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Utilization of Steel Slag in Concrete as a Partial Replacement Material for Fine Aggregate

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ABSTRACT :

Steel slag is used as a partial replacement for fine aggregate in M30 grade concrete and this study looks into it. With respect to the cement, fine aggregate and coarse aggregate ratio of 1: 1.38: 2.61, the concrete mix was prepared. In its different amounts of steel slag were replaced (0%, 10%, 15%, 20%, 25%, 30%, 35% by weight) of fine aggregate. The strength of the concrete samples was tested after they were cured in water for 7 days and 28 days. It is found that using steel slag as a substitute material for fine aggregate strengthens concrete

KEYWORDS: In this paper, M30 Concrete, Compressive Strength, Split Tensile Strength, Curing and Steel Slag, Fine Aggregate Replacement are described and discussed.

I. INTRODUCTION :

Concrete is the most widely used constructable material for its strength, durability and low price. Infrastructure projects like buildings, bridges and roads are an essential component of its part. Nevertheless, concrete production does require natural resources including cement, coarse aggregate and sand. Extraction has risen to such an extent that these raw materials are getting scarce at such a high price and have been subsequently facing ecological imbalance owing to depletion of natural resources and just extraction. On the same time, steel industry produces a lot of industrial waste one of which is steel slag. It is a byproduct from steel manufacturing process, where impurities are separated from molten steel in the form of steel slag. It can, in fact, be used in construction.

Shortage of Aggregates: Demand has been increasing in alarming rates, which is why sand and aggregate shortages are observed and why costs are rising. Besides investigating steel slag as a fine aggregate substitute in concrete, studies are also being conducted to investigate steel slag as an aggregate replacement in asphalt cement mixtures. Being a good replacement of construction, due to it is dense and hard.

This paper research on Steel Slag Usage: in M30 grade of concrete when fine aggregate was replaced with steel slag. Changes in strength and overall performance are assessed at different replacement levels (0% to 35%).

Objective

- The research focuses on evaluating steel slag concrete as a sustainable material for construction purposes.
- A study for the effect of the replacement of fine aggregate by an amount of steel slag of 0%, 10%, 15%, 20%, 25%, 30%, 35%
- The aims are to study and compare the compressive strength of steel slag concrete cured in normal potable water for 7 days and 28 days.
- This study intends to fully examine the effect of it to thoroughly assess and comprehensively compare the split tensile strength of steel slag concrete to normal potable water for 7 day and 28 day curing periods.
- Therefore, it was applied in order to assay variations in the compressive strength and split tensile strength of the two different steel slag replacement level
- To present the findings graphically

1.2 Need for Study

Concrete Demand is Increasing: With an increase in urban areas including buildings, roads, and bridges, there is increase in demand for concrete. In a case of relying on the same natural resources this could lead to depletion. Therefore, other materials must be found to sustain construction growth. River sand for use in concrete is made in abundance, but over mining is declining its supply. It eventually results in environmental damage and more money. It is important that the finding of alternative materials leads to less depletion and more sustainable construction practices. Industrial Byproducts: Steel slag, a by-product of steel manufacturing is usually dumped. It is better utilized in concrete than to be wasted. Construction Costs Reduction: The increase in prices of material such as sand and gravel make concrete costly. By using steel slag as a substitute for part of the fine aggregate in the concrete, economic savings can be achieved with an efficient substitute for sustainable construction. Steel slag has improved strength properties, angular and rough similar to fine aggregate, therefore substituting steel slag in concrete will make concrete stronger.

II. LITERATURE REVIEW :

Several studies have shown that the advantages of steel slag as a replacement for fine aggregate were in the improvement of the mechanical and durability properties of concrete. According to researchers [1] , a 30% replacement level resulted in a 15% increase in compressive strength as compared to conventional concrete. A study [2] reported that concrete with steel slag is more durable in terms of lower water absorption and higher resistance to sulphate attack than normal concrete because the slag particles form dense microstructure during cement hydration. But workability at reduced slag levels was also influenced by the angular and rough texture of steel slag, because, as a study [3] revealed, slump values decreased as the replacement amount increased, and the addition of superplasticizers was required. Moreover, the material has higher specific phishing than natural sand, and thus it is suitable for heavy duty application [4]. Research has also reported that steel slag, when replacing fine aggregate, could enhance flexural strength by 12% while at an optimum replacement of 40%, [5] or have the environmental benefit to minimize the depletion of river sand as well as to reduce steel industry waste. [6] From water absorption tests, it is shown that steel slag concrete has less porosity, which means it is more resistant against freeze thaw cycles [7]. A study [8] was made on the ambient alkali–silica reactivity, which did not constitute in deleterious expansion but needs cautious mix design in order to gain long term stability. It was found that the steel slag performed better in strength and durability aspects than other industrial by product i.e., copper slag and fly ash [9]. In addition, it also increased the modulus of elasticity by up to 10% at levels of replacement of 35% [10]. Also, thermal resistance was increased as the performance of the steel slag concrete was better under elevated temperature [11]. A study [12]performed to test the acid resistance showed that lowered mass loss was found in acidic environments, and the component is therefore suitable for wastewater treatment plants, marine and other structures. SEM and XRD analysis of the microstructure showed that the matrix has become denser resulting in enhanced overall mechanical properties [13]. Michael Raj, Venkatesh [14] investigated replacement of M40 grade reinforced cement concrete (RCC) members with steel slag as fine aggregate and found that significant improvements in flexural strength were possible with increasing steel slag content making it a good option to enhance the structural performance. In their experimental studies, Mahalingam et al. [15] investigated partial replacement of fine aggregate by steel slag of volume proportion of 20%, 40% and 60%, and observed that 40% by volume replacement exhibits maximum values of compressive and split tensile strength and thus steel slag outperforms conventional medium fine aggregate. However, steel slag was analysed comprehensively as a concrete aggregate by Ren and Li [16], in which it has been shown to be a viable substitute for natural aggregates but its volume stability was curtailed by free lime (CaO) that can be stabilized by carbonation creating denser and stronger concrete. Carbonated steel slag is found by Tang et al. [17] to be effective in minimizing ASR expansion, shrinkage, water absorption, and increasing SU, CU, and UFS compared to replacing 50% of the fine aggregate with It, and to yield better durability. The results of Nguyen et al. [18]were based on a systematic review of 140 studies on steel slag concrete, which showed that steel slag replacement in NSC exerted greater influence on enhancing the compressive strength of steel slag concrete as compared to HSC, with electric arc furnace slag (EAFS) working the best at optimum replacement levels 40–80 % for coarse aggregates and 23.2–100 % for fine aggregates, resulting in large strength gains.

III. EXPERIMENTAL INVESTIGATION :

3.1 Mix proportions

- Cement = 438 kg/m3
- Water = 197.16 l/m3
- Fine aggregate = 604.3 kg/m3
- Coarse aggregate 20mm = 1142 kg/m3
- Water-cement ratio = 0.45
- Mix Proportion By weight = 1: 1.38: 2.61

Table -1: Mix proportions for 1 cube (15cm x 15cm x 15cm)

MATERIAL	QUANTITY	UNIT
CEMENT	1.5	kg
FINE AGGREGATE	2	kg
COARSE AGGREGATE	3.9	kg
WATER	700	ml

Table -2: Mix proportions for 1 cylinder mould (d=150mm; h=300mm)

MATERIAL	QUANTITY	UNIT
CEMENT	2.3	kg
FINE AGGREGATE	3.2	kg
COARSE AGGREGATE	6.1	kg
WATER	1.045	litre

Table-3: Quantity of Material for compressive strength

STEEL SLAG REPLACEMENT (%)	CEMENT (g)	FINE AGGREGATE (g)	STEEL SLAG (g)	COARSE AGGREGATE (g)
0	1500	2000	0	3900
10	1500	1800	200	3900
15	1500	1700	300	3900
20	1500	1600	400	3900
25	1500	1500	500	3900
30	1500	1400	600	3900
35	1500	1300	700	3900

Table-4: Quantity of Material for split tensile strength

STEEL SLAG REPLACEMENT (%)	CEMENT (g)	FINE AGGREGATE (g)	STEEL SLAG (g)	COARSE AGGREGATE (g)
0	2300	3200	0	6100
10	2300	2880	320	6100
15	2300	2720	480	6100
20	2300	2560	640	6100
25	2300	2400	800	6100
30	2300	2240	960	6100
35	2300	2080	1120	6100

3.2 Specimens details

Specimens are then cast according to the designed mix for the test Concrete Cubes were used to conduct the Compressive Strength Test. A mild steel mould, of size 150mm x 150mm x 150mm were used to cast these. Concrete Cylinders are used in the Split Tensile Strength test. made using a barrel-shaped form 150 mm in diameter and a length of 300 mm.

Fig -1: Concrete Cubes casting

Fig -2: cylinder mould casting

IV. RESULT AND DISCUSSION:

The results got from testing of concrete specimen are as follows:

4.1 Test result on compressive strength:

The testing of concrete specimens replaced with steel slag as fine aggregate occurred at 7 and 28 days to determine their compressive strength. These test results indicated that concrete strength increased substantially when steel slag substitution included an optimum level of replacement.

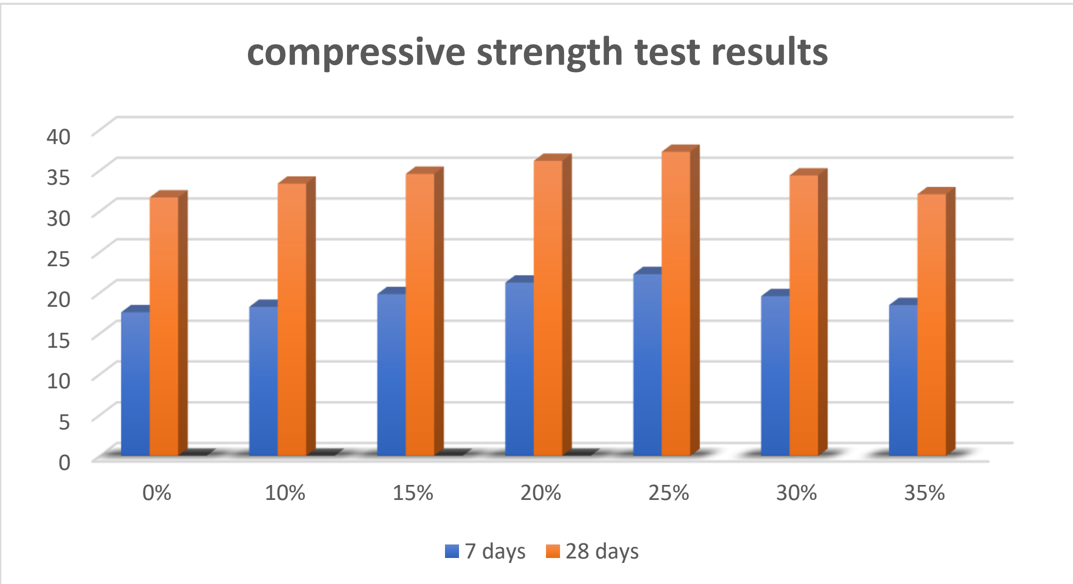
Fig -3: Compressive test on cube

TABLE: 5 COMPRESSIVE STRENGTH TEST RESULT

GRADE OF CONCRETE	STEEL SLAG REPLACEMENT (%)	7 DAYS (N/MM^2)	28 DAYS (N/MM^2)
M30	0	17.62	31.7
	10	18.28	33.4
	15	19.85	34.6
	20	21.26	36.2
	25	22.3	37.3
	30	19.6	34.4
	35	18.5	32.1

The concrete's compressive strength rose when steel slag substituted some fine aggregate up to its best outcome at 25% replacement for all measured durations of 7 days and 28 days. The concrete matrix achieves greater density and strength because improved particle packing and enhanced interfacial bonding as well as increased C-S-H gel formation occurs. The strength began to decrease when steel slag exceeded 25% substitution because higher voids and optimal workability with weak bond formation combined to deteriorate total compressive strength.

The result is show in the graph. The graph is based on the 7 &28 days result of compressive strength



4.2 Test result on split tensile strength:

A split tensile strength test performed at 28 days examined how concrete with steel slag fine aggregates behaved under tension forces using 15 cm diameter and 30 cm deep cylinders that were tested using compressive forces. machine. The testing cylinder needs to occupy a horizontal position during this procedure.

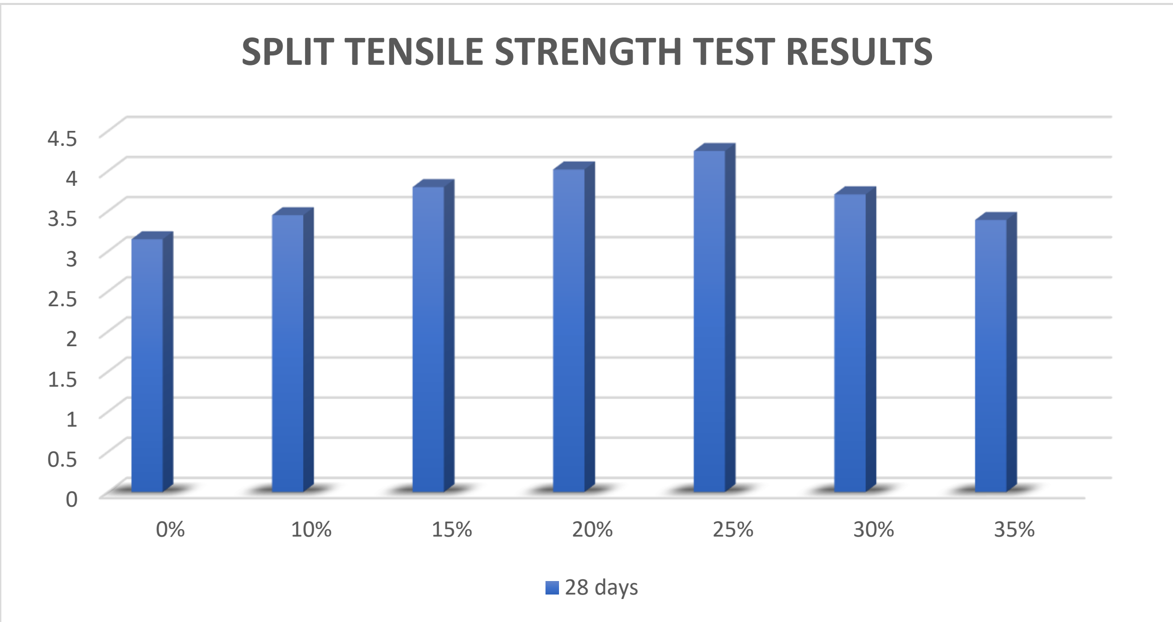
Fig -4: split tensile test on cylinder

TABLE: 6 SPLIT TENSILE STRENGTH TEST RESULT

GRADE OF CONCRETE	STEEL SLAG REPLACEMENT (%)	28 DAYS (N/MM^2)
M30	0	3.15
	10	3.45
	15	3.8
	20	4.02
	25	4.25
	30	3.71
	35	3.39

The replacement of concrete fine aggregate with steel slag resulted in improved split tensile strength which achieved its peak value during day 28 with 25% substitution. The three factors responsible for this strength increase are the improved angular slag particle interlocking and enhanced aggregate-cement paste bond strength and more compact microstructure formation. The tensile strength decreased after 25% of replacement when high slag content caused workability problems and internal stress buildup and damaged bond strength between particles.

The result is show in the graph. The graph is based on the 28 days result of split tensile strength



V. CONCLUTION :

The evaluation found steel slag to improve concrete tensile and compressive strength tests best when used as 25% of the fine aggregate volume.

5.1 For Compressive Strength:

The concrete's strength in compression rose with steel slag substitution reaching maximum results at a 25% replacement for both early testing at 7 days and longer testing at 28 days.
The main reasons for this strength enhancement include:
Better arrangement of the concrete's particles creates a tighter matrix structure with less empty spaces.
The steel slag material enhances cement paste and steel slag particles' bonding connection thereby strengthening concrete materials.
C-S-H (Calcium-Silicate-Hydrate) gel develops more extensively in concrete structures to produce better durability and higher load-bearing abilities.
The strength values started decreasing after reaching a 25% replacement mark because of three main reasons:
The additional void volume weakens the concrete material structure.
The concrete becomes challenging to properly compact and achieve uniform strength distribution because of reduced workability.
Steel slag has the potential to expand which might produce microcracks throughout its service life.
A combination of 25% steel slag content represents the most suitable replacement ratio for concrete materials since it creates the best condition of strength and durability alongside workable characteristics.

5.2 For Split Tensile Strength:

The concrete split tensile strength reached its highest point when steel slag content amounted to 25% during 28 days of curing period. This is due to:
There is better particle interlocking among angular steel slag particles which leads to enhanced resistance to tensile stresses.
The bond between aggregate and cement improved because of this enhancement which decreased microcrack risks and improved concrete tensile resistance.
Concrete matrix achieved its best ability to distribute tensile strain loads because of its densified nature through proper compaction.
The split tensile strength decreased as the replacement amount exceeded 25% because:
The reduced workability leads to poor compaction and formation of voids.
Loosened matrix strength becomes weaker due to increased internal stresses that result from extended slag content.
The concrete becomes more prone to tensile forces because bond formation weakens which results in higher susceptibility to cracking.

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