EXPERIMENTAL INVESTIGATION ON STEEL SLAG AS A PARTIAL REPLACEMENT OF CEMENT IN CONCRETE CUBE

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Abstract: **Steel slag is a derivative of the steel production process. The disposal of slag from steel industries poses environmental problems. The steel slag exhibits the chemical constitution of cement and has the potential to be used as a cementitious material. Cement is one of the most essential components in concrete production, but its production process is also a major source of CO2 emissions. Therefore, partially substituting cement with eco-friendly materials is necessary.**

In this research, the possibility of using steel slag to partially replace cement is explored. Concrete of different compositions was prepared by replacing cement with steel slag. After curing, different experiments were carried out to determine the compressive and tensile strengths of the concrete and compare it with the conventional concrete cube. The results showed strength similar to conventional concrete cubes for replacement up to 15%. This shows that the amount of cement used can be reduced by the usage of steel slag in concrete, solving the issues related to steel slag disposal and CO2 emissions from cement production.

Keywords—Concrete, Cement, Steel Slag

I. INTRODUCTION

Concrete is a flexible and globally used building material made of cement, aggregates (such as sand and gravel), and water. It has a long history of usage and is renowned for its strength, durability, and capacity to tolerate a variety of environmental factors. There are several uses for concrete in the construction sector. Buildings, bridges, roads, dams, and other types of infrastructure are frequently constructed using it. Due to its adaptability, it can be moulded into various shapes, making it appropriate for a variety of architectural and structural projects. Concrete's main component is cement, which serves as a binder. Limestone, clay, seashells, and silica sand are the main ingredients used to make cement, which is a fine powder. In concrete, it acts as a binding agent to keep the aggregates together. There are large carbon dioxide (CO2) emissions related to cement production. The calcination of limestone during the creation of clinker and the burning of fossil fuels to provide the heat required for cement manufacturing are the primary contributors to CO2 emissions in the cement industry. One of the major industrial sources of CO2 emissions worldwide is the cement sector. An estimated 7% of the world's CO2 emissions come from the manufacture of cement. The exact number of emissions can vary depending on several factors, including the type of cement production process, the use of alternative fuels and raw materials, and the energy efficiency of the manufacturing facilities.

Steel slag is a derivative generated in the steelmaking process when molten iron is rapidly cooled. Steel slag, a non-metallic substance, is made mostly of calcium, silicon, iron, and aluminium, with minor quantities of other elements. Steel slag is a versatile material with many uses since it has a number of advantageous characteristics. As a result of its weather resistance, it is perfect for use in building projects. Pozzolanic activity, or the capacity to blend with calcium hydroxide in the presence of moisture to create new cementitious composites, is another property of steel slag. This property enhances the long-term strength and durability of concrete when steel slag is used as a cement replacement. But because of its volume and unique properties, disposing of steel slag can pose difficulties and possible issues. Such a large amount of slag needs to be disposed of, which calls for adequate space and the right disposal techniques. For the disposal of steel slag, conventional landfilling might not necessarily be the best or most ecologically beneficial option. Steel slag disposal may have an effect on the environment if improperly managed. Heavy metals and other pollutants in slag can leak into soil and water, harming ecosystems and perhaps endangering human health. Land use may be impacted by the storage and disposal of steel slag, which can inhabit considerable expanses of land. Steel slag may be used in civil engineering exercises to lessen the requirement for discarding and saving natural resources.

I.

II. LITERATURE REVIEW

Affan Jalil et al. (2018), in their paper entitled "Evaluation of Steel Industrial Slag as Partial Replacement of Cement in Concrete". The aim of this paper is to partially replace cement with an environmentally friendly material, i.e., steel slag. After conducting experiments, they concluded that for a 20% replacement, there is a reduction in the compressive, tensile, and flexural strengths of the concrete cube by 25.5%, 29%, and 31%, respectively. The partial replacement of cement can save on cement production and usage.

Anjali P. (2022), in their paper entitled "A Study on the Utilisation of Activated Steel Slag as Partial Replacement of Cement in Concrete". This study intends to make use of locally accessible steel slag that has been chemically activated for cement mortar. The test's results showed that 4% Na_2SO_4 and 18% fine steel slag produce results that are comparable to those of OPC. The addition of fine steel slag caused the setting time to be prolonged and the early-age strength to be relatively low.

S.P. Palanisamy et al. (2015) in their paper entitled "Steel Slag to Improve the High Strength of Concrete" In this paper, the aim is to increase the strength of concrete by substituting fine aggregate partially with steel slag, which also helps in solving disposal issues. A mixture of different percent replacements was prepared and tested. Partially replacing natural aggregates influences a gain in strength. It was found that up to 36% replacement of steel slag with fine aggregates gave good results.

III. MATERIALS USED

A. Cement

Portland cement is the most widely used form of cement. Grade 53 According to the recommendations, regular Portland cement is used. The cement has a 3% fineness modulus. Cement's specific gravity is calculated to be 3.13. Cement has a consistency of 25 to 35%.

B. Coarse aggregate

Coarse aggregate refers to the larger sized particles or granular materials used in construction. Downsize coarse aggregate of 20mm is used. Crushed coarse aggregate with specific gravity of 2.64 is used.

C. Fine aggregate

Fine aggregate is made up of smaller particles or granular materials used in construction. Fine aggregate is typically composed of sand or crushed stone. Sand obtained from a local supplier is used. The fineness modulus of fine aggregate is

3.045, and the specific gravity is 2.55.

Figure 1. materials

D. Steel slag

Steel slag is an aftermath of the making of steel process. When iron ore is treated to create molten iron and molten slag, it is produced in a blast furnace. Steel slag is created by cooling and solidifying the molten slag. The local steel industry provides the steel slag that is used. The steel slag employed in this research has a specific gravity of 2.82 and a bulk density of 1.13 T/m3.

Parameters	*Slag (%)*
SiO_2	35.60
Al_2O_3	18.00
CaO	35.40
MgO	7.12
Fe_2O_3	1.30
MnO	0.39
TiO_2	0.11
Alkalis	0.30
Sulphide Sulphur (S--)	0.28
Chloride (Cl-)	0.02

Table.1. Chemical composition of steel slag

E. Water

Clean and portable water is used confirming to the requirements of IS: 456 – 2000.

IV. METHODOLOGY

A. *MIX DESIGN:*
Following the technique of Indian Standards IS 10262-1982 for M25 grade of concrete, the mix percentage is designed after completing tests of specific gravity, water absorption for the materials, and workability of concrete. 1:1.7:2.9 (Cement: FA: CA) is the mix ratio, and the water to cement ratio is 0.50.

TEST SPECIMEN:
According to the mix design, the concrete mix was created. Prior to casting the specimens, a slump test was performed in accordance with IS 1199-1959 to assess

the workability of fresh concrete. Three layers of filler were applied to the frustrum of the slump, and voids were removed by tamping each layer 25 times with a rod having a 16 mm diameter. The concrete's top surface was smoothed off. The frustrum is then removed, and the slump height was measured, yielding a 100mm slump value.

For testing compressive strength, the test methods outlined in IS 516-1959 are used. 150 * 150 * 150 mm concrete cubes were cast. Three trials were cast for each percentage replacement. Layer after layer of concrete was poured into the moulds, which were then vibrated by a machine. 45 cubes in total were cast. The concrete cubes were cast, given time to cure, and then tested for compressive strength at 7, 14, and 28 days in accordance with IS protocol.

The split tensile strength test is conducted in accordance with IS 5816-1959. Large 150 x 300 mm concrete cylinders were cast. Three trials were cast for each percentage replacement. 45 cylinders in total were cast and tested in accordance with IS standards.

V. RESULTS & DISCUSSION

A. *Test on compressive strength*

Five distinct types of mixes were created by substituting varying amounts of steel slag for cement. Test specimens that had cement replaced with steel slag to varying degrees (0, 5, 10, 15, and 20%)

Steel slag (%)	***Compressive strength in 7 days (Mpa)***	***Compressive strength in 14 days (Mpa)***	***Compressive strength in 28 days (Mpa)***
0	18.22	24.4	31.56
5	18.89	24.89	33.1
10	19.33	25.78	34.67
15	19.56	26.22	36.22
20	19.1	25.33	34.89

were cast. For each design mix, three distinct samples are created and examined in a compression testing equipment after 7, 14, and 28 days of casting. The test results are then tallied and displayed below in a graph.

Table 2. Compressive strength results of concrete

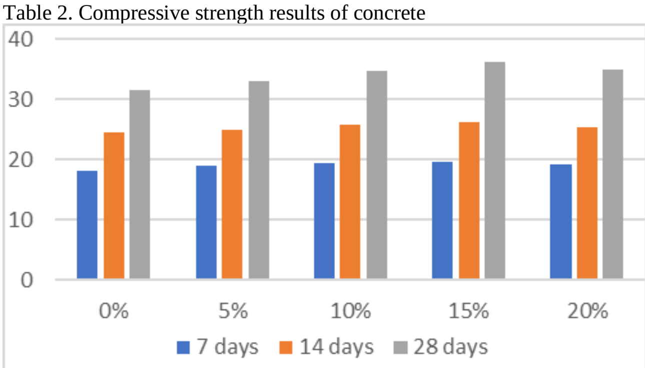

Figure 2. Comparison of compressive strength

Figure 3. Cubes preparation and testing

According to the aforementioned graph, the compressive strength of the concrete gradually grew, reached a maximum value at 15% cement replacement with steel slag, and subsequently fell for 20% steel slag replacement. It was found that the compressive strength of the concrete increases as it ages.

B. *Test on split tensile strength*

By substituting varying amounts of steel slag for cement, five distinct mixes were created. Steel slag was substituted for cement in test specimens to varying degrees (0, 5, 10, 15, and 20%). Each design mix requires the preparation of three distinct samples, which are subsequently evaluated in a compression testing machine 7, 14, and 28 days after casting. The test findings are then listed and represented graphically below.

Table 3. Split tensile strength result of concrete

Steel slag (%)	***Compressive strength in 7 days (Mpa)***	***Compressive strength in 14 days (Mpa)***	***Compressive strength in 28 days (Mpa)***
0	0.84	1.13	1.41
5	1.06	1.13	1.27
10	1.13	1.41	1.55
15	1.27	1.55	1.69
20	0.84	0.99	1.20

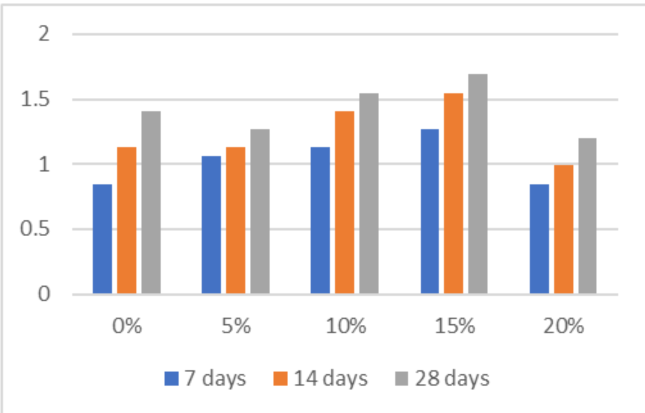

Figure 4. Comparison of split tensile strength

According to the graph above, concrete whose cement was partially replaced with steel slag showed an increase in split tensile strength. Observing the findings, we can see that the maximum value is reached at 15% steel replacement of cement, and then decreases for 20% replacement of steel slag.

V. CONCLUSION

In this study, the potential of partially substituting cement with steel slag and its strength and durability properties were studied. Based on the findings of the experimental investigation and discussions, the following conclusions were drawn:

- When normal concrete and concrete that had steel slag partially replace the cement in the mix were tested, the test results for compressive strength and split tensile strength demonstrated that the strength of the steel slag-replaced concrete was marginally higher.
- Steel slag added to concrete is seen to produce a relatively reduced initial strength. However, the strength of the concrete also grows with age.
- The appropriate quantity of replacement of steel slag for cement is determined to be about 15% of the weight of cement. As the strength for 15% replacement in all 7,14 & 28 days were maximum.
- Concrete made with finely ground steel slag powder has better strength than regular concrete. The disposal issue could be resolved and cement use reduced in future projects by switching to steel slag.
- From further study we can find the effect of use of chemical activators and whether they can speed up concrete's early strength development while also reducing its first setting time.

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