30% cement replacement increased at 56 days whereas the mix 40% cement replacement showed a decrease in strength at 56 days as compared to control mix. The result shown in Table 5 the result of Flexural strength of mix with different cement replacement 10%, 20%, 30%, 40%, showed in decrease for all replacement at 7 & 28 days due to slower rate of reaction. The flexural strength of the mix with 10%, 20%, 30% cement replacement increased after at 56 days where as the mix 40% cement replaced showed a decrease in strength by at 56 days as compared to control mix. It is shown in Table 6 the result of Spilt tensile strength of mix with different cement replacement 10%, 20%, 30%, 40%, showed in decrease for all replacement at 7 days and 28 days due to slower rate of reaction. The Spilt tensile strength of the mix with 20%, 30% cement replacement better performed than control mix at 56

days where as the mix 40% cement replaced showed a decrease in strength by at 56 days as compared to control mix.

A. Compressive Strength for M_{35} grade of Concrete:

% of replacement of GGBS	Compressive strength at 7days N/mm^2	Compressive strength at 14 days N/mm^2	Compressive strength at 28 days N/mm^2
0	32.5	36.32	42.3
10	30.14	35.53	43.25
20	34.2	39.14	44.42
30	27.2	36.23	43.25
40	23.35	32.5	40.56

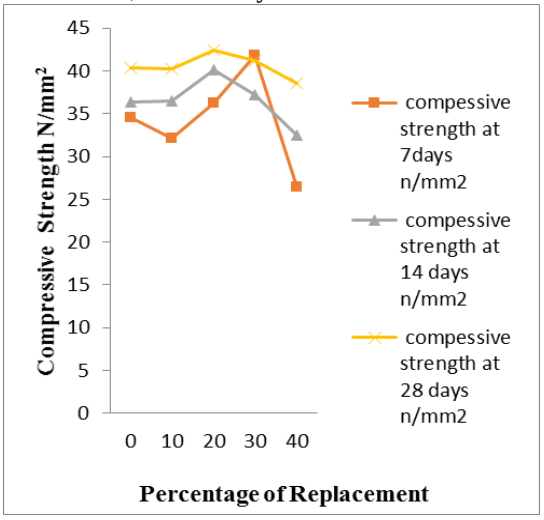
Compressive strength of cubes made with GGBS powder with partial replacement of cement with GGBS at 7, 14 & 28 days.



B. Compressive strength for Durability of 1% HCL

% of replacement of GGBS	Compressive strength at 7daysN/mm^2	compressive strength at 14 days N/mm^2	compressive strength at 28 days N/mm^2
0	34.5	36.34	40.32
10	32.13	36.53	40.25
20	36.2	40.13	42.43
30	41.82	37.23	41.2
40	26.45	32.54	38.5

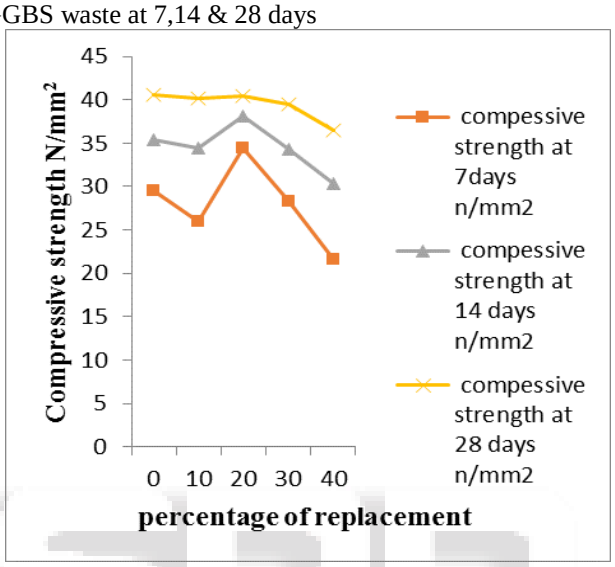
Effect of HCL by 1% concentration on cubes made with GGBS waste at 7,14 & 28 days



C. Compressive strength for Durability of 3% HCL

% of replacement of GGBS	Compressive strength at 7days N/mm^2	Compressive strength at 14 days N/mm^2	Compressive strength at 28 days N/mm^2
0	29.5	35.4	40.53
10	25.98	34.43	40.22
20	34.5	38.1	40.42
30	28.28	34.24	39.43
40	21.61	30.32	36.44

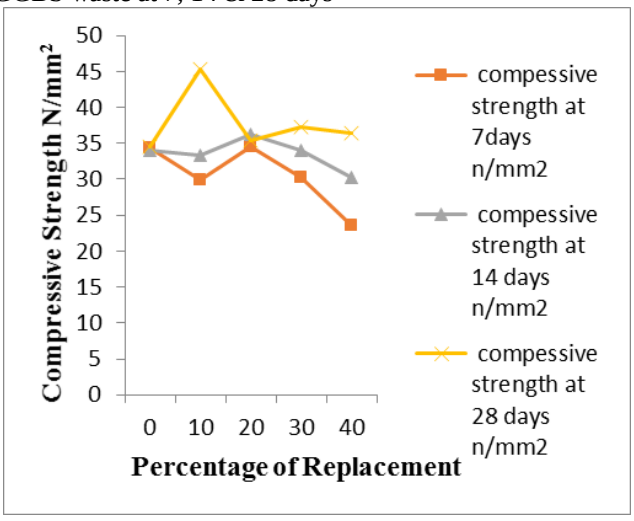
Effect of HCL by 3% concentration on cubes made with GGBS waste at 7,14 & 28 days



D. Compressive strength for Durability of 5% HCL

% of replacement of GGBS	Compressive strength at 7days N/mm^2	Compressive strength at 14 days N/mm^2	Compressive strength at 28 days N/mm^2
0	34.43	34.02	34.53
10	29.92	33.4	45.23
20	34.53	36.23	35.42
30	30.29	34.02	37.22
40	23.6	30.33	36.4

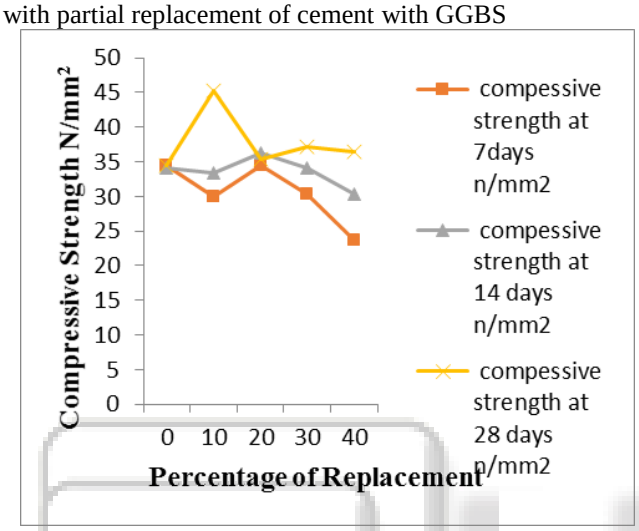
Effect of HCL by 5% concentration on cubes made with GGBS waste at 7, 14 & 28 days



E. Split Tensile for M_{35} grade of Concrete:

% of replacement of GGBS	split tensile strength at 7days N/mm^2	split tensile strength at 14 days N/mm^2	split tensile strength at 28 days N/mm^2
0	2.9	3.2	4.25
10	2.86	3.08	4.04
20	2.81	3.04	4.2
30	2.72	3.95	4.24
40	2.66	3.99	4.18

Split tensile strength of cylinders made with GGBS powder with partial replacement of cement with GGBS



V. Conclusions

- The compressive properties of concrete have increased, when cement is replaced by 20% of GGBS.
- The split tensile properties of concrete have increased, when cement is replaced by 20% of GGBS.
- The durability of concrete has increased when the specimen is treated with 1% HCL.
- Increase in percentage of HCL the strength has decreases.

References

[1] D.G. Mantel, Investigation into the hydraulic activity of five granulated blast furnace slag with eight different Portland cements, ACI Mater. J. 91 (5) (1994) 471 – 477.
[2] K. Ganesh Babu, V. Sree Rama Kumar, Efficiency of GGBS in concrete, Res. 30 (2000) 1031 – 1036.
[3] Arivalagan.S (2014). "Sustainable Studies on Concrete with GGBS as a Replacement Material in Cement", JordanJournal of Civil Engineering, Volume 8, No. 3.
[4] Sujata D. Nandagawali and Dr. N. R. Dhamge (2014). "Study of Blast Furnace Slag for Improving Mechanical Property of Concrete", International Journal of EngineeringScience and Innovative Technology (IJESIT) Volume 3, Issue 4.
[5] Li Q., Li Z. and Yuan G. (2012). "Effect of Elevated Temperatures on Properties of Concrete Containing Ground Granulated Blast Furnace Slag as Cementitious Material, "Construction and Building Materials, Vol. 35, Pages 687-692.
[6] Elahi, P.A.M. Basher, S.V. Nanukuttan and Q.U.Z.Khan (2010). "Mechanical and Durability Properties of High-Performance Concretes Containing Supplementary Cementitious Materials," Construction and Building Materials.

