https://doi.org/10.48047/AFJBS.6.Si4.2024.1951-1959

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

Effects of Different PH Water on Steel Slag Concrete and Thermal Properties of Steel Slag Concrete

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Article History
Volume 6, Issue Si4, 2024
Received: 30 May 2024
Accepted : 20 June 2024
Doi:
10.48047/AFJBS.6.Si4.2024.1951-1959

Abstract:
The primary objective is to comprehensively assess and analyze the influence of incorporating steel slag on the various durability aspects of cement-based materials, including but not limited to strength, thermal properties, and resistance to adverse environmental conditions. The investigation is conducted through a systematic series of laboratory experiments involving concrete specimens with varying percentages of steel slag replacement. The experimental setup includes standard tests such as compressive strength, flexural strength for different PH water condition and durability-related assessments to evaluate the performance of the modified cementitious mixtures. Based on the study, we can see when partial replace the cement and fine aggregate with steel slag then A better results shown in the term of strength and durability aspect. Optimum percentage for cement replacement is 10%, for fine aggregate replacement is 40%, with steel slag. When use optimum percentage then gives a higher value of compressive strength, flexural strength, and durability.

Keywords: Concrete; Steel Slag; Cement; Durability; PH variation; Thermal Reaction.

Introduction:

In today's world, we are focused to use various types of waste and different materials to make concrete in order to reduce the usage of natural resources and improving properties of concrete. During this development phase, a partial replaced cement or fine aggregate with steel slag which is known as steel slag concrete. The main advantage of this type of concrete is that it gives a high strength of concrete, i.e. about 12% to 15 % [1]. The Steel slag concrete is different from ordinary concrete as the main constituents of the steel slag concrete are coarse aggregates, cement, fine aggregate which are replace with steel slag and mixed with water.

As we all know an assemblage of cement, aggregate and water is commonly known as concrete and the research effort in concrete technology have established concrete as versatile material. Several of studies or experiments have been done by replacing of material in concrete either by replacing cement by fly-ash or by replacing aggregate by broken stones or by replacing sand by dust etc. The effect of replacing the cement, sand or aggregates by different materials and their effects in strength and selecting a proper methodology and study the effects on its strength. This experiment is based on the study of usage of Steel slag inside a cement and concrete structure. We know that concrete is the main building material widely used for construction all over the world but we also know that concrete have same main components like water, cement, and aggregate.

The experiment is being conducted in two phases:

- Cement with a replacement of steel slag on 5 mix proportions that is 0%, 5%, 10%, 15%, and 20% in Concrete.
- Fine aggregate with a replacement of steel slag on 7 mix proportions that is 0%, 10%, 20%, 30%, 40%, 50% and 60% in Concrete.

I. Literature Review:

Steel slag and glass can be used to replace coarse aggregates and cement as per the experiment investigation dine by Y.B. Abreha in 2023 [2]. Steel slag and glass were used in broken granular form and powdered form for replacement. At W/C ration of 0.49, they founded that at 30% addition of powdered glass in place of cement and coarse aggregates, the working capability of the mixture reduces by a percentage 25. The increase in compressive strength notice to 6% when they added 5% of powdered glass and 20% slag in place of cement and coarse aggregates respectively. Compressive strength was seen to be inversely proportional to glass powdered percentage.

When fly ash and steel slag are used in concrete as a replacement of sand and cement, the strength reduces. [3]. The maximum compressive strength is noticed when 20 percentage of fly ash and slag is used thereafter reduces for a concrete grade of 20 for both 14 and 28 days. The maximum strength noted to be 23.8 MPa for compressive strength for a replacement of 10 percent in river sand. The value increases by 7 percent in comparison to the original sample. At increasing the percentage to 30, the compressive strength reduces to 9.8 MPa.

When steel slag is used as a replacement of cement, then Pusha et al, the mechanical properties of the concrete drastically changes [4]. The samples are prepared by using steel slag in variation of 5% starting from 5 to 25% replacing of cement in concrete. The maximum results were observed on a replacement of about 10% in cement in concrete.

When steel slag is used in residential building construction, the results shows that higher value of sleet slag can be used for replacing aggregate [5]. The percentage which can be used for replacing aggregates was 60% and for fine aggregates the replacement founded to be 40%. The specimen obtained from utilization of steel slag the strength of compression noted to be 15.04 and 25.67 N/mm2 for 7 and 28 days respectively.

H. Rooholamini conducted an experiment by using a specific type of slag that is obtained from electric arc furnace [6]. He studied the effect of fineness of steel slag. He conclud3ed that when we use finer particles of slag then, due to the higher specific area and lime content the mechanical properties drastically improved.

II. Material Used:

1. Cement: Portland Pozzolana cement is used. Specific gravity of cement is 3.15. Initial and final setting time of cement is 34 minutes and 315 minutes respectively. Fineness of cement is 3180 cm^2/gram. Soundness of cement is 8mm. compressive strength of cement after 28 days is 33.86 N/mm^2 [18].

2. Fine Aggregate: The material which particle size is less than from 4.75mm is called fine aggregate. Fineness modulus of fine aggregate is 3.07. Specific gravity of fine aggregate is 2.73.grading zone of fine aggregate is 1st [23, 24].
3. Course Aggregate: The material which particle size is greater than from 4.75mm is called course aggregate. Specific gravity and water absorption of course aggregate are 2.9 and 0.604% respectively. Crushing Value, Impact value and fineness modulus of course aggregate are 26.7%, 6.897% and 7.17 respectively [23, 24].
4. Steel slag: Steel slag, a byproduct of steel making process. Most of quality parameter is matched with cement and aggregate properties so we can use as a replacement. Fineness modulus of steel slag is 3.155. Fineness of steel slag is 8.9% and specific gravity is 2.75 [18, 23, 24]
5. Water: Clean and fresh water is used. PH value of water is nearby 7 [25].

IV. Mix Design of Concrete:

For this experiment we are considered a design mix of 30 Grade [21]. For Mix design of M-30 the composition of various materials is shown in Table 1.

Table 1: Mixedproportion ratio for grade M30.

Cement (Kg/m³)	Water (Kg)	Fine Aggregate (Kg/m³)	Coarse Aggregate (Kg/m³)	W/C Ratio
450.0	197.20	679.10	1050.50	0.40

The variation is done in two phases. In First phase, for replacing steel slag with cement designated as CS1, CS2, CS3, CS4 and CS5 for having 0, 5, 10, 15 and 20 percent replacement. The varied component for one cube keeping quantity of Fine Aggregate to 2.639 Kg, Coarse aggregate to 4.100 Kg and water content to 0.704 Kg and for 1 beam keeping quantity of Fine aggregate to 3.882 Kg, Coarse aggregate to 6.030 Kg and water content to 1.035 Kg in table 2.

Table 2: Composition of concrete when cement is replaced by Steel Slag.

Specimen Designation	Replacement Percentage	Varied Contents for 1 Cube*		Varied Contents for 1 Beam**	
		Cement (Kg)	Steel Slag (Kg)	Cement (Kg)	Steel Slag (Kg)
CS1	0	1.760	0	2.588	0.000
CS2	5	1.672	0.088	2.459	0.129
CS3	10	1.584	0.176	2.329	0.259
CS4	15	1.496	0.264	2.200	0.388
CS5	20	1.408	0.352	2.070	0.518
Constant Values		* For Cube: Fine Aggregate= 2.639 Kg, Coarse aggregate= 4.100 Kg and water content= 0.704 Kg		** For Beam: Fine Aggregate= 3.882 Kg, Coarse aggregate= 6.030 Kg and water content= 1.035 Kg	

Table 3: Composition of concrete when fine aggregate is replaced by Steel Slag.

Specimen Designation	Replacement Percentage	Varied Contents for 1 Cube##		Varied Contents for 1 Beam#	
		Fine Aggregate (Kg)	Steel Slag (Kg)	Fine Aggregate (Kg)	Steel Slag (Kg)
FS0	0	2.640	0.000	3.882	0
FS1	10	2.376	0.264	3.494	0.3882
FS2	20	2.112	0.528	3.106	0.7764

FS3	30	1.848	0.792	2.717	1.1646
FS4	40	1.584	1.056	2.329	1.5528
FS5	50	1.320	1.320	1.941	1.941
FS6	60	1.056	1.584	1.553	2.3292
Constant Values		## For Cube: Cement= 1.759 Kg, Coarse aggregate= 4.100 Kg and water content= 0.704 Kg		# For Beam: Cement= 2.588 Kg, Coarse aggregate= 6.030 Kg and water content= 1.035 Kg	

In Second phase, for replacing steel slag fine aggregate are designated as FS0, FS1, FS2, FS3, FS4, FS5 and FS6 having 0, 10, 20, 30, 40, 50 and 60 percent replacement. The varied component for one cube keeping quantity of cement to 1.759 Kg, Coarse aggregate to 4.100 Kg and water content to 0.704 Kg and for 1 beam keeping quantity of cement to 2.588 Kg, Coarse aggregate to 6.030 Kg and water content to 1.035 Kg in table 3.

V. Results:

Compressive Strength of Concrete:

For this test a specimen of volume 150*150*150mm^3 is prepared of the above stated design mix. When cement is replaced by slag, then the optimum strength of compression was noted to be found in specimen CS3. The strength of compression was 29.3, 39.8 and 42.3 MPa against 7, 14 and 28 days. When fine aggregate is replaced by slag, then the optimum strength of compression was noted to be found in specimen FS4. The strength of compression was 29.3, 39.8 and 42.3 MPa against 7, 14 and 28 days. Now we conducted the effect of various pH on this sample. The pH which are considered for this study are 4, 7.50 and 12.7 representing Acidic, Neutral and Alkaline stages of pH. The strength of compression is observed at 90 and 120 days and the values are shown in table 4.

For 90 days, the strength of concrete increases when cement is replaced by slag at different pH is 7.30% for 4.0 pH, 2.30% for 7.5 pH and 6.54% for 12.70 pH. For 120 days, the strength of concrete increases when cement is replaced by slag at different pH is 4.77% for 4.0 pH, 3.67% for 7.5 pH and 5.98% for 12.70 pH.

For 90 days, the strength of concrete increases when fine aggregates is replaced by slag at different pH is 14.75% for 4.0 pH, 11.29% for 7.5 pH and 10.36% for 12.70 pH. For 120 days, the strength of concrete increases when fine aggregates is replaced by slag at different pH is 11.23% for 4.0 pH, 12.94% for 7.5 pH and 6.63% for 12.70 pH.

Table 4: Strength of compression of concrete cubes for 90days & 120 days as cement and fine aggregate replacement by steel slag

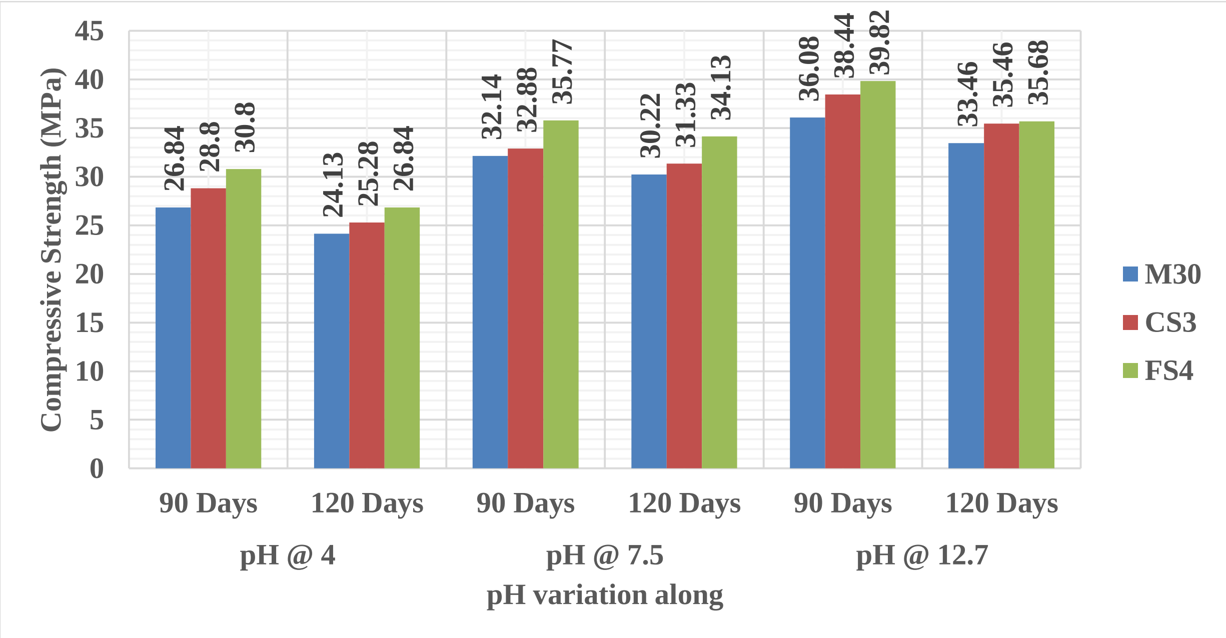
pH	pH @ 4		pH @ 7.5		pH @ 12.7	
Compressive Strength (MPa)	90 Days	120 Days	90 Days	120 Days	90 Days	120 Days
M30	26.84	24.13	32.14	30.22	36.08	33.46
CS3	28.8	25.28	32.88	31.33	38.44	35.46
FS4	30.8	26.84	35.77	34.13	39.82	35.68

Flexural Strength of Concrete:

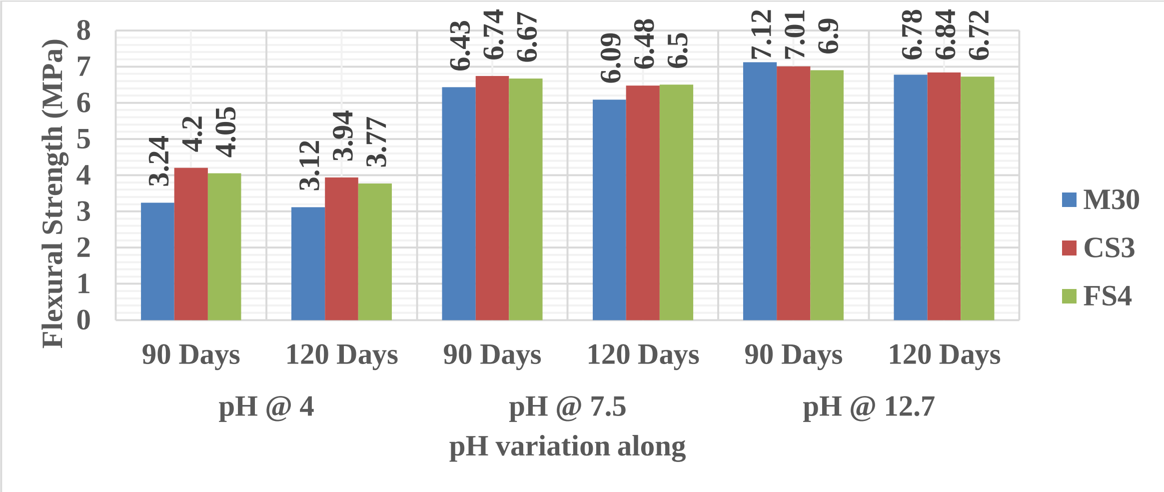
For this test a specimen of volume 500*100*100 mm^3 is prepared of the above stated design mix. When cement is replaced by slag, then the optimum strength of compression was noted to be found in specimen CS3. The strength of flexure was 5.72 and 7.09 MPa against 7 and 28 days. When fine aggregate is replaced by slag, then the optimum strength of compression was noted to be found in specimen FS4. The strength of flexure was 5.71 and 7.08 MPa against 7 and 28 days. Now we conducted the effect of various pH on this sample. The pH which are considered for this study are 4, 7.50 and 12.7 representing Acidic, Neutral and Alkaline stages of pH. The strength of flexural is observed at 90 and 120 days and the values are shown in table 5. For 90 days, the strength of concrete increases when cement is replaced by slag at different pH is 29.63% for 4.0 pH, 4.82% for 7.5 pH and -1.54% for 12.70 pH. For 120 days, the strength of concrete increases when cement is replaced by slag at different pH is 26.28% for 4.0 pH, 6.40% for 7.5 pH and 0.88% for 12.70 pH.For 90 days, the strength of concrete increases when fine aggregates is replaced by slag at different pH is 25.00% for 4.0 pH, 3.73% for 7.5 pH and -3.09% for 12.70 pH. For 120 days, the strength of concrete increases when fine aggregates is replaced by slag at different pH is 20.83% for 4.0 pH, 6.73% for 7.5 pH and -0.88% for 12.70 pH.

Table 5: Strength of flexural of concrete beams for 90days & 120 days as cement and fine aggregate replacement by steel slag

pH	pH @ 4		pH @ 7.5		pH @ 12.7	
Flexural Strength	90 Days	120 Days	90 Days	120 Days	90 Days	120 Days
M30	3.24	3.12	6.43	6.09	7.12	6.78
CS3	4.20	3.94	6.74	6.48	7.01	6.84
FS4	4.05	3.77	6.67	6.50	6.90	6.72



Graph 1: Strength of compression of concrete cubes when cement & fine aggregates are replaced by Steel Slag.



Graph 2: Strength of flexural of concrete beams when cement & fine aggregates are replaced by Steel Slag.

Temperature Test on Concrete:

Tests are done in two phases as the concrete have i.e., Fresh and hardened state. In fresh state concrete, the temperature is tested as soon as the sample is set at room temperature. While in hardened state, the sample is exposed to sum lite from 09:00 hours till 17:00 hours and variation is recorded.

In fresh concrete, the temperature rises as the percentage of steel slag in both the cases by replacing cement and steel slag. The various temperature obtained by both type of replacement i.e., cement and fine aggregates are given in table 6.

In hardened concrete, the temperature rises as the percentage of steel slag in both the cases by replacing cement and steel slag. The various temperature obtained by both type of replacement i.e., cement and fine aggregates are given in table 7. For the maximum value of steel slag i.e., 60% in fine aggregate replacement and 20% replacement of cement. The values are 47.90 ^{o}C and 51.67 ^{o}C respectively which is noted around 15:00 hours.

Table 6: Temperature recorded for various sample in fresh concrete.

Specimen	Steel Slag (%)		Temperature (^{o}C)
	Replacing cement	Replacing Fine aggregate	Fresh Concrete
CS1	0	0	30.3
CS2	5	0	30.2
CS3	10	0	31.25
CS4	15	0	32.1
CS5	20	0	32.4
FS0	0	0	30.3
FS1	0	10	29.5
FS2	0	20	29.85
FS3	0	30	30.1
FS4	0	40	31.7
FS5	0	50	31.95
FS6	0	60	30.05

Table 7: Temperature recorded for various sample of hardened concrete.

Specimen	Steel Slag (%)		Temperature (°C) (09:00 AM to 05:00 PM)				
	Replacing cement	Replacing Fine aggregate	9:00	11:00	13:00	15:00	17:00
CS1	0	0	31.2	38.69	44	45.77	39.61
CS2	5	0	31.2	38.88	45.1	46.84	39.92
CS3	10	0	31.2	39.11	46.18	46.89	40.12
CS4	15	0	31.2	39.5	46.45	47.35	40.96
CS5	20	0	31.2	41.12	46.97	47.9	41.71
FS0	0	0	32.14	39.25	44.25	45.97	39.89
FS1	0	10	32.14	41.19	45.92	46.2	40.13
FS2	0	20	32.14	42.86	46.85	46.97	40.82
FS3	0	30	32.14	44.5	47.56	47.89	41.33
FS4	0	40	32.14	45.63	48.05	49.08	41.59
FS5	0	50	32.14	45.85	49.62	50.15	42.68
FS6	0	60	32.14	46.02	50.43	51.67	42.76

VI. Conclusion:

From this study following point are concluded:

- Mechanical properties such as various type of strength can be increased by up to a certain percent.
- For compressive strength, up to 10 percent for cement replacement and 40 percent for fine aggregate.
- For flexural strength, up to 10 percent for cement replacement and 40 percent for fine aggregate same as in the compressive strength.
- As steel slag percentage increase, the strength against various pH increases for the case of acid and neutral water while it decreases for alkaline water.
- As the slag percentage increases, the temperature rise for both cases of replacing cement and fine aggregates.
- The maximum temperature is recorded at 1700 hours for hardened concrete
- Thermal behavior of Steel slag concrete is shows negative effects on environment.
- Due to increase in temperature the sounding environment absorb/radiate heat waves causing damage to various ecosystems.
- Due to lower PH as we observed a deterioration of concrete in fine particles resulting clogging of soil pores leading to various environmental problems in future.

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IS Code:

17. IS:4031 -1988 (test of cement)
18. IS:2720 (Part-III) -1980 (Specific gravity of steel slag)
19. IS:516 (Compressive strength of Concrete & Flexural Strength of Concrete)
20. IS:10262-2009 (Design mix)

21. IS:456-2000 (Design of concrete)
22. IS:2386 -1963 (Test on Course aggregate)
23. IS:383 -1970 (Fineness modulus and grading of aggregate)
24. IS:10500-1983 (Standard Specification for water)
25. IS:9103-1999 (Specification of Concrete Admixture)