Abstract

In this present construction era Concrete is probably the most extensively used construction material in the world. It is only next to water in terms of per-capita consumption. However, environmental sustainability is at stake both in terms of damage caused by the extraction of raw material and CO2 emission during cement manufacture. This brought pressures on researchers for the reduction of cement consumption by partial replacement of cement by supplementary materials. These materials may be naturally occurring, industrial wastes or by-products that are less energy intensive. These materials (called pozzolanas) when combined with calcium hydroxide, exhibits cementitious properties. Most commonly used materials are fly ash, silica fume, metakaolin, ground granulated blast furnace slag (GGBS). This needs to examine the admixtures performance when blended with concrete so as to ensure a reduced life cycle cost. The present paper focuses on investigating characteristics of M25 grade concrete with partial replacement of cement with ground granulated blast furnace slag (GGBS) by replacing cement via 30%, 40%, 50%. The cubes, cylinders are tested for compressive strength, tensile strength, flexural strength were conducted.

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Introduction

1.1: Introduction

Construction also plays a very important role within this new agenda, not only because of its economic and social contribution, but also because of its impact on the quality of lives, comfort and safety.

With the demand for construction soaring high, there is immense pressure on the natural resources. Also, considerable amount of waste is being generated, with no intentions of using it for other applications. Various construction techniques too are harming the environment and also hampering the economy. Where rules for reusing and recycling have been set down by the government, new materials and techniques are coming into being, that will aid sustainable development. Ground Granulated Blast Furnace Slag (GGBS or GGBFS) is one such material, which when combined with cement, offers myriad advantages over conventional building materials.

Meeting the world's growing needs is a challenge for the construction industry, while also limiting the impact of its burdens by drastic improvement of its activities. Due to exponential growth in urbanization and industrialization, byproducts from industries are becoming an increasing concern for recycling and waste management. GGBS is a by-product from the blast-furnaces of iron and steel industries. It is very useful in the design and development of high-quality cement paste/mortar and concrete. GGBS is considered as a green building material for sustainable construction. By replacing OPC with GGBS, carbon monoxide emissions are highly reduced and it also helps in conserving 2 non-renewable resources of lime stone. The use of GGBS in concrete is also recognized by LEED (Leadership in Energy and Environmental Design).

So far in the literatures most of the work has done in the M30, M40 grade of concrete and very few has covered in the M25 grade of concrete using GGBS. Hence it is worth the experimenting to replace the GGBS in M25 grade of concrete and to find its optimum replacement level. The primary aim of this probe is to examine the mechanical behavior of concrete in the presence of GGBS, compared with conventional concrete. The compressive strength, split tensile strength, flexural strength of the concrete with GGBS were tested and analyzed in this study

1.1 General

Concrete is one of the most frequently used building materials. Its usage worldwide, ton for ton, is twice that of steel, wood, plastics, and aluminum combined. Globally, the ready-mix concrete industry, the largest segment of the concrete market, is projected to exceed $600 billion in revenue by 2025.

Concrete is distinct from mortar. Whereas concrete is itself a building material, mortar is a bonding agent that typically holds bricks, tiles and other masonry units together.

1.1.1 Concrete History

The word concrete comes from the Latin word "concretus" (meaning compact or condensed)

In the Ancient Egyptian and later Roman eras, builders discovered that adding volcanic ash to the mix allowed it to set underwater. Concrete floors were found in the royal palace of Greece, which dates roughly to 1400–1200 BC.

Concrete, as the Romans knew it, was a new and revolutionary material. Laid in the shape of arches, vaults and domes, it quickly hardened into a rigid mass, free from many of the internal thrusts and strains that troubled the builders of similar structures in stone or brick.

1.1.2 Modern Concrete

Regular concrete is the lay term for concrete that is produced by following the mixing instructions that are commonly published on packets of cement, typically using sand or other common material as the aggregate, and often mixed in improvised containers. The ingredients in any particular mix depends on the nature of the application. Regular concrete can typically withstand a pressure from about 10 MPa to 40 MPa , with lighter duty uses such as blinding concrete having a much lower MPa rating than structural concrete. Many types of pre-mixed concrete are available which include powdered cement mixed with an aggregate, needing only water.

1.1.3 Concrete Ingredients

Concrete is a composite material, comprising a matrix of aggregate (typically a rocky material) and a binder (typically Portland cement or asphalt), which holds the matrix together.

Aggregate consists of large chunks of material in a concrete mix, generally a coarse gravel or crushed rocks such as limestone, or granite, along with finer materials such as sand.

A cement, most commonly Portland cement, is the most prevalent kind of concrete binder. For cementitious binders, water is mixed with the dry powder and aggregate, which produces a semi-liquid slurry that can be shaped, typically by pouring it into a form. The concrete solidifies and hardens through a chemical process called hydration.

Other cementitious materials, such as fly ash and slag cement, are sometimes added either pre-blended with the cement or directly as a concrete component and become a part of the binder for the aggregate. Fly ash and slag can enhance some properties of concrete such as fresh properties and durability.

1.1.4 Concrete Making

Concrete production is the process of mixing together the various ingredients—water, aggregate, cement, and any additives—to produce concrete. Concrete production is time-sensitive. Once the ingredients are mixed, workers must put the concrete in place before it hardens. In modern usage, most concrete production takes place in a large type of industrial facility called concrete plant, or often a batch plant.

1.1.5 Type of Concrete

Modern concrete mix designs can be complex. The choice of a concrete mix depends on the need of the project both in terms of strength and appearance and in relation to local legislation and building codes. This allows a user of the concrete to be confident that the structure will perform properly.

Various types of concrete have been developed for specialist application and have become known by these names.

1. High-strength concrete
2. High-performance concrete
3. Pervious concrete
4. Glass concrete
5. Rapid strength concrete
6. Rubberized concrete
7. Geopolymer concrete
8. Innovative mixtures
9. Nano concrete
10. self-healing concrete

1.2 GGBS in concrete

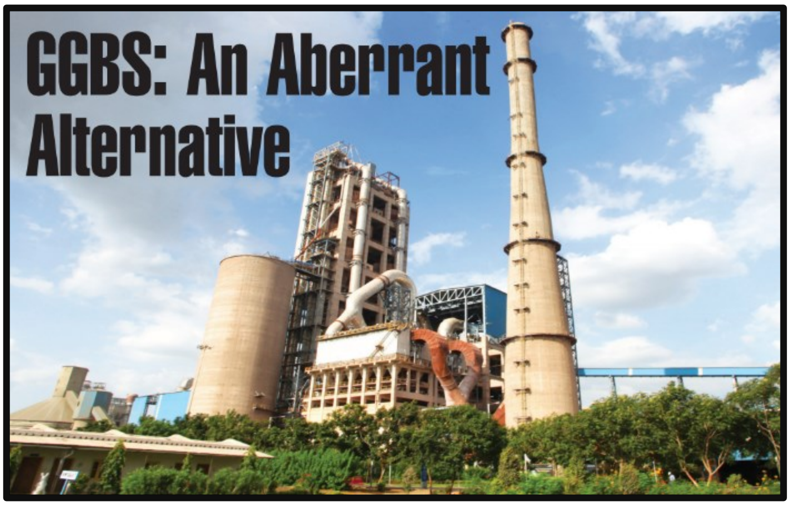

Figure 1 GGBS: An Aberrant Alternative

1.2.1 International Status

Netherlands have almost a century of experience in the use of ground granulated blast furnace slag for major infrastructure projects including marine concrete. But it was first discovered in Germany in 1862 and commercially produced in 1865. Over decades of practice and abundant laboratory investigations, GGBS based concrete performed better in improving durability of structures. With over 100 years of studies and applications worldwide, it has been proved repeatedly that the use of GGBS in making concrete enhances the durability of concrete and other fresh and hardened properties.

1.2.2 Advantages of GGBS Over Conventional Building Materials

GGBS is to be used in conjunction with ordinary Portland cement and/or other pozzolanic materials. GGBS has been widely used in Europe, United States and in Asia (particularly in Japan, Singapore and India) for its superiority in concrete durability and other below mentioned advantages:

1. It reduces the heat of hydration and minimizes the thermal cracks.
2. It helps in absorption of surplus lime released out of OPC to form in to secondary hydrated mineralogy.
3. Pore refinement and grain refinement due the secondary hydrated mineralogy, thus contributing for impermeability and enrichment of transition zones.
4. Reduced requirement of cement for same strength thus reduces the cost of concrete.
5. Long term strength, sulphate resistance, chloride resistance and durability of GGBS blended concrete is always better than that of fly ash blended concrete.
6. GGBS is more consistent than fly ash in concrete performance as it is factory made with state-of-the art technology.

1.2.3 Aim and Objective

Aim: Optimum replacement of cement by using GGBS

Objectives:

1. To compare the mechanical properties of GGBS concrete with that of conventional concrete.
2. To determine the optimum replacement of cement by GGBS.
3. To study the workability property of fresh concrete with partial replacement of cement by GGBS.
4. To find economical solution for high cost construction material
5. To check the temperature effect of GGBS on concrete

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Figure 2 Appearances

Figure 3 Boyne Bridge M1

Chapter: 2

Literature Review

2.1 Literature Review: 1

Title	Partial Replacement of Cement with GGBS in Concrete.
Publication	International journal of advance research, ideas and innovations in technology. 2019
Author	K. N. Lakshmaiah N. V. Narayana
Abstract	We concluded that on 7,28and 56 days maximum compressive strength obtained for the mix having 20%GGBS shows 38.72 MPa The blended GGBS show excellent compressive strength than the conventional concrete. Durability and service life are improved by preparing High-Performance Concrete. With the addition of 40% of GGBS as a replacement of Cement for an M25 grade of concrete, there is an increase in the strength compared to the normal concrete.

2.2 Literature Review: 2

Title	Sustainable Studies on Concrete with GGBS As a Replacement Material in Cement.
Publication	Jordan Journal of Civil Engineering. Vol.8, No. 3
Author	Prof. S. Arivalagan
Abstract	From this study, it can be concluded that, since the grain size of GGBS is less than that of ordinary Portland cement, its strength at early ages is low, but it continues to gain strength over a long period. The optimum GGBFS replacement as cementation material is characterized by high compressive strength, low heat of hydration, resistance to chemical attack, better workability, good durability and cost-effectiveness. Cement with GGBS replacement has emerged as a major alternative to conventional concrete and has rapidly drawn the concrete industry attention due to its cement savings, energy savings, cost savings, environmental and socio-economic benefits.

2.3 Literature Review: 3

Title	Studies on Optimum Usage of GGBS in Concrete
Publication	International Journal of Innovative Science and Research Technology Volume 2, Issue 5
Author	M.Rajaram, A. Ravichandran, A. Muthadhi
Abstract	The concrete has reached its maximum compressive strength at 20% replacement of GGBS which is 11.1% greater strength than the nominal concrete strength. The concrete has reached its maximum split tensile strength at 20% replacement of GGBS which is 31.1% greater strength than the nominal concrete strength. It is observed that the strength level increases at 20% replacement of GGBS and falls at 35% replacement for compressive strength and split tensile strength.

2.4 Literature Review: 4

Title	Studies on Strength Properties of Concrete with Partial Replacement of Cement by GGBS”
Publication	International Journal of Scientific & Engineering Research, Volume 7, Issue 11, November-2016
Author	Dr. G. Sridevi L. Madhusudhan, V. Manikumar Reddy, C. Phaneendra G. Prajwala
Abstract	From mechanical properties optimum cement replacement by GGBS was found to be 30%. Compressive and flexural strength values increased for 30% cement replacement level. Beyond 30% all the strength values decrease when compared with that of control concrete It can be concluded that concrete mix with cement replacement by GGBS will be an economical and environmentally sustainable option

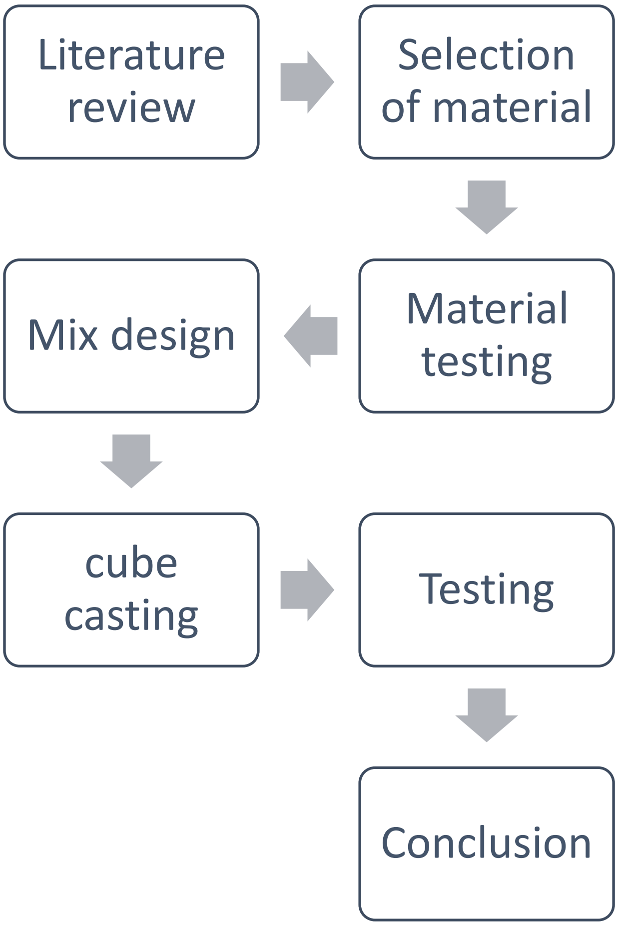
2.5 Literature Review: 5

Title	effect on strength properties of concrete of by using GGBS by Partial Replacing cement and addition of GGBS without replacing cement
Publication	International Journal of Advanced Information Science and Technology (IJAIST) Vol.6, No.7 July 2017
Author	D.Faruq, Selin Ravikumar
Abstract	Maximum compressive strength was observed in M25 -234.69 N/mm (7.94% greater than control mix M25) On 25% addition of GGBS into OPC for M25 grade compressive strength was nearly equal to target strength of M30 grade. By addition of Ground granulated blast furnace slag into OPC, Slump of the concrete mix was increased initially (at 5%) as compared to the slump of control mix concrete due to low water demand of Ground granulated blast furnace slag than OPC at initial stage which tends to increase in slump but the slump gradually decreased

Chapter: 3

Methodology and Materials

3.1 Methodology



3.2 Materials:

3.2.1 Cement:

The cement used in this experimental work is ordinary Portland cement of 43 grade. Cement is manufactured by intimately mixing together calcareous and argillaceous and/or other silica, alumina or iron oxide bearing materials, burning them at a clinkering temperature and grinding the resultant clinker so as to produce a cement capable of complying with this standard. All the properties of cement are tested by referring IS code book Specifications for Ordinary Portland cement. These test results are presented in the below table.

Test	Result	IS criteria
Specific gravity	3.15	IS:4031-1996
Initial setting time	60 min.	
Final setting time	240 min.	
Compressive strength	43N/mm	

Table 3.2.1: Properties of cement

3.2.2 Fine Aggregate:

The fine aggregates within each of these grading zones are suitable for making concrete, but to make concrete of high strength and durability, the mix proportions should be chosen according to the grading characteristics of the fine aggregates used, the ratio of fine to coarse aggregate being reduced as the fine aggregate becomes finer from Grading Zones I to IV. The fine aggregate used for this experimental investigation is natural sand from zone 1 to 3. All properties of the fine aggregate are tested as per IS Specification for fine aggregate. Various tests are conducted such as, sieve analysis. This test results are presented in the given table.

Test	Result
Quality of Sand	Natural sand
Specific Gravity	2.65
Particle shape and size	Round, < 4.75mm

Table 1: Properties of fine aggregate

3.2.3 Coarse Aggregate:

The usual range employed is between 9.5mm and 37.5mm in diameter. - Fine aggregates are usually sand or crushed stone that are less than 9.55mm in diameter. Typically, the most common size of aggregate used in construction is 20mm. A larger size, 40mm, is more common in mass concrete. The coarse aggregate used in this experimental work is 20mm and 10mm.Various tests are conducted such as impact value test, crushing value test, abrasion test, and more. These tests results are presented in the given table.

Test	Result	IS criteria
Aggregate size	20mm	IS:2386-1963
Specific Gravity	2.74	
Water absorption	5%	

Table 2: Properties of coarse aggregate

3.2.4 GGBS:

Ground Granulated Blast Furnace Slag (GGBS) is a by-product from the blast furnaces used to make iron. These operate at a temperature of about 1500 degrees centigrade and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials from a slag that floats on top of the iron. This slag is then dried and ground to a fine powder. It can also be referred to as “GGBS” or “Slag cement”.

Since, it has less emission of CO_2 and also more durable compared to ordinary Portland cement and other pozzolanic material. It extends the life span of building from 50-100 years and it produced less heat of hydration, low temperature rises and avoid cold joint easier

GGBS	Cement
Lime = 40%	Lime = 70%
Silica = 35%	Silica = 25%
Alumina = 13%	Alumina = 16%
Magnesia = 8%	Magnesia = 10%

Table 3: Typical chemical composition

GGBS	Cement
Colour = Off White	Colour = Grenish Gray
Specific gravity = 2.9	Specific gravity = 3.15
Bulk Density = 1200 Kg/m^3	Bulk Density = 1100Kg/m^3
Fineness = 350 m^2/Kg	Fineness = 384 m^2/Kg

Table 4: Typical physical properties

Chapter: 4

Experimental Programme

4.1 Method of Experiment:

The Experimental investigation is planned as follows.

1. To find the properties of the materials such as cement, sand, coarse aggregate, water and GGBS.
2. To obtain Mix proportions of OPC concrete for M25 by IS method (10262-2009).
3. To calculate the mix proportion with partial replacement such as 30%, 40% and 50% of GGBS with OPC.
4. To prepare the concrete specimens such as cubes for compressive strength, cylinders for split tensile test, and also cubes for durability studies.
5. To cure the specimens for 28 days.
6. To evaluate the mechanical characteristics of concrete such as compressive strength, split tensile test, flexural strength.
7. To evaluate the durability studies of M25 grade GGBS replacement concrete.
8. To evaluate and compare the results.
9. To check the economic viability of the usage of GGBS, Keeping in view of the safety measures.

4.2 Mix Design:

The mix design was carried out based on draft code IS: 10262:2009. For the present investigation, mix design for M25 grade of concrete was carried out using the above coarse aggregate, fine aggregate, and the binder. The proportion of the materials by weight was 1:1.9:2.501 (cement: fine aggregate: coarse aggregate) with w/c ratio 0.49. The cement constituent was subsequently replaced with percentage of GGBS (by weight). The percentage of GGBS is 30%, 40%, 50%.

Group Mix	% of GGBS	% of Cement
M1	30	70
M2	40	60
M3	50	50

Mix Design (as per IS 10262: 2009) The following specifications were considered for Mix design. Volume of cube of size 0.15×0.15×0.15m = 0.003375 m^3

Type of Cement	OPC 43 grade
Maximum Nominal Aggregate	Size 20 mm
Minimum Cement Content	300 kg/m3
Maximum Water Cement Ratio	0.50
Workability	100 mm (Slump)
Exposure Condition	Mild
Degree of Supervision	Good
Type of Aggregate	Crushed Angular Aggregate
Maximum Cement Content	540 kg/m3
Chemical admixture type	No
Type of fine aggregate	Normal river sand
Type of vibration	Mechanical

The mix proportions for One cube of concrete are presented in Table

	30%	**40%**	**50%**
Cement(gm)	949.7	814.05	678.375
GGBS (gm)	120.6	160.8	201
FA (kg)	2.576	2.576	2.576
CA (kg)	3.4046	3.4046	3.4046
Water(litre)	0.665	0.665	0.665

Table 5: Weight of materials for M25 grade cube

Mix design for M30 grade of concrete was carried out using the above coarse aggregate, fine aggregate, and the binder. The proportion of the materials by weight was 1: 2.21: 3.09 (cement: fine aggregate: coarse aggregate) with w/c ratio 0.49.

	30%	40%	50%
Cement(gm)	251	215	180
GGBS (gm)	108	144	180
FA (kg)	2.693	2.693	2.693
CA (kg)	3.729	3.729	3.729
Water(liter)	0.665	0.665	0.665

Table 6 Weight of materials for M30 grade cube

Mix design for M40 grade of concrete was carried out using the above coarse aggregate, fine aggregate, and the binder. The proportion of the materials by weight was 1: 1.77: 2.537 (cement: fine aggregate: coarse aggregate) with w/c ratio 0.36.

	30%	40%	50%
Cement(gm)	301.7	258.6	215.5
GGBS (gm)	129.3	172.4	215.5
FA (kg)	2.573	2.573	2.573
CA (kg)	3.690	3.690	3.690
Water(liter)	0.725	0.725	0.725

Table 7 Weight of materials for M40 grade cube

4.3 Testing Methods:

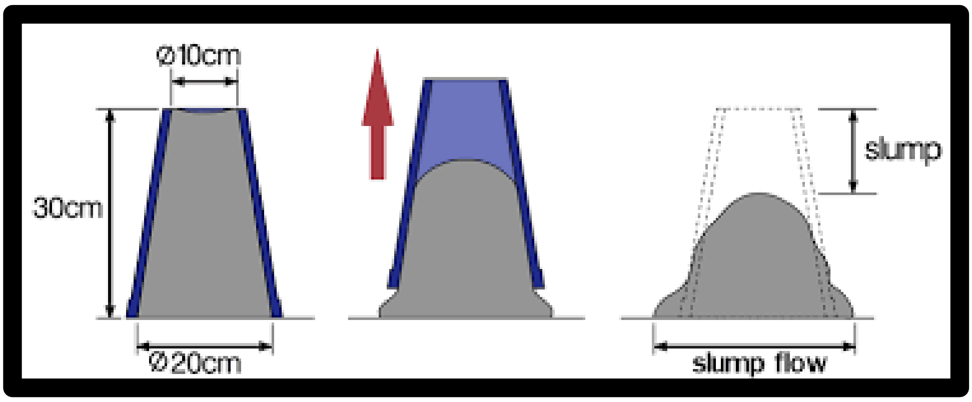
4.3.1 Fresh property concrete test:

4.3.1.1 Slump Flow Test:

Slump test is used to determine the workability of fresh concrete.

Workability is the ability of a fresh (plastic) concrete mix to fill the form/mold properly with the desired work (vibration) and without reducing the concrete's quality. Workability depends on water content, aggregate (shape and size distribution), Cementitious content and age (level of hydration and can be modified by adding chemical admixtures, like Super plasticizer.

Slump is normally measured by filling an "Abrams cone" with a sample from a fresh batch of concrete. It is then filled in three layers of equal volume, with each layer being tamped with a steel rod in order to consolidate the layer. When the cone is carefully lifted off, the enclosed material will slump a certain amount due to gravity.



4.3.2 Casting of Cubes:

After the mix design the proportions were arriving Initially the dry materials, Cement, Aggregates & Sand are mixed. Further, GGBS were added into the dry mixture for another 1 minute. The fluid part of the mixture was then added to the dry materials and the mixing continued for further about 4 minutes. The total mixing time was 5 minutes. Compaction of concrete in three layers with 25 strokes of 16mm rod was carried out for each layer is done. The concrete was left in the mold and allowed to set for 24 hrs. before the cubes were de-molded and placed in the curing tank until the day of testing.

The specimens of standard cubes (l50 mm X 150 mm X 150 mm) 3 No.'s is cast for each cycle. In all specimens the cement was replaced by GGBS by (30%, 40%, 50%) with M25 case.

Figure 4: Concrete cube

4.3.3 Curing:

24 hours after casting the test specimens, cubes, cylinders are de-molded and immediately immersed in clean and fresh water tank and allow it for curing for 28 days in potable water.

Figure 5: Curing of concrete

4.3.4 Compressive Strength:

After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen

CTM of 2000 kN capacity was used with load rate of approximately 140 kg/cm /min until failure for Compressive strength test. The test results for compressive strength are presented in Diagram (30%, 40% and 50% of GGBS concrete) for M25grades of concrete at room temperature for 28days.

Figure 6: Compression Testing Machine

Chapter: 5

Result and Discussion

5.1: Fresh Property Test:

GGBS	Slump (M25)	Slump (M30)	Slump (M40)
30%	85	87	90
40%	110	105	112
50%	130	110	120

Table 8: Slump Value Test

5.2 Compressive Strength Test:

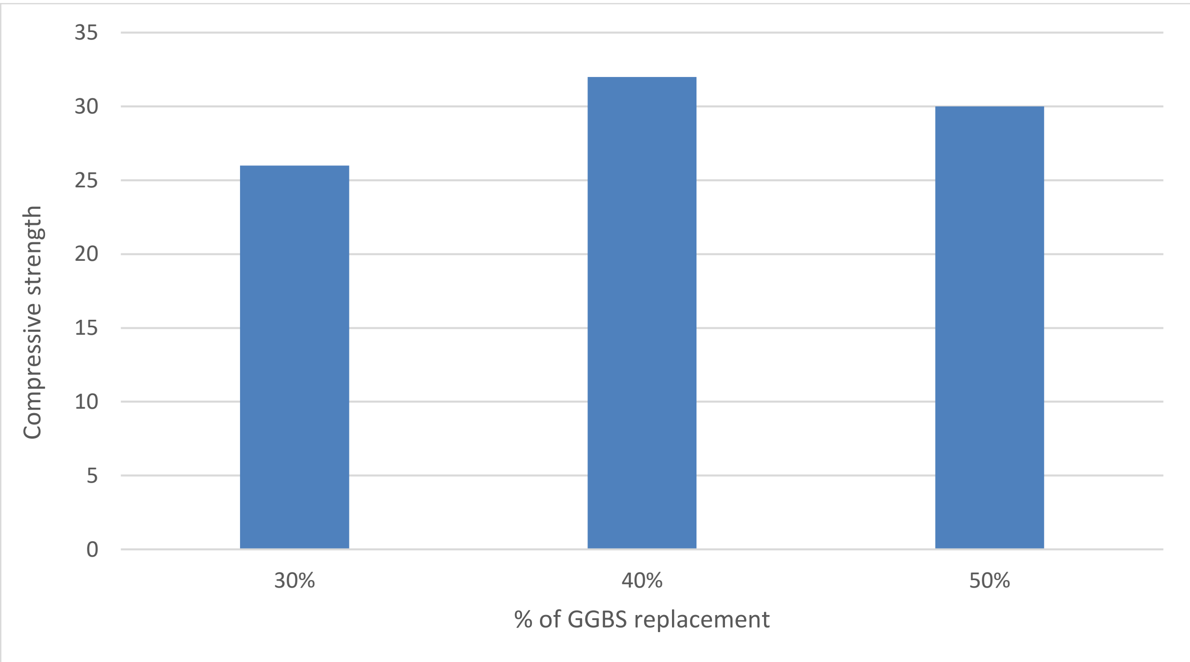


Table 9 : Compressive strength of M25 grade concrete

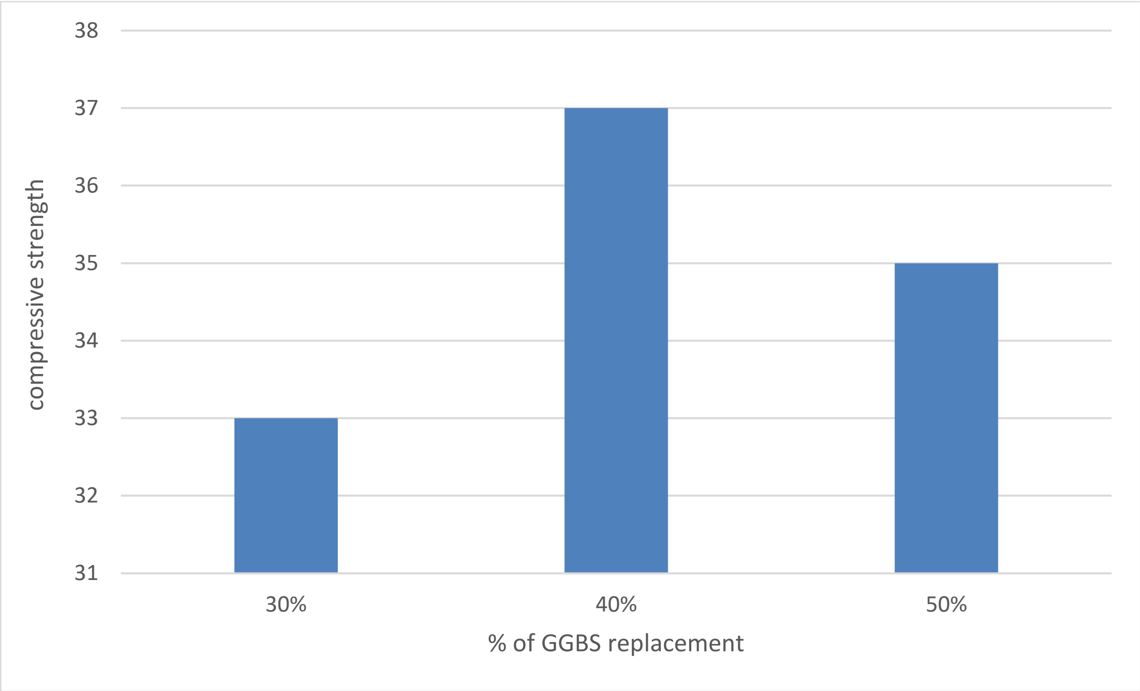


Table 10 : Compressive strength of M30 grade concrete

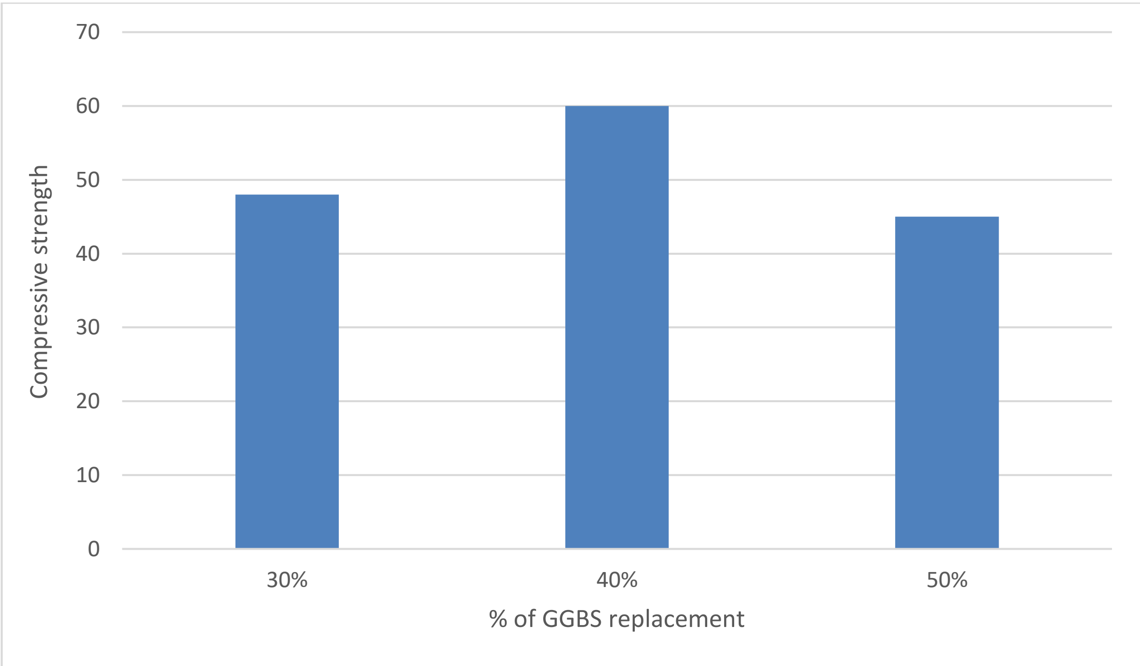


Table 11 : Compressive strength of M40 grade concrete

Chapter: 6

Scope of Work

6.1: Scope of work:

- Other levels of replacement with GGBS can be researched.
- Combination of GGBS with different another admixture can be carried out.
- Studies on replacements levels of high-grade concrete can be carried out.
- For use of GGBS concrete as a structural material, it is necessary to investigate the behavior of reinforced GGBS concrete under flexure, shear, torsion and compression.
- Some tests relating to durability aspects such as water permeability, resistance to penetration of chloride ions, corrosion of steel reinforcement, durability in marine environment etc. need investigation.
- The study may further be extended to know the behavior of concrete whether it is suitable for pumping purpose or not as present-day technology is involved in ready mix concrete where pumping of concrete is being done to large heights.

Chapter: 7

Conclusion

7.1: Conclusion:

- The workability of the concrete increases with the increase in the GGBS content and the workability reaches its maximum at 50% replacement of GGBS. Which is 7.69% more than the normal slump value.
- Compressive and flexural strength values increased for 40% cement replacement level. Beyond 40% all the strength values decrease.
- The concrete has reached its maximum compressive strength at 40% replacement of GGBS which is 16.12% greater strength than the nominal concrete strength.
- The inclusion of GGBS has desirable effect on concrete mechanical properties which is comparable to normal concrete.
- From the above results, it can be concluded that GGBS can be effectively used in concrete.

Chapter: 8

References

8.1: References:

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- IS-383:1970 (Coarse and Fine Aggregates from Natural Sources for Concrete)
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- IS 2386(Part 4):1963 Methods of test for aggregates for concrete: Part 4 Mechanical properties.
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