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Study on Strength Properties of Concrete by Partially Replacing Fine Aggregate as Steel Slag

J. Vidhya, R. Dhilipkumar
Assistant Professor, The Kavery College of Engineering, Mecheri,Salem

***Abstract*—Most of the volume of concrete is aggregates. Replacing all or some portion of natural aggregates with steel slag would lead to considerable environmental benefits. The primary aim of this research was to evaluate the durability of concrete made with steel slag as replacement for aggregates. For this present study M20 concrete will be designed. Partial replacement of sand with steel slag will be made for varying percentages such as 10%, 20%, 30%, 40% and 50% of weight of sand. Studies on compressive strength, tensile strength, flexural strength and stress-strain curve will be made by experimental investigation and the strength of concrete attain optimum value at a particular replacement percentage of natural aggregates by steel slag and further replacement affect negatively the strength of concrete**

***Index Terms*— Steel Slag, Durability, Stress-Strain, Tensile Strength, Concrete**

I. INTRODUCTION

Concrete is unique among major construction materials because it is designed specifically for civil engineering projects. Concrete is a composite material composed of granular materials like coarse aggregates embedded in a matrix and bound together with cement or binder which fills the space between the particles and glues them together. Concrete plays a critical role in the design and construction of the nation‘s Infrastructure. Almost three quarters of the volume of concrete is composed of aggregates. To meet the global demand of concrete in the future, it is becoming a more challenging task to find suitable alternatives to natural aggregates for preparing concrete.

II. WHAT IS STEEL SLAG

Steel slag is a byproduct obtained either from conversion of iron to steel in a Basic Oxygen Furnace (BOF), or by the melting of scrap to make steel in the Electric Arc Furnace (EAF). These impurities consist mainly of carbon in the form of gaseous carbon monoxide, silicon, manganese, phosphorous and some iron as liquid oxides, which combine with lime and dolomitic lime to form steel slag. The main constituents of iron and steel slag's are silica, alumina, calcium, and magnesia, which together make about 95% of the total composition. Minor elements included are manganese, iron, sulfur compounds and traces of several other elements.

III. APPLICATIONS OF STEEL SLAG

- Steel slag is used as an ideal aggregate in hot mix asphalt (HMA) surface mixture application due to its high frictional resistance and skid resistance characteristics. The cubical nature of steel slag and its rough texture provides more resistance than round, smooth and elongated aggregates.
- It is also used in making Stone Matrix Asphalt (SMA) because the particle-to-particle contact of the aggregate does not break down during the manufacturing, laying down, or compaction process.
- It is used in base application, construction of unpaved parking lots, as a shoulder material, and also in the construction of embankment.

IV. NEED FOR RESEARCH

River sand used as fine aggregate in concrete becoming very scarce. The cost of construction becoming uneconomical due to excessive cost of transportation from natural sources.
The purpose of this study is to find out the suitable material for replacement of fine aggregate in concrete and explore feasibility of utilizing the steel slag produced by steel mills in Tamilnadu region as a replacement for natural aggregate in the concrete. Steel slag aggregates generally exhibit the potential

to expand due to the presence of un-hydrated free lime and magnesium oxides which hydrate in humid environments. If such a product is used in the concrete, it enhances both the mechanical and physical properties of concrete along with its durability.

V.METHODOLOGY

- In this study initially the preliminary tests for cement, fine aggregate, coarse aggregate, steel slag is conducted and the properties of the materials are determined.
- A concrete mix design for M20 grade was developed using IS383 – 1970, IS10262 – 2009.
- Steel slag of varying percentage such as 10%, 20%, 30%, 40%, 50% were replaced to fine aggregate.
- Test on compressive strength , flexure test , tensile test of concrete for M20 grade at 7 days and 28 days curing were conducted.
- Based on the results the optimum percentage of steel Slag for M20 grade concrete will be arrived.

VI.TEST ON MATERIALS

A. Introduction

In the existing scenario there has been growing trend towards the use of supplementary materials for fine aggregate because of their scarcity. This experimental study aimed to investigate the compressive strength of concrete with different percentage of steel slag as partial replacement.

B. Cement

The cement used should confirm to IS specifications.. OPC 53 grade was used for this study. The physical properties of the cement tested according to standard procedure conform to the requirement of IS 12269: 1989.

Table: 6.1 Physical properties of cement

S.No	Characteristics	Value of obtained experimentally
1	Standard consistency	33%
2	Fineness of cement	3%
3	Initial setting time	30min
4	Specific gravity	3.0

C. Fine Aggregate

Locally available river sand passing through 4.75mm sieve conforming to the recommendation of IS383-1970 is used. The physical properties of fine aggregate are listed below in Table no.6.2.

Table 6.2. Physical properties of fine aggregate

S.No	Characteristics	Value of obtained experimentally
1	Specific gravity	2.66
2	Zone of fine aggregate	Zone III

D. Coarse Aggregate

Coarse aggregates to be used for production of concrete must be strong, impermeable, durable & capable of producing a sufficient workable mix with minimum water cement ratio to achieve proper strength. Locally available coarse aggregate retaining on 4.75mm sieve is used. The physical properties of coarse aggregate are listed below in Table no.3

Table 6.3 Physical properties of coarse aggregate

S.No	Characteristics	Value of obtained experimentally
1	Specific gravity	2.9
2	Nominal size of aggregate	20mm

E. *Steel slag*

In this study Steel slag with specific gravity 3.10 is used for replacement of fine aggregates. The steel slag is shown in Figure

Fig 6.1.Steel slag

F. Water

The quality of mixing water for concrete has a visual effect on the resulting hardened concrete. Impurities in water may interfere with setting of cement & will adversely affect the strength and durability of concrete with steel slag. Fresh and clean water which is free from organic matter, silt, oil, and acid Material as per standards is used for casting and curing the specimens.

VII.CONCRETE MIX DESIGN

As per IS10262-2009 the concrete mix design prepared for M20 grade concrete the water cement ratio is taken as 0.48 from IS10262-2009 for maintain workability

For cubic meter of concrete:

Water = 186 kg/m^3
Cement = 387.5 kg/m^3
Coarse aggregate = 1292 kg/m^3
Fine aggregate = 597 kg/m^3

Mix Proportion Ratio:

Cement	Fine aggregate	Coarse aggregate	W/C
1	1.54	3.33	0.48

VIII.TEST ON FRESH CONCRETE

A.Slump Cone Test

A slump test is a method used to determine the consistency of concrete. The consistency, or stiffness, indicates how much water has been used in the mix. The stiffness of the concrete mix should be matched to the requirements for the finished product quality

Fig.8.1.Slump cone

Table: 8.1 Slump value

S.No	*sample*	*Slump value*
1	Conventional concrete	40 mm
2	10% replacement	36 mm
3	20% replacement	33 mm
4	30% replacement	30 mm
5	40% replacement	25 mm
6	50% replacement	20 mm

B.Compaction Factor Test

Work-ability of concrete is the ability/ease with which concrete can be mixed, transported and placed. This is a major factor which contributes to the other properties of concrete also. If concrete is workable enough then it can be compacted with less compacting effort.

So there is a relation between the amount of work required to compact a given fresh concrete and the work-ability of the concrete. This relation is well suited for the concrete of the low water cement ratio.

Fig.8.2. compaction factor test

TABLE: 8.2 compaction factor test

S.No	sample	Compaction factor
1	Conventional concrete	0.89
2	10% replacement	0.90
3	20% replacement	0.94
4	30% replacement	0.95
5	40% replacement	0.91
6	50% replacement	0.93

IX.EXPERIMENTAL PROGRAMME FOR EVALUATING COMPRESSIVE STRENGTH

A.Preperation Of Concrete Cubes

For this study, experimental work involves casting of concrete cubes of size 150mm X 150mm X 150mm for determination of compressive strength for 7 days and 28 day. Totally 36 cubes were casted. Cubes were casted for various percentage of replacement of fine aggregate with steel slag. Replacement made for 0%, 10%, 20%, 30%, 40% and 50%. For the study the water cement ratio of 0.48 is maintained uniform.

B.Casting Of Cubes

Before casting the cubes the entire mould is oiled. So the cube can be easily removed from the mould after the desired period. The concrete is filled in the cube three layers and each layer tamped evenly by tamping rod.

C. Testing Of Concrete Cubes

The concrete cubes after casting allow 7 days and 28 days curing. After the curing cubes were allow to one day drying. The cubes are tested by means of compression testing machine (CTM) to find the ultimate load.

From the ultimate load, the compressive strength is obtained by the following formula,

Compressive strength = Load/Area (N/mm^2)

Fig.9.1. Testing of cubes

Table: 9.1 Compressive strength of M20 grade concrete for 7 Days

Specimen Name	Percentage of steel slag used (%)	Average Compressive Strength (N/mm^2)
A00	0	13.70
A10	10	14.14
A20	20	15.21
A30	30	17.03
A40	40	15.18
A50	50	14.22

TABLE: 9.2 Compressive strength of M20 grade concrete for 28Days

Specimen Name	Percentage of steel slag used (%)	Average Compressive Strength (N/mm^2)
B00	0	27.85
B10	10	28.40
B20	20	30.67
B30	30	33.11
B40	40	31.63
B50	50	30.59

X.EXPERIMENTAL PROGRAMME FOR EVALUATING TENSILE STRENGTH

For this study, experimental work involves casting of concrete cylinders of size 150 mm diameters, and 300mm length for determination of split tensile strength for 7 days and 28 days. Totally 36 cylinders of M20 grade concrete were casted. Cylinders were casted for various percentage of replacement of fine aggregate with steel slag.

The concrete cylinder after casting is allowed for 7 days and 28 days curing. After the curing cylinder were allowing for drying. After drying cylinder are tested in compression testing machine (CTM) to determine the ultimate load. The testing of cylinder is shown in figure.

From the ultimate load, the tensile strength is obtained by the following formula,

Split tensile strength= 2P/πLD (N/mm^2)

Fig.10.1.Testing of cylinders

Table: 10.1spilt tensile strength of M20 grade concrete for 7 Days

Specimen Name	Percentage of steel slag used (%)	Average tensile Strength (N/mm^2)
A00	0	1.44
A10	10	1.51
A20	20	1.58
A30	30	1.67
A40	40	1.60
A50	50	1.46

Table: 10.2 spilt tensile strength of M20 grade concrete for 28 Days

Specimen Name	Percentage of steel slag used (%)	Average tensile Strength (N/mm^2)
B00	0	3.35
B10	10	3.47
B20	20	3.59
B30	30	3.77
B40	40	3.44
B50	50	3.42

XI.EXPERIMENTAL PROGRAMME FOR EVALUATING FLEXURAL STRENGTH

For this study, experimental work involves casting of concrete prisms of size 50cm x 10cm x 10cm for determination of flexural strength for 7 days and 28 days curing. Totally 36 prisms of M20 grade concrete were casted. Cylinders were casted for various percentage of replacement of fine aggregate with steel slag. Replacement made for 0%, 10%, 20%, 30%, 40% and 50%. For the study the water cement ratio of 0.48 is maintained uniformly.

Flexural strength = $3pa / (bd^2)$ (N/mm^2)

Where, a = distance between the loads,
b = measured width of the specimen,
d = measured depth at the point of failure

Fig.11.1. Testing of prism

Table: 11.1. Flexural strength of M20 grade concrete for 7 Days

Specimen Name	Percentage of steel slag used (%)	Average flexural Strength (N/mm^2)
A00	0	1.47
A10	10	1.47
A20	20	1.60
A30	30	1.87
A40	40	1.60
A50	50	1.60

Table: 11.2. Flexural strength of M20 grade concrete for 28 Days

Specimen Name	Percentage of steel slag used (%)	Average tensile Strength (N/mm^2)
B00	0	2.93
B10	10	3.07
B20	20	3.07
B30	30	3.20
B40	40	2.67
B50	50	2.40

XII.RESULT AND DISCUSSION

The results obtained from the experimental investigations are shown graphically. All the values are average of the three specimens tested in each case during testing program of this study. The results are discussed as follows

A.compressive strength

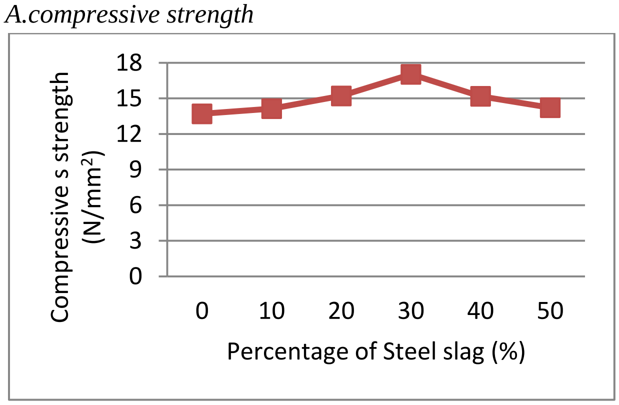

Fig.12.1. 7 day's compressive strength of M20 grade concrete

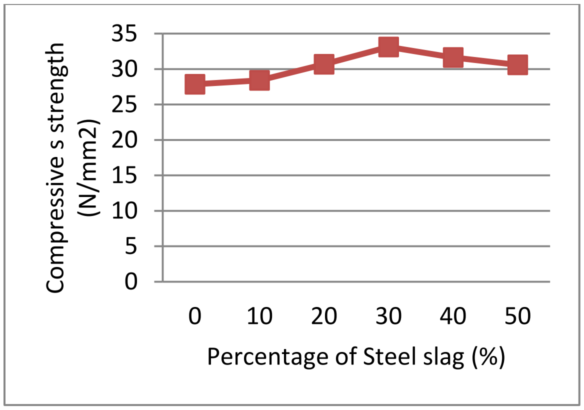

Fig.12.2. 28 day's compressive strength of M20 grade concrete

- It is obvious that compressive strength increases with increase in percentage of steel slag up to 30% by weight of fine aggregate
- The enhancement in compressive strength is about 25% for 7days curing and 18.85% for 28 days curing
- From the graph it is apparent that compressive strength as high as 17.03 N/mm^2 for 7 days curing and 33.11 N/mm^2 for 28 days curing were obtained
- It is obvious that compressive strength increases up to 30% of replacement of fine aggregate by steel slag and decreases considerably in further replacement of slag

B.split tensile strength

The results obtained from the experimental investigations are shown graphically. All the values are average of the three specimens tested in each case during testing program of this study. The results are discussed as follows,

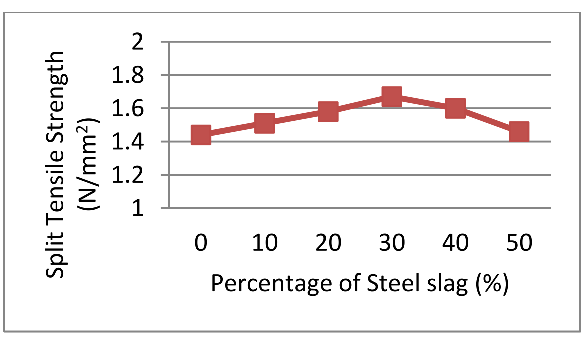

Fig.12.3. 7 day's split tensile strength of M20 grade concrete

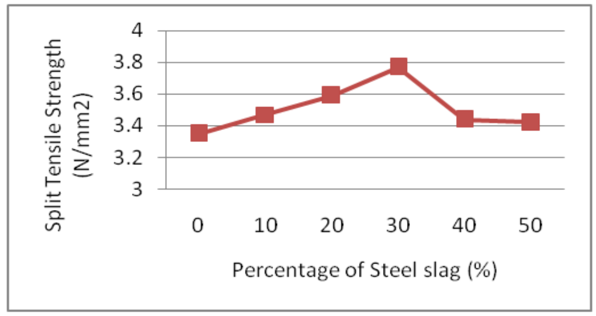

Fig.12.4. 28 day's split tensile strength of M20 grade concrete

- It is obvious that split tensile strength increases with increase in percentage of steel slag up to 30% by weight of fine aggregate
- The enhancement in split tensile strength is about 15.97% for 7days curing and 12.53% for 28 days curing
- From the graph it is apparent that split tensile strength as high as 1.67 N/mm^2 for 7 days curing and 3.77 N/mm^2 for 28 days curing were obtained
- It is obvious that split tensile strength increases up to 30% of replacement of fine aggregate by steel slag and decreases considerably in further replacement of slag.

C.Flexural strength

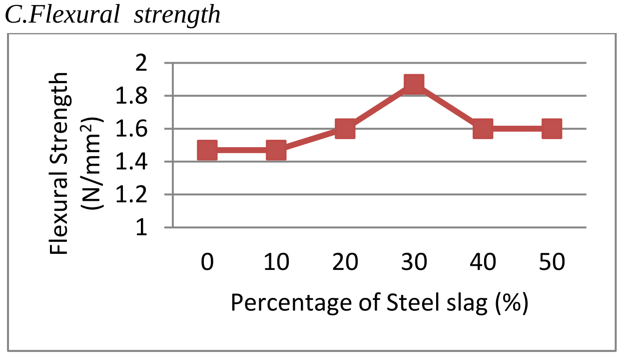

Fig.12.5. 7 day's flexural strength of M20 grade concrete

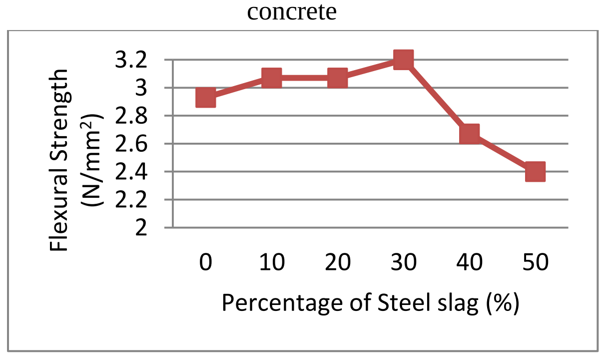

Fig.12.6. 28 day's Flexural strength of M20 grade concrete

- It is obvious that flexural strength increases with increase in percentage of steel slag up to 30% by weight of fine aggregate
- The enhancement in flexural strength is about 27.2% for 7days curing and 9.21% for 28 days curing
- From the graph it is apparent that flexural strength as high as 1.87 N/mm^2 for 7 days curing and 3.20 N/mm^2 for 28 days curing were obtained
- It is obvious that flexural strength increases up to 30% of replacement of fine aggregate by steel slag and decreases considerably in further replacement of slag.

D.Stress strain relationship

- The graphs depict the enhancement of flexural strength of M20 grade concrete for 28 days curing
- The trend of curve presented in the graph for various percentage of replacement of steel slag seems to be identical for conventional concrete and concrete with 30% steel slag

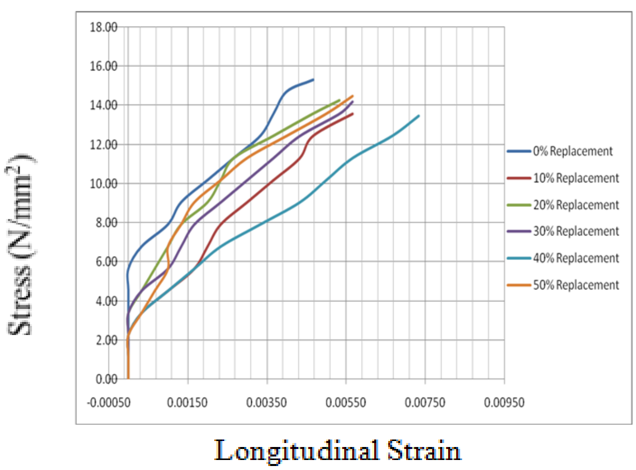

Fig.12.8. stress strain relationship

XIII.CONCLUSION

- It is obvious that compressive strength increases with increase in percentage of steel slag up to 30% by weight of fine aggregate
- The enhancement in compressive strength is about 25% for 7days curing and 18.85% for 28 days curing
- It is obvious that split tensile strength increases with increase in percentage of steel slag up to 30% by weight of fine aggregate
- The enhancement in split tensile strength is about 15.97% for 7days curing and 12.53% for 28 days curing
- It is obvious that flexural strength increases with increase in percentage of steel slag up to 30% by weight of fine aggregate
- The enhancement in flexural strength is about 27.2% for 7days curing and 9.21% for 28 days curing
- From the results of compressive strength, split tensile strength and flexural strength of 7 days and 28 days curing, 30% replacement of fine aggregate by steel slag is the optimum percentage of replacement of M20 grade concrete.
- Further stress-strain curve for 30% slag replaced M20 concrete is similar to that of M20 conventional concrete

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