Performance and Evaluation for Durability Enhancement of Self Compacting Concrete (SCC) Using Ground Granulated Blast Furnace Slag (GGBFS)

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Abstract:- Ground granulated blast furnace slag (GGBFS) is an industrial-based pozzolanic substance with high silica content. Utilizing Natural River sand harms riverbanks, drastically alters the water table, and drives up the price of river sand daily. This experimental study utilizes manufactured sand (M-sand) and ground granulated blast furnace slag (GGBFS) to develop a self compacting concrete (SCC). M-sand is a synthesized material and GGBFS is a byproduct of industrial waste from steel industry. This substance has the potential to produce a sustainable building material. In this study, evolution and mechanical characteristics of SCC produced with M-sand and GGBFS are presented. Six different combinations of partial replacement of cement with GGBFS (0%, 5%, 10%, 15%, 20%, 25%, and 30%) are experimented. In addition to density comparisons, mechanical properties such as Compressive strength, Split Tensile strength, and Flexural strength and fresh quality characteristics such as Slump flow and L-Box Test for each mix have been compared for 7 days, 28 days, and 90 days time periods.

Keywords: *M-sand; Ground Granulated Blast Furnace Slag (GGBFS); Self Compacting Concrete (SCC); Compressive strength; Tensile strength,*

1. Introduction

Self-Compacting Concrete was created for densely reinforced, skin-reinforced structures and deep shafts in Japan in 1988. Under its own weight, SCC can pass through dense reinforcement without segregating or bleeding. There is no need for vibration. It may flow and spread evenly across the space because of its own weight. A key component of construction is sand. The use of concrete is growing daily, and sand mining is following suit. The biodiversity is also at risk from this. Sand is heavily used, which causes river bottoms to lose their natural qualities and ground water levels to drop. Natural sand can be substituted with manufactured sand. It had a more angular and cubical shape than natural sand, which increases its strength and ability for interlocking. It is far less expensive than natural sand. M-sand completely replaces natural river sand and exhibits a 19% increase in compressive strength and other mechanical parameters [1]. GGBFS, a pozzolanic material renowned for its exceptional reactivity, is obtained as a by-product from industrial waste, often referred to as GGBFS. When subjected to combustion, GGBFS's abundant silicon content undergoes a transformation into silica and oxygen, with the resultant silica contributing significantly to the development of strength in various applications."

GGBFS has a significant amount of silica. Utilizing GGBFS helps save money on building supplies. Due to GGBFS's lower density, concrete density also drops. Within 90 days, GGBFS improved the strength qualities and provided acceptable workability test results in accordance with EFNARC guidelines [2].

Self-compacting concrete (SCC) of the present can be categorized as a modern building material. As the name implies, complete compaction can be achieved without vibrating the material. Compared to traditional concrete, this has a number of advantages and benefits. These include increased concrete quality, less on-site repairs, quicker building timeframes, cheaper overall costs, and easier automation introduction into concrete construction. The

SCC mixes' composition contains significant amounts of fine-grained inorganic minerals, which opens up the possibility of using mineral admixtures.

The mechanical properties of self-compacting concrete (SCC) and similarly sized properties of regularly compacting concrete, such as strength, elastic modulus, creep, and shrinkage, were studied experimentally and computationally by Bertil Person [1]. The experiment included eight mix proportions of sealed or air-cured specimens with water binder ratios (w/b) ranging from 0.24 to 0.80. 50% of the mixes were made up of SCC, and the remaining 50% were made up of NCC. The age of the concretes at loading in the creep studies ranged from 2 to 90 days. Strength and relative humidity were also found. The results showed that elastic modulus, creep, and shrinkage of SCC were not significantly different from the corresponding NCC parameters.

Nan Su et al. [2] proposed a novel method of mix design for self-compacting concrete. The amount of aggregates required was initially determined in order to ensure that the finished concrete had the flow ability, self-compacting ability, and other desired SCC properties. The paste of binders was then used to fill the gaps created by the aggregates. The quantity of aggregates, binders, and mixing water as well as the kind and dosage of super plasticizer to be employed are the major factors influencing the characteristics of SCC. Slump flow, V-funnel, L-flow, U-box, and compressive strength tests were used to analyze the performance of the SCC. The outcomes demonstrated that the suggested strategy may be successfully applied Compared to the approach created by the Japanese Ready-Mixed Concrete Association (JRMCA), this one is simpler, quicker to deploy, and less time-consuming. Additionally, it saves money because it uses less binder material. Successfully produce SCC of a superior caliber.

Drying shrinkage, according to Safiuddin et al. [3], happens when concrete hardens and goes through drying at a young age. These tiny fissures, which are caused by drying shrinkage, enable harmful substances access and ultimately reduce the durability of concrete. When compared to regular concrete, conventional concrete's (CC) drying shrinkage exhibits very little variance. Self-compacting concrete (SCC) may actually experience even less drying shrinkage, according to maximum amount of studies. In general, it is projected that SCC will experience more drying shrinkage because tothe reduction in coarse aggregate content and the rise in cementing material. However, concrete's porosity also has a big impact on drying shrinkage.For SCC, the reduction in porosity counteracts the negative impacts of the aggregates and binder, reducing the effect on drying shrinkage. Additionally, drying shrinkage tends to be a smaller amount in SCC due to the system's limited supply of free water. Additionally, SCC has few empty spaces visible on the superficial of the concrete, which is a major factor in drying shrinkage.

The effect of the water-to-cement (w/c) ratio on the characteristics of SCC when it was fresh and after it had hardened were examined by Felekoglu et al. [4] in their study. The author highlights that the proportioning of SCC combinations must account for modifying the w/c ratio and superplasticizer dosage. In this study, combinations of fine mixes with different w/c ratios and super plasticizer doses were the focus of the investigation. The optimal w/c ratio for the production of SCC, according to the study's findings, is between 0.84 and 1.07 by volume. The mixture may block or segregate depending on the ratio above and below this range.

Bui et al. [5] discussed a simple method to assess the resistance to segregation of self-compacting concrete. Many different paste volumes, combinations of coarse and fine aggregates, water-binder ratios, and mineral admixture kinds and concentrations remained used in the thorough testing of SCC. The experiment helped identify the tools and procedures for measuring SCC's resistance to segregation in both vertical and horizontal directions.

Materials

Portland cement: Typically, powdered cementations are made by finely grinding alumina, iron oxide, lime, magnesia, and silica, then burning the mixture in a kiln. When combined with water and sand (or gravel), it becomes masonry mortar (or concrete), and after a series of complex internal processes, it hardens into stone. The British bricklayer Joseph Aspdin (1779–1855) gave this substance its name in 1824 which comes from the fact that it resembles famous Portland limestone, which has historically been used to construct churches, mansions, and palaces. This limestone is sourced from quarries on the Isle of Portland. In the experiment, regular Portland cement of a typical brand that is readily available in local markets was employed. The cement in use has passed several IS 12269-1987 requirements after being examined for an amount of characteristics in accordance with IS 4031-1988. The 53 Grade cement had a specific gravity of 2.91. Ordinary Portland Cement's

Sl No	Characteristics of the materials	The code's requirement is IS 12269-1987.	The results of the experiments
1	Fitness of cement in(m2/kg)	225(m^2/kg) (minimum)	298m^2/kg
2	Specific gravity of cement	3.15	3.18
3	Setting Time of Cement (min) Initial and Final	30min (min) & 600min (max)	85 minutes 244 minutes
4	Soundness of cement By Le Chatelier apparatus in (mm)	10 mm (maximum)	3 mm

Table 1 : Physical and Chemical Characteristics

Fine Aggregate (FA): In the current experiment, the locally accessible river sand was utilized as fine aggregate. The cleaned fine aggregate passed tests for a number of characteristics, including specific gravity, fineness modulus, bulk modulus, etc., and is in compliance with industry standards. A fine aggregate is made of M-sand. In Table.3 their characteristics are listed.

Sl No	Characteristics of Aggregates	Fine Aggregates (FA)	Coarse Aggregates(CA)
1	Specific gravity	2.61	2.63
2	Bulk Density(kg/m3)	1700	1560
3	Fineness Modulus Of Aggregates	2.514	6.55

Table 2: The characteristics of coarse and fine aggregates.

Coarse Aggregate (CA): As coarse material, 10 mm-sized chunks of crushed angular granite metal from a nearby quarry were employed. The cleaned coarse aggregate underwent testing for a number of characteristics, including bulk modulus, fineness modulus, and specific gravity. For the creation of SCC, When crushing the aggregates, a maximum particle size of an aggregate is 12 mm is used. The qualities of the coarse aggregates are listed in the Table.3. All aggregate tests are carried out in accordance with IS:2386 (Part-3)-1963 code provisions.

Ground Granulated Blast Furnace Slag (GGBFS): JSW Cement, in the Vijayanagar district, provided ready-to-use ground granulated blast furnace slag(GGBFS). The physical and chemical characteristics of GGBFS comply with IS: 16714A by-product of the blast furnaces used to make iron is called blast furnace slag.

The granulated blast furnace is ground to produce slag, which has a highly pozzolanic content. Slag has significantly greater cement replacement values than other pozzolanic materials like microsilica,flyash and silicafume.

In general, GGBS contains more CaO than other pozzolanas. Ground granulated blast-furnace slag(GGBS). It is picked up at the closest steel plant. It has a 2.8 Specific Gravity. As below Table:2

Sl No	Property	Value
1	Specific Gravity of GGBS	2.92
2	Color	Half white
3	Setting Time (minutes)	30 (minimum) 600 (maximum)

Table 3: GGBS's chemical characteristics.

Figure 1: Ground Granulated Blast Furnace Slag (GGBFS).

SUPER-PLASTICISER: The super-plasticiser uses FOSROC Super-plasticiser AUROMIX 400. It is in accordance with IS 9103-IS 2645.

Viscosity Modifying Admixture (VMA): The two viscosity-modifying agents utilized were Sika and Glenium Stream. It gives the SCC mix more viscosity and prevents segregation.

Water: Concrete Samples are prepared and cured using fresh portable water that fulfils with IS: 3025 - 1964 part 22, part 23, & IS: 456 - 2000 code.

2. Objectives

- To study the effect of different percentage addition of GGBS as industrial waste and as the properties of self compacting concrete.
- Development of M20, grades of SCC with GGBS as admixture and studies on fresh and hardened properties such as Slump, Flowability of SCC developed,
- To study the strength and workability characteristics of Self compacting concrete such as compressive strength, tensile strength, flexural strength,

3. Test Results:

Workability Character Test Results for Self Compacting Concrete of M20 Grade Concrete (SCC): bwp-is calculated by weight of powder utilized Bwc-is calculated by weight of cement utilized.

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Sample MIX No.		S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8
GGBFS in % (bwc)		0	5	10	15	20	25	30	35
Cement in Kg		400	380	360	340	320	300	280	260
Course Agg in Kg		785	785	785	785	785	785	785	785
Fine Aggregate in Kg		840	840	840	840	840	840	840	840
Water in Kilograms		182	182	182	182	182	182	182	182
GGBFS in Kg		0	20	40	60	80	100	120	140
S.P %(bwp)		0.80	0.82	0.85	0.82	0.76	0.70	0.62	058
VMA %		0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
SLUMP TEST	SLUMP mm	760	761	763	748	732	760	758	748
V FUNNEL	T-50 sec	3.08	3.21	3.41	3.84	3.45	3.21	3.85	4.03
	T-0 sec	6.23	6.32	6.58	6.20	6.08	6.01	6.98	6.10
	T-5min sec	8.02	8.12	8.58	5.45	7.54	7.98	8.72	7.91
L BOX	T-20 sec	2.84	2.90	2.95	4.15	2.94	3.09	4.15	3.21
	T-40 sec	4.08	4.25	5.84	5.08	5.12	4.85	6.18	5.99
	H2/H1	0.95	0.92	0.94	0.96	0.98	0.97	0.99	0.98

Table 4: Workability character test results for self compacting concrete of M20 grade concrete (SCC)

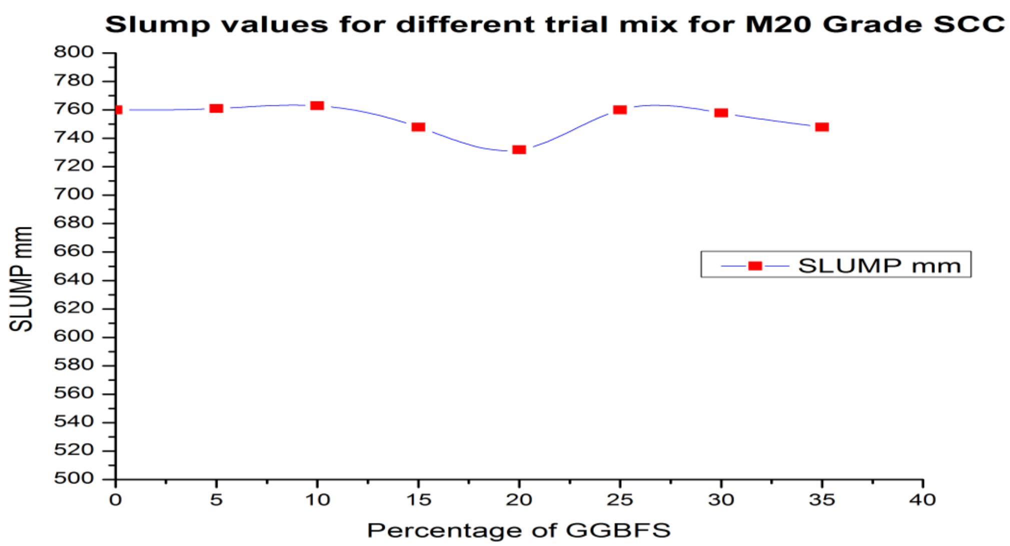

Figure 2: The graph above illustrates how the slump value of M20 grade self-compacting concrete (SCC) varies depending on the mix proportions that GGBFS replaces.

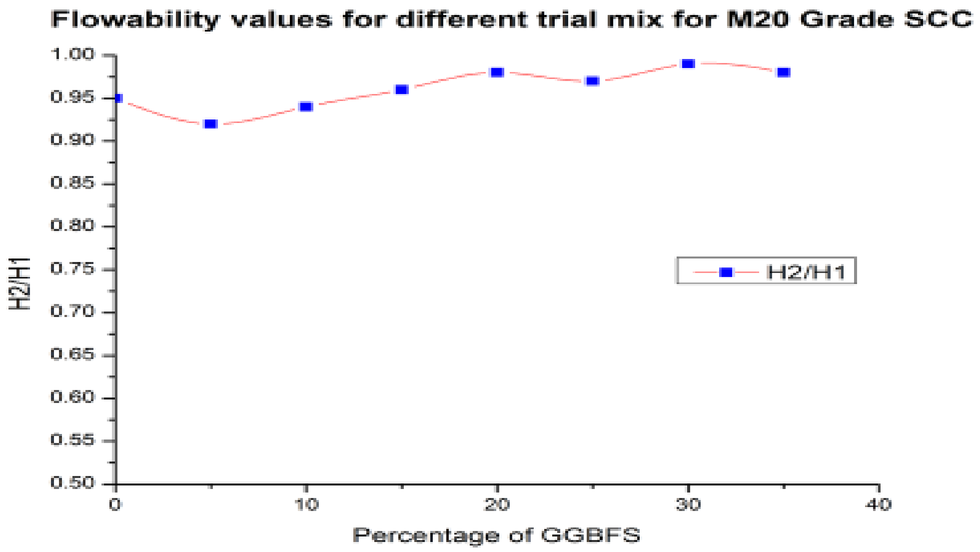

Figure 3: The graph above illustrates how the Flowability value of M20 grade self-compacting concrete (SCC) varies depending on the mix proportions that GGBFS replaces.

Compressive Strength: The One of the most significant characteristic of concrete is its compressive strength, which evaluates a concrete specimen's capacity for withstanding axial loads or stresses that tend to compress or crush the substance. Mega pascals (MPa) are common unit of measurements. By pouring concrete into cube molds with the required dimensions, concrete cube examples are prepared. For standard testing, typical measurements are 150x150x150 mm, In order to eliminate air spaces and guarantee correct compaction, compact the concrete in the molds using a tamping rod, vibrator, or other suitable techniques. By using the following formula to calculate compressive strength: $\sigma = P / (A)$ of concrete. In the above empirical formula σ is denoted by compressive strength, expressed in MPa The Ultimate load at failure (P) is expressed in N or kN. A is defined by cross-sectional area of the cube specimen, Which canbe computed by multiplying the length by the width (in square meters).

Mix. Sample No	Percentage of GGBFS Replacement	Compressive strength at 3 days in Mpa	Compressive strength at 7 days in Mpa	Average Compressive strength at 28 days in Mpa
S-1	0 %	18.92	30.24	27.35
S-2	5 %	15.02	27.68	21.25
S-3	10 %	15.24	27.84	22.08
S-4	15 %	16.98	29.24	24.33
S-5	20 %	16.54	29.34	27.54
S-6	25 %	15.24	32.74	29.24
S-7	30 %	15.33	28.81	30.40
S-8	35%	15.20	27.95	29.80

Table 5: Average Compression strength of SCC Cube Samples after 3 days, 7days and 28days of Water curing for M20 grade of SCC.

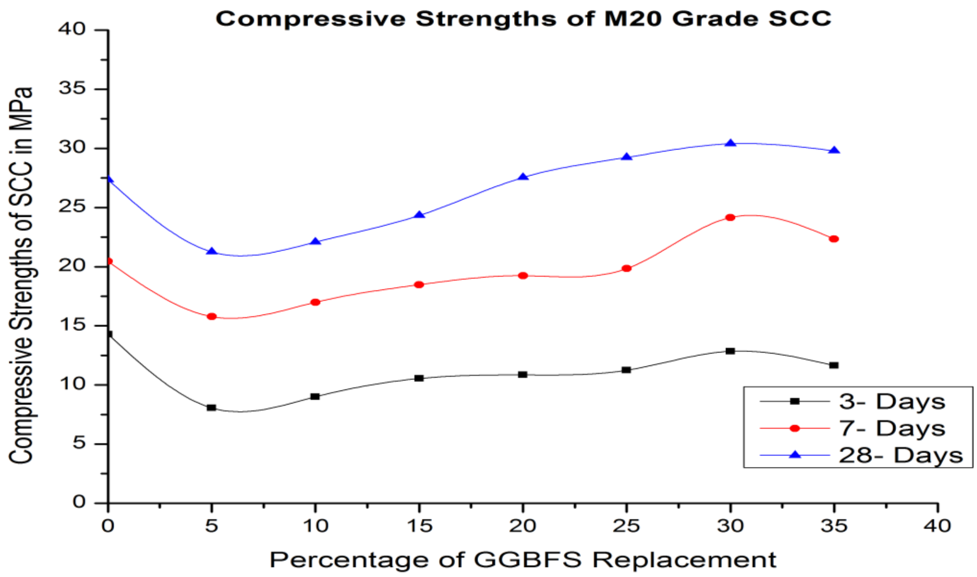

Figure.4: After 3 days, 7days, and 28Days of curing Compressive strength variation of M20 Grade of SCC for various GGBFS replacement percentages

Split tensile strength of concrete (SCC): The capacity of concrete to withstand a tensile (pulling or stretching) force is known as its tensile strength. Concrete is relatively weak in tension, in contrast to compressive strength, which assesses a material's resistance to compression (pressing or squeezing). This indicates that when exposed to tensile loads, concrete is vulnerable to cracking and failure.
either the split tensile test or the direct tension test. Both techniques require applying a tensile strain to a cylindrical or prismatic concrete specimen until it breaks, For prismatic specimens, the standard size is 150x150x300 mm, whereas for cylindrical specimens, the standard size is 150 mm in dia & 300 mm in length.

Using the following formula to determine the split tensile strength of Concrete (ts): $\sigma ts = 2P / (\pi * d * h)$

Where as: σts is Concrete's splitting tensile strength (measured in MPa) and P is Maximum Load at Specimen Breaks d is the specimen's diameter in meters. h is the specimen's height or length (in meters).

The concrete's split tensile strength was tested at SCC mixtures' split tensile strength at varying percentages GGBFS At all ages, the combination 30%GGBFS yields the highest strength. The results in Graph 4.2 According to the findings in Graph 4.2, the split tensile strength rise as the proportion of GGBFS was raised at every 5% increment and For mix the mix of 30% Replacement of GGBFS, we have got maximum values and after 30% replacement Strength values starts decreasing tha graph shows there is a decline in strength, although the values are greater than control mix at all ages. almost 35%-40% Strength is increased after 28 days of curing.

The following tables, for the tested Splitting tensile strength at 28 days for M20SCC, respectively.

Mix. Sample No	Percentage of GGBFS Replacement	Average Tensile strength of SCC Samples at 28 days in Mpa
S-1	0%	2.12
S-2	5%	2.09
S-3	10%	2.9
S-4	15%	2.48

S-5	20%	2.74
S-6	25%	2.89
S-7	30%	3.09
S-8	35%	2.64

Table 6: Average Tensile strength of SCC Samples after 28days of curing tested from UTM Machine for M20 grade of SCC.

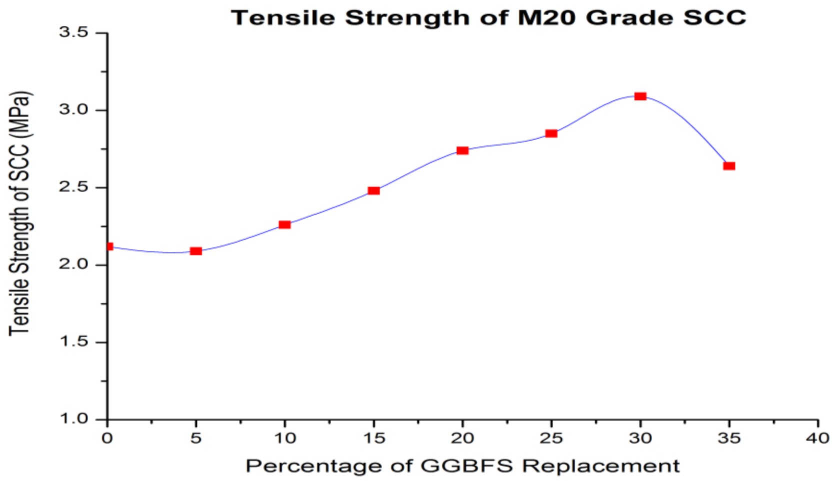

Figure.5: After 28Days of curing Split Tensile strength variation of M20 Grade of SCC for various GGBS replacement percentages.

Flexural Strength: The greatest stress a material can withstand when subjected to a bending or flexural load is known as flexural strength, often referred to as modulus of rupture. Flexural strength, as it relates to concrete, is the capacity of a concrete specimen (beam) to withstand bending or cracking under an applied load. This test measures a concrete be am resistance to bending forces. bending under two points test. Test specimens for flexural strength had dimensions of 100 mmX100 mmX500mm. Flexural strength tests were carring out in accordance with IS 516:1959 using two point loading across an effective span of 400mm. Apply the following equation to determine the flexural strength of concrete samples (modulus of rupture): $\sigma = (3 * P * L) / (2 * b * d2)$.Where, σ =The flexural strength is expressed (in MPa), P represents the greatest load at failure (in N), L stands for the span length (in mm), B is the specimen's width (in millimeters), d is the specimen's depth (in millimeters).The concrete Specimens to determine Flexural strength was tested at SCC different mixes flexural strength at varying percentages of GGBFS At all ages, the combination 30%GGBFS yields the highest strength. The results in Graph 5 According to the results in Graph shows the flexural strength rise as the proportion of GGBFS was raised at every 5% increment and For mix the mix of 30% Replacement of GGBFS, we have got maximum values and after 30% replacement Strength values starts decreasing the graph shows there is a decline in strength, although the Results are still greater than control mix at all ages. almost 35%-40% Strength is increased after 28 days of curing

Mix. Sample No	Percentage of GGBFS Replacement	Avg Tensile strength at 28 days in Mpa
S-1	0 %	2.49
S-2	5 %	2.15
S-3	10 %	2.58

S-4	15 %	2.63
S-5	20 %	2.88
S-6	25 %	3.06
S-7	30 %	3.86
S-8	35%	3.24

Table 6: Average Flexural strength of SCC Samples after 28days of curing tested from Machine for M20 grade of SCC

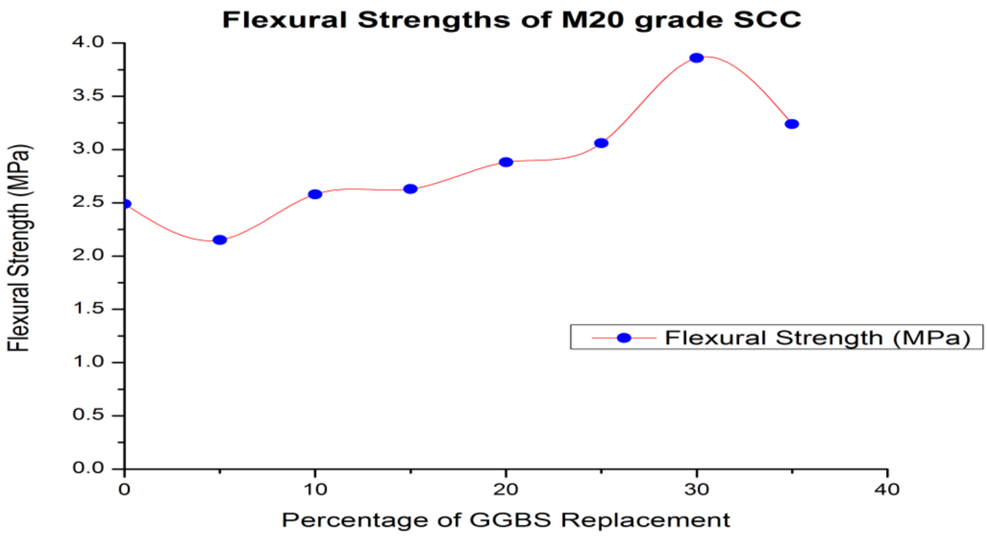

Figure.6: After 28 Days of curing Flexural strengthof concrete variation of M20 Grade of SCC for various GGBFS replacement percentages.

3. Observations and discussions

When Specimens are subjected to a 28-day water curing process, it was found that the Tensile Strength of Concrete , Flexural Strength of concrete, and Compressive Strength of concrete specially Self Compacting Concrete (SCC) formed with the combination of industrial waste GGBFS as an admixtures in different percentages varied.

The Strength values continuously increasing while increasing percentage of GGBFS content is replaced by cement and reaches its maximum values and starts decrease of Tensile strength, and the optimum values and best results is found at 25% -30% replacement respectively as compared with the reference mix

- Similar observations are made when SCC with above combination of admixtures are subjected to Flexural strength and compressive strength and found that 25% gives best results .
- By Considering grade M20 Partial replacement of GGBFS with cement is suitable 25-30% for SCC
- SCC's workability declines as the proportion rises. GGBFS is used in place of cementitious material. All mixes, with the exception of M-6, meet the SCC fresh requirements according to EFNARC rules.

- Utilizing GGBFS because each 5% replacement of GGBFS results in a 0.56% weight reduction, the structure's own weight similarly drops. 3. Strength variants demonstrating unequivocally that the Mix S-4 that is 30% Replacement is superior for long-term strength requirements.

- The most suggestible mixture is one that has 25% replacement, and it weighs 1.7% less than a standard mixture

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