# Assessment Of Industrial Waste and Additives Materials Use in The Sustainable Design of Concrete

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**Abstracts:** The sustainable design of concrete is of paramount importance in the construction industry as it strives to minimize environmental impact while maintaining performance and durability. A key aspect of this endeavor is the assessment and integration of industrial waste materials and additives into concrete formulations. Concrete is the most frequently used construction material in the world. Each year, over ten billion tonnes of concrete are produced, resulting in the depletion of natural resources and a colossal carbon footprint. One of the primary objectives of contemporary concrete technology is to reduce the use of Portland cement and natural fine aggregates by partially substituting them with various waste materials and industrial byproducts. This paper summarises the findings of a study in which steel slag aggregate, silica fume and glass refuse were successfully used to partially replace river sand and Portland cement.

**Keywords:** Sustainable Design of Concrete, Industrial Waste, Steel, Slag Aggregate, Silica Fume, Glass Waste, Environment Effect

## 1. INTRODUCTION

Concrete is the most versatile and second-most-used building material. Aggregates make about 75% of concrete. Most concrete mixtures include river sand as fine aggregate. Due to the lack of river sand, construction-grade concrete substitutes are essential. The project may be cost-effective and environmentally friendly by employing fewer high-quality natural materials. Environmental deterioration from industrial byproducts and other wastes threatens economic and environmental stability. Engineering solutions that address environmental, economic, and social challenges reduce the need to dispose of this trash. Many academics have studied these difficulties and are still working to improve concrete's sustainable design.

GGBS may replace cement and aggregate. GGBS particles, used to replace fine aggregates, are typically less than 5 mm [1], whereas cement substitutes range from 0.1 to 250 mm, reflecting the normal spread of cement particles. According to [2], crushing time greatly affects GGBS particle size for cement substitutes. As an aggregate substitute in concrete, steel slag cement concrete had greater durability and properties than conventional concrete, and it had lower slump and flow values mixture content rises [3]. Glass trash is available in powder, coarse, and fine aggregate forms. Using glass waste as coarse and fine particles up to 50% in 32 MPa concrete demonstrated good strength growth [4]. Several studies compared workability, water absorption, density, and compressive strength to typical mix controls. At 12% hill sand substitution with waste glass, test findings showed the greatest improvement [5].

Silica fume and glass waste at 20% replacement rate gave concrete optimal compressive and splitting tensile strengths. Silica fume enhances concrete mechanical qualities, such as compressive, flexural, and cracking tensile strengths, by accelerating cement hydration [6], examined glass waste and steel slag in concrete. They found these materials excellent substitutes for natural aggregates[7]. We also found that steel making slag did not affect concrete hardness and was recommended for road concrete manufacture.

Glass waste 4–8 mm has a compressive strength of 35 MPa, near to concrete. This product is suggested for high-quality concrete surfaces. examined industrial sludge. Researchers found that sludge, with a particle size of 0-4 mm, may be utilised in self-compacting concrete. Admixtures change concrete qualities when artificial materials are added. Park and Seung [9] examined the impact of super-plasticizers on concrete [8]. The study found that highly plasticized concrete significantly improved the workability of new concrete. They also found that super-plasticizer reduced water usage without separating concrete. Adding super-plasticizers to concrete increases its hardened qualities, including compressive, tensile, and flexural strength. Overdosing super-plasticizers may reduce compressive strength and increase porosity, therefore use the right amount [10].

This study working with silica fume to partly replace Portland cement and partially substitute fine aggregate for glass waste and steel slag. To prevent pan moisture, each concrete mix was mixed daily. Workability, air content pressure, and fresh density were tested on the same day as mixing for each concrete mix, followed by a hardened strength test. Destructive and non-destructive procedures assessed hardened strength at 56 days. Each mix's compressive strength and Ultrasonic Pulse velocity and Rebound Hammer tests were performed.

## 2. OBJECTIVES OF THE STUDY

1. The main objective of contemporary concrete technology is to reduce the use of Portland cement and natural fine aggregates by partially substituting them with various waste materials and industrial byproducts.

2. This research successfully replaced some of the river sand and Portland cement with steel slag aggregate, silica fume, and crushed glasses.

## 3. MATERIALS AND METHODOLOGY

### 3.1. Properties of Materials

**Table 1. The characteristics of both natural and man-made aggregates [3]**

| Materials | Natural sand | Natural aggregate | Slag | Crushed glass |
|---|---|---|---|---|
| Particle size [mm] | 0–4 | 4–16 | 0–4 | 0–4 |
| Specific density [kg/m3] | 2.6 | 2.6 | 2.7 | - |
| Fineness modulus | 3.6 | 7.9 | 4.6 | 5.5 |
| Water absorption (%) | 1.2 | 0.7 | 0.9 | 0.0 |

**Figure 1.** Used Materials in present analysis

### 3.2. Analysis

### 3.2.1 Preparation Concrete Mix Design

The design of the concrete mix adhered to EN 1992-1-1:2004 [11]. The mixture ratio was calculated at 1,100 8C for oven-dried materials. The conventional mix's proportions were as follows: 350 kg/m3 of cement, 1,098 kg/m$^3$ of coarse aggregate, 732 kg/m$^3$ of fine aggregate, 182 kg/m$^3$ of water, and 0.875 L/m$^3$ of super-plasticizer Sika ViscoCrete-7710 were applied to each specimen.

**Table 1. Preparation Concrete Mix Design**

| | Mix 1 | Mix 2 | Mix 3 | Mix 4 | Mix 5 | Mix 6 | Mix 7 | Mix 8 |
|---|---|---|---|---|---|---|---|---|
| **Material kg/m³** | | | | | | | | |
| Cement | 7 | 6.3 | 6.3 | 7 | 6.3 | 7 | 7 | 7 |
| Silica fume | – | 0.7 | 0.7 | – | 0.7 | – | – | – |
| Water | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 |
| Aggregate (0.4 mm) | 14.6 | 13.2 | 13.2 | 13.2 | 14.6 | 13.2 | 11.7 | 10.3 |
| Aggregate (4–8 mm) | 9.5 | 9.5 | 9.5 | 9.5 | 9.5 | 9.5 | 9.5 | 9.5 |
| Aggregate (8–16 mm) | 12.4 | 12.4 | 12.4 | 12.4 | 12.4 | 12.4 | 12.4 | 12.4 |
| Slag (0–4 mm) | – | – | 1.5 | – | – | 1.5 | 2.9 | 4.4 |
| Glass waste (0–4 mm) | – | 1.46 | – | 1.46 | – | – | – | – |

### 3.2.2 Test Analysis

A Ultrasonic pulse velocity testing, rebound hammer testing, and standard destructive testing were performed on the newly designed and reference concrete specimens in order to determine the compressive strength of the tubes. The grading of glass waste and steel slag was established and compared to the natural aggregates prior to mixing. First, the characteristics of both fresh and cured concrete were tested as part of the experimental programme. The components of both regular and modified concrete have been well combined to produce a homogeneous mixture. Fresh concrete's characteristics were assessed using the guidelines in [12, 13].

## 4. RESULTS

### 4.1. Result of Slump and Air Content Pressure of Concrete Mixtures

According to EN 12350-7:2009 [14], the air content pressure in each combination was measured, and the results, as shown in Fig. 2, indicated considerable variations in air content levels when compared to the slump of all mixes.

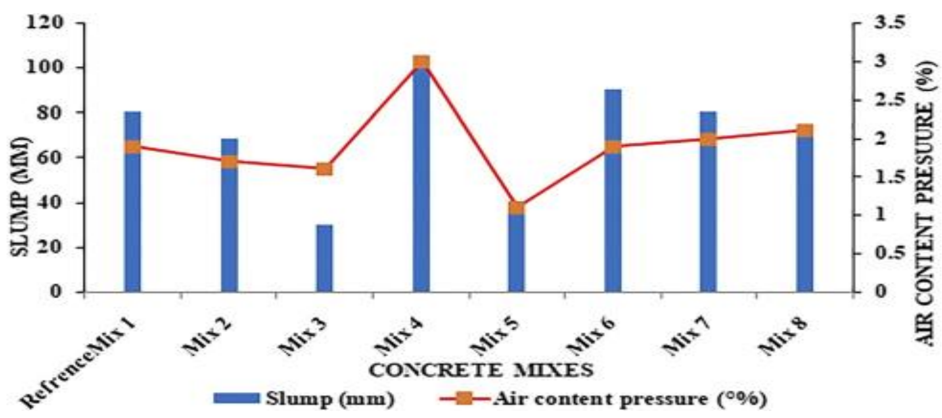


**Figure 2.** Slump and Air Content Pressure of Concrete Mixtures

### 4.2. Result of density, hardened density and compressive strength values for different concrete mixes

Aggregate made of steel slag and silica fume. figure 3 show the effectiveness of the hardened concrete density's compaction degree outcomes in relation to compressive strength

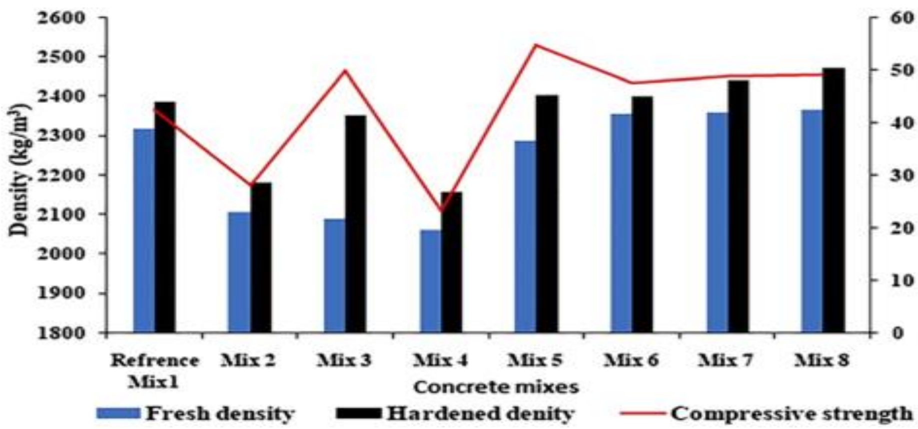


**Figure 3.** density, hardened density and compressive strength values for different concrete mixes

## CONCLUSIONS

1. The compressive strength of concrete mixtures containing 10% glass waste, with or without silica fume, as measured by ultrasonic pulse velocity, rebound hammer, and destructive experiments on cube specimens, was lower than that of conventional concrete. The weakened bond between the glass particles and the cement matrix due to an increase in porosity is primarily responsible for the decreased strength.

2. The compressive strength of concrete mixtures containing 10% silica fume by cement weight was greater than that of other concrete mixtures. The increased compressive strength is primarily attributable to the interaction between the cement particles and the silica fume, which resulted in a dense clustering of particles and decreased porosity. However, the long-term potency may be affected by the alkali-silica reaction, necessitating further research into this phenomenon.

3. The addition of silica particulate to concrete mixtures reduces their workability. For improved performance, it would be necessary to examine the chemical composition, shape, size, and surface texture of the applied silica fume.

4. The steel slag applied up to 30% of the fine aggregate weight provided a greater compressive strength than the conventional mixture and can be used as a partial substitute for sand for concrete grades up to and including C30/37. The increase in compressive strength is attributable to a stronger bond between the steel slag aggregate and cement matrix.

5. Test effect confirmed that the use of steel slag aggregates and silica fume can increase the compressive strength of normal concrete and can be used successfully in the production of normal grade concrete. Glass waste is primarily suggested for lower grade concrete mixtures.

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