IARJSET

ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Vol. 8, Issue 7, July 2021

DOI: 10.17148/IARJSET.2021.8775

Mechanical Properties of concrete with Silica Fume and Partial Replacement of Coarse Aggregate by Steel Slag

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Abstract: Our natural resources are depleting and alternative materials as partial replacement would provide better strength and eco-friendly concrete having low CO_2 foot print. Silica fume as mineral admixture in partial replacement of cement with different percentages of 0, 5,7.5 and 12.5% by weight of cement and to protect the natural sources like coarse aggregates, we are partially replacing coarse aggregates by steel slag of 0 ,10,20,30,40,50 and 60% by weight. In this study, concrete cubes and cylinders were casted by replacing cement alone with silica fume and coarse aggregates alone by steel slag and as well as combinations of optimum partial replacements of cement and coarse aggregate at a time. At 7.5% the optimum compressive strength with partial replacement of cement with silica fume and at 40% the optimum compressive strength with partial replacement of coarse aggregate with steel slag is achieved.

Keyword: - Compressive strength, Silica fume, Steel slag aggregates, Split tensile strength.

1. INTRODUCTION

Most notably, the production process for cement produces large volumes of greenhouse gas emissions, leading to net 8% of global emissions. Significant research and developments is being done to try to reduce the emissions or make concrete a source of carbon sequestration. Other environmental concerns include widespread illegal sand mining, impacts on the surrounding environment such as increased surface runoff or urban heat island effect and potential public health implications from toxic ingredients. Concrete is also used to mitigate the pollution of other industries, capturing wastes such as coal fly ash or bauxite tailings, silica fume and residue.

In this experimental study, we are partially replacing natural aggregates with steel slag aggregates (due to over quarrying and depletion of natural resources) and cement with silica fume up to a particular extent for enhancing concrete strength as well as for reducing permeability and thermal cracking (caused by heat of cement hydration). Thus eco-friendly sustainable concrete can be obtained by partial replacement of cement and natural stone aggregates by silica fume and steel slag (an industrial waste product).

2. OBJECTIVES

The objectives of this study are as follows

a) To optimize the partial replacement of cement with silica fume.

b) To optimize the partial replacement of coarse aggregate by steel slag.

c) To investigate the strength characteristics of concrete with combined partial replacements of cement and coarse aggregate together by optimum percentage of silica fume and steel slag.

3. LITERATURE REVIEW

RA.B. Deepa, Dr T Felix Kala: Steel slag is an industrial waste product from steel manufacturing industries. It is produced in large quantities during steel manufacturing operations which utilize Electric Arc Furnaces (EAF). It is also produced by smelting iron ore in the Basic Oxygen Furnaces (BOF). Steel slag can be widely used in construction industry as aggregate in concrete as natural aggregate. Natural aggregates are becoming scarce and their production is

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difficult. So there arises a need for alternate material as coarse aggregate. In this study, it is proposed to utilize steel slag as replacement of coarse aggregate in concrete. Concrete cube, cylinders and prisms were cast with steel slag as coarse aggregate replacement materials up to 100% and the compressive strength characteristic has been studied. Based on the compressive strength results it was concluded that the optimum replacement of coarse aggregate by steel slag is 80%.

S.I. ADEDOKUN, M.A ANIFOWOSE, S.O. ODEYEMI: This study presents a review on the utilization of steel slag as replacement for coarse aggregate in concrete. Merits and demerits of steel slag in concrete as well as its physical properties and chemical compositions of steel slag are also presented. It has been reported that it is economical to use steel slag, as the costs of steel slag are just about 50% of that of conventional aggregates. However, the optimum replacement of coarse aggregate with steel slag that gives better mechanical properties (compressive strength, tensile strength and flexural strength) than conventional concrete is found to be between 30 and 60%. In South Western part of Nigeria, there are numbers of steel/iron producing company with large deposits of steel slag. Therefore, there is need for the utilization of this by-product (steel slag) in concrete production in Nigeria as cost of natural aggregates (fine and coarse aggregate) is becoming higher.

4. MATERIALS

4.1. Cement

The property of cement is presented in table 1.

Table 1: Properties of cement

S.No.	Property	Cement
1	Specific gravity	3.15
2	Fineness	6%
3	Consistency	35%
4	Initial setting time	54 min
5	Final setting time	412 min

4.2 Silica fume:

Silica fume is a by-product in the carbothermic reduction of high-purity quartz with carbonaceous materials like coal, coke, wood-chips, in electric arc furnaces in the production of silicon and ferrosilicon alloys.The physical properties of silica fume is shown in table 2.

Table 2: Physical properties of silica fume

Sl.No	Property	Value
1	Specific gravity	2.2
2	mean grain size (micro meters)	0.15
3	Specific surface area(cm^2/gm)	150000-300000
4	Colour	light to dark grey

4.3 Steel slag

Steel slag is a by-product formed during the steel manufacturing process. It is a non metallic ceramic material formed from the reaction of flux such as calcium oxide with the inorganic non-metallic components present in the steel scrap. The use of steel slag reduces the need of natural rock as constructional material, hence preserving our natural rock resources, maximum utilization and recycling of by-products and recovered waste materials for economic and environmental reasons has led to rapid development of slag utilization. The physical and mechanical properties are presented in table 3 and 4.

Table 3: Physical properties of steel slag

Property	Value
Specific gravity	>3.2 -3.6
Dry rodded unit weight(kg/m^3)	.1600-1920
Water Absorption	upto 3%

Table 4: Mechanical properties of steel slag

Property	Value
Los Angeles Abrasion	20 -25
Sodium sulphate soundness loss	<12

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Angle of Internal friction	40° -50°
Hardness	6-7

5. CONCRETE MIX DESIGN

The mix design adopted is 1:2.56 : 3.27.

6. EXPERIMENTAL INVESTIGATIONS

6.1 Compressive strength results

The compressive strength conducted in compression testing machine for the cast and cured specimens and are furnished in table 5 to 7.

Table 5: Compressive strength of concrete for silica fume

Mix.no	Silica fume(% replacement of cement content)	Compressive strength, N/mm^2	
		7 days	28 days
1	0%	33.27	48.15
2	5%	35.04	50.43
3	7.5%	38.29	55.82
4	12.5%	36.57	52.25

Table 6: Compressive strength of concrete for various proportions of steel slag

Mix No	Steel slag	Compressive strength, N/mm^2	
		7 days	28 days
1	0%	33.27	48.15
2	10%	35.09	50.43
3	20%	36.51	53.23
4	30%	38.63	54.18
5	40%	39.33	56.51
6	50%	36.43	53.11
7	60%	35.54	52.27

Table 7: Compressive strength of concrete for combined partial replacement of cement and coarse aggregate by 7.5% of silica fume and 40% by steel slag aggregates

Mix No	Combined replacements (%)	Compressive strength, N/mm^2	
		7 days	28 days
1	0	33.27	48.15
2	40%steelslag+7.5%SF	42.18	60.35

6.2 Split Tensile Strength Results

Cylindrical specimens of 150mm diameter and 300mm height were casted and tested under CTM for tensile strength of concrete and presented in table 8 to 10.

Table 8: Split tensile strength of concrete for various proportions of silica fume

S.No.	Silica fume	Split tensile strength, N/mm^2	
		7 days	28 days
1	0%	3.27	4.71
2	5%	3.42	4.96
3	7.5%	3.65	5.35
4	12.5%	3.48	5.06

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Table 9. Split tensile strength of concrete for various proportions of steel slag

Mix No.	Steel slag	Split tensile strength, N/mm^2	
		7 days	28 days
1	0%	3.27	4.71
2	10%	3.42	4.96
3	20%	3.49	5.11
4	30%	3.61	5.25
5	40%	3.96	5.59
6	50%	3.43	4.77
7	60%	3.24	4.70

Table 10: Split tensile strength of concrete for combined partial replacement of cement and coarse aggregate by 7.5% of silica fume and 40% by steel slag aggregates

Sl. No	Combined replacements	Split tensile strength, N/mm^2	
		7 days	28 days
1	0	3.27	4.71
2	40%steelslag+7.5%SF	3.69	5.30

7.CONCLUSIONS

1. At 7.5% partial replacement of cement alone by silica fume, the optimum compressive strength of concrete is 38.29 and 55.82 N/mm^{2}for 7 and 28 days.
2. At 40% partial replacement of coarse aggregate alone by steel slag, the optimum compressive strength of concrete is 39.33 and 56.51 N/mm^2 for 7 and 28 days.
3. The percentage increase in compressive strength at 7.5% of silica fume is 15.08 and 15.92% for 7 and 28 days when compared to that strength of conventional concrete.
4. The percentage increase in compressive strength at 40% partial replacement of coarse aggregate by steel slag is 18.21 and 17.36% for 7 and 28 days.
5. By partial replacement of cement and coarse aggregate together by 7.5% of silica fume and 40% of steel slag, the optimum compressive strength of concrete is 42.18 and 60.35 N/mm^2 for 7 and 28 days.
6. At 7.5% of silica fume + 40 % of steel slag, the percentage increase in compressive strength is 26.78 and 25.33% for 7 and 28 days when compared to that conventional concrete strength at that age.
7. At 7.5% of partial replacement of cement alone by silica fume, the optimum split tensile strength of concrete is 3.65 and 5.35 N/mm^2 for 7 and 28 days.
8. At 40% partial replacement of coarse aggregate alone by steel slag , the optimum split tensile strength of concrete is 3.96 and 5.59 N/mm^2 for 7 and 28 days.
9. The percentage increase in split tensile strength of concrete at 7.5% replacement of silica fume is 11.62 and 13.58% N/mm^2 for 7 and 28 days.
10. The percentage increase in split tensile strength of concrete at 40% partial replacement of coarse aggregate by steel slag is 21.1 and 18.68% for 7 and 28 days.
11. By partial replacement of cement and coarse aggregate together by 7.5% of silica fume and 40% of steel slag, the optimum split tensile strength of concrete is 3.69 and 5.30 N/mm^2 for 7 and 28 days.
12. At 7.5% of silica fume + 40 % of steel slag, the percentage increase in split tensile strength is 12.84 and 12.52% for 7 and 28 days when compared to that conventional concrete strength at that age.

8. REFERENCES

1. Beshr, H., Almusallam, A. A., Maslehuddin, M., “Effect of coarse aggregate quality on the mechanical properties of high strength concrete”, Construction and Building Materials, Vol. 17, May 2003, pp.97- 103.
2. Fujii, T., Ayano, T., Sakata, K., “Strength and durability of steel-slag hydrated matrix without cement”, Proceedings of 29th conference of our world Concrete & Structures, Jan 2004, pp.253-258. [6] Fujii, T., Tayano, T., Sakata, K., “Freezing and thawing Resistance of Steel making slag concrete”, Journal of Environmental Sciences for sustainable society, Vol. 1, Dec 2007, pp.1-10.
3. Garg, M., Singh, M., “Strength and durability of cementious binder produced from fly ash–lime sludge-portland cement”, Indian Journal of Engineering & Materials Sciences, Vol. 13, Dec 2006, pp.75-79.
4. Hisham, Q., Faissal, S., Ibrahim, A., “Use of low CaO unprocessed steel slag in concrete as fine aggregate”, Construction and Building Materials, Vol. 23, Sep 2009, pp. 1118-1125.

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5. Khidhair, J., Falak, O., Mohammed, O., "Using of Steel Slag in Modification of Concrete properties", Engineering & Technology journal., Vol. 27, No. 9, Dec 2009, pp. 1711-1721.

6. Improvement of Strength Properties on the Partial Replacement of Cement with Copper slag in Concrete", IJATIR, Vol .9, Issue. 05, April-2017, ISSN: 2348-2370.

7. Utilization of Bagasse Ash as Partial replacement of Cement in High Strength concrete" ISSN: 2348 – 8352, SSRG International Journal of Civil Engineering (SSRG - IJCE) – Special Issue ICITSET Sep 2018.

8. "Experimental Study On Partial Replacement Of Cement With Fly Ash And Complete Replacement Of Sand With M sand" ISSN: 2348 – 8352, SSRG International Journal of Civil Engineering (SSRG - IJCE) – Special Issue ICITSET Sep 2018.

9. Chandramouli,K, Pannirselvam,N, Vijayakumar,D, (2019), Strength Studies on Pine Apple Fibre Concrete with Nano Silica, International Journal of Innovative Technology and Exploring Engineering, 8(7), pp. 3063-3065.

10. Pannirselvam,N, Chandramouli,K, Anitha,V, (2018), Pulse Velocity Test on Banana Fibre Concrete with Nano Silica, International Journal of Civil Engineering and Technology, 9(11), pp. 2853-58.

11. Chandramouli,K, "Chloride Penetration Resistance Studies on Concretes Modified with AR-Glass Fibres", is published in American Journal of Engineering and Applied Science. 7 (3): 371-375, 2010 (ISSN 1546-9239) 2010 Science Publications.

12. Pannirselvam,N, Chandramouli,K, Anitha,V, "Experimental Investigation on Special Concrete using Steel Nail" is published in International Journal of Recent Technology and Engineering (IJRTE); ISSN: 2277-3878, Volume-7, Issue- 6S; March 2019.

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