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# Utilization of By-product of Steel from Scrap for Concrete

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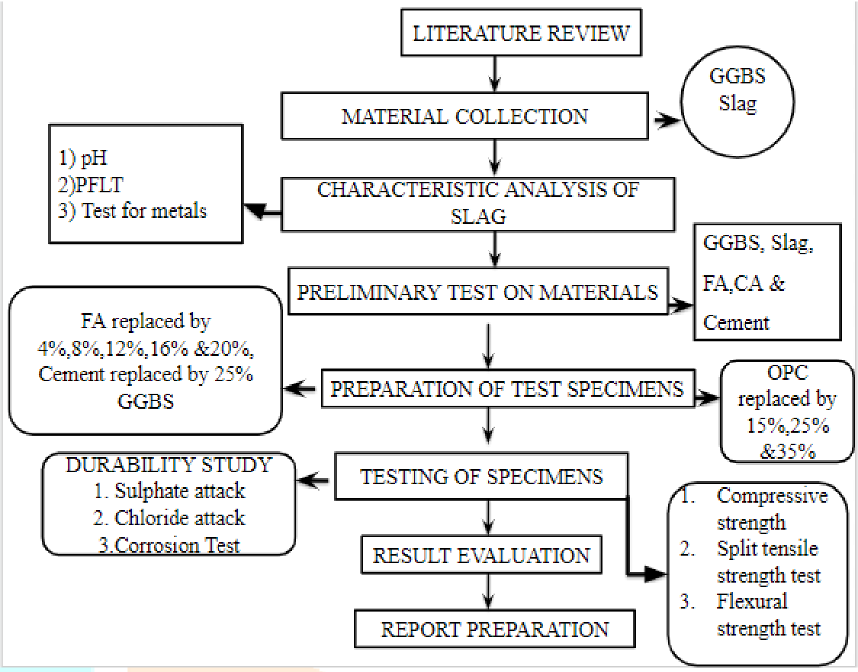
*Abstract:* The development of infrastructures involves the use of many natural resources resulting in their depletion. The production of the cement causes many problems like emission of carbon-di-oxide gas to the atmosphere can be reduced by the replacement of cement with GGBS. Similarly, the replacement of SS as a fine aggregate also enables to eliminate the problems associated with production of aggregates. This study aims to generate specific experimental data on the potential use of ground granulated blast furnace slag (GGBS) as a cement replacement as well as scrap slag (SS) as a fine aggregate replacement in concrete. This study analyses the mechanical strength for compressive strength, split tensile strength and flexural strength were conducted to find the optimum usage of alternative material GGBS with proportions of 15%, 25% and 30% of total weight of concrete and SS as fine aggregate in GGBS incorporated concrete with varying proportions of 4%, 8%, 12%, 16% and 20% of total weight of concrete. Also durability tests of sulphate, chloride resistance and corrosion test were performed. The experimental results have been shown that SS is a non- hazardous industrial by- product from steel making units. Optimum percentage of GGBS as binder was found to be 25% in M25 grade concrete. From the research study, the optimum percentage of SS as fine aggregate in optimum GGBS incorporated concrete was found as the concrete made with 12% replacement of fine aggregate with SS. The duration of concrete exposure in sodium sulphate solution increases the weight loss increases and compressive strength decreases. As the duration of concrete exposure in hydrochloric acid solution increases the weight loss is less affected and the compressive strength decreases.

**Keywords:** GGBS, Sodium Sulphate, Chloride, Hydrochloric acid

## I.INTRODUCTION

Although there are many studies that assess the suitability of different alternative materials as a replacement of Portland cement (as a binder) and secondly, aggregates in concrete were focused on the strength properties with little emphasis on the durability. The production of the cement causes many problems like emission of carbon-di-oxide gas to the atmosphere can be reduced by the replacement of cement with GGBS. Similarly, the replacement of SS as a fine aggregate also enables to eliminate the problems associated with production of aggregates. The cement industry is held responsible for some of the carbon dioxide emission, because the production of one ton Portland cement emits approximately one ton of carbon dioxide gas into the atmosphere. The emission of carbon dioxide will increase the effect of global warming. Among the greenhouse gasses, carbon dioxide contributes about 65% of global warming. Stone crushing plants for the production of aggregates have a daily input of 21,550 tons of raw materials. The main pollution associated with rock quarrying is particulate matter <10 μm emissions which directly affect human health while other impacts include noise, vibration and landscape deterioration when the relief of the land is modified. With respect to groundwater pollution, the fluoride concentration was 1.5–3.8 mg/L in shallow aquifers and 1.1–2.7 mg/L in deep aquifers nearby a quarrying activity while the maximum limit in drinking water set by the World Health Organization is 1.5 mg/L.

## II. METHODOLOGY




## III. LITERATURE REVIEW

**Guo and Shi (2019)** investigated the feasibility of steel slag powder as a combined admixture with ground granulated blast-furnace slag (GGBFS) in cement based materials. The effects of steel slag powder on the normal consistency water requirement, setting times, compressive strength, and hydration products of cement paste/mortar were studied in this journal. The authors investigated that the preferred additional content of steel slag powder in a combined admixture was less than 20%. Steel slag powder decreased the normal consistency water requirement and also it retarded the setting time of cement paste. As the curing ages increasing, the compressive strength of mortars with the combined admixture increases higher than that of the ordinary sample. Hydration products primarily included C-S-H gel, C- S Al-H gel, and Ca(OH)2. Mixing these two powders of GGBS and steel slag powder had a positive effect regarding the hydration of steel slag powder.

**Shi et.al (2019)**, studied the production, processing, and characteristics of steel slag, and its use as a cementing component in different cementing systems. Steel slag with high basicity, being cooled properly can exhibit cementing property. Blast furnace slag can give much higher strength than conventional cements in the presence of proper alkaline activators. Ground steel furnace slag exhibits some cementing property when it contacts with water. It can be expected that the ground steel slag also shows much better cementitious properties in the presence of alkaline activators. Alkali- activated steel slag–blast furnace slag cement can show excellent corrosion resistance. It can even exhibit much higher strength than conventional cements. Since the production of Portland cement is an energy intensive process and generates a large amount of green house gasses, the use of steel slag should first be considered as a cementing component from technical, economical, and environmental considerations.

**Marriaga et.al (2018)** conducted an experimental study of the influence of steel basic oxygen slag (BOS) and ordinary portland cement (OPC) on the compressive strength and the hydration mechanisms of blended grounded granulated blast furnace slag (GGBS) pastes. The compressive strength, the mineralogical changes, the setting times, the alkalinity of the raw materials, and the pore solution as well as the volume stability was measured. They concluded that the steel slag can be used as an activator of GGBS and the optimum composition of those materials was determined with a proposed parameter called "slag index." The properties measured in blended OPC GGBS-BOS mixes showed encouraging.

**Shariq. M et.al (2017)** studied the effect of curing procedure on the compressive strength development of cement mortar and concrete incorporating ground granulated blast furnace slag. The compressive strength development of cement mortar incorporating 20%, 40% and 60% replacement of GGBS as binder for different types of sand and strength development of concrete on two grades of concrete are investigated. Test results show that the incorporating 20% and 40% GGBS is highly significant to increase the compressive strength of mortar after 28 days and 150 days, respectively. So they concluded that the replacement of OPC in concrete with GGBS gives the optimum strength at 40% after curing of 56 days.

## V. EXPERIMENTAL STUDY

Concrete is a heterogeneous mixture consisting of cement, aggregate and water with some other additives like GGBS, SS etc. to impart special properties. This when proportioned, mixed and allowed to harden gives a rock like material. Materials used for this project are GGBS, OPC, fine aggregate (M-sand), SS and coarse aggregate. The detailed descriptions of the materials used are given below:

1. Ground granulated blast furnace slag (GGBS) is a non-metallic material resulting from the combination of the calcium and magnesium in calcareous stones with the aluminates and silicates in iron ore. The chemical and mineralogical composition of GGBS is depends on the character of the metallurgical process and materials from which it was formed. The compounds are CaO, SiO, Al2O, and MgO are present in most hydraulic binders. Compared to ordinary portland cement (OPC), slag has a higher silica and lower calcium contents, and contains low quantities of ferric oxide. The more basic the slag, it greater it's hydraulic reactivity. GGBS operate at a temperature of about 1500 degrees centigrade and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials form floats on top of the iron. This slag is intermittently removed as a molten liquid and it is used for the manufacture of GGBS by quickly put out large volumes of water. It optimizes cementations properties and also produces granules like coarse aggregate. This granulated slag is then dried and grinded to a fine powder. As their main principal constituent is generally used. The main raw materials used in producing Portland cement are the oxides: lime (CaO), produced by heating calcium carbonate; silica (SiO2),

2. Scrap slag (SS) is produced during the manufacture of thermo mechanically treated steel bars by the electric arc furnace (EAF) process. In this process steel scrap with addition of fluxes (e.g., lime [stone] and/or dolomite) are heated to a liquid state by means of electric current in the electric arc furnace. The liquid slag is form from the melting process of fluxes combine with non-metallic scrap components and steel incompatible elements. If the slag has a lower density than steel, it floats on top of the molten bath of steel. The liquid slag is tapped at temperatures around 1600 °C and allowed to slowly air-cool slag. SS is a strong, dense, nonporous aggregate that is cubical in shape, has good resistance to polishing and has an excellent affinity to bitumen. This makes it an ideal aggregate for asphalt surface materials and road surface treatments as it produces materials that are resistant to deformation, safe and durable.

GGBS

SS

**Mix Proportion**

- Cement = 224.18 kg/$m^3$
- GGBS = 56.045 kg/$m^3$
- Fine aggregate = 785.28 kg /$m^3$
- Coarse aggregate = 1331.01 kg/$m^3$
- Water cement ratio = 0.37
- Mix proportion = 1: 2.8: 4.74

**Mixing and Casting**

Three mixes are prepared to determine optimum GGBS percentage and five mixes are prepared to determine optimum percentage of SSin GGBS incorporated concrete. Mix combinations to determine optimum GGBS percentage are detailed in table

Quantity of materials for 1m$^3$ of concrete with GGBS

| Sl. No. | Mix Designation | Mix Proportion | | |
|---|---|---|---|---|
| | | GGBS | OPC | S |
| 1 | G15S0 | 15 % | 85 % | 0 % |
| 2 | G25S0 | 25 % | 75 % | 0 % |
| 3 | G35S0 | 35 % | 65 % | 0 % |

A series of concrete mixes were cast in cubic moulds of nominal size 150×150×150 mm using the mix design of M25 grade concrete. The materials were weighed using a digital balance and mixed in a rotating drum mixer. The cubes were cast according to the combination in table 3.2 and demoulding after 24 hours curing in the standard laboratory conditions. The specimens were water cured in a water tank, at temperature of 20±1 ºC and tested at the required age of curing. The water curing control the temperature and it affects the rate of cement hydrates. Optimum percentage of GGBS as binder was fixed based on the compressive strength results at the age of 28 days. Optimum percentage of GGBS obtained was fixed and cubes were cast by varying the proportion of SS as fine aggregate according to the mix combinations detailed in table 3.3. The cast cubes were demoulded after 24 hours curing in the standard laboratory conditions. The specimens were water cured in a water tank, at temperature of 20±1 ºC and tested at the required age of curing.

Quantity of materials for 1 m$^3$ of concrete with SS

| **Sl No.** | **Designation** | **Mix Proportion** | | |
|---|---|---|---|---|
| | | **OPC (%)** | **GGBS (%)** | **SS(%)** |
| 1 | G25S0 | 75 | 25 | 0 |
| 2 | G25S4 | 75 | 25 | 4 |
| 3 | G25S8 | 75 | 25 | 8 |
| 4 | G25S12 | 75 | 25 | 12 |
| 5 | G25S16 | 75 | 25 | 16 |
| 6 | G25S20 | 75 | 25 | 20 |

## VI. TEST RESULTS

The optimum percentage of GGBS as binder in concrete was fixed by compression strength testing of cubes of 15%, 25% and 35% of replacement of cement with GGBS by total weight. Five Mixes were prepared to find the optimum percentage of SS for partial replacement of fine aggregate in optimum GGBS incorporated concrete. G25S0 mix represents the control mix for M25 grade concrete. G25S4, G25S8, G25S12, G25S16 and G25S20 labeled specimens indicate the mixes with 4%, 8%, 12%, 16% and 20% replacement of fine aggregate with SS in 25% GGBS incorporated concrete respectively.

**WORKABILITY OF CONCRETE WITH GGBS**

| Sl No | SPECIMEN | SLUMP IN mm |
|---|---|---|
| 1 | G15S0 | 80 |
| 2 | G25S0 | 75 |
| 3 | G35S0 | 73 |

Workability decreases with the addition of GGBS

**STRENGTH TEST RESULTS**

| Sl No. | SPECIMEN | COMPRESSIVE STRENGTH IN N/mm² | | SPLIT TENSILE STRENGTH in N/mm² | |
|---|---|---|---|---|---|
| | | 7th day | 28th day | 7th day | 28th day |
| 1 | G15S0 | 21.26 | 30.8 | 3.41 | 3.44 |
| 2 | **G25S0** | **19.25** | **31.22** | **3.75** | **3.77** |
| 3 | G35S0 | 20.86 | 30.5 | 3.59 | 3.54 |

Optimum percentage of GGBS is 25%

**WORKABILITY OF GGBS CONCRETE WITH SS**

| Sl No | SPECIMEN | SLUMP mm |
|---|---|---|
| 1 | G25S0 | 85 |
| 2 | G25S4 | 83 |
| 3 | G25S8 | 79 |
| 4 | G25S12 | 76 |
| 5 | G25S16 | 74 |
| 6 | G25S20 | 74 |

Workability decreases with the addition of SS

**STRENGTH TEST RESULTS**

| Sl No | SPECIMEN | COMPRESSIVE STRENGTH IN N/mm² | | SPLIT TENSILE STRENGTH in N/mm² | |
|---|---|---|---|---|---|
| | | 7th day | 28th day | 7th day | 28th day |
| 1 | G25S0 | 19.25 | 31.22 | 5.61 | 5.84 |
| 2 | G25S4 | 22.25 | 34.22 | 5.55 | 5.67 |
| 3 | G25S8 | 23.86 | 37.5 | 5.69 | 5.7 |
| 4 | G25S12 | 24.89 | 41.74 | 5.7 | 5.72 |
| 5 | G25S16 | 24.93 | 38.18 | 5.75 | 5.77 |
| 6 | G25S20 | 24.96 | 35.51 | 5.81 | 5.86 |

**FLEXURAL STRENGTH RESULTS**

| Sl No | SPECIMEN | FLEXURAL STRENGTH in N/mm² 28th day |
|---|---|---|
| 1 | G25S0 | 5.03 |
| 2 | G25S4 | 5.35 |
| 3 | G25S8 | 6.66 |
| 4 | G25S12 | 6.78 |
| 5 | G25S16 | 6.05 |
| 6 | G25S20 | 6.01 |

**SULPHATE ATTACK RESULT**

| Specimen | Percentage Weight Difference in % | | Percentage Difference in Compressive Strength of Cube in N/mm² | |
|---|---|---|---|---|
| | 28th Day | 56th Day | 28th Day | 56th Day |
| G25S0 | 4.8 | 16.02 | 14.2 | 12.24 |
| G25S4 | 5.6 | 6.5 | 13.8 | 5.5 |
| G25S8 | 4.7 | 6.5 | 11.8 | 4.92 |
| G25S12 | 4.7 | 7.4 | 9.03 | 4.58 |
| G25S16 | 3.7 | 8.2 | 9.09 | 4.85 |
| G25S20 | 2.86 | 10.6 | 9.01 | 4.55 |

**CHLORIDE ATTACK RESULT**

| Specimen | Percentage Weight Difference in % | | Percentage Difference in Compressive Strength of Cube in N/mm² | |
|---|---|---|---|---|
| | 28th Day | 56th Day | 28th Day | 56th Day |
| G25S0 | 3.86 | 3.8 | 10.39 | 9.69 |
| G25S4 | 2.91 | 2 | 7.56 | 6.31 |
| G25S8 | 3.83 | 2.91 | 6.35 | 6.13 |
| G25S12 | 2.9 | 1.08 | 5.59 | 5.1 |
| G25S16 | 2.89 | 0.98 | 5.86 | 5.14 |
| G25S20 | 2.86 | 0.78 | 6.12 | 5.28 |

**RAPID CHLORIDE PERMEABILITY TEST-RCPT**

| Charge passed ( C ) | Chloride ion penetrability |
|---|---|
| >4000 | High |
| 2000-4000 | Moderate |
| 1000-2000 | Low |
| 100-1000 | Very low |
| <100 | Negligible |

**CHLORIDE PERMEABILITY OF VARIOUS CONCRETE MIXES**

| Specimen | Charge passed ( C ) | Chloride ion penetrability |
|---|---|---|
| G25S0 | 2357.8 | Moderate |
| G25S4 | 2194.3 | Moderate |
| G25S8 | 1116.6 | Low |
| G25S12 | 1055.1 | Low |
| G25S16 | 1052.23 | Low |
| G25S20 | 1001.65 | Low |

## VII CONCLUSION

The experimental results have been shown that SS is a non- hazardous industrial by- product from steel making units. Hence it can be directly utilized as a material for construction. It has been seen that the optimum level of replacement of OPC with GGBS is 25% from both economic and environmental point of view. An increase in compressive strength was observed with the addition of GGBS in concrete to a certain limit due to the formation of extremely thin surface film of silica rich gel when GGBS reacts with water which acts as a barrier for further reaction. Based on the results of the experimental studies conducted in the research work, the following conclusions can be drawn:

The compressive strength for concrete made with SS was higher than those for normal M25 grade concrete. The 28$^{th}$ day compressive strength of the specimen G25S12 with a compressive strength of 41.74N/mm² gives the highest compressive strength. Hence the optimum percentage of SS in optimum GGBS incorporated concrete is inferred as 12%. The split tensile strength of concrete was observed to be incremented with the addition of SS. It may be due to the tensile properties of SS obtained from the scrap metals. Hence it can be inferred from the results that addition of SS will improve the tensile nature of the concrete.

As the duration of concrete exposure in sodium sulphate solution increases the weight loss increases and compressive strength decreases. As the duration of concrete exposure in hydrochloric acid solution increases the weight loss is less affected and the compressive strength decreases.

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