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Microstructure Analysis and Material Properties of Weld Slag as Fine Aggregate in Concrete

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Abstract

To reduce the amount of river sand used, researchers and engineers have developed their own solutions. The well-known technique of submerged-arc welding can create high-quality welds in a variety of thicknesses for ferrous, stainless, and even some non-ferrous metals. The procedure involves an electric current flowing constantly between a welding wire and the work piece, creating an arc. In submerged arc welding, the shielding flux is transformed into slag during the welding process, which is waste that needs to be disposed of. The microstructural and tensile characteristics of two varieties of Submerged Arc Welding Slag (SAWS), SAWS 1 and SAWS 2, which were utilized in concrete as a partial substitute for fine aggregate, are presented in this study. X-ray powder diffraction (XRD) analysis was used to identify the elemental chemical composition of the SAWS 1 and SAWS 2 crystalline phases, while scanning electron microscopy (SEM) was used to analyze their microstructure. Energy dispersive X-ray analysis (EDS) identified the qualitative and quantitative elemental analysis. It was discovered that SAWS 1's compressive strength was significantly greater than SAWS 2's after 7 and 28 days.

Keywords: Weld slag, concrete, microstructure, compressive strength, Submerged Arc Welding Slag (SAWS), fine aggregate replacement, sustainable construction materials, X-ray Diffraction (XRD), scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS), mechanical properties, waste utilization, cementitious composites

INTRODUCTION

The necessity to locate a concrete aggregate source other than river sand in construction projects has become more critical as river sand is becoming more rare. To use less river sand, researchers and engineers have developed their own ideas [1]. In ferrous, stainless, and even some non-ferrous metals, submerged-arc welding is a proven technique that can create high-quality welds in a variety of thicknesses. The welding process involves a constant electric current flowing between a welding wire and the work piece, creating an arc. Since river sand is becoming more and more limited, it is more important than ever to find a substitute concrete aggregate ingredient for construction projects. For every kilogram of weld metal placed, 1 kg of flux is typically used. In 1982, about 2500 t of slag were produced in India; by 2006, that amount had increased to 10,000 t [2]. Because it is typically considered waste, SAW slag is thrown away. You can have it for free. In order to reuse flux, it must be properly collected, crushed, and sieved to the appropriate particle size. This collecting and processing comes at a very low cost. According to estimates, the submerged-arc welding technique in Tamil Nadu, South India, presently produces a significant volume of SAWS each month. Such slag is non-biodegradable and can cause a variety of environmental issues if improperly disposed of. In order to dispose of such slag safely, it must be handled, transported, and dumped in a landfill, all of which are expensive. Sometimes the slag dumped

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in the landfills can become a source of soil pollution and groundwater contamination. Furthermore, dumping of slag leads to wastage of natural resources and minerals which are used in making of flux, which is also an environmental concern [3, 4].

Furthermore, these byproducts are the primary source of CO_2 and other dangerous gases evaporating, which contributes to global warming and the depletion of the ozone layer, which shields Earth from dangerous cosmic rays. Because it will safeguard the environment, researchers are more interested in employing industrial waste and byproducts as substitute materials for concrete and building than in disposing of them [5]. Sand is used extensively as a fine aggregate in the manufacturing of concrete worldwide, and in recent years, the availability of natural sand has been under pressure in a number of developing nations to satisfy the growing demands of infrastructure development [6]. The two main types of solid waste produced by submerged electric arc furnaces used in the production of steel and stainless steel are SAWS 1 and SAWS 2. The use of SAWS as fine aggregates in concrete results in a cost-effective and environmentally friendly concrete since the waste slag has good mechanical and engineering qualities for use as concrete aggregate material. the possibility of using Slag of Welding Flux (SWF) waste, which comes from Submerged Arc Welding (SAW), as an alternate raw material for making clay bricks.

The technological characteristics of bricks made with up to 10% SWF waste in place of clay were shown to be consistent with those required for ceramic bricks [7]. The compressive strength of furnace and welding slags as a substitute for fine aggregates in concrete was examined. The findings indicate that a practical replacement of 10% furnace slag with fine aggregates and 5% welding slag is highly effective [8].

MATERIALS AND METHODS

The following are the materials used in the M35 Concrete Mix:

- *Cement:* The cement used was an ordinary Portland cement (OPC) of 53 grade conforming to IS 12269-1987 specifications.
- *Coarse aggregate:* Coarse aggregate with 12 mm nominal size was used conforming to IS: 383-1970 Specifications.
- *Fine aggregate:* River sand conforming to Zone II conforming to IS: 383-1970.
- *Water:* Potable water comprising to IS 456:2000 Specifications.
- *SAWS 1 and SAWS 2:* SAWS was obtained from local steel fabrication industries and grinded to powder to meet the IS: 383-1970 Specifications.

Mix Proportions and Preparation of Specimen

SAWS 1 and SAWS 2 were used to create two mixes, with 10% fine aggregate replacement. After fully mixing the necessary amounts of cement, fine aggregate, and coarse aggregate in a 40-l Concrete Pan mixer for 2 min, water was added to finish the concrete mixing process. For 7 and 28 days, a control mix was made in accordance with Indian standard specifications IS: 10262-2009. Concrete of M35 grade was used, and the mixtures were poured into cube moulds measuring 100 mm×100 mm×100 mm. The specimens were then demoulded, allowed to sit at room temperature for 7 and 28 days, and then put through a compression test [8].

In accordance with IS516:1959, the Compressive Strength test was conducted. Table 1 lists the material properties for the concrete mix. For the microstructural examination, the SAWS are ground to the necessary fineness. Figures 1 and 2 depict the two SAWS's physical characteristics. XRD analysis was used to determine the chemical composition of the material, SEM analysis was used to examine the crystalline shape, and EDS analysis was used to determine the percentage of chemical composition. Table 2 lists the physical attributes of the materials employed in this investigation. Table 3 lists the mechanical characteristics of SAWS, including its compressive strength, assuming a 10% substitution.

Table 1. Material properties for concrete mix.

Properties	Values
Specific gravity of cement	3.14
Specific gravity of water	1
Specific gravity of sand (FA)	2.61
Specific gravity of coarse aggregate (CA)	2.64
Specific gravity of SAWS 1	2.76
Fineness modulus of SAWS 1	1.93
Specific gravity of SAWS 2	2.98
Fineness modulus of SAWS 2	2.05
Dry rodded bulk density of coarse aggregate (kg/m^3)	1492
Dry rodded bulk density of fine aggregate (kg/m^3)	1695
Fineness modulus of fine aggregate (FA)	2.74
Fineness modulus of coarse aggregate (CA)	7.88

Table 2. Physical characteristics of ingredients.

S.N.	Properties	Fine aggregates	SAWS 1	SAWS 2
1	Specific Gravity	2.61	2.76	2.98
2	Fineness Modulus	2.78	1.93	2.05

Table 3. Mechanical property of SAWS.

Compressive Strength	7 days	28 days
Control mix	25.8 N/mm^2	44.7 N/mm^2
SAWS 1	26.8 N/mm^2	49.5 N/mm^2
SAWS 2	25.63 N/mm^2	42.9 N/mm^2

Figure 1. SAWS 1.

Figure 2. SAWS 2.

RESULTS AND DISCUSSION

XRD Analysis

Using an X-ray diffraction assay, the chemical makeup of these SAWS was determined. Cu radiation was used to expose the prepared samples to X-rays with a 2θ angle that varied from 10 to 80°. 40 kV and 30 mA, respectively, were the applied voltage and current. Table 4 contains the SAWS 1's chemical composition. Table 5 contains the SAWS 2's chemical makeup. Figures 3 and 4 show the XRD curves of SAWS 1 and SAWS 2 respectively. According to the XRD curves, SAWS 1 is dominated by wollastonite, silica, and manganese oxide, while SAWS 2 is dominated by calcium carbonate, manganese oxide, and chromium silicide.

SEM Analysis

The SAWS 1 particles are closely packed and have irregularly shaped grains, according to a closer look at the SAWS particle morphology displayed in Figure 5(a and b). The cavities in SAWS1 are bigger than those in SAWS2. SAWS 2 has sharp-edged grains, as seen in Figure 6(a and b). According to the SAWS's SEM image, SAWS 2 has more micropores than SAWS 1.

EDS Analysis

Comparatively big particles may be silica and manganese oxide particles, based on the findings of the EDS investigation for SAWS 1. Manganese has an atomic weight percentage of 40.9% and silica 41.92%. The calcium concentration makes up roughly 17.18%. $CaCO_3$ particles make up the majority of the EDS analysis for SAWS 2.

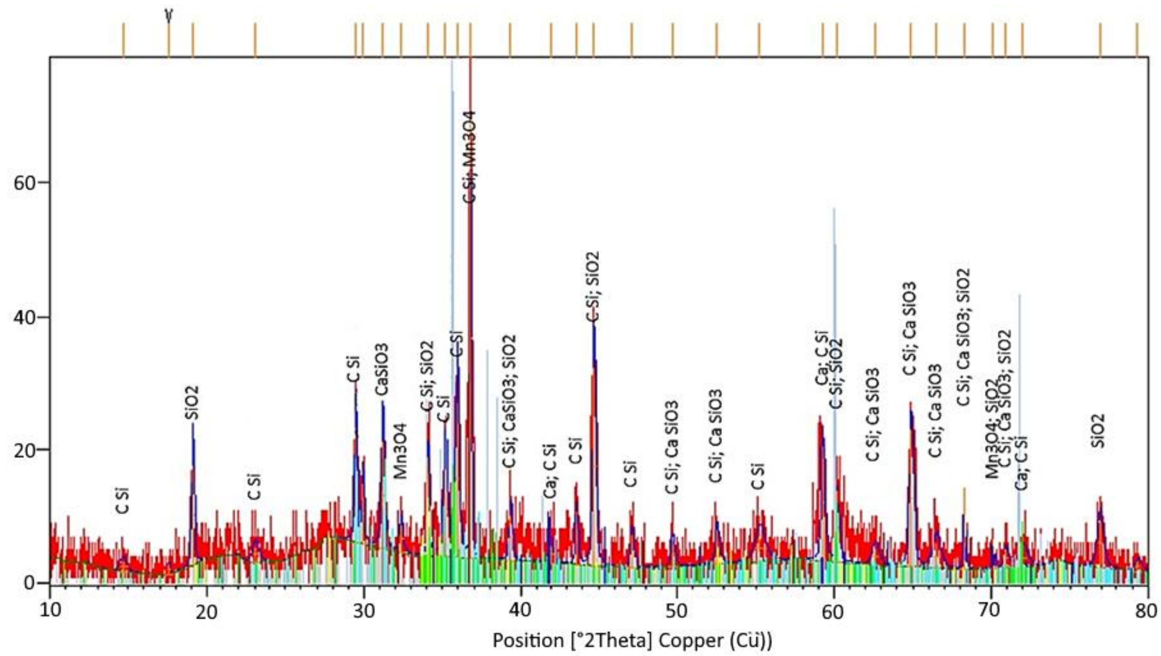

Figure 3. XRD of SAWS 1.

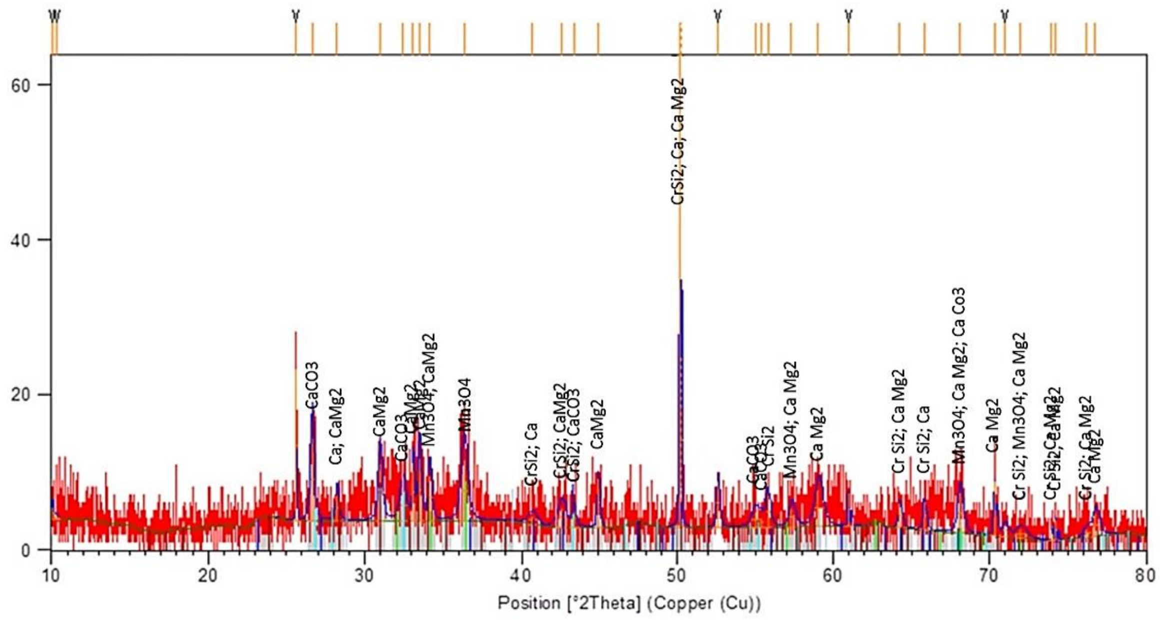

Figure 4. XRD of SAWS 2.

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Table 4. Chemical composition of SAWS 1.

S.N.	Compound Name	Chemical Formula
1	Calcium	Ca
2	Moissanite	$C\ Si$
3	Wollastonite	$CaSiO_3$
4	Manganese oxide	Mn_3O_4
5	Silica	SiO_2

Table 5. Chemical composition of SAWS 2.

S.N.	Compound Name	Chemical Formula
1	Calcium Carbonate	$CaCO_3$
2	Manganese oxide	Mn_3O_4
3	Calcium	Ca
4	Calcium Magnesium	$CaMg_2$
5	Chromium Silicide	$CrSi_2$

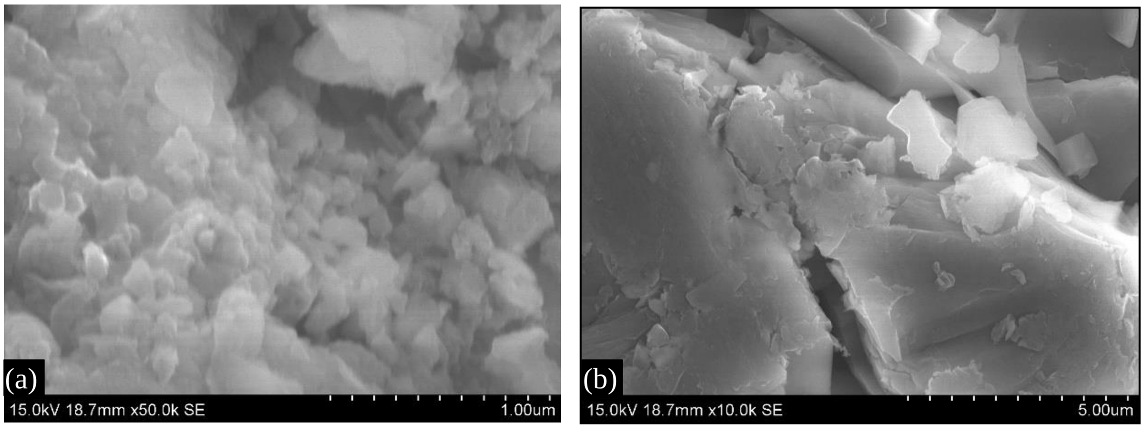

Figure 5. (a, b) SEM image of stainless steel SAWS.

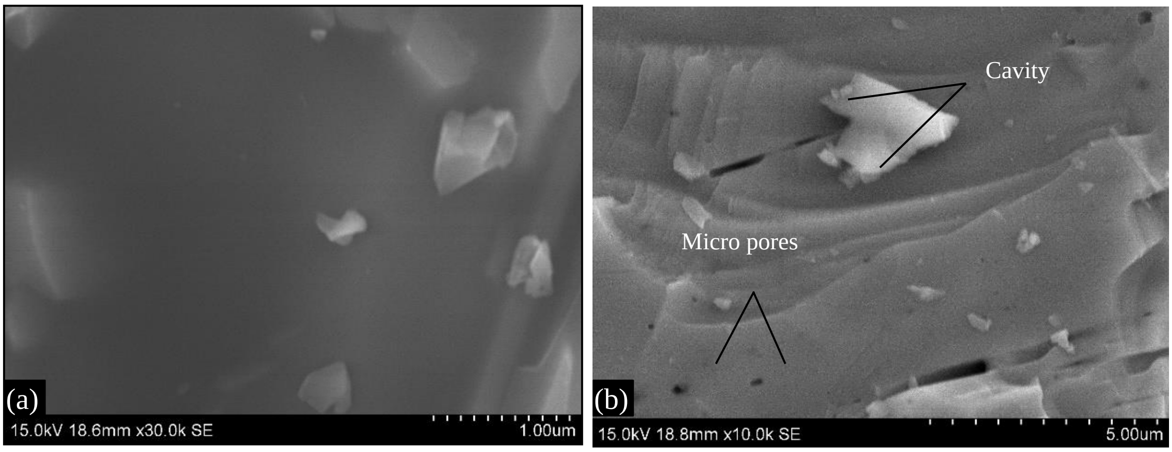

Figure 6. (a, b) SEM image of Steel SAWS.

CONCLUSION

1. The SEM images of SAWS indicate that there are less holes and micropores in SAWS, and the chemical composition of SAWS is rich in silica, manganese oxides, calcium carbonate, and wollastonite.
2. Because SAWS are high in oxygen, they can be added to concrete as fine aggregates or as a binder, which lowers the cost of the finished product.

3. The SAWS 2 achieves early compressive strength, which subsequently declines. At 7 and 28 days, SAWS 1's compressive strength gradually increases in comparison to the control mix.

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