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Characteristic Strength of Concrete Using Steel Slag as a Fine Aggregate

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***Abstract:** This paper describes the experimental inspection performed to evaluate the properties of concrete using steel slag as a fine aggregate. Concrete is the most commonly used material in the world, so it's abounded used in civil engineering construction field leads to increasing in aggregate scarcity. Because it reduces the use of natural resources, industrial waste is encouraged in the construction industry. Common industrial waste materials include fly ash, silica fume, and steel slag. These materials are successfully used in the construction industry for partial and complete concrete replacement. In present study, partial replacement of fine aggregate by 0%,5%, 10% and 15% in M30 concrete grades with w/c ratio of 0.44.*
***Keywords:** Concrete, steel slag, compressive strength, split tensile strength and flexural strength test.*

I. INTRODUCTION

Cement, fine aggregate, coarse aggregate, and water are the components of concrete. Fine aggregate contributes as a filler material in concrete, coarser aggregate acts as a dense mass, and cement acts as a binder substance that holds all of the materials together. Steel slag is one such alternative material that can be used as a filler material in construction to replace fine aggregate. Steel slag is a by-product of the steel-making process. M-sand is rapidly being used as a fine aggregate substitute for natural sand. Due to environmental concerns, river sand mining is prohibited. Crushed materials are treated to washing to remove particles while crushing rocks to the desired gradation sizes in a specific rock crusher. The remaining dried powder is M-sand, which is allowed to dry on an open field. Availability is not much complicated as natural sand. As a result, M-sand is used as a fine aggregate replacement in the present study.

II. OBJECTIVE OF THE STUDY

A. To study physical properties of steel slag to use as a fine aggregate in concrete.
B. To Determine The Optimum Quantity Of Steel Slag As A Fine Aggregate To Conduct The Different Tests Like Compressive Strength, Tensile Strength And Flexural Strength At Replacement Level Of 0%, 5%, 10% And 15%.
C. Comparison The Test Results Of Conventional Concrete V/S Steel Slag Concrete.

III.LITERATURE REVIEW

1) P. Sateesh Kumar (2015), in their paper entitled "Study on Behaviour of Concrete Mix Replacing Fine Aggregate with Steel Slag at different Properties". The aim of this experiment is to study the effect of partial replacement of steel slag on various strength and durability properties of concrete by using mix design. The test is carried out at the replacement level of 10%, 20%, 30%, 40% at the ages of 28 days. They conclude that for conventional concrete, partial replacement of fine aggregate by steel slag improve the compressive, tensile, flexural strength. The viability of steel slag in concrete is found.

2) S.T.Borole, et.al.(2016), in their paper entitled" Replacement of Fine Aggregate by Steel Slag". In this research paper M30 concrete with high volume steel slag replacement for fine aggregate is studied to examine the changes in properties of compressive strength, flexural strength and split tensile strength. After comparison with conventional concrete property results shows that replacing about 0%, 25 % and 50% of steel slag aggregates by that of fine aggregate will not show any harm and any adverse effect to the durability and strength. The test is carried out after 7 and 28 day of curing.

3) Sultan A.Tarawneh, et.al .(2014), in their study entitled "Effect of using Steel Slag aggregate on Mechanical Properties of Concrete". In this experiment their investigation is to evaluate the physical and mechanical properties and characteristics of steel slag aggregate concrete in comparison with the typical crushed limestone stone aggregate concrete. After proper investigation they founds that compressive strength at the stage of 7 days shows much more strength as compared to that of 28 days. They conclude that the added slag show good results at early age. Hence steel slag could be utilized as partial replacement.

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4) J. Emery (1980) reported that the use of pelletized light weight slag as aggregate in concrete shows better results than that of the ordinary slag. Pelletized expanded slag has significant production and usage advantages when compared to conventional expanded vesicular slag. The major current use of pelletized slag is in lightweight concrete blocks. Structural concrete applications have generally been in semi-lightweight mixes. Other uses such as in slag cement manufacture are outlined.

IV. MATERIALS AND METHODOLOGY

A. *Materials*

1) *Cement:* Ordinary Portland cement of grade 43 is used. In concrete cement is used as a binding agent. The cement properties are shown in the table 4.1, which was determined using relevant IS codes.

Table 4.1. Physical Properties Of Cement

Sl.No	Properties	Unit	Specification as per IS: 12269 (1987)	Obtained Results	Remarks
1	Specific gravity	-	2.90-3.15	3.15	Satisfied
2	Normal consistency	mm	5-7	5	Satisfied
3	Initial setting time	min	>30	51	Satisfied
4	Final setting time	min	<600	463	Satisfied
5	Fineness	%	<10%	7	Satisfied

2) *Coarse Aggregate:* The coarse aggregate in concrete are in greater volume which contributes stability and durability to the concrete. The size of aggregate used is 20mm and down. The properties of coarse aggregate are shown in the table 4.2.

Table 4.2. Coarse Aggregate Test results

Sl.No	Properties	Unit	Specification Rang	Obtained Results	Remarks
1	Specific gravity	-	2.5-3.0	2.75	Satisfied
2	Water absorption	%	< 2	0.795	Satisfied
3	Impact value	%	< 45	28.53	Satisfied
4	Flakiness and Elongation index	%	< 30	15.47	Satisfied

3) *M-Sand:* In the present study, locally available M-sand of high quality is used. The maximum size of fine aggregate, or M- sand, is 4.75mm. The fine aggregate's basic test results are listed in the table. 4.3.

Table 4.3. Basic Test Results Of M-Sand

Sl.No	Properties	Unit	Specification Rang	Obtained Results	Remarks
1	Specific gravity	-	2.3-2.7	2.5	Satisfied
2	Sieve analysis	-	-	Zone II	Satisfied
3	Water absorption	%	< 2	1.80	Satisfied

4) *Steel Slag:* In the present study, steel slag is collected from the steel production industry. It is obtained either through the conversion of iron to steel in a Basic Oxygen Furnace (BOF) or through other means. The properties of steel slag are listed in table in 4.4.

Table 4.4. Test Results Of Steel Slag

Sl.No	Properties	Unit	Specification Rang	Obtained Results	Remarks
1	Specific gravity	-	2.5-2.7	2.56	Satisfied
2	Sieve analysis	-	-	Zone III	Satisfied
3	Water absorption	%	< 2	1.82	Satisfied

5) *Water:* In the present experiment the clean and pure portable water is use for mixing the preparation of concrete.

B. Methodology

In the present study M30 mix proportion is designed as per the guidelines of Indian Standard recommended method IS 456-2000. Cement of 43 grade is used and the basic material tests are carried out on cement, aggregate and M-sand as per the specification. And Steel slag is replaced by 0%, 5%, 10% and 15%.Tests of standard size of concrete were used in the experiment. The casting and tests were carried out to determine the compressive strength of 150mm X 150mm X 150mm cubes and the split tensile strength of a cylinder with a diameter of 150mm and a length of 300mm. Furthermore, the flexural strength of beams measuring 100mm X 100mm X 5000mm.

1) *Test for Compressive Strength of Concrete:* Compressive strength is the primary physical property of concrete, and is the one most used in design. It is one of the fundamental properties. Compressive strength may be defined as the measured maximum resistance of a concrete specimen to axial loading. It is found by measuring the highest compression stress that a test cube will support.
2) *Split Tensile Strength Test:* The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.
3) *Flexural Strength Test:* The Flexural strength of concrete is determined by subjecting a plain concrete beam to flexure under transfer loads. Concrete is relatively strong in compression and weak in tension. In reinforced concrete the tensile stress are resisted by the provision of reinforced steel. However tensile stressed are likely to develop in concrete due to drying shrinkage rousting of steel reinforcement, temperature variations and many other reasons.

4) *Mix design for M30 grade of concrete As per IS 456-2000*

a) Characteristic strength of concrete is 38.25 N/mm^2
b) Water cement ratio 0.44
c) Water content 148 ltr
d) Cement content 336 kg/m^3
e) Fine aggregate 703 kg/m^3
f) Coarse aggregate 1261.7 kg/m^3
g) Mix design Ratio 1:2.09:3.75
h) Steel slag 0%, 5%, 10% and 15% is a partial replacement for fine aggregate, ie M-sand

V. RESULTS AND DISCUSSION

A. Compressive Strength

Compression test is done on cube specimens with dimensions of 150 mm x 150 mm x 150 mm. The obtained results show that maximum compressive strength of 42.26 N/mm^2 after a 10 % replacement of M-Sand with steel slag at 28 days of curing.

B. Splitting Tensile Strength

The tensile strength was determined using a concrete cylindrical specimen having a diameter of 150mm and a length of 300mm. The concrete achieves a maximum tensile strength of 5.21 N/mm² after 10 % M-Sand replacement at 28 days of curing.

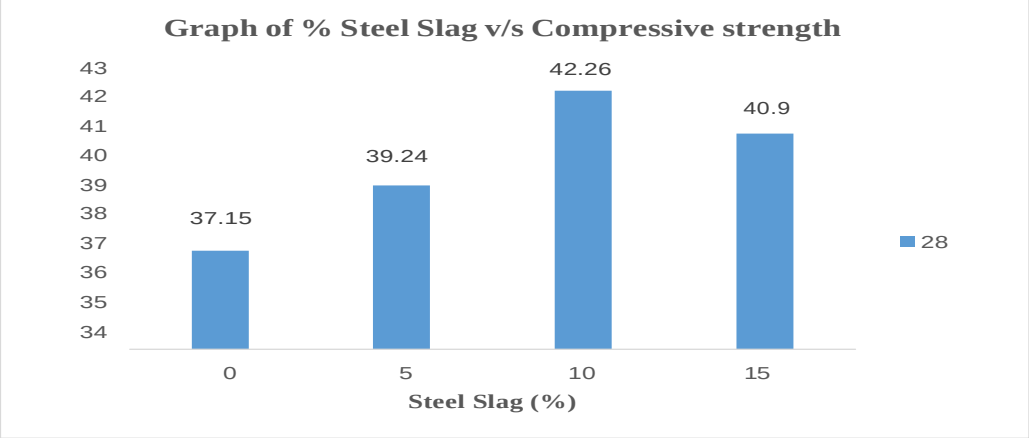
C. Flexural Strength

The flexural strength test is performed on beam specimen having dimensions are 100 mm x 100 mm x 500 mm. Concrete with 10% steel slag as M-sand achieves a maximum flexural strength of 6.99 N/mm^2 replacements at 28 days of curing.

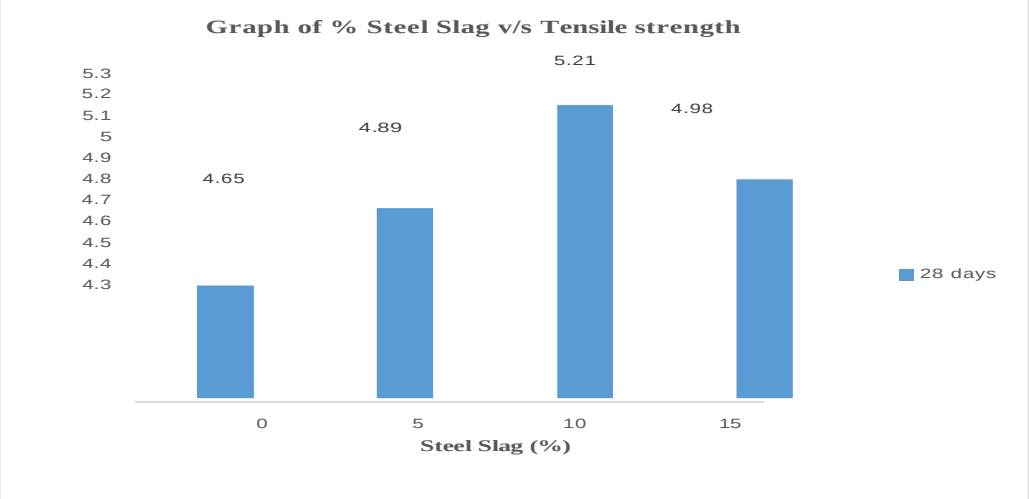
Table 5.1.Test Results

Sl.No	Percentage of steel slag	Percentage of M-sand	Compressive strength (N/**mm²**) 28 days	Tensile strength (N/**mm²**) 28 days	Flexural strength (N/**mm²**) 28 days
1	0	100	37.15	4.65	6.29
2	5	95	39.24	4.89	6.53
3	10	90	42.26	5.21	6.99
4	15	85	40.90	4.98	6.87

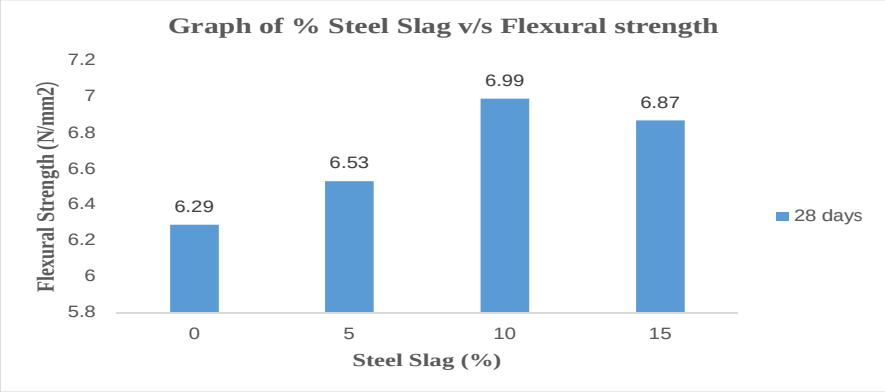
Graph 5.1 Compressive Strength test results



Graph.5.1. Compressive Strength test results



Graph.5.2.Tensile Strength test results



Graph 5.3 Flexural strength test results

D. Cost Estimation

The appropriate cost and savings in cost of concrete for 1Cum quantity is shown Table 5.4

Table 5.4 Cost comparison of concrete with steel slag

Material Cost Analysis						
Sl.No	Description	Unit	Qty	Rate (Rs)	Amount (Rs)	Remark
Case-1 : For M-Sand 100%+0% Steel slag						
1	Cement	Bags	6.72	400	2688	Rs.400/Bag
2	M-sand	Cum	0.47	1765	830	Rate Rs.1765/Cum
3	Aggregates	Cum	0.84	882	741	Rate Rs.882/Cum
Total Material Cost in Rupees					4259	
Case- 2 : For M-Sand 90% +10% Steel slag						
1	Cement	Bags	6.72	400	2688	Rs.400/Bag
2	M-Sand	Cum	0.42	1765	741	Rate Rs.1765/Cum
3	Steel slag	MT	0.05	750	38	Rate Rs.750/MT
4	Aggregates	Cum	0.84	882	741	Rate Rs.882/Cum
Total Material Cost in Rupees					4208	

VI. CONCLUSIONS

The following are the conclusion drawn from the laboratory experiments.

1) The basic material test is carried out on cement, aggregate and M-sand and it satisfies the specification as per the relevant codal provisions.

2) The obtained mix design for M30 grade concrete is 336 kg/m3 of cement, 703 kg/m3 of fine aggregate, 1261.7 kg/m3 of coarse aggregate. The mix ratio is 1:2.09:3.75 with w/c of 0.44.

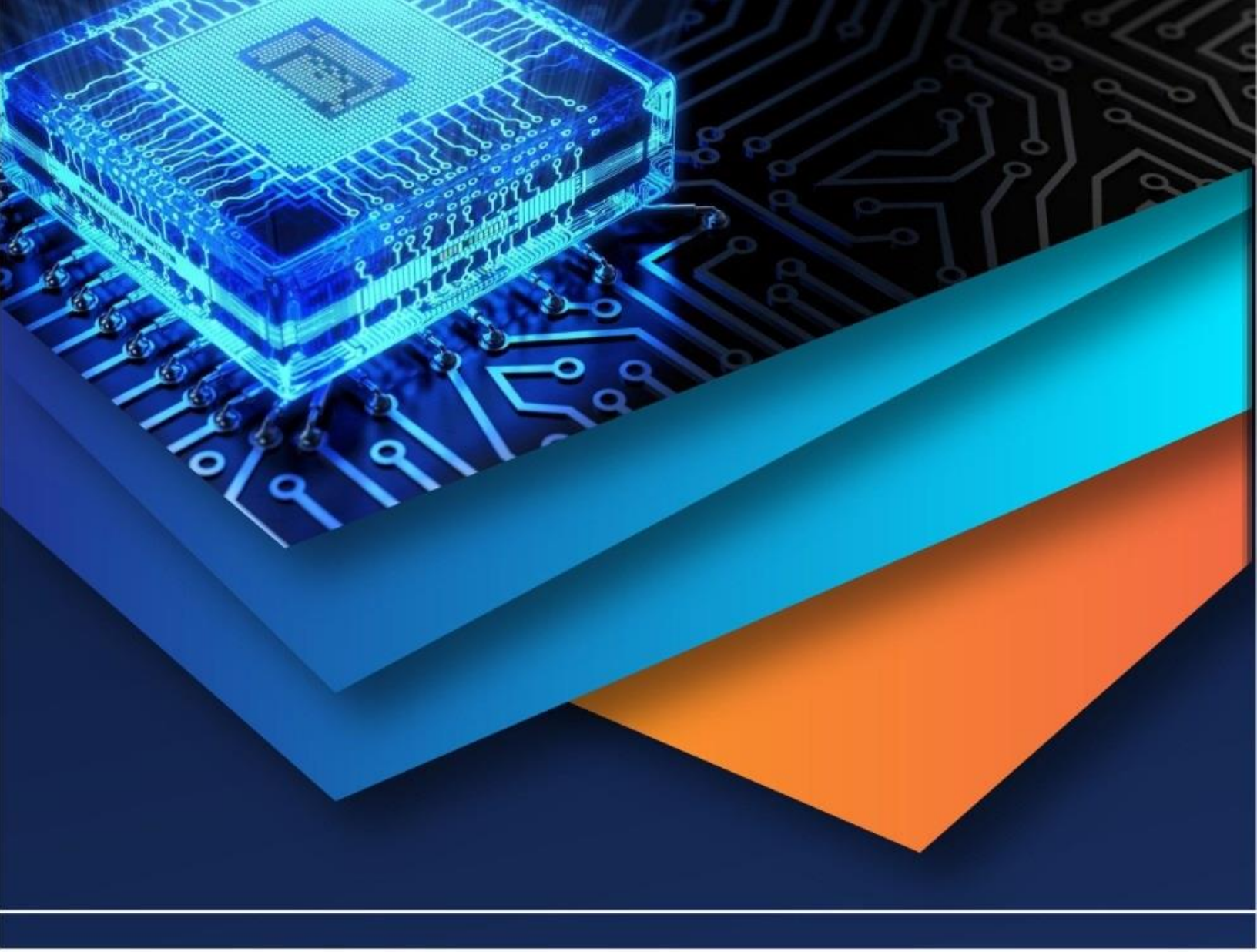
3) The 28 days Compressive strength of concrete increased by 13.7% when compared with Conventional concrete with 10% usage of steel slag.

4) The tensile strength and flexural strength of concrete increased by 12.04% and 11.13% respectively, when compared with conventional concrete with 10% usage of steel slag.

5) There is a savings of 1.2% per cum of concrete with the usage of 10% steel slag.

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