EXPERIMENTAL INVESTIGATION OF PARTIAL REPLACEMENT OF CEMENT BY USING STEEL SLAG

Shreyash Nitinrao Wakode

Student, Master of Technology, G. H. Raisoni University Amravati, Maharashtra, India

ABSTRACT

This paper aims to study experimentally, the effect of partial replacement of cement by steel slag, on the various strength and miscellaneous properties of concrete, by using a mix design Mortar. The major aim of this research work is to find the ideal percentage of replacement of cement so as to retard the use of deficient natural aggregates. Steel slag is an industrial by-product of steel industry. It carries the disposal problem and creates environmental issues. Cement is replaced by steel slag to study its imp act on concrete in proportions of 0%, 5%, 10% and 15%. Various strength parameters such as compressive strength of all proportion samples are studied. Also, from the obtained results of different sample proportions of steel slag, it will compare to the results of control mix. From the experimental investigations, optimum percentage of replacement of cement by steel slag will worked out. It has been found that some kinds of slag (Industrial steel slag) are very suitable as substitutes for cement, providing properties above those of the reference concrete. A circular economy is a current tenet that must be implemented in the field of construction. That would imply the study of the possibilities of the use of waste generated, for obtaining materials the used in construction as replacements for the raw material used. One of these possibilities is the substitution of the cement by slag, which contributes to the reduction of cement consumption, decreasing CO2 emissions, while solving a waste management problem. In the present paper, different types of concrete made by cement substitution with different type of slags have been studied in order to evaluate the properties of these materials.

Keyword: - *Steel Slag, Cement, Compressive strength, Morter etc….*

1. INTRODUCTION

Cement, which makes up 33% of the Mortar volume, is one of the major ingredient materials in mortar production. Due to the high cost of binders used as a cement and the rising importance on sustainable construction, there is a need for the construction industry to search for an alternative material. Steel making slag, one of the most common industrial wastes, is a byproduct of steel production. One ton of steel results in the production of [130] – [200] kg of slag, depending on the composition of the steel and on the steel production process. Slag often appears as granulated materials containing large clusters, coarse and very fine particles. Serious environmental problems formerly originated from unrestrained sand and gravel taken from rivers.

1.1 Steel Slag Making Processes

Steel Furnace Slag is produced in a (BOF) Basic Oxygen Furnace or an (EAF) Electric Arc Furnace. Hot iron (BOF) and/or scrap metal (EAF) are the primary metals to make steel in each process. Lime is injected to act as a fluxing agent. The lime combines with the silicates, aluminum oxides, magnesium oxides, manganese oxides and ferrites to form steel furnace slag, commonly called steel slag. Slag is poured from the furnace in a molten state. After cooling from its molten state, steel slag is processed to remove all free metallic and sized into products.

In Basic Oxygen Furnace**,** Oxygen is blown into the furnace vessel through a water-cooled oxygen lance oxidizing carbon and the other unwanted elements in the molten iron. Fluxes are added to remove other unwanted elements yielding high quality steel. In Electric Arc Furnace, Charged material is heated to a liquid state by means of an electric current. The electricity has no electrochemical effect on the metal making it perfectly suited for melting scrap. Steel slag is processed as an air-cooled material. The free metallic are magnetically separated and

sized into construction aggregates, used as an agricultural soil amendment, as a raw ingredient in Portland cement production, as an environmental remediation material and other uses.

Fig -1 : Blasted Slag on Site

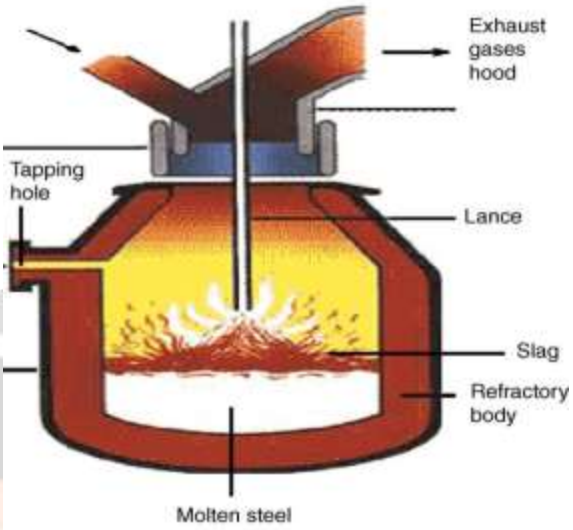

Fig -2 : Oxygen Furnace

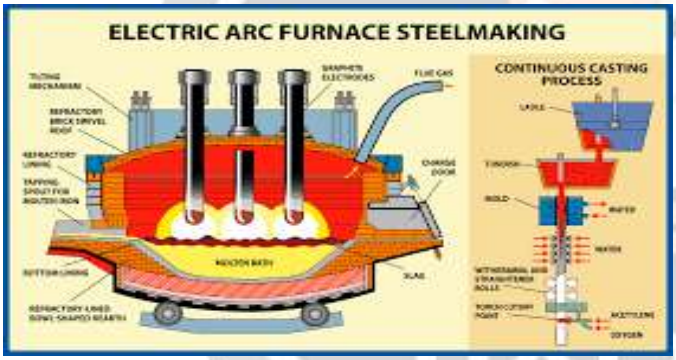

Fig -3 : Electric Arc Furnace

1.2 SCOPE AND OBJECTIVES OF THE EXPERIMENT

The main scope of this project work is to arrive the mix proportion of Mortar made up of replacing some percentage of cement with steel slag. Compressive strength for various trial mixes of slag and cement proportioned mortar element is to be found out.

- To findout change in Strength and the Effectiveness of Partial replacement of Steel Slag with cement.
- To investigate the necessity of consumption of the waste material for manufacturing of sustainable concrete for construction. To use locally available material and to reduce the cost of producing concrete.
- To overcome the problems faced by cement industries to a little extent.
- The experimental investigation was work out the suitability of addition of steel slag as partial replacement of ordinary Portland cement in concrete with the following objective.

- To investigate the compressive strength of concrete with steel slag to that of normal concrete.
- To prepare high strength, eco-friendly and cost effective concrete.
- To reduce cost of the concrete material (cement) and economical.

- To attain conventional concrete strength by partial replacement of cement with Steel slag.

2. METHODOLOGY

MATERIAL USED AND THEIR PROPERTIES

In this work, Portland cement (PC) is used; this cement was chosen as it is free of any additives. In the design of high performance mortar the selection of proper ingredients evaluating the properties and understanding the interaction between different materials plays a major role in performance of the mortar. The ingredients used are cement, steel slag ash, natural sand as a fine aggregate.

2.1 Cement

Ordinary Portland Cement of 50 grade was used throughout the investigation. The cement was available in the local market Amravati City and kept in dry location. The tests were conducted to determine the properties of cement

Characteristics	Experimentally Obtained Values	Values Required as per IS 8112:1989
Specific Gravity (maximum)	3.14	
Fineness	3%	10%
Standard Consistency, percent	31	
Soundness:- By Le Chatelier method, mm 3	3	10 (maximum)
Initial Setting Time, minutes	149	30 (minimum)
Final Setting Time, minutes	312	Final Setting Time, minutes 312 600 (minimum)

Chart -1: Properties of cement.

2.2 Industrial Steel Slag

Property	Steel slag	Type of steel slag	Natural aggregate	Type of natural aggregate	Reference
Specific gravity	3.51	EAF-slag	2.71	Quartzite	Almusallam et al. (2004)
Los Angeles abrasion (%)	11.6		19.2		
Water absorption (%)	0.85		1.60		
Specific gravity	3.64	EAF-slag	2.66	–	Al-Negheimish et al. (1997)
Water absorption (%)	0.54		1.67		
Specific gravity	3.35	EAF-slag			Manso et al. (2004)
Los Angeles abrasion (%)	– 20				
Water absorption (%)	3.29				
Porosity (%)	10.5		–		
Specific gravity	3.02	EAF-slag	2.63	Limestone	Ahmedzade and Sengoz (2009)
Los Angeles abrasion (%)	20		29		
Shape (flat and long) (%)	&(lt; 10	BOF-slag	10	Basalt	Xue et al. (2006)
LA abrasion (%)	13.1		14.9		
Crushing value (%)	12.0		12.9		
Water absorption (%)	1.18		0.70		
Specific gravity	3.48	BOF-slag	2.66	River crushed stone	Shen et al. (2009)
Water absorption (%)	2.2		1.3		
LA abrasion (%)	20.96		23.52		
Shape (flat and elongated) (%)	5.14		7.55		
Roundness index (%)	0.60		0.54		

Fig -4 : Physical Properties Of Steel Slag

2.3 Water

Water is calculated from Standard Consistancy Test.

Tap water, portable without any salts or chemicals was used in the study. The water source was the concrete laboratory in G.H. Raisoni College of Engineering, Amravati

pH value of water used in the experiment = 6.5

2.4 Aggregates (Fine)

In this study, coarse aggregates were used to prepare a controlled as well as treated concrete. The various physical properties of coarse aggregate were assessed with IS 383:1970. The physical properties of coarse aggregates are tabulated .

Maximum size of Aggregates passing through sieve = 4.75mm.

Table -1: Characteristics of aggregates

Characteristics	Experimentally Obtained Value
Colour	Grey
Shape	Angular
Specific Gravity	2.64
Fineness Modulus	6.95
Water Absorbtion	0.81%

3. NO OF TEST PERFORMED ON MATERIALS.

3.1 Cement

Fineness Test of Cement (Procedure) :

- Collect a sample of cement and rub with your hands.
- The Fineness test sample should be free of lumps.
- Take 100 gm of cement sample and note its weight as W1
- Drop 100 gm of cement in 90 µm sieve and close it with the lid.
- Now, shake the sieve with your hands by agitating the sieve in planetary and linear movements for 15 minute .
- After that take weight the retained cement on the 90 µm sieve as W2

To calculate fineness of cement formula is given below,

Fineness = (W2/W1) * 100

3.2 Water

Calculation of Standard or normal consistency of cement by VICAT Appartus.
The Consistency of cement test is performed to determine the amount of water content that is to be added in cement to attain Standard consistency or normal consistency of cement.

Apparatus required
Weighing balance of 1000g with accuracy 1g and Measuring cylinder of 200ml, VICAT apparatus, VICAT Mould, Glass plate, the plunger of 10mm dia and Hand Trowel.

Procedure :

- Take 400g of cement and place it in a bowl or tray.
- Now Assume standard consistency of water is 28% and add the same quantity of water in cement and mix it.

- Mix the paste thoroughly within 3-5 minutes. The time taken to obtain cement paste after adding water is called gauging time.
- Now fill the paste in Vicat mould correctly any excessive paste remained on Vicat mould is taken off by using a trowel.
- Then, place the VICAT mould on Glass plate and see that the plunger should touch the surface of VICAT mould gently.
- Release the Plunger and allow it to sink into the test mould.
- Note down the penetration of the plunger from the bottom of mould indicated on the scale.
- Repeat the same experiment by adding different percentages of water until the reading is in between 5-7mm on the Vicat apparatus scale.

Standard Consistency by vicat apparatus calculations:

Weight of cement = 400gm= W1

Percentage of water =25 to 35% (normal consistency of OPC range between this)

Take 32% of water for this test then the amount of water to be added

In 400 gm cement will be

400*32% (normal consistency use)

400*(32/100)

=128 ml -------- weight of the water= (W2)

Normal consistency = (weight of water / weight of cement)*100

= (128 ml/400)*100

=32%

Normal consistency =32%

Now ,

Calculate the water for casting the cube per the IS 4031 part 6

consistency of cement is 32 % (assumed) calculation of water will be done as below:

(P/4+ 3.0) x 1/100 x 800 = (32 /4+ 3.0) x 1/100 x 800 =88 gram.

The experiments and steps will carry out in this research work to study the effect of Blast furnace slag on Morter properties are as under:

- Collection of raw materials. Sieve Analysis of Fine aggregate, Blast furnace slag is done.

- Prepare the concrete mix samples like cube (3-from each mix, at every percentage level) i.e., from the control Mix A and also from the Morter mixes which are made after replacing the 10%, 20% & 30% respectively of Cement.
- Test of compression is done on the cube samples after 3, 7 and 28 days to determine the compressive strength gained by the designed mixes.

3.3 Procedure of Casting of Cubes

- Cubes of size 7.6X7.6X7.6(cm^3) used for determination of compressive Strength.
- The concrete cube should be clean properly for lubrication.
- Assemble them Mould and tightly fix with bolt.
- A thin layer of oil should be applying on all side of concrete cube.
- The concrete sample filled in cube in 3 layers each layer should be compact by 25 number of stroke with the help of tampering rod.
- Then cubes placed on vibration table for vibration.
- The casted cubes remaining mould for 24 hours at the temperature 22^0C to 33^0C.
- After 24 hours Specimen is taken out and placed in water for curing.
- After curing cubes tested for compression in compression testing machine.

5. RESULT

Sr. no.	Dry weight of cube (kg)	wet weight of mortal cube	after curing 3 days	after curing 7 days	after curing 28 days
1	2.37	3.21	0.84	-	-
2	2.05	2.86	0.81	-	-
3	2.39	3.18	0.79	-	-
4	2.44	3.26	-	0.82	-
5	2.38	3.21	-	0.83	-
6	2.46	3.3	-	0.84	-
7	2.36	3.18		-	0.82
8	2.16	3.22	-	-	0.86
9	2.77	3.57	-	-	0.8

Table -2: 0% replacement of Steel Slag with Cement

Sr. no.	Dry weight of cube (kg)	wet weight of mortal cube	after curing 3 days	after curing 7 days	after curing 28 days
1	2.37	3.15	0.78	-	-
2	2.05	2.82	0.77	-	-
3	2.39	3.14	0.78	-	-
4	2.44	3.21	-	0.77	-
5	2.38	3.06	-	0.85	-
6	2.46	3.16	-	0.84	-
7	2.36	3.17		-	0.81
8	2.16	2.95	-	-	0.79
9	2.77	3.59	-	-	0.82

Table -3: 5% replacement of Steel Slag with Cement

Sr. no.	Dry weight of cube (kg)	wet weight of mortal cube	after curing 3 days	after curing 7 days	after curing 28 days
1	2.37	3.19	0.82	-	-
2	2.05	2.87	0.82	-	-
3	2.39	3.21	0.82	-	-
4	2.44	3.27		0.83	-
5	2.38	3.18	-	0.8	-
6	2.46	3.24	-	0.78	-
7	2.36	2.95		-	0.79
8	2.16	2.98	-	-	0.82
9	2.77	2.57	-	-	0.8

Table -4: 10% replacement of Steel Slag with Cement

Sr. no.	Dry weight of cube (kg)	wet weight of mortal cube	after curing 3 days	after curing 7 days	after curing 28 days
1	2.37	3.21	0.84	-	-
2	2.05	2.94	0.89	-	-
3	2.39	3.24	0.85	-	-
4	2.44	3.31		0.87	-
5	2.38	3.24	-	0.86	-
6	2.46	3.3	-	0.84	-
7	2.36	3.2		-	0.84
8	2.16	2.96	-	-	0.8
9	2.77	3.61	-	-	0.84

Table -5: 15% replacement of Steel Slag with Cement

Sr. no.	Dry weight of cube (kg)	wet weight of mortal cube	after curing 3 days	after curing 7 days	after curing 28 days
1	2.37	3.18	0.81	-	-
2	2.05	2.88	0.83	-	-
3	2.39	3.22	0.83	-	-
4	2.44	3.26		0.82	-
5	2.38	3.22	-	0.84	-
6	2.46	3.28	-	0.82	-
7	2.36	3.2		-	0.84
8	2.16	3.02	-	-	0.86
9	2.77	3.67	-	-	0.9

Table -6: 20% replacement of Steel Slag with Cement

6. CONCLUSIONS

- The replacement of cement with Steel slag 15% and 20% leads to increase in compressive strength.
- The compressive strength is increased when the cement was replaced by 10% of CDA and decreased with increase in the steel slag content. Hence, it is concluded that the 10% cement can be replaced with CDA in Concrete.
- These materials are locally available and they can also reduce the cost of producing concrete.
- The workability of concrete had been found increase with decrease of CDA.
- The concrete preparation is for eco-friendly and cost effective.
- Based on test results we conclude the partial replacement of cement with 15% of steel slag increase the compressive strength of the concrete than that of conventional concrete. So, it should use in construction of any structure.

7. REFERENCES

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BIOGRAPHIES

NAME : Shreyash Nitinrao Wakode

D.O.B. : 09/07/1999

DESIGNATION : Student [B.E. (Civil Engg.) , M. Tech (Structure)]

EMAIL ID : shreyash.wakode.123@gmail.com

CONTACT NO : 7058553771

ADDRESS : Kathora Square, Maharshi colony, Amravati 444604