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Experimental Investigation on Replacement of Fine Aggregate with Manufactured Sand and Partial Replacement of Cement with (GGBS)

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ABSTRACT: One of the most widely used construction materials in civil engineering industry is concrete because of its high structural strength and stability. The concrete industry is looking for supplementary cementitious material or industrial by-product with the objective of reducing the carbon dioxide emission which is harmful to environment. Ground-granulated blast-furnace slag (GGBS), the solid wastes generated by industry, is used as a replacement material for cement. Manufactured sand is used to reduce the excessive natural sand consumption. This paper deals with the effective utilization of waste material in concrete production as a partial replacement for cement and partial replacement for sand. The cement has been replaced by GGBS in the range of 10%, 20% and 30% by the weight of cement for M15 and M20 grade mix. Workability test was carried out on fresh properties of concrete while the compressive strength was carried out on hardened concrete. It is found that the partial replacement of cement with GGBS and partial replacement of sand with manufactured sand helped in improving the strength of the concrete substantially compared to normal mix concrete. Compressive strength test was carried out for 7 & 14 days.

I. INTRODUCTION

One of the most widely used construction materials having high compressive strength is concrete. The ordinary Portland cement (OPC) is the main component for making concrete. Production of one ton of cement requires about two tons of raw materials of shale and limestone, and also releases large amount of carbon dioxide to the atmosphere that significantly contributes to greenhouse gas emissions. One method to reduce the carbon dioxide emissions of the concrete is the replacement of ground-granulated blast-furnace slag (GGBS), which is the by-product of the industrial waste used as supplementary cementitious material in concrete. The supplementary cementitious materials not only improve the mechanical properties of concrete but also reduce the cement consumption by replacing part of cement with these pozzolonic materials. Manufactured sand, produced from granite stone, has been used as an alternative to fine aggregate that 50% replaces the river sand which is far superior to river sand in all aspects. This project work is to determine the material properties of cement, GGBS, aggregates and manufactured sand, and to study about the mechanical and durability properties.

II. RELATED WORK

MATERIALS USED

FINE AGGREGATE

Fine aggregate (Sand) Fills voids between aggregates. It forms the bulk and makes mortar or concrete economical. It provides resistance against shrinking and cracking. It is naturally available. Fine aggregate conforms to the grading curve zone II with specific gravity 2.55, and a fineness modulus 2.1 was thus obtained as per IS 383-1970 specifications



FIG.1

COARSE AGGREGATE

Foreign materials in coarse aggregates such as coal, lignite, soft fragments and clay lumps should not exceed 5 per cent of its weight. Coarse aggregate 20 mm nominal size with specific gravity 2.66 and water absorption 0.5% conforming to IS:383-1970 specifications and tested as per IS 2386 standards.



FIG.2

MANUFACTURED SAND

M Sand is nothing but artificial sand made from crushing of rock or granite for construction purposes in cement or concrete. M sand differs from natural river sand in its physical and mineralogical properties. Nowadays, sources of natural sand such as river sand, pit sand, stream sand, sea sand and other sands for use as an aggregate construction are becoming scarce and exhausted due to environmental degradation. The driving need for alternative aggregates in construction has given the source to M Sand. Another cause for the use of M sand is its active availability, reducing transport distances and minimize pollution. M Sand is a better substitute to river sand as it is produced by machines in proper proportion with particle size.

Greater Durability:-

The physical and chemical properties in M Sand are balanced and can withstand any harsh climatic conditions. It has the ability to overcome the defects in concrete like segregation, honeycombing, corrosion of reinforcement steel, voids, capillary, bleeding etc.



Higher Strength:-M Sand has smooth surface texture and free from elongated and flaky particles as it is shaped by using VSI shaping machine. The cubicle shaped particles provide greater durability, higher strength and long life to the concrete

Greater Workability:-The cubical shape and proper gradation (particle should be from 150 microns to 4.75 mm in proper proportion) give good flexibility to mortar producing excellent workability.

Reduce Construction Defects:-Use of M sand in concrete reduces voids, bleeding, segregation, etc. as it has optimal initial and final setting time with excellent fineness properties.

GROUNDGRANULATED BLAST-FURNACE SLAG:-The chemical composition of a slag varies considerably depending on the composition of the raw materials in the iron production process. Silicate and aluminate impurities from the ore and coke are combined in the blast furnace with a flux which lowers the viscosity of the slag. In the case of pig iron production the flux consists mostly of a mixture of limestone and forsterite or in some cases dolomite. In the blast furnace the slag floats on top of the iron and is decanted for separation. Slow cooling of slag melts results in an unreactive crystalline material consisting of an assemblage of Ca-Al-Mg silicates.

The main components of blast furnace slag are CaO (30-50%), SiO₂ (28-38%), Al₂O₃ (8-24%), and MgO (1-18%). In general increasing the CaO content of the slag results in raised slag basicity and an increase in compressive strength. The MgO and Al₂O₃ content show the same trend up to respectively 10-12% and 14%, beyond which no further improvement can be obtained. Several compositional ratios or so-called hydraulic indices have been used to correlate slag composition with hydraulic activity; the latter being mostly expressed as the binder compressive strength.

GGBS is the granular material formed when molten iron blast iron slag is rapidly chilled by immersion in water. It is a granular product with very limited crystal formation, is highly cementitious in nature and ground to cement fineness, and hydrates like OPC. The specific gravity of GGBS is 2.88.

PROPERTIES OF GGBS

Durability:-GGBS cement is routinely specified in concrete to provide protection against both sulfate attack and chloride attack. GGBS has now effectively replaced sulfate-resisting Portland cement (SRPC) on the market for sulfate resistance because of its superior performance and greatly reduced cost compared to SRPC. Most projects in [Dublin's Docklands](#), including [Spencer Dock](#), are using GGBS in subsurface concrete for sulfate resistance. Bulk Electrical Resistivity is a test method that can measure the resistivity of concrete samples. (ASTM 1876-19) The higher electrical resistivity can be an indication of higher ion transfer resistivity and thus higher durability. By replacing up to 50% GGBS in concrete, researchers have shown that durability can be significantly improved.

Strength:-Concrete containing GGBS cement has a higher ultimate strength than concrete made with Portland cement. 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. Concrete made with GGBS continues to gain strength over time, and has been shown to double its 28-day.

CEMENT:-Ordinary pozzolona cement conforming to IS 12269:53 was used and tested as per the Indian Standards IS 4031-1988. A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together.

WATER:-Portable water conforming to the requirements of IS 456-2000 specifications was used. Water is an important ingredient of concrete as it actively participates in chemical reaction with cement.

III.OBJECTIVES

The main objective of this experiment is to evaluate the mechanical properties of concrete made with manufactured sand as fine aggregate. Also 20% GGBS is replaced with cement and material properties, workability and compressive strength are studied in detail since to protect surplus natural river extraction.

Why Manufactured Sand Is Used?

- Manufactured sand is an alternative for river sand.
- Due to the fast growing construction industry, the demand for sand has increased tremendously, causing deficiency of suitable river sand in most parts of the world.
- Due to the depletion of good quality river sand for the use of construction, the use of manufactured sand has been increased.
- Another reason for the use of M-sand is its availability and transportation cost.



- Since this sand can be crushed from hard granite rocks, it can be readily available at the nearby place, reducing the cost of transportation from far-off river sand bed.

Advantages of Manufactured Sand

- M Sand has higher Fineness Modules Index compared to the natural river sand, which gives good workability for concrete.
- M sand is free from silt and clay particles which offer better abrasion resistance, higher unit weight and lower permeability.
- Less disruptive to the environment, as it reduces sand mining from river beds.
- Perfect grading and cubical shape of M Sand gives high strength and great durability to concrete.
- More cost-effective than river sand due to low transportation cost and consistency in availability.

Why Ground-Granulated Blast-Furnace Slag Is Used?

- GGBS or ground-granulated blast-furnace slag (GGBFS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder.
- However, it can also be blended with OPC clinker in a cement factory and marketed as 'Portland-slag' or 'Blast furnace' cement. These alternative routes have little effect on the properties of the finished concrete and the savings in carbon dioxide emissions are broadly similar.
- GGBS cement can be added to concrete in the concrete manufacturer's batching plant, along with Portland cement, aggregates and water. The normal ratios of aggregates and water to cementitious material in the mix remain unchanged. GGBS is used as a direct replacement for Portland cement, on a one-to-one basis by weight. Replacement levels for GGBS vary from 30% to up to 85%. Typically 40 to 50% is used in most instances.
- The use of GGBS in addition to Portland cement in concrete in Europe is covered in the concrete standard EN 206:2013. This standard establishes two categories of additions to concrete along with ordinary Portland cement: nearly inert additions (Type I) and pozzolanic or latent hydraulic additions (Type II). GGBS cement falls in the latter category. As GGBS cement is slightly less expensive than Portland cement, concrete made with GGBS cement will be similarly priced to that made with ordinary Portland cement.
- It is used partially as per mix ratio.

IV. TESTS PERFORMED

Quality Tests on Fresh Concrete :

SETTING TIME :-

The action of changing mixed cement from a fluid state to a solid state is called "Setting of Cement".

INITIAL SETTING TIME is defined as the period elapsing between the time when water is added to the cement and the time at which the needle of 1 mm square section fails to pierce the test block to a depth of about 5 mm from the bottom of the mold.

FINAL SETTING TIME is defined as the period elapsing between the time when water is added to cement and the time at which the needle of 1 mm square section with 5 mm diameter attachment makes an impression on the test block

WORKABILITY TESTS :-

Workability of concrete mixture is measured by, Compaction factor Test, and Slump test.

Compaction factor Test:-The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field. It is more precise and sensitive than the slump test and is particularly useful for concrete mixes of very low workability and normally used when concrete is to be compacted by vibration.

The method applies to plain and air-entrained concrete, made with lightweight, normal weight or heavy aggregates having a nominal maximum size of 38 mm or less but not to aerated concrete or no



Slump test:-

FIG.4

The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows. It can also be used as an indicator of an improperly mixed batch. The test is popular due to the simplicity of apparatus used and simple procedure. The slump test is used to ensure uniformity for different loads of concrete under field conditions.

A separate test, known as the flow table, or slump-flow, test, is used for concrete that is too fluid (non-workable) to be measured using the standard slump test, because the concrete will not retain its shape when the cone is removed.

V. TESTS ON HARDENED CONCRETE

COMPRESSIVE STRENGTH :-

The compressive strength of concrete cube test provides an idea about all the characteristics of concrete. Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to reduce the size, while in tension, size elongates.

Procedure: Compressive Strength Test of Concrete Cubes

For cube test two types of specimens either cubes of 15cm X 15cm X 15cm or 10cm X 10cm X 10cm depending upon the size of aggregate are used. For most of the works cubical mould of size 15cm x 15cm x 15cm are commonly used. This concrete is poured in the mold and appropriately tempered so as not to have any voids. After 24 hours, molds 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 placing cement paste and spreading smoothly on the whole area of the specimen. These specimens are tested by compression testing machine after 7 days curing or 14 days curing. Load should be applied gradually at the rate of 140 kg/cm² per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.



VI. PROJECT DESCRIPTION

M20 GRADE CONCRETE :-

PROCEDURE:-

- Plain cement concrete of M20 grade is prepared.
- Ratio for one cube – 1.36:2.04:4.08
- Representative samples of concrete are taken and used for casting cubes of $150 \times 150 \times 150$ mm³.
- Concrete is prepared using GGBS (10%, 20%, 30% of cement) cement, water and fine aggregate.
- In that concrete, 50% of sand was replaced with M-sand
- Representative samples of concrete are taken and used for casting cubes of $150 \times 150 \times 150$ mm³.
- These specimens are tested after 7 and 14 days and are placed in the machine in such a way that the loads are applied to the opposite sides of the cubes.
- The loads were applied without shock until the resistance of the specimen to the increased load breaks down. The maximum load applied to the specimen is recorded:
- Compressive strength = $\frac{\text{Breaking load (N)}}{\text{Area of Cube (mm}^2\text{)}}$

CALCULATION:-

For M20 Grade (1:1.5:3)

$$1+1.5+3=5.5$$

$$\text{Volume of one cube} = 0.15 \times 0.15 \times 0.15 = 3.375 \times 10^{-3} \text{ m}^3$$

$$\text{Volume of wet material} = 3.375 \times 10^{-3} \text{ m}^3$$

Accounting 54% for dry volume

$$\text{Total dry volume} = 5.1975 \times 10^{-3}$$

Calculation for cement

$$\text{Volume of cement} = \frac{1}{5.5} \times 5.1975 \times 10^{-3}$$

$$= 9.45 \times 10^{-4} \text{ m}^3$$

$$= 9.45 \times 10^{-4} \times 1440$$

$$= 1.36 \text{ Kg}$$

$$\text{Volume of sand} = 1.36 \times 1.5 = 2.04 \text{ Kg}$$

$$\text{Volume of aggregate} = 1.36 \times 3 = 4.08 \text{ Kg}$$

$$\text{Water cement ratio} = 0.49$$

OBSERVATION TABLE:-

PCC:

Date OF Casting	Date of testing	No of days	Breaking load(N)	Area of cube(mm ²)	Compressive strength N/mm ²
25/02/2020	03/03/2020	7	304006.2	22500	13.5
25/02/2020	11/03/2020	14	402072.7	22500	17.87

10% GGBS :-

Date OF Casting	Date of testing	No of days	Breaking load(N)	Area of cube(mm ²)	Compressive strength N/mm ²
26/02/2020	04/03/2020	7	353039.4	22500	15.69
26/2/2020	11/3/2020	14	46091206	22500	20.49

30% GGBS :-

Date OF Casting	Date of testing	No of days	Breaking load(N)	Area of cube(mm ²)	Compressive strength N/mm ²
26/02/2020	04/03/2020	7	274586.2	22500	12.20

Test Results of Cubes for Compression

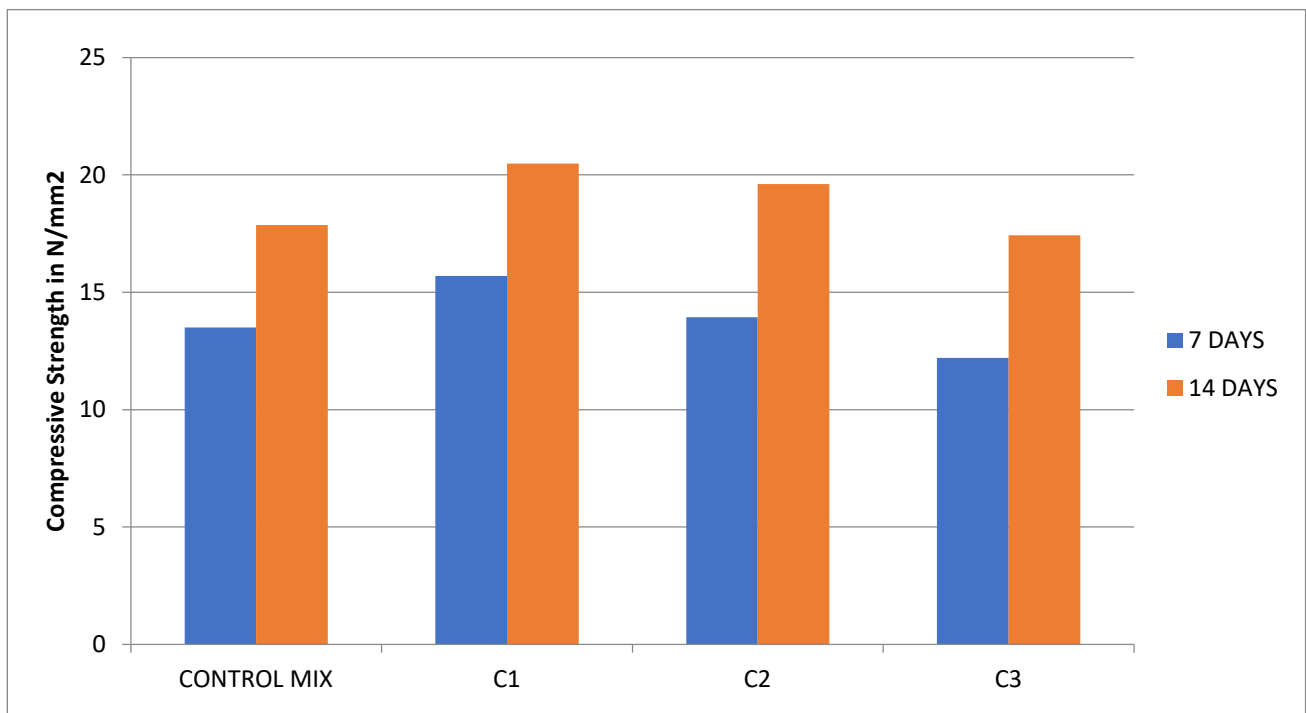


FIG.5 Percentage of GGBS

C1- GGBS 10%& M-Sand 50%

C2- GGBS 20%& M-Sand 50%

C3- GGBS 30% & M-Sand 50%

M15 GRADE CONCRETE :-

PROCEDURE:-

- Plain cement concrete of M15 grade is prepared.
- Ratio for one cube – 1.06:2.12:4.24
- Representative samples of concrete are taken and used for casting cubes of 150 × 150 × 150 mm³.
- Concrete is prepared using GGBS (10%, 20%, 30% of cement) cement, water and fine aggregate.
- In that concrete, 50% of sand was replaced with M-sand
- Representative samples of concrete are taken and used for casting cubes of 150 × 150 × 150 mm³.



- The specimens is tested after 7 and 14 days and is placed in the machine in such a way that the loads are applied to the opposite sides of the cubes.
- The loads were applied without shock until the resistance of the specimen to the increased load breaks down. The maximum load applied to the specimen is recorded:

$$\text{Compressive strength} = \frac{\text{Breaking load (N)}}{\text{Area of Cube (mm}^2\text{)}}$$

Calculations :-

For M15 Grade (1:2:4)

$$1+2+4=7$$

$$\text{Volume of one cube} = 0.15 \times 0.15 \times 0.15 = 3.375 \times 10^{-3} \text{ m}^3$$

$$\text{Volume of wet material} = 3.375 \times 10^{-3} \text{ m}^3$$

Accounting 54% for dry volume

$$\text{Total dry volume} = 5.1975 \times 10^{-3}$$

Calculation for cement

$$\text{Volume of cement} = \frac{1}{7} \times 5.1975 \times 10^{-3}$$

$$= 7.425 \times 10^{-4} \text{ m}^3$$

$$= 7.425 \times 10^{-4} \times 1440$$

$$= 1.06 \text{ Kg}$$

$$\text{Volume of sand} = 1.06 \times 2 = 2.12 \text{ Kg}$$

$$\text{Volume of aggregate} = 1.06 \times 4 = 4.24 \text{ Kg}$$

$$\text{Water cement ratio} = 0.49$$

OBSERVATION TABLE :-**PCC :-**

Date OF Casting	Date of testing	No of days	Breaking load(N)	Area of cube(mm ²)	Compressive strength N/mm ²
28/02/2020	06/03/2020	7	32361905	22500	14.38
28/02/2020	13/03/2020	14	421685.9	22500	18.74

10%GGBS :-

Date OF Casting	Date of testing	No of days	Breaking load(N)	Area of cube(mm ²)	Compressive strength N/mm ²
28/02/2020	06/03/2020	7	411879.3	22500	18.30
28/02/2020	13/03/2020	14	441299.3	22500	19.61

30%GGBS :-

Date OF Casting	Date of testing	No of days	Breaking load(N)	Area of cube(mm ²)	Compressive strength N/mm ²
28/02/2020	06/03/2020	7	333426.1	22500	14.82
28/02/2020	13/03/2020	14	392266.0	22500	17.43

Test Results of Cubes for Compression



COMPONENTS & COST

Rates of materials in market :-

- **Riversand** –Fine aggregate (Sand) Fills voids between aggregates. It forms the bulk and makes mortar or concrete economical. It provides resistance against shrinking and cracking. It is naturally available. The cost of the sand is Rs-2200/ton.
- **Msand** – M Sand is nothing but artificial sand made from crushing of rock or granite for construction purposes in cement or concrete. M sand differs from natural river sand in its physical and mineralogical properties. Nowadays, sources of natural sand such as river sand, pit sand, stream sand, sea sand and other sands for use as an aggregate construction are becoming scarce and exhausted due to environmental degradation. The cost of manufactured sand is Rs-900/ton.
- **Cement** –A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. The cost of cement is Rs 300/bag.
- **GGBS** –GGBS is the granular material formed when molten iron blast iron slag is rapidly chilled by immersion in water. It is a granular product with very limited crystal formation, is highly cementitious in nature and ground to cement fineness, and hydrates like OPC. The cost of ggbs is Rs-3/kg.

VII.CONCLUSION

The concrete was prepared for the M20 and M15 grade concrete with partial replacement of cement with GGBS with various percentages of 10% , 20%, 30% and also 50% of fine aggregate by M sand. The specimens were casted for 7 days and 14 days then tested. The results are presented below.

From the above results following conclusions are made;

- Based on the compressive strength result, the strength of concrete with 10% ggbs and 50% of M-Sand are higher than the conventional concrete of m20 grade and similar result obtain for m15 grade concrete.
- Due to decrease in cement heat of hydration will be reduced.
-

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