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Impact of GGBS as cement substitute on workability and compressive strength of self-compacting Concrete

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Abstract: Self-compacting concrete (SCC) refers to a type of concrete that has the ability to compact and settle by its own weight, without requiring any external vibration. The usage of ground granulated blast furnace slag (GGBS) as a substitute for cement in SCC is becoming more popular due to its positive impact on both the environment and economics.

The slump test was first employed to evaluate the workability of SCC, and the results appeared to show sufficient levels. The compressive strength of SCC was found to be greatly raised by rapid curing values, which is the second finding. The compressive strength of cubes of grades M25, M30, M35, M40, M45 and M50 was compared between standard curing and the accelerated curing process to achieve this.

The curing procedure is particular to the Indian Standard code and may vary based on the nation or location and it is vital to mention. The SCC's mix design can also have an impact on the curing process and the resulting compressive strength. As a result, the compressive strength attained with the Accelerated curing process could not be comparable to the strength attained by conventional curing technique.

This study looked at the effects of using 25% weight of cement with GGBS in SCC. Among the qualities looked at include workability and compressive strength. The test's results were in opposition to the control mixture. Comparing accelerated curing to regular curing, the compressive strength increased.

Keywords: *Self-compacting concrete (SCC), Normal curing (NC), Accelerated Curing Technique (ACT), Workability.*

I INTRODUCTION

Concrete that can fill and compress itself under its own weight without the use of outside vibration is known as SCC. It is a desirable alternative for usage in structures with complicated geometry and crowded reinforcing due to this special property. SCC is frequently employed in situations where it is challenging to vibrate concrete, such as in densely fortified structures or small areas. High-range water-reducing admixtures, fine powders, and particular aggregate gradations are combined to provide the attributes of SCC.

However, due to its high viscosity and self-compacting characteristics, using SCC can be difficult. SCC must be carefully chosen in terms of both materials used and mix design in order to produce the desired qualities. Because to its advantages in both the environment and the economy, the use of sustainable materials like ground granulated blast furnace slag (GGBS) as a partial replacement for cement in SCC has grown in favor[4].

GGBS is a by-product of the steel industry and is produced by quenching molten iron slag from a blast furnace with water or steam. GGBS can partially replace cement in concrete, reducing the amount of cement required and reducing the carbon footprint of the concrete.

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The workability of the mix is evaluated using the flow table device[2]. The test results reveal that the flow value is within acceptable bounds, which satisfies the criteria for SCC. As a result, the mix is used for SCC. And The range of the compressive strength varies is 0.1% to 3.1%.

II MATERIALS AND METHODOLOGY

2.1 Materials used

Cement: OPC 53-grade cement means that a test after 28 days reveals that the cement's compressive strength is 53 N/mm^3. Comparing 53 grade cement to 43 grade cement, 53 grade cement sets up more quickly. For routine jobs, this grade of cement is not employed.

When it comes to reinforced cement concrete, it is mostly employed for structural purposes. To make concrete mixtures larger than M25, 53 grade cement is appropriate. Concrete that has been restressed can also use it. Some pre-stressed and pre-cast concrete projects that frequently call for high strength concrete can benefit greatly from the use of OPC 53 grade cement. This type of cement guarantees strong, quick construction with early formwork removal, which significantly lowers building costs.

Table 1. Physical Properties of Cement

(Please refer last page of this article)

Ground Granulated Blast-furnace Slag (GGBS): A by-product of the blast furnaces used to create iron, GGBS (Ground Granulated Blast-furnace Slag) is a cementitious material that is mostly utilized in concrete.

Around 1,500°C is the operating temperature of blast furnaces, which are supplied with a precisely regulated mixture of limestone, coke, and iron ore. The leftover components create a slag that floats on top of the iron, once the iron ore is converted to iron.[9]

Table 2. Physical Properties of GGBS

S. No	Property	GGBS
1	Colour	White Powder
2	Specific Gravity	2.91

Fine Aggregate: As a fine aggregate, river sand is frequently utilized in concrete. The use of river sand is restricted in several regions of the world to conserve river beds, which has resulted in a large rise in the demand for alternative fine aggregates in the building industry.

One of the most widely used non-renewable resources in the construction industry is river sand. River sand mining has dramatically risen over the past few decades in order to supply the demand for concrete in the building industry. The balance of the ecology is maintained by sand in the riverbed.

Table 3. Values showing the sand confirming to Zone-II

(Please refer last page of this article)

Coarse Aggregate (10mm): Coarse aggregate produced by either artificial rock crushing or natural rock disintegration. 80 mm is the maximum allowed size for coarse aggregate. In reality 10mm, contains around 70% aggregate that is smaller than 10mm and almost 90% between 4.75mm and 10mm is mostly employed in reinforced concrete elements with thin sections that are closely spaced apart.

Table 4. Properties of Coarse aggregate (10 mm)

S. No	Test Parameters	Units	Results	Requirement as per IS 383:2016
1	Specific Gravity	-	2.830	2.1 to 3.2
2	Water Absorption	%	0.60	Max 5%
3	Crushing Value	%	24	Max 30%
4	Impact Value	%	23	Max 30%

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Water: Municipal or tap water is sourced from vast wells, lakes, rivers, or reservoirs. Usually, this water is treated at a water treatment facility before being pumped. Tap water is typically safe, practical, and environmentally beneficial. For this experiment, tap water is utilised for cube mixing and curing. As per IS 456:2000, pH value of water should be 6 to 8.5

2.2 Methodology

Materials considered are GGBS, cement, aggregate, water and admixture which are required for the trail mix in this study are collected in order to understand SCC qualities, benefits, and limitations as well as how GGBS affects those characteristics. When creating an SCC mix, other factors are taken into consideration including each material's specific gravity, fineness, chemical composition and particle distribution, since they help determine if the mix is appropriate for use in SCC. The mix design was then completed using the trial-and-error method for several grades ranging from M25 to M50, for both control and SCC cubes which are moulded for accelerated curing and normal curing respectively. After the test method is finished, the significance of the test results is determined.[5][8]

Multiple SCC Proportions: This work contains 6 Design mixes from M25-M50 (M25, M30, M35, M40, M45, M50)[6][7].

Table 5. Multiple SCC Proportions
(Please refer last page of this article)

Accelerated Curing Technique: [1]

Accelerated curing techniques are used to speed up the curing process of concrete, which typically takes several weeks to achieve maximum strength. Accelerated curing can lead to a higher early strength gain, reduced curing time, and increased productivity.

The benefits of using accelerated curing include:

Faster construction schedule: By reducing the curing time, the construction schedule can be accelerated, allowing the structure to be completed sooner.

Higher early strength gain: SCC mix can gain higher early strength compared to conventionally cured concrete.

Increased productivity: Accelerated curing can allow more batches of SCC mix to be produced and cured in a shorter period of time, increasing productivity and reducing costs.

III RESULTS AND DISCUSSION

3.1 Workability

The SCC's slump flow value normally falls between 600 and 800 mm. The precise slump flow limit, however, may change based on the project's requirements and specifications. A high slump flow value SCC may be prone to bleeding and segregation, whereas a low slump flow value SCC may be challenging to lay and compress. Therefore, depending on the particular application and project conditions, it is crucial to carefully choose the right slump flow value.

Table 6. Flow Table values

Grade of Concrete	Flow Value (mm)		
	60 (minutes)	120 (minutes)	180 (minutes)
M25	680	650	600
M30	700	670	670
M35	710	670	620
M40	700	690	650
M45	720	690	650
M50	680	640	580

3.2 Strength Results

SCC strength has been calculated taking into account 7 and 28 days for typical curing. Study is also done on the strength of accelerated cure. Below are the results of a 7-day compression test:

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Table 7. Compressive Strength at 7 Days of Normal Curing (N/mm²)

S. No	Grade of concrete	Compressive Strength at 7 Days of Normal Curing (N/mm²)
1	M25	24.66
2	M30	27.68
3	M35	32.97
4	M40	38.54
5	M45	43.21
6	M50	48.25

Strength of normal curing and accelerated curing and its variations are tabulated below:[3]

Table 8. Variation of compressive strength of Normal & Accelerated curing ***(Please refer last page of this article)***

The following graph shows the variation of compressive strength of Normal & Accelerated curing: ***(Please refer last page of this article)***

IV CONCLUSION

The following conclusions are drawn from the above study:

- GGBS incorporated SCC showed better performance compared to the normal SCC.
- Accelerated curing test results demonstrated higher values compared to the normal curing values.
- There is a decline in strength increase when concrete grades are raised, which suggests the strength gap between accelerated curing and conventional curing test results is narrowing.
- 7 days strength of SCC having 25% replacement of GGBS gave 90% of strength of control mix concrete.
- When compared to standard concrete, the compressive strength data show an increase of 2-4% from M50 to M25. However, as the grade of concrete is raised, the strength increment decreases.

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Table 1. Physical Properties of Cement

Properties	Units	Results	Requirement as per IS 269:2015 for OPC 53 GRADE
Is Classification			
Fineness	m^2/kg	320	Min 225
Specific Gravity	-	3.13	-
Consistency	%	29.0	-
Setting Time **a)** Initial Setting Time **b)** Final Setting Time	 minutes minutes	 195 305	 Min 30 minutes Max 600 minutes
Density	g/cc	3.11	-

Table 3. Values showing the sand confirming to Zone-II

S. No	IS Sieve	Results % Passing	Requirements as per IS 383:2016			
			ZONE			
			I	II	III	IV
1	10 mm	100	100	100	100	100
2	4.75 mm	98	90-100	90-100	90-100	95-100
3	2.36 mm	82	60-95	75-100	85-100	95-100
4	1.18 mm	62	30-70	55-90	75-100	90-100
5	600 µm	43	15-34	35-59	60-69	80-100
6	300 µm	16	5-20	8-30	12-40	15-50
7	150 µm	4	0-10	0-10	0-10	0-15

Table 5. Multiple SCC Proportions

MATERIALS (kg/m^3)	GGBS CONTENT 25%					
	M25	M30	M35	M40	M45	M50
Cement	300	300	318	355	375	395
GGBS	100	100	107	120	125	130
Coarse Aggregate (10mm)	931	932	937	935	943	948
Fine Aggregate	928	929	897	860	834	802
Water	195	195	198	195	195	198

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Table 8. Variation of compressive strength of Normal & Accelerated curing

S. No	Grade of Concrete	Compressive Strength 28 Days (N/mm^2)		Variation
		Normal Curing	Accelerated Curing	
1	M25	36.28	39.43	+3.15
2	M30	39.44	40.89	+1.45
3	M35	44.30	44.39	+0.09
4	M40	49.72	51.09	+1.37
5	M45	54.26	56.92	+2.66
6	M50	59.70	61.30	+1.60

The following graph shows the variation of compressive strength of Normal & Accelerated curing:

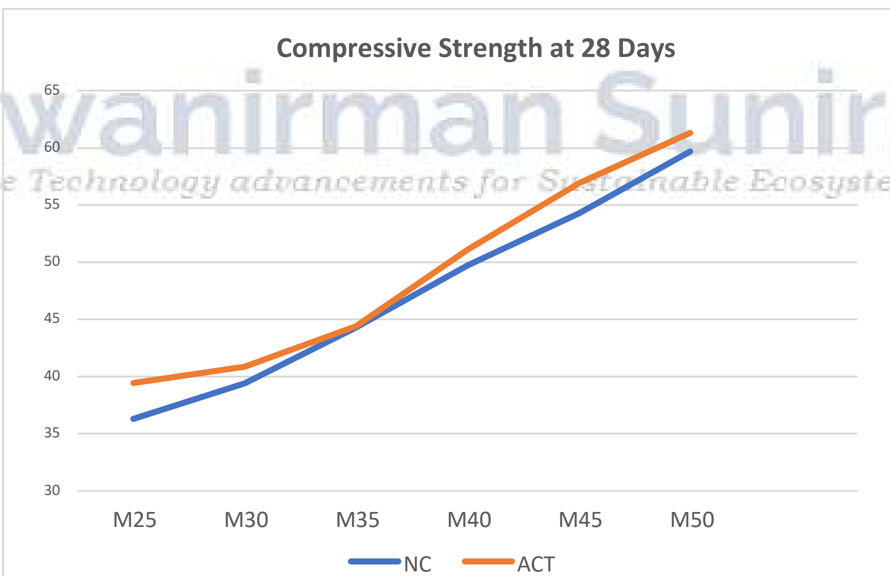

Fig. 1Compressive Strength variation of NC & ACT