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A Study on Influence of Dosage of Silica Fume on GGBS based Concrete

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KEYWORDS
Cementitious Material, Steel Slag, Slag Cement, Silica Fume, Fly Ash Cement.

ABSTRACT:
Concrete is the most adaptable building material since it can be made to resist the most extreme conditions while still taking on the most beautiful forms. With the aid of cutting-edge chemical admixtures and additional cementitious materials, engineers are always pushing the boundaries to increase its performance. Nowadays, the majority of concrete mixtures include supplemental cementitious material as a cementitious component. The majority of these materials are byproducts of other operations. SCMs' primary advantages include their capacity to partially replace cement while retaining cementitious properties, which lowers the cost of utilising Portland cement. Numerous byproducts or waste products, such as fly ash, silica fume, ground granulated blast furnace slag, steel slag, etc., that can be utilised as SCMs have been produced as a result of the rapid rise of industrialization. The usage of these byproducts not only aids in the use of these waste products but also improves the characteristics of fresh and hydrated concrete. The two SCMs that are utilised in concrete the most frequently are slag cement and fly ash. Silica fume is perhaps the most effective SCM since it increases concrete's strength and durability to the point that it is required by contemporary design standards for the creation of high strength concrete. Good-quality aggregates are also necessary when designing high-strength concrete.

flexible and sticky when silica fume was added, especially when used with fly ash cement. When silica fume % is increased with either kind of cement, porosity and capillary absorption tests on mortar mixtures reveal a reduction in both. With fly ash cement, the drop is greater than with slag cement. However, the results demonstrate that the addition of silica fume in the matrix decreased the compressive strength of concrete during 7 days, 28 days, and 56 days. At every stage, the silica fume dosage increases while the strength continues to decline. For flexural strength as well, almost the same trend was seen. Fine fractures were present in the examples free of silica fume, which are more noticeable in concrete built with slag cement as opposed to fly ash cement.

INTRODUCTION

Cement, sand, coarse aggregate, and water are the main ingredients of concrete. Its popularity is due to its adaptability since it can be made to survive the roughest conditions while still taking on the most inspiring forms. With the aid of cutting-edge chemical admixtures and other supplemental cementation materials SCMs, engineers and scientists are now working to extend its boundaries.

SUPPLEMENTARY CEMENTITIOUS MATERIAL:

Fly ash, silica fume, powdered granulated blast furnace slag, and other industrial wastes that can be utilised as SCMs have become more prevalent in

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recent years as a result of rigorous environmental pollution controls and legislation. SCMs are used in concrete structures to improve the qualities of the material in its fresh and hydrated forms as well as to avoid pollution from being caused by these materials.

STEEL SLAG:

Steel slag is a byproduct of the steel-making process that is created in steel-making furnaces when molten steel is separated from impurities. Concrete can utilise this as aggregate. Due to the existence of free lime and magnesium oxides, which have not yet interacted with the silicate structure and can hydrate and expand in humid settings, steel slag aggregate typically demonstrate a tendency to expand. This potentially expansive character, which might pose problems with products containing steel slag (volume changes up to 10% or more due to the hydration of calcium and magnesium oxides), is one of the reasons steel slag aggregate are not utilised in concrete construction. There is a need for greater research to assess the viability of using steel slag more intelligently as a replacement for both fine and coarse aggregates in a typical concrete mixture. Currently, steel slag is utilised as aggregate in hot mix asphalt surface applications. Aggregates make up the majority of concrete's volume. There would be significant environmental advantages if steel slag were used in place of all or part natural aggregates. Aside from its disadvantages, such as higher water absorption and strong alkalis, steel slag has a higher specific gravity and abrasion value than naturally occurring aggregate. As a result, it may be utilised as coarse aggregate in concrete when properly treated.

LITERATURE SURVEY:

The advantages of employing pozzolanic materials in creating and improving the characteristics of concrete have been the subject of several studies.

D.A. Thomas, M.H.Shehata[1] et al. have shown that Portland cement, silica fume, and fly ash ternary cementitious mixes provide considerable benefits over binary blends and much bigger improvements over plain Portland cement.

Sandor Popovics[2]have examined the Portland cement-fly ash-silica fume systems in concrete and come to various positive conclusions regarding the strength, workability, and outcomes of ultrasonic velocity tests regarding the addition of silica fume to the fly ash cement mortar.

Jan Bijen[3] have investigated the advantages of adding slag and fly ash to OPC-made concrete in terms of alkali-silica reaction and sulphate attack.

Lam, Y.L. Wong, and C.S. Poon[4] The authors of the study Effect of fly ash and silica fume on compressive and fracture behaviours of concrete came to the conclusion that adding various amounts of fly ash and silica fume improved the strength qualities of the concrete.

Tahir Gonen and Salih Yazicioglu[5] Numerous enhanced concrete qualities in the fresh and hardened stages were found as a result of research on the effects of binary and ternary mineral admixtures on the short and long term performances of concrete.

Mateusz Radlinski, Jan Olek and Tommy Nantung[6]Researchers have examined the effects of various ratios of the ingredients in a ternary blend of binder mix on the scaling resistance of concrete in low temperatures in their experimental study entitled "Effect of mixture composition and Initial curing conditions on the scaling resistance of ternary concrete."

A. **A. Barbhuiya, J.K. Gbagbo, M.I. Russeli, P.A.M. Basheer** After examining the characteristics of fly ash concrete that had been amended with hydrated lime and silica fume, researchers came to the conclusion that these additions enhance concrete's durability and long-term strength development.

B. Susan Bernal, Ruby De Gutierrez, Silvio Delvasto, Erich Rodriguez performed research on the performance of steel fiber-reinforced, alkali-activated slag concrete. The produced AASC have greater compressive strengths than the OPC reference concretes, according to their analysis. With the addition of fibres at day 28 of curing, the splitting tensile strengths of both OPCC and AASC concretes rise.

MATERIALS

Silica Fume

When high-purity quartz is reduced with coke in electric arc furnaces to create silicon and ferrosilicon alloys, silica fume is produced as a byproduct. When measured using nitrogen adsorption techniques, the surface area of silica fume's small particles ranges from

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215,280 ft2/lb (20,000 m2/kg) to around a hundredth of the size of the typical cement particle. Silica fume is an extremely effective pozzolanic material particle due to its extreme fineness and high silica concentration.

Steel Slag

Steel slag is the byproduct of the steel-making process and is made up of silicates and oxides of impurities in the chemical makeup of steel. As a byproduct of the Basic Oxygen Process (BOP), LD slag was produced worldwide in quantities of 50 million tonnes annually.

Fly ash cement

Fly ash, which mostly consists of silicon dioxide and calcium oxide, can be used in place of or in addition to Portland cement. Fly ash is composed of pozzolanic elements, which can be used to bind cement components together. Concrete is made stronger and more durable with pozzolanic ingredients, such as fly ash cement.

SLAG CEMENT

In American concrete constructions for more than a century, slag cement has been utilised. The earlier use of slag cement in Europe and other regions shows that concrete performance is improved in a variety of ways over the long term. Modern designers have discovered that these enhanced durability features assist further cut life-cycle costs, lower maintenance expenses, and make concrete more sustainable based on these early experiences. To learn more about how slag cement is created and how it improves the longevity and sustainability of concrete, go here.

SAND

Sand is a naturally occurring granular substance made up of tiny pieces of rock and mineral. Silica (silicon dioxide, or SiO2), most frequently in the form of quartz, is the most prevalent mineral resistant to weathering and is the most common component of sand in inland continental settings and non-tropical coastal environments. In concrete, it serves as fine aggregate.

METHODOLOGY AND TESTS

TEST PROCEDURE:

There were two stages to the experimental programmer.

Stage 1: Experiments were conducted on mortar mixtures using various binder mixes that had been changed with varying amounts of silica fume.

Stage 2: Experimental work was done on steel slag concrete mixtures using various binder mixes that had silica fume added in varying amounts.

LABORATORY TEST CONDUCTED:

Compressive Strength Test

Using slag cement + silica fume as a binder mix with varying proportions of silica fume, sand as fine aggregate, and steel slag as coarse aggregate, concrete of mix proportions 1: 1.5: 3 will be prepared in this phase. From 0% to 10% to 20% of the mixture, silica fume will vary in percentage in the concrete mix. The following strengths of the concrete mixtures will be tested.

- Compressive strength at 7, 28, and 56 days
- Flexural strength at days 28 and 56.
- Compressive strength as determined by the rebound hammer method.

Porosity tests were conducted after 28 and 56 days

Capillary absorption Test

For both (concrete cube and mortar), two cube specimens were produced in order to calculate the capillary absorption coefficients after 7, 28, and 56 days of cure. This test is performed to examine the capillary absorption of various binder mix mortar matrices, which serves as an indirect indicator of the robustness of the various mortar matrices

Porosity Test

After 7 days and 28 days of curing, two cylindrical specimens, each measuring 65 mm in diameter and 100 mm in height, were cast for a porosity test. This evaluates the mortar matrices' resilience in an indirect manner..

- The vacuum saturated porosity is calculated by the formula:

$$P = ((W_{sat} - W_{dry}) / (W_{sat} - W_{wat}))*100$$

Where,

p = vacuum saturation porosity (%)

W_{sat} = the weight in air of saturated sample

W_{wat} = the weight in water of saturated sample

RESULTS AND DISCUSSIONS

EXPERIMENTAL STUDY ON MORTAR.

Here, we made mortar in a 1:3 ratio using a combination of various cement types, silica fume replacement as a binder, and sand as the fine aggregate. Its physical characteristics, including porosity,

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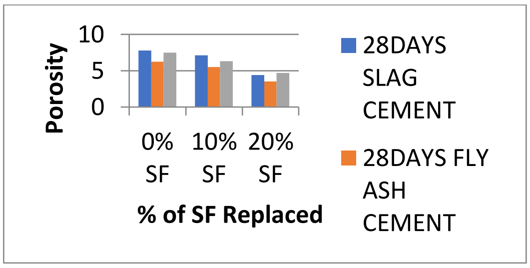
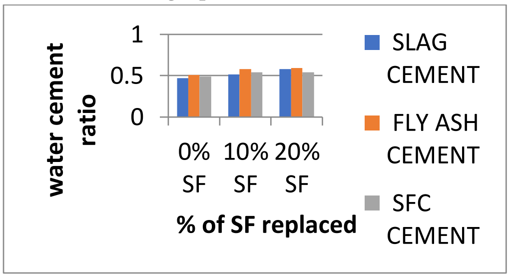
compressive strength, and capillary absorption consistency, were then anticipated. The test results are presented below in both tabular and graphical form.



EXPERIMENTAL STUDY ON CONCRETE CUBE.

Here, we made concrete in the following proportions: sand as the fine aggregate, steel slag as the coarse aggregate, and various types of cement with silica fume replacement as the binder mix. Then, it was projected based on its physical characteristics, including capillary absorption, water/cement ratio, compressive strength, porosity, flexural strength, and wet-dry test. The test results are presented below in both tabular and graphical form.



Capillary Absorption Test:

The capillary coefficients for different types of steel slag is given below.

Table 5.11

Type of cement	% of SF replaced	28 days (k*10^{-3} cm/s)	56 days (k*10^{-3} cm/s)
Fly ash cement	0	2.09	1.83
	10	1.142.30	0.95
	20	0.838	0.621
Slag cement	0	2.30	1.92
	10	1.46	1.02
	20	1.04	0.81
Slag and fly ash	0	2.01	1.63
cement blend (1:1)	10	1.21	0.98
	20	0.85	0.671

From the above table, we can conclude that capillary absorption decreases with increase in percentage of replacement by silica fume. The reason could be the inclusion of silica fume to the different cements actually forms denser matrices thereby improve resistance of the matrices against water ingress which is one of the most important reasons that increases the deterioration of concrete.

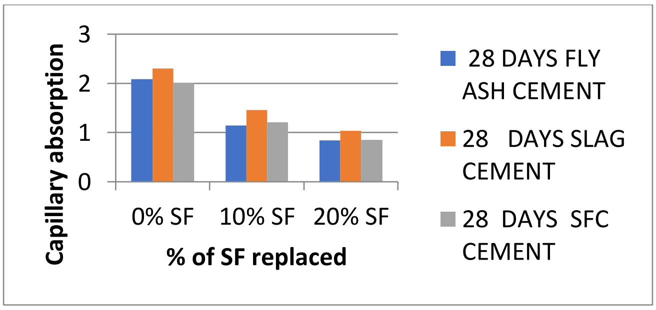


Figure.5.23 Capillary Absorption of concrete for 28 days

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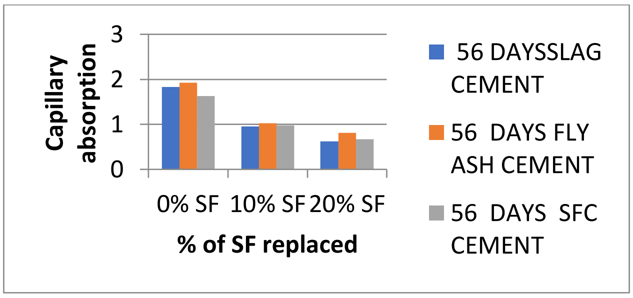

Figure.5.24 Capillary Absorption of concrete for 56 days

CONCLUSION

The following findings are drawn from this study:

- The addition of silica fume increases the density of various binder mixes, enhancing their strength.
- The addition of silica fume improves the fly ash cement's early strength gain, but it boosts the slag cement's later age strength.
- The development of overall strength is improved at any stage by using an equal mixture of slag and fly ash cements.
- Because silica fume's small particles combine with the lime in cement to create hydrates dancer and crystalline in composition, adding silica fume to any binder mix minimises capillary absorption and porosity.
- When silica fume is used in place of mortar, capillary absorption and porosity both decrease with dose increases of up to 20%.
- The strength of concrete is decreased at any age by the addition of silica fume to concrete that uses steel slag as its coarse aggregate
- This is because the entrapped air cannot escape since silica fumes make the concrete mixture sticky or more cohesive during mixing and compacting on the vibration table. Utilizing a needle vibrator could reduce this issue.
- The alkali aggregate reaction between the binder matrix and the steel slag used as coarse aggregate is the primary cause of the drop in strength.
- Cement paste is naturally alkaline. Concrete becomes more alkaline due to the presence of the alkalis Na2O and K2O in steel slag. The binding between the aggregate and the binder matrix is harmed when silica fume is added to concrete because the silica in the fume reacts with the alkalis and lime to generate a gel. Higher doses of silica fume cause a more pronounced reduction in this value.

In comparison to concrete containing slag cement and silica fume, fly ash cement makes the concrete more cohesive or sticky, which leads to the creation of more voids. In comparison to concrete mixtures comprising slag cement and silica fume, those containing fly ash and silica fume exhibit increased capillary absorption and porosity.

- It is not advised to completely substitute natural coarse aggregate in concrete with steel slag. In order to create high strength concrete with correctly treated steel slag, a partial substitution with fly ash cement may be helpful.
- To effectively cure the steel slag, stockpile it in the open for at least a year. This will allow the free CaO and MgO to hydrate and lessen the expansion in the future.

The presence of alkalis that can negatively affect the connection between the binder matrix and the aggregate should be determined through a comprehensive chemical study of the steel slag.

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