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Effect of Steel Slag as Partial Replacement of Cement on Property of Concrete

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ABSTRACT

A well-maintained infrastructure is a fundamental necessity for a modern society that provides great value, but ensuring that it meets all the requirements is challenging. Concrete as a construction material is in use for several decades. Concrete can withstand the severest environments and engineers are constantly trying to improve its performance with the aid of modern admixtures and waste materials with or without cementious properties. The use of waste material in concrete helps to consume these waste materials and also improves the properties of concrete in fresh and hydrated states.

Civil structures are designed considering the target compressive strength of the concrete. Although, few other parameters such as workability, water to cement ratio, setting time of cement and surface hardness influence the performance of concrete.

In the present research a series of experiments had been performed to compare the use of Steel Slag as partial replacement of cement in different proportions. Concrete mixes are modified by 5% 10%, 15%, 20% and 25% of Steel Slag as replacement of cement.

The main conclusions drawn are inclusion of Steel Slag increases the compressive strength up-to a certain proportion and then reduces the strength. Steel powder increases the strength but reduces the workability. Comparatively higher early strength gain (3- days, 14- days, 28- days) is obtained with Steel Slag concrete.

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INTRODUCTION

General

Concrete is a mixture of cement, sand, coarse aggregate and water. Its success lies in its versatility as can be designed to withstand harshest environments while taking on the most inspirational forms. Engineers are trying to increase its limits with the help of suitable admixtures and various waste materials.

Utilization of Steel Slag or other desecrate materials in preparing concrete for various civil engineering projects is a subject of high significance. Integration of extra materials in concrete or mortar affects its several characteristics such as strength, workability and other relative performances.

There are various purposes of applying additional materials as substitute to cement and other components in concrete – first is the financial saving obtained by replacing a considerable part of the sand or other ingredients with these materials and second is enhancement in the properties of concrete.

The ecological aspects of cement are now receiving more concern of researchers, as cement developing is liable for about large amount of total worldwide waste emissions from manufacturing sources. The trend of mixing several kinds of additional materials in building engineering is now growing. This has double advantage -

1. To reduce the quantity of deposited waste.
2. To conserve natural resources.

Partial substitution of sand in concrete minimizes the use of natural resources and thus, decreases the global warming. Current practice may permit up to a certain limit of reduction in the content of cement in the concrete mix.

ADDITIVE USED IN THE PRESENT STUDY

Sand is the main material needed for fulfilling the modern infrastructure needs. As an outcome, the construction and concrete industry worldwide is facing growing challenges in conserving material and energy resources. According to the International Energy Agency, the main concern for material producers are the increase in energy efficiency and the use of substitute wastes or other waste materials. Consequently, it is converting into employ the substitute material in cement concrete.

Steel Slag is formed from steel cutting factories during the sawing and finishing of steel parts, and almost 20 - 25% of the processed steel is converted into the powder. Deletion of the Steel Slag from the steel cutting places is a noteworthy environmental trouble today. Though, waste material from steel industry can be used to enlarge several properties of concrete. It has been analyzed that typically compressive strength increased with accumulation of this powder in place of cement. Therefore, employment of the steel dust in a variety of industrial sectors particularly the civil engineering projects, would aid to defend the surroundings.

Reprocess of these waste materials in construction industry is an inventive run towards sustainable and ecological construction. Utilization of waste materials in construction has been considered as ecological, however, this thought has been not accepted widely between the researchers as these materials imposes severe deleterious effects on the concrete. But, through proper concrete mix design the reprocessed concrete can achieve target strength and is appropriate for broad variety of applications in Civil engineering.

Present work intend spotlight on the chances of using waste materials from numerous manufacturing activities in the making of modern mortar and concrete. The use of waste Steel Slag has been proposed in partial replacement of cement, for the manufacturing of Concrete and Mortar Mix. In particular, tests were performed on the mortars and concrete mix cured for dissimilar times in order to decide their workability as well as compressive strength. Fractional replacement of sand at different percentages of waste material reveals that deviation of waste material ratio affects workability and compressive strengths of the mortar and concrete.

Global utilization of concrete presently is around 9 billion tons per year and it is expected to increase during this century because concrete has become the most important material for construction of highways, dams, bridges, and other types of civil construction works. This means, more than 1.3 ton concrete is required per person in the world. In other words, the production of concrete could be more than the production of food. The researches on concrete have been introducing innovative types of cements based on the utilization of wastes and byproducts from the industries. The investigators and field experiences have been shown that the benefits attained when the basic ingredients of concrete is intermingle with wastes, that have been verified not to be deleterious to the performance of cement based products.

Today it is possible to produce cement with specific properties, not only from the mechanical point of view but durability and chemical stability in more destructive surroundings. As some experts told that we are in the modern age where one of distinct signs is the ease of use of new types of cements which are energy-saving materials and a good business, but primarily they are superior quality materials for long life concrete structures. These modern largely fused cements improve the characteristics of concrete and become potential materials for improved applications. The durability of cement concrete is defined as its "capability to oppose chemical attack, abrasion weathering action or any other process of deterioration.

High compressive strength, constructability and durability are the basic conditions to be fit by a concrete of high performance. By utilizing high performance concrete in high demanding applications, reduction in number and size of structural elements, therefore important construction savings are attained. Here, the concept of durability has been extended to the high strength concrete because of risks linked with the harsh environments.

It is usually believed that concrete structures designed for a service life of more than 60 years would actually last much longer with no maintenance. But by the use of an inappropriate specification or the use of regular and improper materials or construction practice could be the cause of early deterioration.

The utilization of mineral admixtures or so called supplementary construction materials offers new chances to concrete technology. With the appropriate selection of the blending material and its chemical admixture, it is now possible to make concrete for focused applications, having ultra high strength, low permeability and high performance in different environments.

The main factor that adds value to concrete is that it can be designed to withstand harshest environments. The growth of concrete technology can reduce the utilization of natural resources and energy sources and reduce the trouble of pollutants on environment.

Currently enormous amounts of fly ash are generated in thermal industries with an important impact on environment and humans. In recent years, many investigators have established that the use of supplementary cementations materials (SCMs) like fly ash (FA), Steel Slag, blast furnace slag, Steel Slag, metakaolin (MK), rice husk ash (RHA) and hypo sludge etc. not only improve properties of concrete both in its fresh and hardened states, but also reduces the construction costs.

To estimate the efficiency of Steel Slag and Steel Slag as substitute construction material, following properties of concrete were requisite to be tested.

1. Compressive strength after different curing periods
2. Flexural strength test
3. Workability
4. Slump cone test
5. Compaction factor test
6. Initial and final setting time test
7. Fineness test
8. Specific gravity and water absorption test

OBJECTIVE OF PRESENT WORK

In the present research a series of experiments had been performed

1. To compare and determine various mechanical properties of concrete mixes prepared by ordinary Portland cement.
2. To determine the effect on properties of concrete mixes which are modified by adding 5% 10%, 15% and 20% and 25% of Steel Slag as partial replacement of Cement.
3. To study the variation of properties when ingredients are mixed in M40 proportions. The properties studied are 7 days, 14 days and 28 days compressive strengths, workability and setting time.

Advantages and drawbacks of Steel Slag –

Advantages

A. It's made of Industrial waste.
B. It's low cost.
C. It's high impact strength.
D. It's light weight.
E. It is well available within the field.
F. It's governed primarily by economic consideration.
G. It's improved structural Efficiency.
H. It's reduces the load of a structure.
I. It's improved Constructability.
J. It's ease to move.
K. It's Quick production.

Disadvantages

The flow spread decreased with an increasing amount of Steel slag within the material.

Material Used

Steel Slag

Steel Slag is formed from steel cutting factories during the sawing and finishing of steel parts, and almost 20 - 25% of the processed steel is converted into the powder. Deletion of the Steel Slag from the steel cutting places is a noteworthy environmental trouble today. Though, waste material from steel industry can be used to enlarge several properties of concrete. It has been analyzed that typically compressive strength increased with accumulation of this powder in place of cement or sand. Therefore, employment of the steel dust in a variety of industrial sectors particularly the civil engineering projects, would aid to defend the surroundings.

Required data for design mix:

M_{40}

Characteristic Compressive strength required in field at 28 days =40 N/mm

Type of Exposure =Severe

Design mix Target slump =25-75 mm (for Light structure)

Maximum size of coarse aggregate =20mm

Fine aggregate =Zone III

Grade of Cement =43

Specific gravity of Cement =2.87

Specific gravity of Water =1

Specific gravity of Coarse aggregate =2.83

Water absorption of Coarse aggregate =0.81%

Specific gravity of Fine aggregate =2.54

Water absorption of fine aggregate=0.8%

SSD= Saturated surface dry condition

1. Target mean strength of concrete

f'ck = fck + 1.65 S

= 40+1.65(5)

= 48.25N/mm^2

f'ck =Target mean Compressive Strength at 28 days in N/mm

fck =Characteristics Compressive Strength at 28 days in N/mm =40N/mm^2

S=Standard deviation (5N/mm^2)

From IS =456-2000

Table -8 (page -23)

1.65 =Tolerance Factor

2. Determination of Water –cement ratio

Water Cement ratio depends on Exposure =Moderate
As per table 5 of IS 456-2000 (page-20)
Maximum Water cement ratio =0.5
Based on experience adopt water cement ratio = 0.45-0.05
= 0.40

3. Determination of water- content

From Table -2 of IS 10262-2009 (page -3) we get that

Maximum water Content for 20mm Coarse aggregate =186 litres

(This value is for 25 to 50mm slump range Ref. IS 10262-2009, clause 4.2 page -2)

Now

Our Target of slump is =25-75mm

(As per IS 10262-2009, clause 4.2, we can increase 3% for every additional 25 mm slump)

Estimated water content for 75 mm slump = 186 + 6/100 ×186
=197.16 litres

4. Calculation of Cement content

As per table 5 of IS 456-2000 (page-20) for server exposure minimum Cement =360 kg/m^3

Water cement ratio =0.40

Water used =197.16litres

Cement Content =Water Content/Water cement ratio
=197.16/0.40
=492.90kg/m^3 (which is greater than 300 hence ok)

5. Calculation of volume of coarse and fine aggregate content

From table 3 of IS 10262-2009 ,Volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate Zone III for water cement ratio of

0.5=0.64

Now

Actual water cement ratio =0.40

It is less by (0.5-0.40) =0.10

As the W/C ratio is reduced, it is desirable to increase the coarse aggregate proportion to reduce the fine aggregate.

The coarse aggregate is increased at the rate of 0.01 for every decrease in W/C ratio of 0.05

So for decrease of every 0.05 W/C ratio = Coarse aggregate increase by 0.01

For decrease of every 1 W/C ratio = Coarse aggregate increase by 0.01/0.05

For decrease of every 0.05 W/C ratio = Coarse aggregate increase by 0.01/0.05×0.05

=0.01

Corrected proportion of volume of coarse aggregate =0.64+0.01

=0.65

Volume of coarse aggregate =0.65

Volume of fine aggregate =1-0.65

=0.35

6. Design mix Calculation (Ref. IS 10262-2009)

The mix Design Calculation per unit volume of concrete shall be as follows

- Volume of Concrete =1m^3
- Volume of Cement =Mass of Cement /Specific gravity of cement ×1/1000
  = 492.90/2.87×1/1000
  = 0.171 m^3
- Volume of Water = Mass of Water /Specific gravity of water ×1/1000
  = 197.16/1×1/1000
  = 0.197 m^3
- Volume of entrapped air =2% for 20mm coarse aggregate
  2/100 =0.02m^3

As per IS 10262-2009 .The percentage of entrapped air in zero, Still 2% is considered on practical experiences

- Volume of all aggregate (Coarse + fine)
  =Volume of concrete – (Vol. of cement +Vol. of Water +Vol. of entrapped air)
  =1-(0.171+0.197+0.02)
  =1-0.369
  =0.612m^3
- Mass of Coarse aggregate =Vol. of all agg. ×Vol. of Coarse agg. × Sp. grevity×1000
  =0.612×0.65×2.83×1000
  =1327.84kg
- Mass of fine aggregate =Vol. of all agg.× Vol. of fine agg.× Sp. gravity ×1000
  =0.612×0.35×2.54×1000
  =544.06kg

Proportion for Trial Mix:

Cement =492.90kg/m

Water =197.16 kg/m

Fine aggregate =544.06 kg/m

Coarse aggregate = 1327.84 kg/m

Water Cement ratio =0.40

The mix proportion then becomes:

Mix proportions for M40 by weight

Water	:	Cement	:	Fine Aggregate	:	Coarse Aggregate
197	:	492.90	:	544.06	:	1327.84
0.40	:	1.0	:	1.10	:	2.69

Results and Discussion

Initial and final setting time:-

The initial setting time of concrete is the time when cement paste starts hardening while the final setting time is the time when cement paste has hardened sufficiently in such a way that a 1 mm needle makes an impression on the paste in the mound but 5 mm needle does not make any impression.

Table NoInitial and Final Setting time of Steel Slag Mix Cement

Steel Slag % mix Cement	Initial Setting Time (min)	Final Setting Time (min)
0	165	380
5	128	372
10	118	370
20	99	359
30	87	290
40	80	245

The physical properties of cement are tested according to IS 10262- 2009.

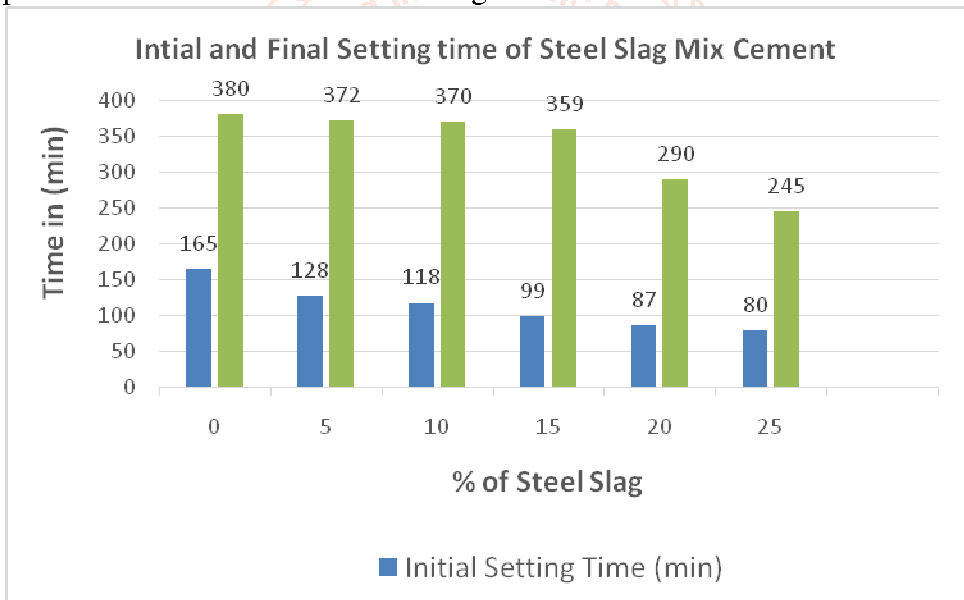


Fig Initial and final setting time

Slump cone test:-

Slump cone test is used to check the workability of concrete. A constant water cement ratio of 0.45 is used throughout the research work. Additional water reducing admixture is used to increase the workability of concrete.

Table Slump test value of Steel Slag mixing Concrete

Sr. No	Sample designation	% of Steel Slag	Slump value(mm)
1	M0	0	33.62
2	M1	5	35.53
3	M2	10	44.25
4	M3	15	49.74
5	M4	20	63.32
6	M5	25	76.42

Degree of workability Good

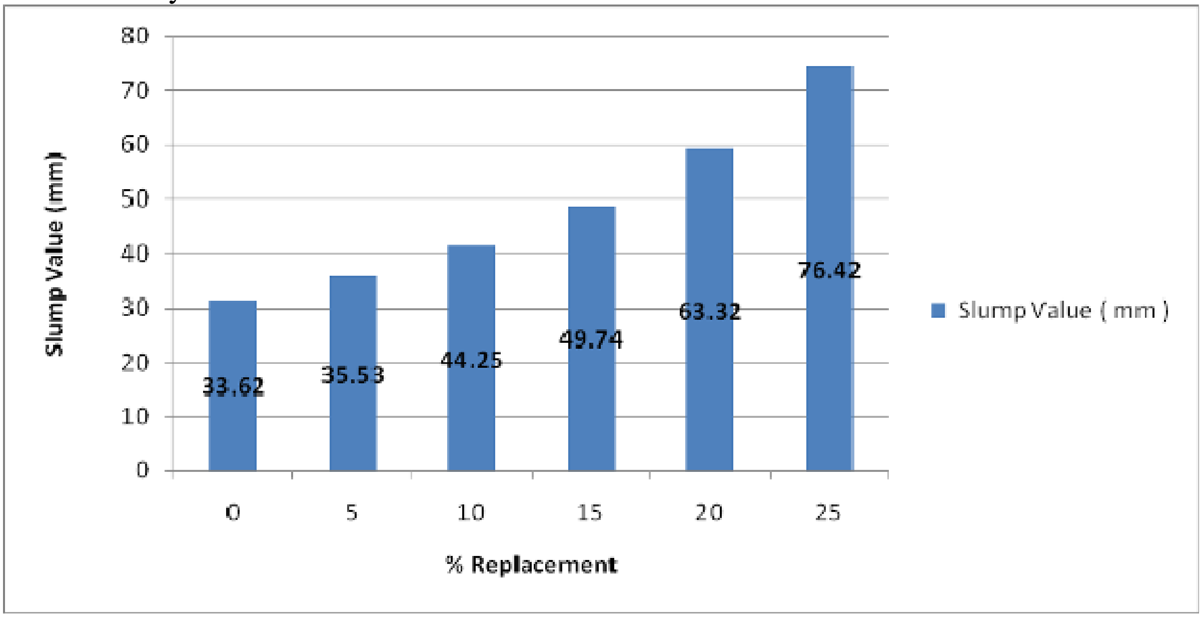


Figure slump value Vs.% of Steel Slag

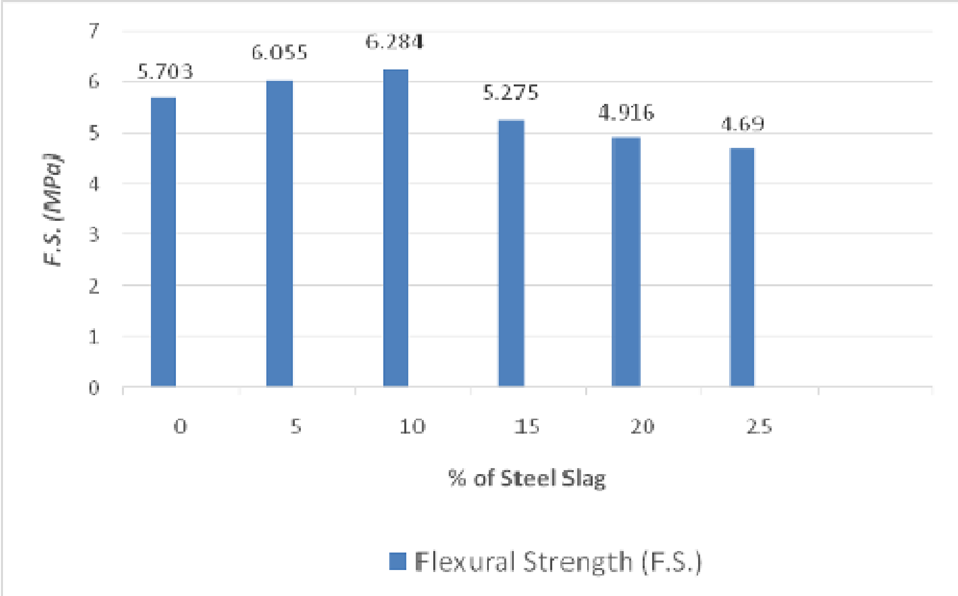
FLEXURALSTRENGTH TEST

The flexural strength test is used to measurement of tensile strength of unreinforced concrete in an indirect way. It is also known as Modulus of rupture and it is defined as the measure of extreme fiber stresses when a member is subjecting to bending moment. Apart from external loading, tensile stresses can also be caused by warping, corrosion of steel, drying shrinkage and temperature gradient. Concrete is strong in compression but weak in tension because of which the flexural strength account for only 10% to 20% of the compressive strength.

Fig -Flexural strength test

Table Flexural Strength (F.S.) of 5.5 MPa flexure design. (w/c =0.45)

% of Steel Slag	*Avg Load (KN)*	*F.S. (MPa)*	*F.S.(kg/cm2)*
0	35.3475	5.703	57.03
5	34.0575	6.055	60.55
10	32.0775	6.284	62.84
15	29.67	5.275	52.75
20	27.6525	4.916	49.16
25	26.38	4.69	46.87



Compressive Strength:- The compressive strength increases with 10% Steel Slag mix after that gradually decreases for the increasing replacement percentage of Steel Slag mix in concrete. This is negative sign using it as structural concrete. For mix M0 (Normal Mix), the characteristics compressive strength after 28 days is 47.25. mm for M40 grade (1.0:1.10:2.69) of concrete. It decreases continuously with increase in replacement proportion of Steel Slag mix in concrete.

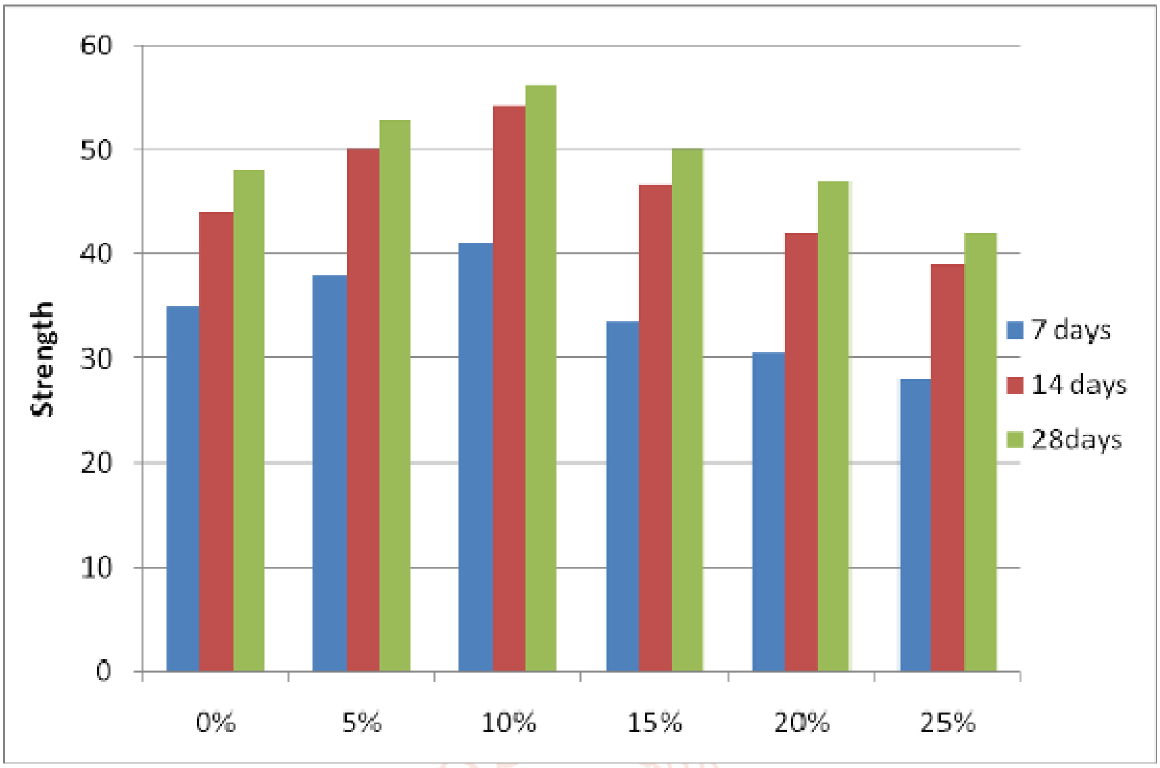
The frequency of testing of compressive strength by cube test is as follows:

Table no Concrete Mix Proportion

Sr. No	Designation Specimen	% Replacement Of Steel Slag with Cement	Proportion by Weight C:F.A:C.A	Water Cement Ratio by Weight	7 days Compressive St.	14 days Compressive St	28 days Compressive St.
1	M0	0	1.0:1.10:2.69	0.40	33.25 35.78 32.97	42.24 43.14 43.59	48.34 47.23 46.18
2	M1	5	1.0:1.10:2.69	0.40	36.24 37.17 38.57	48.68 49.49 49.74	53.22 51.55 53.20
3	M2	10	1.0:1.10:2.69	0.40	40.2 41.9 40.05	55.10 52.38 54.80	56.13 55.48 57.24
4	M3	15	1.0:1.10:2.69	0.40	31.21 33.24 33.50	44.34 46.23 46.53	50.24 49.13 47.72
5	M4	20	1.0:1.10:2.69	0.40	30.29 28.09 30.09	42.11 40.23 40.84	45.74 44.27 48.11
6	M5	25	1.0:1.10:2.69	0.40	28.90 26.05 27.20	37.50 38.11 38.48	42.41 41.13 40.60

Table no Compressive strength of various Mix proportion at 7, 14, 28 days (use normal water)

Sample Designation	% Replacement of Steel Slag in cement	Compressive strength at 7 days	Compressive Strength at 14 days	Compressive Strength at 28 days
M0	0	34	43	47.25
M1	5	37	49	52.00
M2	10	41.02	53.2	55.20
M3	15	32.62	45.68	50.02
M4	20	30.56	41.07	46.08
M5	25	27.05	38.02	41.32



% Replacement of Steel Slag Mix in concrete

Fig Compressive Strength of specimen from 7, 14, 28 days

CONCLUSION AND DISCUSSION

- The main conclusions drawn are
- Experiments have been done in order to examine Steel Slag as replacement of Cement in concrete.
- Various Concrete mixes were prepared by replacing sand with these materials for determining compressive strength and slump values.
- It has also been noted that with the increase in content of supplementary materials decreases the slump value or workability.
- Inclusion of Steel Slag increases the compressive strength up-to a certain proportion.
- Steel Slag increases the strength but reduces the workability.

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