

Experimental Study on Ternary Blended Concrete with Micro Silica and GGBS

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Abstract- The use of supplementary cementitious materials (SCM) in concrete has been promoted due to the rising demand for high-performance concrete and due to the environmental impacts of Portland cement production. Ground Granulated Blast Furnace Slag (GGBS) and Micro Silica (MS) are industrial by-products which can partially substitute cement and help to make more sustainable concrete. The effect of GGBS and Micro Silica on the mechanical properties and internal quality of M55 grade concrete is experimentally studied and the effect is considered at 0.29 W/C ratio. In the experimental programme, Micro Silica was kept constant at 5% and GGBS was added at the rate of 0%, 20% and 30% of cement by weight. These mixes were assessed for performance by conducting the Compressive Strength test at 7, 14 and 28 days, and the non-destructive test of the concrete was done by Ultrasonic Pulse Velocity (UPV) and Rebound Hammer test. The compressive strengths of the control mix (0% GGBS and 5% Micro Silica) were obtained as 52.33 N/mm², 61.23 N/mm² and 65.67 N/mm² at 7, 14 and 28 days, respectively. The 20% GGBS with 5% Micro Silica and 30% GGBS with 5% Micro Silica had the compressive strength of 64.33 N/mm² and 63.13 N/mm² respectively after 28 days. These results showed a continuous decrease in compressive strength with the increase of GGBS percentage in the range tested. The UPV values of the concrete samples under investigation were 4463, 4745 and 4365 m/s, respectively, which showed that the investigated blended concrete samples had a dense and relatively homogeneous internal concrete matrix respectively. The Rebound Hammer test was also used to measure surface hardness and to give a non-destructive measure of the strength of the concrete. The results of both the destructive and non-destructive tests illustrate the effect of GGBS and Micro Silica on the performance of M55 concrete. As a whole, the study indicates that the use of properly proportioned GGBS–Micro Silica blended concrete has the potential to reduce the use of cement in concrete while preserving the satisfactory mechanical performance and internal quality of the concrete, thus helping to advance high performance concrete for structural applications that is environmentally sustainable.

Keywords - M55 Concrete, GGBS, Micro Silica, Compressive Strength, Ultrasonic Pulse Velocity, Rebound Hammer, Non-Destructive Testing, Sustainable Concrete.

I. INTRODUCTION

Concrete is one of the most popular building materials because of its superior compressive strength, durability and versatility. The production of ordinary Portland cement (OPC) requires a lot of energy and emits a lot of CO₂, though. Hence, the use of supplementary cementitious materials (SCMs) has emerged as a significant strategy to create sustainable and superior performing concrete.

Commonly used SCM materials are Ground Granulated Blast Furnace Slag (GGBS) and Micro Silica which can be used to partially replace cement and enhance mechanical and durability characteristics of concrete. The very fine particles and high pozzolanic activity of Micro Silica provide better particle packing and lower permeability, the GGBS helps in long term strength development and durability. When used together, these materials can help to achieve a synergistic effect and help to minimize the environmental footprint from cement use.

In the present study, experimental investigation of performance of cement using ternary blended concrete with Micro Silica and GGBS as partial replacement of cement has been carried out. The various proportions of Micro Silica and GGBS are tested to understand their effect on fresh, mechanical and durability characteristics of concrete. The experimental investigation contains slump, compressive strength, Ultrasonic Pulse Velocity (UPV), rebound hammer and other related performance tests. The study is to find an optimum combination of Micro Silica and GGBS which would give better performance with the reduction of conventional cement.

Ullah et al. (2026) [1] found that the Micro Silica–RHA ternary system can be optimized to increase strength by increasing the amount of silica and RHA, while also reducing the amount of cement used. Sharma et al. (2026) [2] reported that using optimum GGBS-SF ratio could enhance the mechanical properties of ternary blended concrete.

Raman and Shalu (2026) [3] concluded that SF-GGBS ternary blends offer a beneficial combination of strength and durability properties in high performance concrete. Reddy and Rao (2020) [4] have found that the optimum proportions of Micro Silica and GGBS can enhance both workability and mechanical properties of ternary blended concrete. Basha et al. (2020) [5] have shown that the concrete comprised of GGBS and silica fume further enhances chloride resistance and service life prediction of reinforced concrete structures. Subathra Devi et al. (2018) [6] showed that the formulation of cement-free alkali-activated cement based on GGBS-silica fume concrete can attain high early strength and durability. Kumar and Joon (2016) [7] revealed that the optimum percentage of GGBS in M55 concrete is 20% with Micro Silica of 5% for the workability and 28-day strength of concrete. Vijaya Bhaskar Reddy and Srinivasa Rao (2016) [8] carried out an investigation on various combinations of Micro Silica, GGBFS and its effect on the development of compressive strength on ternary blended concrete.

II. METHODOLOGY

A. METHODOLOGY OR STEPS



Fig 1: Flow chart of methodology

B. Experimental programme

The experimental programme aimed to develop Ternary Blended Concrete mix with lower dosage of Portland cement. Different percentages of GGBS & MS were added to the cement content. The material used and the mixing, casting and testing of the specimens is described in a way that can be done on a trial basis. nos. cubes of size 15x15x15cm filled for checking of compressive strength at the age of 7, 14, 28 days, 9 nos. cubes of size 15 x 15 x 70cm filled for checking of flexural strength at the age of 7, 14, 28 days, similarly 9 nos. cylindrical cubes of size length=30cm, dia=15cm filled for checking of The 7-day and 28-day splitting tensile strength values of the test specimens have been compared at the age of 7 and 28 days with W/C ratio 0.29 from each trial. and The quality, uniformity, surface hardness and approximate compressive strength of concrete can be

Determined by non-destructive tests such as the UPV test and

Chemical Properties	Cement	GGBS	MS
Silica – SiO ₂ (%)	21.41	32.98	92.9
Alumina – Al ₂ O ₃ (%)	4.88	21.64	1.20
Iron Oxide – Fe ₂ O ₃ (%)	3.82	1.01	0.74
Calcium Oxide – CaO (%)	63.69	35.95	0.02
Magnesium oxide – MgO (%)	1.56	7.85	1.00
Loss of Ignition (%)	-	0.25	1.80
Insoluble Residue (%)	-	0.39	-
Mno (Manganese Constant)	-	0.12	-
Sulphide Sulphur - Na ₂ S (%)	-	0.50	-
Glass Content (%)	-	90	-
Moisture Content (%)	-	4	0.70
Sodium oxide – Na ₂ O	0.47	0.31	0.42
Potassium oxide – K ₂ O	-	0.98	1.32
Sulphur Trioxide (SO ₃)	2.36	0.85	0.1
Chloride – Cl	-	0.008	-

the Rebound Hammer test

Table 1: chemical composition of cement, GGBS and MS

Table 2: physical properties of cement

Description	Result
Material	Cement
Grade	43 OPC
Colour	Off-white
Sp. Gravity	3.15
Bulk Density	1400 kg/m ³
Fineness	350 m ² /kg
Fineness of cement (%)	2.63
Consistency of cement	29%
Initial Setting Time (minutes)	205
Final Setting Time (minutes)	340

Table 3: Sieve Analysis of Coarse Aggregate (10mm)

Pan	Individual Gradation of 10mm Down		Cumm.% Weight retained (gm)	% of passing	Permitted Limit (%)
	IS Sieve (mm)	Weight retained (gm)			
		% of weight Retained			
	12.5	0	0.00	100	
	10	687.5	13.75	86.25	
	4.75	4040	94.55	5.45	
	2.36	202.50	98.60	1.4	
	70				

Pan	Individual Gradation of 20mm Down		5000Gram	Permitted Limit
	IS Sieve (mm)	Weight retained(gm)		
		% of weight Retained		
	40	0	100	100
	20	168.5	96.63	85-100
	10	4759	1.45	0-20
	4.75	51	0.43	0-5
	22			

Table 4: Sieve Analysis of Coarse Aggregate (20mm)

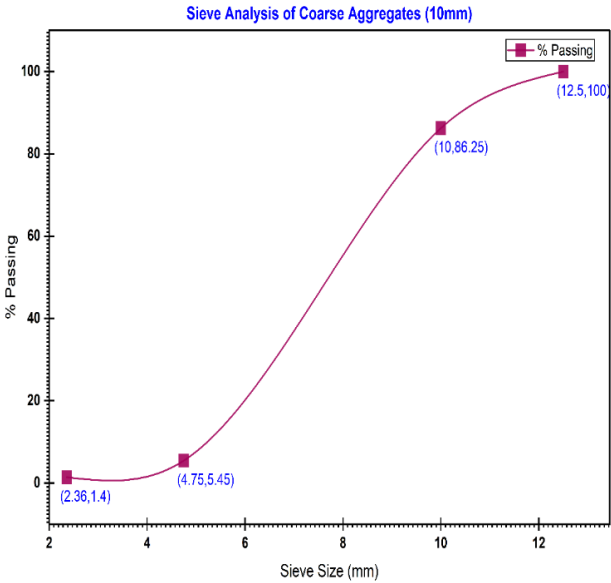


Fig 2: Sieve analysis of coarse aggregate (10mm)

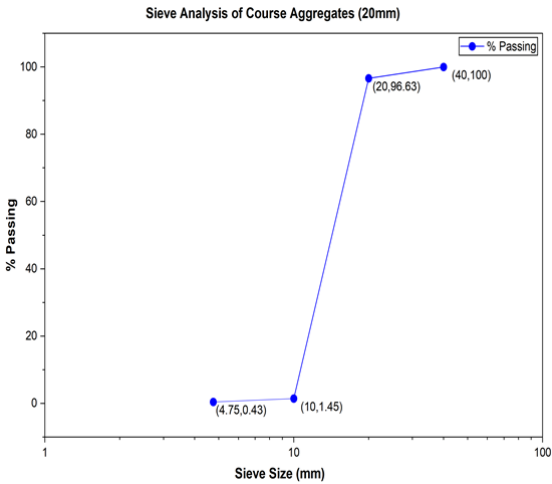


Fig 2: Sieve analysis of coarse aggregate (20mm)

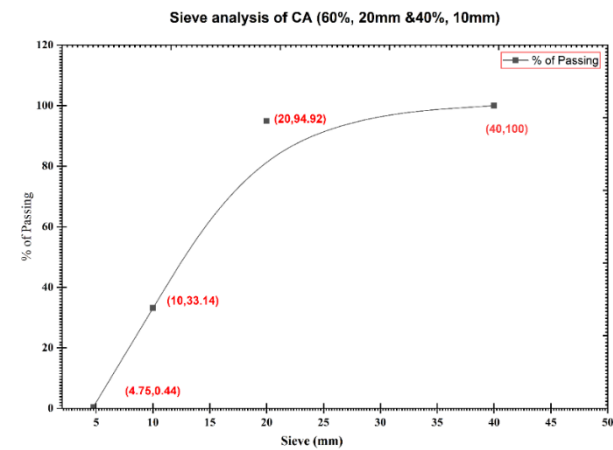


Fig 4: Sieve analysis of coarse aggregate (10mm & 20mm)

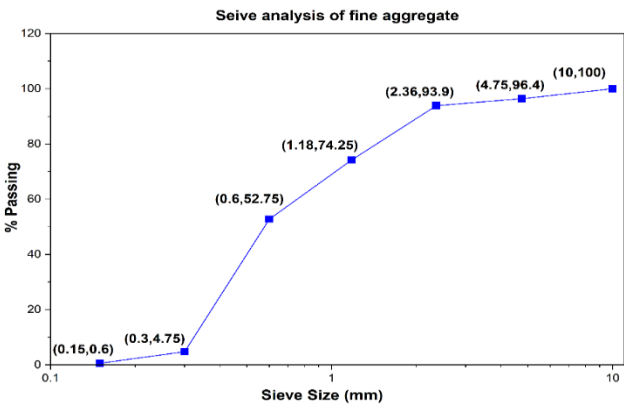


Fig 5: Sieve analysis of fine aggregate

Table 5: Sieve Analysis of Coarse Aggregate (20mm & 10 mm)

Table 6: Sieve Analysis of Fine Aggregate

Pan	IS Sieve (mm)				Permitted Limit (%)
	40	20	10	4.75	
	Weight retained (gm)	Weight retained (gm)	Weight retained (gm)	Weight retained (gm)	
	% of weight Retained	% of weight Retained	% of weight Retained	% of weight Retained	
	Cumm.% Weight retained (gm)	Cumm.% Weight retained (gm)	Cumm.% Weight retained (gm)	Cumm.% Weight retained (gm)	
22	0	254	3089	1635	As per IS 383: 2016 Table 7 (Clauses 6.1 and 6.2)/Method of test as per IS : 2386(Part-1)
	0.00	5.08	61.78	32.7	
	0.00	5.08	66.86	99.56	
	100	94.92	33.14	0.44	

Sample Complies to the requirements of IS 383 2016 (Zone II) & Method of test as per IS:- 2386 (Part-1)/Table 4.	Sieve Size in mm	Weight retained in gm.	% Weight retained	Cumulative % weight Retained	% of Passing	Remarks
	10	0	0	0	100	100
	4.75	36	3.6	3.6	96.4	90-100
	2.36	25	2.5	6.1	93.9	75-100
	1.18	196.5	19.65	25.75	74.25	55-90
	0.600	215	21.5	47.25	52.75	35-59
	0.300	480	48	95.25	4.75	8-30
	0.150	41.5	4.15	99.4	0.6	0-10
	Pan	6				
				277.35		

III. RESULT

Table 7: Compressive Strength Test (W/C 0.29)

Sr no	Trial Mix NO.	GGBS %	MS %	W/C Ratio	Compressive strength (N/mm ²)		
					7 d	14d	28 d
1	TM-1	0%	5%	0.29	52.33	61.23	65.67
2	TM-2	20%	5%	0.29	49.21	57.43	64.33
3	TM-3	30%	5%	0.29	48.10	55.67	63.13
4	TM-4	40%	5%	0.29	46.32	49.81	58.85
5	TM-5	50%	5%	0.29	44.33	45.56	54.56

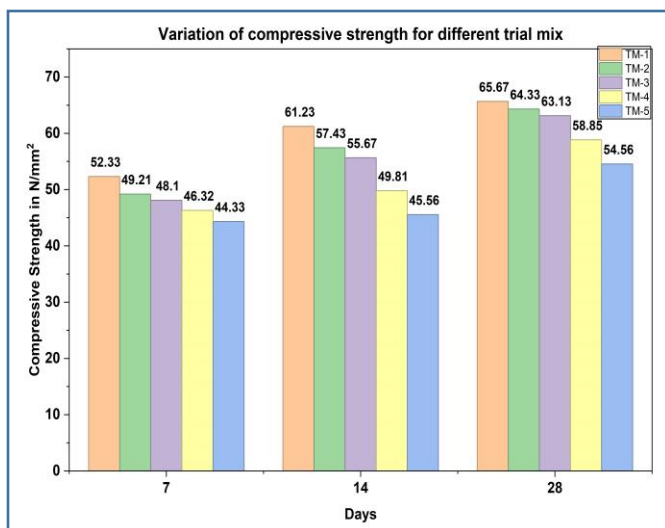


Fig 6: Variation of compressive strength of different trial mix

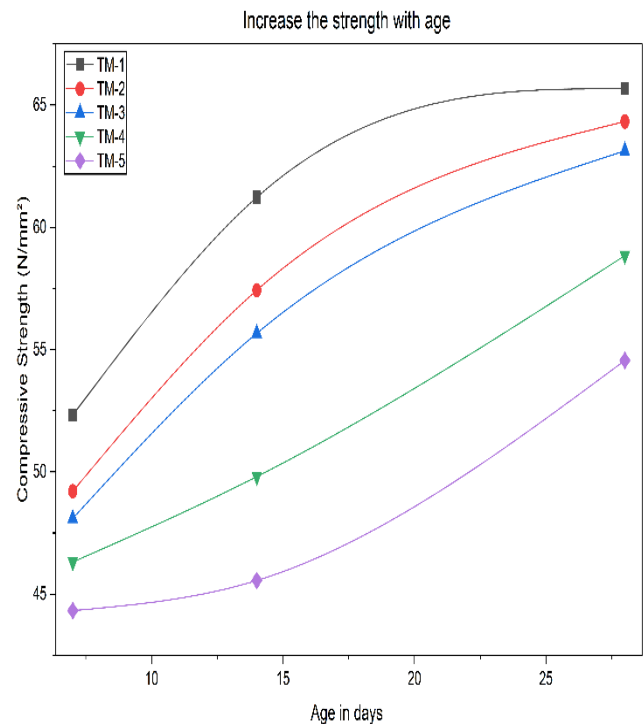


Fig 7: Compressive strength graph

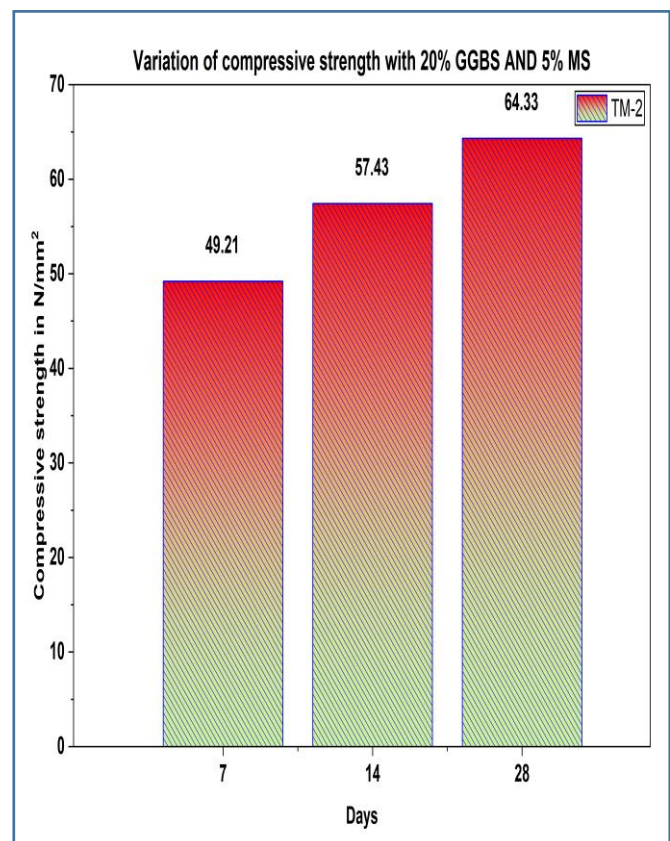


Fig 8: Variation of compressive strength (20% GGBS & 5% MS)

Table 8: Flexural Strength Test (W/C 0.29)

Sr. No.	Trial Mix No.	GGBS %	MS %	W/C Ratio	Flexural Strength (N/mm ²)	
					7d	28d
1	TM-1	0%	5%	0.29	4.85	5.67
2	TM-2	20%	5%	0.29	4.67	5.58
3	TM-3	30%	5%	0.29	4.42	5.53
4	TM-4	40%	5%	0.29	4.23	5.44
5	TM-5	50%	5%	0.29	4.11	5.37

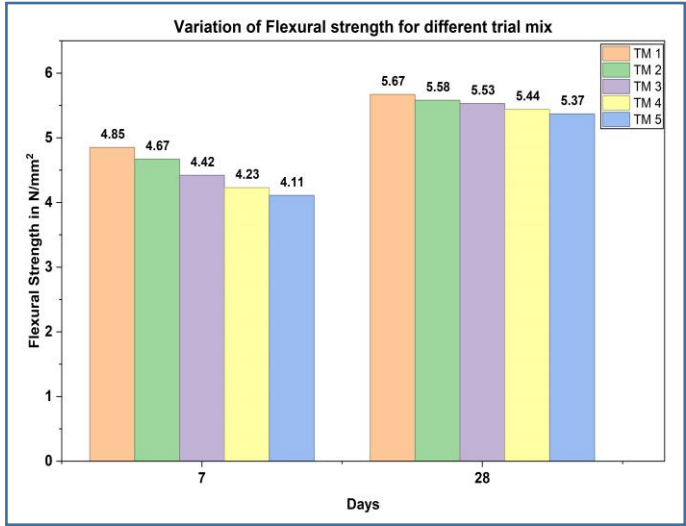


Fig 9: Variation of flexural strength

Table9: Splitting Tensile Strength Test (0.29)

Sr.No.	Trial Mix No.	GGBS %	MS %	W/C Ratio	Splitting Tensile Strength (N/mm ²)	
					7d	28d
1	TM-1	0%	5%	0.29	3.87	4.95
2	TM-2	20%	5%	0.29	3.73	4.82
3	TM-3	30%	5%	0.29	3.64	4.76
4	TM-4	40%	5%	0.29	3.54	4.55
5	TM-5	50%	5%	0.29	3.43	4.37

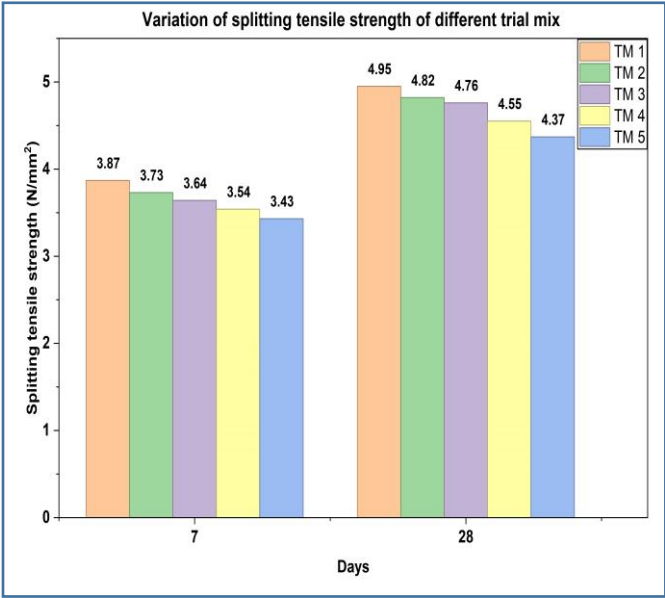


Fig 10: Variation of split tensile strength of different trial mix

The experimental results show that the compressive strength of ternary blended concrete increased with curing age. Generally with above optimum level of GGBS replacement, the strength reduced. The 20% GGBS, 5% Micro Silica mix had a water-cement ratio of 0.29 and the 28-day strength was 64.33 N/mm². The workability improved with the GGBS up to 30% and decreased thereafter. A lower ratio of water to cement also increased the compressive strength. Overall, the results showed that the best combination of GGBS and Micro Silica can be used to achieve better strength, workability and sustainability.

IV. CONCLUSION

The following conclusions are reached based on observations and discussions of this investigation: The W/C ratio is more effective in affecting the strength of the concrete mix. It is observed that with reduction in W/C ratio there is increase in the compressive strength. Loss of strength is indicated by higher W/C ratio. The workability of fresh ternary blended concrete improves as the percentage of GGBS increase up to 30% replacement. Workability of concrete is getting reduced with increasing the mineral admixtures at higher percentages. It is observed that the water demand of the concrete mix was also affected by the chemical admixture. It contributes to improving the workability of the mix, and minimizes the water content required by the concrete mix. The water absorption of the concrete mix is less when chemical admixture added to the concrete mix. The optimum combination of GGBS (20%) + MS (5%) for Ternary blended concrete mix with W/C ratio (0.29), gives more workable and good compressive strength at the age of 28 days when compared to Binary concrete mix. It was noticed that the compressive strength of ternary mixes increased with the increase of curing age, and decreased with the increasing percentage of GGBS.

- Based on the above studies and test results, in case of ternary blended concrete it is advisable to replace the cement by mineral admixtures at an optimum percentage of GGBS 20% and Micro Silica 5% at which we can get better results in workability and compressive strength comparatively with reference to ordinary concrete.

- Experimental studies show that the mineral admixture i.e. GGBS & Micro Silica plays an excellent performance in developing ternary mixes economically.

- By using industrial waste materials we can make environment more sustainable.

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