Investigation on Granulated Blast Furnace Slag Replacement for Fine Aggregate in Concrete

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***Abstract*-In building engineering research, sustainable materials are currently being researched and investigated. Recycled concrete aggregates, coal fly ash, crushed clay brick, and pervious paver block systems are some examples of sustainable research that are employed around the world. Fibre-reinforced concrete, which is made up of a mix of hydraulic cement, aggregates, water, and reinforcing fibres, has also been the subject of research. The growing demand for concrete in construction has resulted in a significant decline in natural river sand, creating environmental damage and an ecological imbalance.**

The experimental investigation includes the substitution of fine aggregate, such as natural river sand. This fine aggregate is replaced by granulated blast furnace slag (GBFS). The blast furnace produces GBFS, which is a by-product of the iron and steel production process. It's a solid waste product that's thrown away. Because it is a waste product, GBFS may be utilised as a fine aggregate rather than being disposed of, which will considerably assist the environment, as solid waste management is a serious concern worldwide.

Part of this project is using GBFS to partially substitute fine aggregate in cement concrete. The percentage of natural river sand replaced with GBFS in the compression test ranged from 0% to 30%, 40%, and 50%. This variation was used to cast 12 cubes to test the compression strength of concrete. In quantities of 25%, 30%, and 35%, GBFS was utilised to replace natural river sand. Concrete properties such as compression, tension, and flexure were evaluated using this version. For the compression test, nine cubes were manufactured. 12 cylinders were made for the split tensile test, with tensile strengths of 0%, 25%, 30%, and 35%. To display the findings, tables and graphs are employed.

INTRODUCTION

Concrete is a cost-effective combination of cement, aggregates, and water. Sand is an essential ingredient in the creation of mortar and concrete. Natural river sand (fine aggregate) is widely utilised in India for mortar and concrete. Manufactured sand differs from natural river sand in a few ways. The distinction is that it has different surface properties than natural sand. Artificial sand is generally more porous and uneven than natural sand. Grading varies widely, resulting in increased internal porosity and decreased concrete workability.

Slag from a blast furnace that has been granulated

A by-product of iron and steel manufacture, granulated blast furnace slag is granulated in a blast furnace. Blast-furnace slag, also known as blast-furnace slag, is a non-metallic product made composed of calcium silicates and alumina-silicates, as well as other bases, that may be created in a blast furnace in a molten state with iron or steel. Blast furnace slag provides both environmental and economic benefits as a concrete ingredient. GBFS is used as a sand replacement by various steel plants in India.

Types of blast furnace slag

Blast furnace slag comes in a variety of shapes and sizes. The first sort of slag is blast furnace rock slag, which may be utilised as a coarse material in building construction but is primarily used for road construction. Blast furnace rock slag is the common name for it. After exiting the blast furnace, molten slag is routed to the ground berths, where it is air-cooled to produce a rock-like substance.BFS is used in the construction of buildings and in the manufacturing of concrete as an aggregate. It's also utilised in road building for base and sub-base coarse preparation. As a cementitious substance, it may also be used with other materials to mechanically stabilise them. Because of its rough texture, BFS produces a high degree of mechanical particle interlock when compacted, resulting in high shear strength.

Durability

GBFS can be used in concrete to protect it from both sulphate and chloride assault. To guard against chloride attack, GBFS can be used to replace 30 to 50 percent of the cement in concrete. In maritime situations, where the concrete is exposed to the environment, there is a lot of chloride attack, which may be mitigated by using GBFS as a fine aggregate in the concrete. Bridges, abutments, and piers are also subjected to chloride attack as a result of their surroundings, which may be avoided by utilising GBFS. By incorporating GBFS into the concrete, corrosion in reinforcements can be minimised as well.

Appearance

After mixed with cement, GGBS produces a very lovely lighter white colour that has a wonderful architectural benefit at a reasonable cost. To get this colour in concrete, the GGBS percentage in the cement should be between 50 and 70 percent. The addition of GGBS to cement creates a smooth surface on which dirt does not stick, lowering maintenance costs.

Strength

When GBFS is added to concrete, it provides a better level of strength for a given replacement quantity. Concrete's compressive strength is enhanced to an optimal level of replacement. Flexural strength grows modestly in both early and later life. Abrasion resistance is also improved.

Applications of GBFS

1. Workability is improved, making placement and compaction easier.
2. Reduce the danger of thermal cracking by lowering early age temperature increase.
3. Elimination of the possibility of internal reactions that might be harmful, such as the alkali-sulphate reaction.
4. High chloride resistance, which lowers the danger of reinforcement corrosion.
5. Excellent resistance to sulphate and other chemicals.
6. It provides significant long-term advantage.

METHOD AND MATERIALS

Cement

Ordinary It was made with Portland cement (OPC). Concrete's most important component is typically cement. Cement binds sand and then fills in the spaces between sand and other particles like aggregates to form a compact mass. Changes in cement quantity have an impact on concrete compressive strength. Portland cement (Ordinary Portland Cement), a fine powder created by grinding Portland cement clinker, is the most popular type of cement. The cement was brand new and lump-free when it was delivered. Cement was carefully placed in a dry area to prevent loss of properties owing to moisture contact. The cement's colour is due to the iron in it. To avoid deterioration of the characteristics due to moisture interaction, cement was carefully put in a dry environment. Iron oxide is responsible for the cement's colour. The colour of cement is grey in the absence of impurities. The cement used is Ordinary Portland Cement (OPC) 53 grade (Birla Shakti Cement).

A. FineAggregate

This project uses natural river sand as a fine aggregate. For the initial stages of concrete manufacture, natural river sand is utilised as a fine aggregate. Later, granulated blast furnace slag (GBFS) is utilised as a fine aggregate in place of natural river sand. For the manufacturing of concrete, natural coarse aggregate was employed. The aggregates utilised were 10mm and 20mm in diameter. Because of the mechanism of interlocking of the angular particles, coarse aggregate tends to increase concrete strength. The percentage of coarse aggregate in the concrete was around 62 percent. Aggregate qualities that conform to IS 383:1970.

Granulated blast furnace slag

The granulated blast furnace slag was obtained from Jaidev building material supplier, Hingoli. The material was crushed and sievedpassing through 4.75 mm sieve.

Water

The water utilised throughout the method is tap water with a density of 1000 kg/m3, a pH of 6.2, and a TDS of less than 500 ppm, as well as being clear and colourless. Before mixing with concrete, the water is kept in plastic containers and sealed with a cover to keep dirt and other particles out. The fineness modulus variation for medium sand is 2.6 to 2.9, according to IS: 2386 (Part I 1963).

CASTINGANDTESTING

Concrete blending

A pan mixer is a piece of machinery that makes concrete by uniformly mixing cement, aggregate (such as sand or gravel), and water. For little quantities of labour, this type of mixer is used. In labs, a pan mixer is routinely used to combine materials. On construction sites, a typical concrete mixer is often utilised. In a spinning drum, the components of a concrete mixer are blended. Portable concrete mixers are widely used to mix concrete on-site. Mixing concrete by hand is an alternative in addition to utilising a concrete mixer or a pan mixer. On construction sites, this is often done for little quantities of work. This job required manual

Casting of Specimens

As available standard mould sizes, 150 mm x 150 mm x 150 mm cubes had to be casted. Three cubes were cast at a time in the laboratory. First, the insides of the casting moulds were lubricated to prevent the concrete from sticking to the surface. Then the nuts and bolts were examined to see if they were properly tightened. The concrete immediately filled the mould in three levels after mixing. Each layer was tamped 25 times to ensure optimum concrete compaction. There were a total of 18 cubes cast.

The cylinders casted are 150 mm x 300 mm in dimension. At the laboratory, there were 150 mm x 300 mm moulds available. In the laboratory, three cylinders were cast at the same time. Moulds used for casting were lubricated from the inside to prevent the concrete from sticking. Then the nuts and bolts were examined to see if they were properly tightened. The concrete immediately filled the mould in three levels after mixing. With a 16mm diameter and 0.6m length tamping rod, each layer was tamped 25 times. There were a total of 12 cylinders cast.

Curing of specimen

The specimens were correctly removed from the moulds after the concrete had been in the mould for 24 hours. Following that, the specimens were put in a curing tank located within the laboratory. The specimens were stored in an environment at a temperature of 272oC. The specimens were submerged in water after the tank was filled with water. The specimens were stored for a total of 28 days to cure.

Specimen analysis

A compression test's ultimate purpose is to evaluate the compressive strength of hardened concrete after 28 days of curing. For compression testing, cube tests of two types of specimens are used, depending on the size of the aggregate: 150mm x 150mm x 150mm or 100mm x 100mm x 100mm. For the bulk of the jobs, cube moulds measuring 150mm x 150mm x 150mm are typically used. This test determines the greatest resistance of a concrete cube to axial force delivered by a compression machine. The goal of a compressive strength test is to identify the concrete cube samples' greatest resistance to axial loading at failure. These specimens are tested using compression testing equipment after 28 days of cure. Increase the weight gradually until the specimens fail. The compressive strength of each variant will be equal to the average of the three cubes' strengths. Concrete's compressive strength is estimated by dividing the load at failure by the specimen's area.

One of the most fundamental and significant features of concrete is its tensile strength. A cylinder with a diameter of 150mm and a length of 300mm is used for the split tensile test. A way for determining the tensile strength of concrete is to perform a splitting tensile strength test on a concrete cylinder. Because of its brittle nature, concrete is exceedingly weak under tension and is not anticipated to withstand direct tension. When tensile pressures are applied to concrete, fractures appear. As result shows, the tensile strength of concrete have to determined.

The specimens are taken for testing after 28 days of cure. The cylindrical specimen is positioned so that the longitudinal axis of the load is perpendicular to it. The load should be applied gradually and without shock, increasing at a nominal pace. At the point of failure, record the maximum applied load given by the testing equipment.

Estimate for 1 m^3 of concrete grade M25

Ratio = Cement: Sand: Aggregate = 1:1:2.

Volume = 1 m^3

Dry volume of concrete = 1.54 x wet volume

= 1.54x1 m^3.

Volume of cement required,

$= \frac{1}{1+1+2}$ x 1.54
=0.385 m³.

Volume of cement per bag = 0.03472m³
No. of bags bag = $\frac{0.385}{0.03472}$
=11.08 Nos.
=11bags.(approxs)

weight of cement = 11x50
=550 kgs

2. Volume of sand,
= 1/4x1.54
=13.60 ft³

3. Volume of aggregate,
=2/4 x1.54
= 0.77 m^3
=27.19 ft

Reduction in sand use (30%)
Volume of Sand = 70% of total
= 0.2695 m³.

Volume of GGBS = 30% of total sand volume
= 0.1155 m³

Cost of sand = 952 Rs ….. For 1 m³

Cost of sand after
adding GGBFS = 666 Rs …… For 1 m³
So, we save about 286 Rs. Per For 1 m³.
For 100 m³ we save around 28,500 Rs we per For 1 m³.
This will impact major cost cutting of project.

RESULT

Compression test

At first compression test was conducted on the cubes of GBFS replacement 30%, 40%, and 50% with sand. The compression tests on cubes carried out at age of 28 days for the conventional as well as for different replacement percentages as shown in Table. For each variation three specimens were prepared and the average of three test results is stated as below. The maximum compressive stress is for the replacement of 30% slag. Hence to check further, cubes were casted for 25%, 30% and 35% replacement of GBFS with sand. The test results were obtained is shown in Table.
The test results show that the maximum compressive stress obtained is for 30% replacement of GBFS with natural sand. A bar chart shows the test results in givenFigure. The Figure shows the different compressive stresses for different variations in concrete along with conventional concrete. For each variation, an average of three test results is shown below.

Sr. No	Cube Specification	Load (KN)	Compressive stress (MPa)	Average Compressive stress (MPa)
1	CC-1	747	33.2	33.63
2	CC-2	756	33.6	
3	CC-3	767.25	34.1	
4	C25-1	552.82	24.57	27.36
5	C25-2	612.45	27.22	
6	C25-3	681.97	30.31	
7	C30-1	823.5	36.6	37.60
8	C30-2	865.8	38.48	
9	C30-3	848.92	37.73	
10	C35-1	766.8	34.93	34.44
11	C35-2	751.95	34.1	
12	C35-3	771.97	34.31	
13	C40-1	766.8	34.08	33.87
14	C40-2	767.25	33.42	
15	C40-3	771.97	34.13	
16	C50-1	684.22	30.41	30.28
17	C50-2	672.1	29.87	
18	C50-3	688.2	30.58	

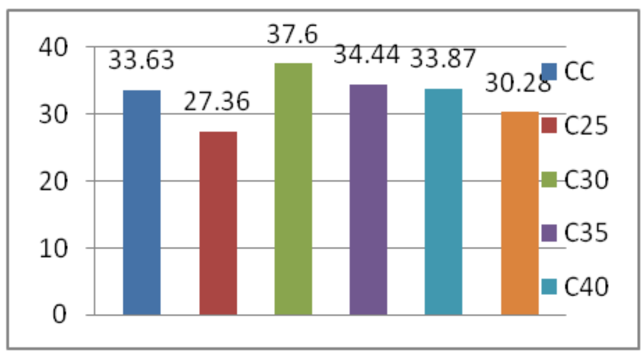

Fig. Graphical representation of compression test results

Tensile test

For the percentage variations of 25%, 30%, and 35%, a split tensile test was performed. Three cylindrical concrete examples were produced for each variation. The test was conducted out on a 28-day-old puppy. The test was conducted using a UTM machine. The test is performed by inserting a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and applying a load along the vertical diameter until the cylinder fails. Table shows the maximum applied load determined by the testing equipment upon failure.

Sr. No.	Cylinder Specification	Tensile Strength (MPa)	Average Tensile Strength (MPa)
1	CCYL-1	1.59	1.59
2	CCYL-2	1.55	
3	CCYL-3	1.65	
4	CYL25-1	1.06	1.01
5	CYL25-2	1.01	
6	CYL25-3	0.96	
7	CYL30-1	1.97	1.95
8	CYL30-2	1.95	
9	CYL30-3	1.95	
10	CYL35-1	1.76	1.77
11	CYL35-2	1.77	
12	CYL35-3	1.80	

The test results show that the maximum stress obtained is for 30% replacement of GBFS with natural sand. Hence the optimum percentage of GBFS replacement for natural river sand is of 30%. A bar chart is shown to check the test results in Figure

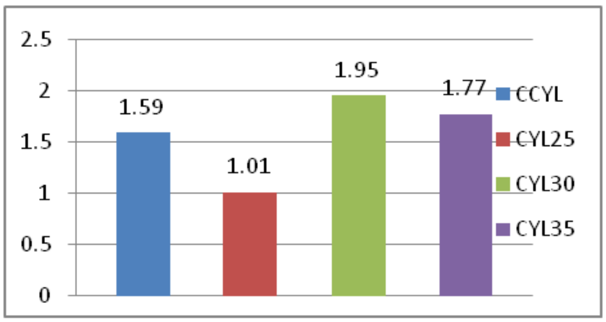

Fig. Graphical representation of split tensile test results

CONCLUSIONS

1. The maximum strength is obtained at 30% GBFS for the replacement of natural river sand. Soan optimum percentage for replacement of natural sand is 30%.
2. In compression test, the maximum percentage increase is 11.80% more than that of control specimen in 30% replacement of GBFS. In split tensile test, the maximum tensile strength is on 30% replacement of GBFS than that of control specimen. The percentage increase was 22.64%. In flexure test 12.53% increase flexure strength is for 30% GBFS than control beam.
3. At first, the strength in concrete was increased by increasing the GBFS content at a level of 30% replacement. Later it goes on decreasing.

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