PARTIAL REPLACEMENT OF CEMENT WITH GROUND GRANULATED BLAST FURNANCE SLAG AND FULLY REPLACEMENTOF FINE AGG. WITH SAND DUST (ROBO SAND) IN CONCRETE

Valaboju Mythri Sree[1], Mrs. B. Sumalatha[2] and B. Sharath Chandra[3]

[1]PG Scholar

[2]Assiatant Professor

[3]Head Of the Department

Abstract: *Concrete is frequently utilized in the building sector because it provides the structure with strength, durability, and workability at an affordable price. Additionally, it is imperative to reduce the quantity of cement used at the same time. Pozzolanic materials, which are employed in part place of cement, are being used in this to some level. In this project, sand dust (Robo-Sand) and ground granulated blast furnace slag (G.G.B.S.) are used to create the M30 concrete mix design. whereby cement is partially replaced by ground granulated blast furnace slag (G.G.B.S.) at 20%, 40%, and 60%, while fine Agg. is completely replaced by sand dust (robo sand).The slump cone test is utilized in this experiment to assess workability for consistency. The cast specimens must have their compressive strength evaluated at 7, 14, and 28 days in order to use the produced M30 mix design. The test materials include cement, coarse Agg., water, sand dust (robo sand), and ground granulated blast furnace slag (GGBFS). Comparable results will be identified and duly counted.*

1. INTRODUCTION

The most popular artificial building material in the world is concrete. It is made by combining cement, fine and coarse Agg.s, water, and occasionally admixtures in the necessary amounts. Concrete, often known as plastic concrete or fresh concrete, is a newly mixed substance that may be molded into any shape before hardening into a mass that resembles rock. This is hardening as a result of a prolonged chemical reaction between the cement and water, which gets stronger with time. the practicality, beauty, and longevity of concrete structures constructed in the first half of the 20th century using ordinary Portland cement (O.P.C) and simple round mild steel bars; the accessibility of the components of concrete; and the understanding that almost any combination of the components yields a mass of concrete.

Its tensile strength is noticeably reduced, but its compressive strength is comparatively good. In typical structural concrete, the ratio of cement to water greatly influences the concrete's characteristics. Concrete strength is expressed in pounds per square inch or kilograms per square centimeter, or the amount of force required to crush a sample with a specific age or hardness. Environmental conditions, particularly temperature and moisture, have an impact on the strength of concrete. Concrete is produced or blended using a specific amount of cement.Nominal mix and design mix are the two categories of concrete mixes. Small constructions typically employ nominal mixes, but tall buildings typically use design mixes..

It is a reasonably low-cost material with low maintenance needs and a long lifespan. It is an extremely malleable material that is easily sculpted before it hardens. It doesn't catch fire. Metal rods, wires, cables, or mesh can be added to concrete to increase its tensile strength. Ordinary Portland Cement (O.P.C) is one of the primary ingredients used to make concrete and is irreplaceable in the construction of civil infrastructure. Sadly, the process of making cement releases a significant amount of carbon dioxide gas into the atmosphere, which is a major contributor to the Green House Effect and global warming. Therefore, in order to save our resources, we must either look for another material or partially replace it with some other materials.

2. LITERATURE REVIEW

[1] QUAID JOHAR BHATTIWALA examined the connection between a concrete mortar's workability and compressive strength. Based on his experimental findings, he deduces that while concrete's compressive strength declines with increasing workability, it increases when GGBFS concrete is substituted 40%.

[2] A. ONER and S. AKYUZ (2007) conducted a trial where he replaced cement by weight in a range of ratios from 15% to 110% using GGBFS. We tested the compressive strength of test specimens that cured at 7, 14, 28, 63, 119, 180, and 365 days. The findings demonstrated that the early age strength values of the GGBFS concrete mix were lower than its strength as more days passed. This is because to the sluggish and calcium hydroxide-dependent pozzolanic reaction in GGBFS concrete, which slows down the rate at which strength grows.Additionally, it was observed that strength gain rises as the GGBFS percentage rises. GGBFS content values between 55% and 59% are optimal for maximal strength. Additionally, he discovered when the GGBFS content rises, thewater/binder ratio decreases for the same workability.

[3] DR. SURESH AND K. NAGARAJU (2015) had looked into the properties of concrete that had some of the cement replaced with GGBFS. This essay discusses GGBFS and covers its consistency, temperature rise at a young age, strength gain in GGBFS concrete, sustainability, durability, and benefits and drawbacks of utilizing it in concrete. The experiment was conducted by the author on GGBFS, substituting O.P.C by 50%, 60%, 80%, and 90%. The study concludes that the high resistance of GGBFS mixes to attack in aggressive environments like silage pits is likely caused by moisture mobility in the mixes, which is likely a result of the dense and robust micro structure of the interfacial Agg./binder transition zone. This resistance is most likely influenced by the mineral makeup of GGBFS cement paste, which has lower levels of portlandite and aluminates than Portland cement.

It has been observed that GGBFS can serve as a good substitute for cement in certain situations, though it cannot entirely replace cement. Nevertheless, even in cases when it can, it provides excellent results and a more environmentally friendly approach to building and sustainable growth, which is something we are extremely interested in these days.

[4] RAMALEKSHMI, R. Y. SHEEJA, R. GOPINATH (2018) examined the impact of replacing a portion of the cement with 50% to 80% GGBFS on the concrete's compressive strength after 7, 14, and 28 days. Additionally determined are the bulk densities of the fine and coarse Agg.s, their specific gravities, sieve analyses, and fineness moduli. The compressive strength of a cube with and without GGBFS was investigated in five set trials. Forty-five cube examples in all were cast. Nine cubes from the initial batch were cast using traditional concrete with no replacement..Nine cubes in the second set were cast with 50% GGBFS replacement, nine cubes in the third set were cast with 60% GGBFS replacement, Nine cubes total were cast in the fourth set using 70% replacement of GGBFS and in the fifth set using 80% replacement of GGBFS. Three sets of cubes were examined for seven, fourteen, and twenty-eight days, respectively. Consequently, 50% GGBFS can be utilized in Cubes in place of cement, as demonstrated

Concrete has a Max. compressive strength of about 28% days. Three beam-column experiments, both with and without GGBFS, were carried out. Three specimens total; two control specimens had no GGBFS added, while the other two had 50% GGBFS added. The specimens underwent both reverse lateral stress and a continuous axial force throughout testing. The specimens' lateral load carrying capacity—both with and without GGBFS—is examined. This project's goal is to demonstrate that industrial waste from steel can be used in place of cement by conducting experiments using locally accessible materials to strengthen beam columns. Concrete is made from the physical and chemical qualities of industrial waste. In order to obtain a mixed proportion for the necessary grade, they swapped out 50%, 60%, 70%, and 80% of the GGBFS.

Concrete's compressive strength is evaluated after 7, 14, and 28 days.When compared to O.P.C, it was found that the short-term strength of concrete is lowered by the replacement of slag. Long-term, nonetheless, it shows more ultimate strength. Consequently, after 28 days, 50% GGBFS replacement exhibited the highest compressive strength. Additionally, experiments were carried out on beam columns with and without 50% replacement GGBFS. The specimen's load carrying capacity increased by 6.6% after 28 days of testing with constant axial force and variable lateral load. Thus, the specimen can be utilized with 50% GGBFS as a replacement.

[5]. ARIVALAGAN (2014) examined the cured concrete's strength and strength efficiency parameters by substituting 20%, 30%, and 40% of GGBFS for cement at varying ages. The quantity, strength, and efficiency of ground blast furnace slag (GGBFS) at different replacement levels are assessed in concrete. Because of the cement, energy, and cost reductions as well as the environmental and socioeconomic advantages, cement with GGBFS replacement has become a significant alternative to conventional concrete industry attention. This study assesses the strength and strength efficiency characteristics of hardened concrete by substituting different percentages of ground, granulated blast furnace slag for cement in order to achieve the necessary grade. This study concludes that while GGBFS's grain size is smaller than O.P.C.'s, its strength at a young age is low, but it continues to gain strength. High compressive strength, low heat of hydration, and resistance to chemical assault define the ideal GGBFS. The specimens demonstrated an increase in compressive strength for a 20% replacement of cement when tested at 7 and 28 days.Concrete's split tensile and flexural strengths both increased with 20% cement replacement; the GGBFS filling effect is responsible for this strength gain. It was discovered that the inclusion of GGBFS increased the concrete's normal degree of workability.

[6]. RACHANA M N, E. RAMESH BABU studied that "Experimental investigation on Robosand as partial replacement of Fine Agg. in normal concrete". In this the experimental work has done for M30 and M40 grades by replacing natural sand with Robosand in varying percentages 0%, 25%, 50%, 75% and 100%. The main cause of concern is the non renewable nature of natural sand and the corresponding increasing demand of construction industry. River sand which is one of the basic ingredients in the manufacture ofconcrete has become highly scarce and expensive. Therefore looking for an alternative to river sand has become a necessity. Hence, the crusher dust which is also known as Robosand can be used as an alternative material for the river sand.

However, sea sand must first be cleaned of all impurities before it can be used. According to the study mentioned above, robo sand should be used for all significant structures in areas without rivers. For M30 and M40 classes, they have found that concrete that contains 50% Robosand and 50% natural sand has the highest strengths. The authors have come to the conclusion that 100% Robosand can be employed for affordable constructions. Better outcomes could be obtained with a 75% replacement of Robosand.

[7]. SAI LAKSHMI, DR.B.S.R.K PRASAD, V.MALLIKARJUNA, and S. KRISHNARAO (2013) studied that "Strength and Workability characteristics of High performance concrete with partial replacement of cement and sand with GGBFS and Robosand". In this the sand had replaced with Robosand at a various percentages of 0%, 25%, 50%, 75% and 100%. Along with this, cement has been replaced with GGBFS at percentages of 40%, 50% and 60%. Based on experiment it is concluded that as percentage of Robosand replacing River sand is increased, the slump decreases irrespective of percentage of GGBFS replacing cement. At constant percentage of River sand with Robosand. The variation in the percentage of GGBFS replacing the cement has no effect on the slump value.

100% of river sand can be replaced by robot sand without compromising compressive strength. To get the highest compressive strength, 50% of GGBFS should be used in place of cement. As the percentage of GGBFS and Robosand increases, so does the flexural strength. It has been discovered that GGBFS can be substituted in cement up to 50% and Robosand can be 100% replaced with natural sand. A 53 MPa Max. strength was attained.

[8]. VIJAYA, DR. S. ELAVENIL (2013) conducted research on the topic of "Manufacture Sand: A Solution and Alternative to River Sand in the Manufacturing of Concrete." The current study examines the workability, strength, and durability of concrete that contains manufactured sand in proportions of0%,20%,40%,60%, and 100% in place of natural sand. 450 specimens of concrete grades ranging from M25 to M60 were used in the studies. According to their research, the typical mix containing only produced sand has a Max. strength of 53 MPa, whereas the mix containing natural sand has a Max. strength of 49 MPa. Additionally, they discovered that the artificial sand had high physical qualities and improved particle packing, which produced a stronger binding effect.

They came to the conclusion that the physical characteristics needed to calculate a mix design and assess the consistency of a material source are bulk sp. gravity and absorption capacity. It is necessary to conduct research on the impact of using manufactured sand on long-term and early age Vol.tric qualities such creep and shrinkage. Particle size contributes to better packing density, which increases concrete's endurance. According to research findings, high fines concrete filled the pores with micro fines, which reduced permeability and enhanced abrasion resistance, flexural strength, and unit weight when compared to river sand concrete.

3. METHODOLOGY

3.1 Introduction

The right ingredients, cementations materials, admixtures, mix percentage, water cement ratio, and application of appropriate mixing, putting, and curing techniques can all contribute to the quality of concrete. Each of these factors is dependent upon the choice of ingredients and fillers.

The goal of the current study is to produce high-strength concrete using plain concrete, replacing cement with varying percentages of ground glass fiber (GGBFS) at total percentages of 0%, 20%, 40%, and 60%, and replacing all of the fine Agg. with Robosand for M30 concrete mix.

3.2 Material properties

3.2.1 Cement

Fig 3.1 Cement

In the presence of water, cement is a substance with cohesive and adhesive qualities. We refer to these cements as hydraulic cements. There are several varieties of cement; however, for this project, 53 grades of ordinary Portland cement (O.P.C) are utilized.

Table 3.1 Physical properties of O.P.C of 53 grade cement

1.Fineness	4.52
2.Specific gravity	3.15
3.Initial setting time (min)	65
4.Final setting time (min)	300

Table 3.2 Chemical properties of cement

S.No.	Characteristics of Cement	Result (0% by Mass)
1	Loss of ignition	3.15
2	Silica (SiO2)	2.27
3	Alumina (Al2O3)	4.42
4	Iron oxide(Fe2O3)	11.38
5	Calcium oxide (CaO)	58.51

3.2.2. Ground Granulated Blast Furnace Slag (GGBFS)

In the process of making pig iron, molten slag is quenched or rapidly chilled with water to produce ground granulated blast furnace slag (GGBFS). This produces molten slag that water rapidly taps and quenches. Melted slag cools quickly, forming "granulated slag". Ground Granulated Blast Furnace Slag (GGBFS) is created by converting granulated slag. If treated properly, slag can take on hydraulic qualities and serve as a pozzolanic material. However, won't slag become crystalline and hydraulically inert if air cools it gradually, rendering it unfit for use as pozzolanic material.

Fig 3.2 GGBFS

Table 3.3 Physical property of GGBFS

1.Fineness	390 m^2/kg
2.Specific gravity	2.875
3.Colour	Off-White
4.Initial setting time	85 min
5.Final setting time	600 min

Table 3.4 Chemical property of GGBFS

SiO2	30-38
Al2O2	16-23
Fe2O3	1.6-3.5
CaO	30-42
MgO	8-13
MnO	0.1-0.4
S	0.5-0.8

3.2.3 Sand Dust (Robo sand)

Crushed stone, gravel, or slag is used to make Robo Sand, a fine Agg.. used for processed crushed rock or gravel Agg. material (less than 4.75 mm) destined for construction applications. While coarse Agg. production produces non-refined surplus, robo sand is a high-quality material. As seen in Fig. 3.3, robosand is also known as artificial sand, which is made by crushing natural granite stone.A crushed granite Agg. made from naturally occurring granite stone is known as robosand.

Fig 3.3 Robo sand

Table 3.5. Physical property of Sand dust (Robo sand)

1.Specific gravity	2.6
2.Fineness modulus	3.18
3.Silt content	Absent
4.Grain size	0-4.5 mm
5.Shape	Cubical

3.2.5 Coarse Agg.

Table 3.6 Physical property of Coarse Agg.

Specific gravity	2.69
Fineness Modulus	7.61

Table 3.7 Sieve analysis of coarse Agg.

S. L. No.	IS Sieve size	Weight retained (g)	Cumulative Weight retained	Cumulative % weight retained (g)	Cumulative % passing
1		0.00	0.00	0.00	100.0
2	40 mm	0.00	0.00	0.00	100.0
3	20 mm	3376.50	3376.50	67.52	32.48
4	10 mm	1385.00	4761.00	95.22	4.78
5	4.8 mm	169.00	4930.00	98.60	1.40
6	2.4 mm	70.00	5000.00	100.0	0.00
7	1.18 mm	0.00	5000.00	100.0	0.00
8	600 mm	0.00	5000.00	100.0	0.00
9	300 mm	0.00	5000.00	100.0	0.00
10	150 mm	0.00	5000.00	100.0	0.00

3.2.4 Water

In this experimental program, general water has been used for both mixing and curing.

3.3. Mix Design

Calculation of concrete mix design for M30 grade of concrete

I. Selection for Proportioning

a) Grade designation: M30

b) Type of cement: O.P.C 53 grade conforming to IS 12269

c) Max. normal size of Agg.: 20mm

d) Min. water-cement ratio: 0.45 (Table 5 of IS 456:2000)

e) Workability: 100mm (slump)

f) Exposure condition: Serve (for reinforced concrete)

g) Method of concrete placing: Pumping

h) Degree of supervision: Good

i) Type of Agg.: crushed angular Agg.

II. Tests for Materials

j) Cement used: O.P.C 53 grade conforming to IS 12269

k) Sp. gravity of cement:3.15

l) Sp. gravity of GGBFS: 2.875

m) Sp. gravity of:

a) Coarse aggregat:2.69

b) Sand Dust-Robo sand:2.6

n) Target strength for Mix proportion $f^{f'ck} = f_{ck} + 1.65_s$

Where

$f^{''ck}$ = Target average compressive strength at 28 days

f_{ck} = Characteristic compressive strength @ 28 days

s = Standard deviation

From IS 10262:2009 Table 1,

standard deviation (s) = 5 N/mm^2

Therefore, target strength = 30+1.65(5) = 38.25 N/mm^2

$f^{''ck}$ = 38.25 N/mm^2

o) Selection of Water/Cement Ratio

Based on experience Min. water/cement ratio= 0.45

Water Content Selection

From IS 10262:2019 Table 2, Max. water content For 20mm Agg. = 186.0 litres

We are targeting a slump of 100mm; we need to increase water content by 3% for every 25mm and above 50mm for 6%

Estimated water content for 100 mm slump = 186+ (6/100) x 186 = 197 litres

p) Calculations of Cement Content

Water/content ratio = 0.45

Cement content (c) = 197 /0.45 c = 437.7 kg/m^3

From Table5 of IS 456, Min. cement content for „Serve" exposure conditions 320 kg/m^3, hence OK

Water content = 197 kg/m^3

So, water cement ratio = 197/437.7 = 0.45

3.4.1. Trail 1

a)GGBFS @ 0% of total cementations material content = 437.7= 437.7 kg/m^3

b) Cement (O.P.C) = 437.7 kg/m^3

c) Vol. of coarse Agg. and Robo sand

From IS 10262:2009 Table 3, Vol. of coarse Agg. corresponding to 20mm size Agg.

Vol. of coarse Agg. as per IS 10262:2009 W/C = 0.50 = 0.62

In the present case water cement ratio is 0.45.

Therefore, Vol. of coarse Agg. is required to increase to decrease sand dust content. As the water cement ratio is lower by 0.05, the proportion of Vol. coarse Agg. is increased by 0.01 (at the rate of 0.01m^3 for every 0.05 change in water cement ratio). Therefore the corrected Vol. of coarse Agg. for water/cement ratio of 0.45 = 0.62 + 0.01= 0.63 m^3

i. Vol. of coarse Agg. = 0.63 x 0.9 = 0.567 m^3

ii. Vol. of Robo sand = 1- 0.567 = 0.433 m^3

3.4.1.a. Mix Calculations

a. Vol. of concrete = 1 m^3

b. Vol. of cement = mass of cement/sp. gravity of cement x (1/1000)

= (437.7/3.15) x (1/1000) = 0.1389 m^3

c. Vol. of water = mass of water / sp. gravity of water x (1/1000)

= (197/1) x (1/1000) = 0.197 m^3

d. Vol. of total Agg. = [a-(b + c)] = 0.6641 m^3

e. Mass of coarse Agg. = d x Vol. of coarse Agg. x sp. gravity o

Coarse Agg. x (1000)

= 0.6641 x 0.567 x 2.69 x1000 =1012.90 kg/m^3

f. Mass of Robo sand = d x vol. of Robo sand x sp. gravity of Robo sand x 1000

= 0.6641 x 0.433 x 2.6 x 1000 =747.64 kg/m^3

3.4.1.b. Mix proportions:

i. Cement = 437.7 kg/m^3

ii. GGBFS = 0 kg/m^3

iii. Water = 197 kg/m^3

iv. Robo sand = 747.64 kg/m^3

v. Coarse Agg. = 1012.9 kg/m^3

vi. Water cement ratio = 0.45

In the same above manner Trail 2, Trail 3, Trail 4 and Trail 5 mix proportions are calculated. In the table 3.8, the mix proportions are shown for all Trail Mixes.

Table 3.8 Details of mix proportions for M30 grade

Trail mixes	Ingredients	Cement	GGBFS	Coarse Agg.	Robo sand	Water
Trail mix 1	Kg/m^3	437.7	0	1012.9	747.64	197
	Proportion	1	0	2.314	1.708	0.45
Trail mix 2	Kg/m^3	350.16	87.54	1009.9	744.8	197
	Proportion	0.8	0.2	2.307	1.701	0.45
Trail mix 3	Kg/m^3	262.62	175.08	1004.97	741.78	197
	Proportion	0.6	0.4	2.295	1.694	0.45
Trail mix 4	Kg/m^3	175.08	262.62	1000.85	738.74	197
	Proportion	0.4	0.6	2.289	1.687	0.45
Trail mix 5	Kg/m^3	131.31	306.39	998.87	737.28	197
	Proportion	0.3	0.7	2.282	1.684	0.45

4. RESULTS AND DISCUSSION

4.1. PRESENTATION OF RESULTS

Condensed GGBFS is used in place of cement in the current experimental inquiry at varying percentages (0%, 20%, 40%, 60%, and 70%). M30 grade concrete design mix was used to cast the cubes. Following seven, fourteen, and twenty-eight days of curing for compressive strength and flexural strength, the findings are shown as follows.

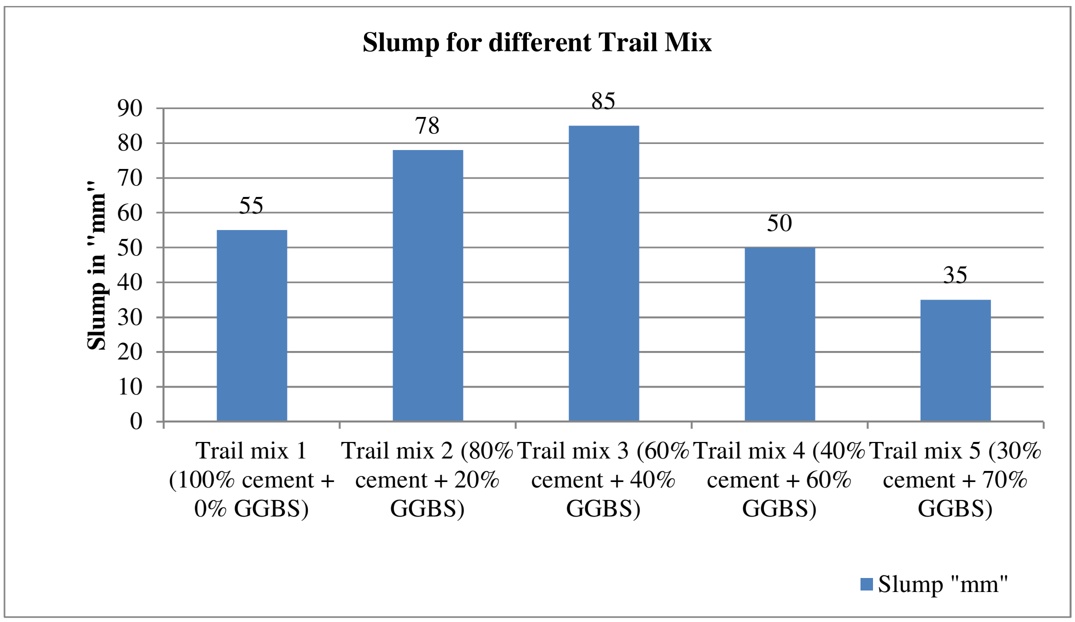
4.2 Slump cone test results:

The results of testing the slump cone of M30 concrete show that GGBFS may substitute cement by0%,20%,40%,60%, and 70%, respectively. The findings are plotted and displayed in Figure 4.1, and they are summarized as Table No. 4.1.

Table 4.1 Slump Value of various concrete mixes

TRAIL MIX	SLUMP (mm)
Trail mix 1 (100% cement + 0% GGBFS)	55
Trail mix 2 (80% cement + 20% GGBFS)	78
Trail mix 3 (60% cement + 40% GGBFS)	85
Trail mix 4 (40% cement + 60% GGBFS)	50
Trail mix 5 (30% cement + 70% GGBFS)	35

Fig 4.1. Slump Cone Test Result for different mixes



From the above table and graph we can understand that Trail Mix 3 got highest Slump and Trail mix 5 got lowest slump value.

4.3 Compression strength results :

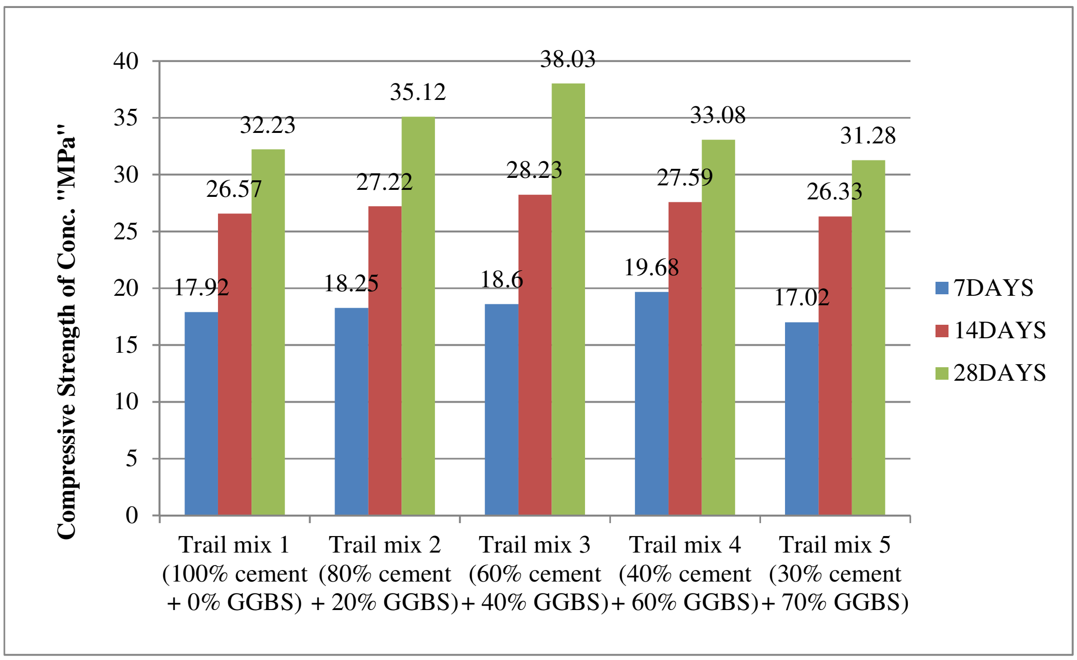
After 7, 14, and 28 days, the compressive strength of M30 concrete is tested. The findings are tallied from Table No. 4.2, plotted, and displayed in Figure 4.2.

Table 4.2. Compressive Strength of Concrete for various concrete mixes

Mix	7Dys		14Days		28Days	
	3Cubes	Avg. Value	3Cubes	Avg. Value	3Cubes	Avg. Value
Trail mix 1 (100% cement + 0% GGBFS)	18	17.92	26.4	26.57	32	32.23
	17.75		26.5		32.7	
	18		26.8		32	
Trail mix 2 (80% cement + 20% GGBFS)	18.35	18.25	27.2	27.22	35.05	35.12
	18.15		27		35.05	
	18.25		27.46		35.26	
Trail mix 3 (60% cement + 40% GGBFS)	18.5	18.60	28.3	28.23	38	38.03
	18.9		28.1		38.02	
	18.4		28.3		38.06	
Trail mix 4 (40% cement + 60% GGBFS)	19.5	19.68	27	27.59	33	33.08
	19.75		27.79		33.03	
	19.8		27.98		33.2	
Trail mix 5 (30% cement + 70% GGBFS)	17.06	17.02	26	26.33	31.2	31.28
	17		26.4		31.25	
	17		26.6		31.4	

From the above table 4.2 and graph 4.2 we can understand that Trail Mix 3 got highest Slump and Trail mix 5 got lowest slump value.

Fig 4.2. Graph of Compressive Strength of Concrete for various concrete mixes



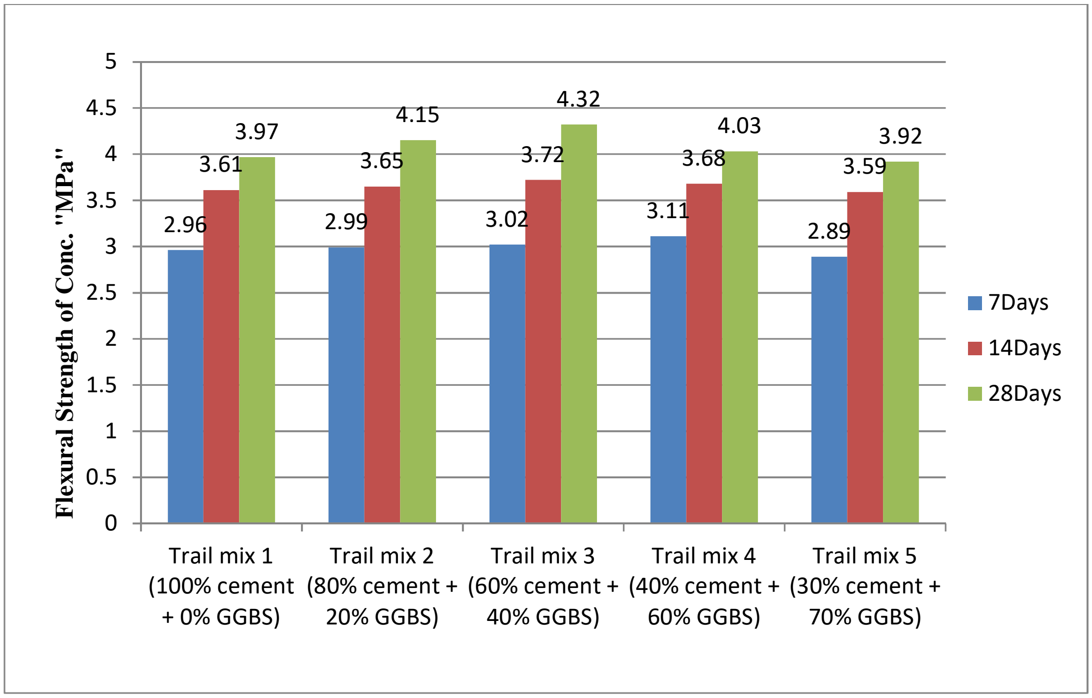
4.4. Flexural strength results :

The results of flexural strength of M30 concrete is tested after 7 days, 14 days and 28 days. The results are tabulated from table no 4.3 and are plotted and shown in fig 4.3

Table 4.3. Flexural Strength of Concrete for various concrete mixes

Mix	**7Days**		**14Days**		**28Days**	
	3Beams	Avg. Value	3Beams	Avg. Value	3Beams	Avg. Value
Trail Mix 1	2.97	2.96	3.60	3.61	3.96	3.97
	2.95		3.60		4.00	
	2.97		3.62		3.96	
Trail Mix 2	3.00	2.99	3.65	3.65	4.14	4.15
	2.98		3.64		4.14	
	2.99		3.67		4.16	
Trail Mix 3	3.01	3.02	3.72	3.72	4.32	4.32
	3.04		3.71		4.32	
	3.00		3.72		4.32	
Trail Mix 4	3.09	3.11	3.64	3.68	4.02	4.03
	3.11		3.69		4.02	
	3.11		3.70		4.03	
Trail Mix 5	2.89	2.89	3.57	3.59	3.91	3.92
	2.89		3.60		3.91	
	2.89		3.61		3.92	

Fig 4.3. Graph of Flexural Strength of Concrete for various concrete mixes



From the above table 4.3 and graph 4.3 we can understand that Trail Mix 3 got highest Slump and Trail mix 5 got lowest slump value.

5. CONCLUSION

1. In the current study, we talked about replacing fine Agg. entirely with robot sand and replacing cement partially with GGBFS at0%,20%,40%,60%, and 70%.
2. When 20% or 40% of the cement is swapped out for GGBFS, it has been observed that the strength increases for 7, 14, and 28 days.
3. It has been noted that replacing cement with GGBFS results in a 60% and 70% reduction in strength.
4. The slump values drop below 50% as well.

Thus, GGBFS should not be used to replace cement to the extent that it does not account for more than 50% of the total.

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