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# A STUDY ON CONCRETE PROPERTIES USING STEEL SLAG AS PARTIAL REPLACEMENT OF COARSE AGGREGATE

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## ABSTRACT

This paper aims to study experimentally, the effect of partial replacement of coarse aggregate by steel slag (SS), on the various strength and durability properties of concrete, by using the mix design of M40 grade. In this study, steel slag was used as a coarse aggregate replacement in conventional concrete mix. Steel slag was selected due to its characteristics, which are almost similar to conventional aggregate and the fact that it is easily obtainable as a by-product of the steel industry, slag aggregate has better abrasion factor and impact value than conventional aggregate. As a result, utilization of steel slag will save natural resources and clean environment. The optimum percentage of replacement of coarse aggregate by steel slag is found. Workability of concrete gradually decreases, as the percentage of replacement increases, which is found slump test. Compressive strength, tensile strength, flexural strength and durability tests such as sorpitivity and Rapid Chloride Penetration are experimentally investigated. The result indicate that for conventional concrete, the partial replacement of coarse aggregate by steel slag improves the compressive strength, modulus of elasticity and flexural strength. The degree of chloride ion penetrability is assessed based on the limits, gives in ASTM C 1202. The viability of usage of SS in concrete is found.

## I. INTRODUCTION

Concrete is a composite construction material made primarily with aggregate, cement, and water. There are many formulation of concrete, which provide varied properties, and concrete is the most-used man-made product in the world. Concrete is widely used for making architectural structures, foundations, brick/block walls, pavements, bridges/overpasses, motorways/roads, runways, parking structures, dams, pools/reservoirs, pipes, footing for gates, fences and poles and even boats.

Historically the word concrete comes from the Latin word "concretes" (meaning compact or condensed). During the Roman Empire, Roman concrete (or opusaementicium) was made from quicklime, pozzolana and an aggregate of pumice. Its wide spread use in many Roman structure, a key event in the history of architecture termed the roman architectural revolution, freed roman construction from the restriction of stone and brick material and allowed for revolutionary new design in terms of both structural complexity and dimension.

Concrete is the most widely used material on earth after water. Many aspect of our daily life depend directly or indirectly on concrete. Conventional concrete a versatile material is prepared by mixing various constituents like cement, aggregate, water, etc. which are economically available. Concrete is unique among major construction material because it is designed specifically for particular civil engineering project

Concrete plays a critical role in the design and construction of the nation 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.

More than ten billion tons of concrete are consumed annually .Based on global usage it is placed at second position after water. Aggregate content is a factor, which has direct and far –reaching effects on the quality of concrete. Unlike water and cement, which do not alter any particular characteristic expect in the quantity in which they are used, the aggregate component is infinitely variable in terms of shape and grading.

High quality aggregate, both coarse and fine for concrete, is of extreme importance. Aggregate occupy 65 to 80% of the total volume of concrete and affect the fresh and hardness properties of the concrete. Out of the total composition of the concrete, the coarse aggregate consumes around 40 to 60% of the volume

**1. Problem Statement**

Concrete plays the key role in construction and a large quantum of concrete is being utilized in every construction practice. Coarse aggregate, which is one of the constituent used in the production of concrete, has become very expensive and also becoming scarce due to the depletion of natural sources. Due to size specification, the material selected to substitute this purpose is steel slag since it is a coarse waste material and its utilization as coarse aggregate replacement could perhaps increase the strength to enhance the properties of concrete at the same time resulting in a cheaper concrete mix.

**2. Coarse Aggregate**

Natural aggregate are obtained from natural rocks. They are inert, filler material and depending upon their size they can be separated into coarse aggregate and fine aggregates. Aggregates are important components for making concrete and properties of concrete are substantially affected by various characteristics of the aggregates used. Aggregates from natural sources form the major variety used for making concrete, mortar and other applications. This Indian Standard has been formulated to cover requirements for aggregates derived from natural sources for use in production of concrete. The coarse aggregate fraction is that retained on 4.75 mm sieve, while the fine aggregate fraction is that passing the same sieve. According to some estimate after the year 2010, the global concrete industry will require annually 8 to 12 billion metric tons of natural aggregates (U.S.G.S and nationalatlas.gov, accessed Nov 2008).

Basically, coarse aggregate occupy a major volume in concrete, the occupying coarse aggregate volume can be various can be various from 50% to 70%. Up to now, we have been using natural coarse aggregate with huge volumes such as andesite, basalt and lime stone in concrete production. As a result, the natural coarse aggregate resources becomes exhausted. Also, in some cases, construction are far from the good quality aggregate resource or the natural aggregate or not easily available for concrete production. Aggregate shall consist of naturally occurring (crushed or uncrushed) stones, gravel and sand or combination thereof. They shall be hard, strong, dense, durable, clear and free from veins and adherent coating; and free from injurious amounts of disintegrated pieces, alkali, vegetable matter and other deleterious substances. As far as possible, scoriaceous, flaky and elongated pieces should be avoided.

Deleterious Materials Aggregate shall not contain any harmful material, such as pyrites, coal, lignite, mica, shale or similar laminated material, clay, alkali, soft fragments, sea shells and organic impurities in such quantity as to affect the strength or durability of concrete. Aggregate to be used for reinforced concrete shall not contain any material liable to attack the steel reinforcement.

**3. Need For Aggregate Replacement**

The aggregate typically account about 75% of the concrete volume and play a substantial role in different concrete properties such as workability, strength, dimensional stability and durability. Conventional concrete consists of sand as fine aggregate and gravel, limestone or granite in various sizes and shapes as coarse aggregate. There is a growing interest in using waste materials as aggregate substitutes such as coal ash, blast furnace slag, and steel slag aggregate. This type of use of waste material as can solve problem of lack of aggregate in various construction sites and reduce environment problems related to aggregate mining and waste disposal. The use of waste aggregate can also reduce the cost of the concrete production.

**4. Demand For Construction Products**

With an increasing demand for construction products, comes the obvious deflection or strain of these limited resources. So there arises a necessity to develop and produce the construction products in a manner that ensures minimal input in terms of cost and expenses but still be able to achieve same or even better results than the conventional methods of concrete production. Modern day has enabled cutting edge technological advances to be applied in the construction industry thus accurate test can be done on different types of society men without much effort.

Cost while at the same time making proper use of these material that would be otherwise be considered as a waste.

## 5. Steel Slag

Steel slag is a by-product of the steel making process, which is formed when iron and or scrap metal are melted together with fluxes such as lime and dolomite under oxidizing conditions by injection large amount of air or lime and other components forms the slag. Steel slag is generated as a melt at about 1600°C during steelmaking from hot metal in the amount of 15%–20% per equivalent unit of steel. The function of this slag is to refine the steel of sulphur and to absorb the oxides formed as a result of deoxidation during steel production. Steelmaking slags are composed principally of calcium silicates, calcium aluminoferrites, and fused calcium oxides, iron, magnesium, and manganese. Organic, semi-volatile and volatile compounds are not present in the steel slag due to the fact that they are made at high temperatures during production process.

Practically all steel slags are air-Cooled, but the current technology of slag production cannot always provide its immediate cooling which can influence its quality. As a consequence, it is not always suitable for further usage and that is the reason why quality control of steel slag production must be provided (Cerjan et al 1995, National Slag Association 1982). Long since steel slags had been extensively used as protective armour stones for rivers, sea and coastal erosion schemes and in various land reclamation projects due to their high density, but a certain amount of produced steel slag is still dumped (National Slag Association 1982). The only potential problem with steel slag aggregate is its expansive characteristics and undesirable reactions between slag and components of concrete.

- Lighter in weight than most natural aggregate
- Reduced Cost to Transport >Volume per Truckload
- Reduced CO 2 > Fewer Delivered Truckloads
- Better Friction Asphalt Mixtures
- Higher Stability (Less Rutting)
- Excellent Base Aggregate Due to Stability
- High Angle of Internal Friction

### *Use of Steel Slag*

Always, construction industry has been at forefront in consuming these waste products in large quantities. The consumption of slag in concrete not only helps in reducing greenhouse gases but also helps in making environmentally friendly material. During the production of iron and steel, fluxes (lime stone and / or dolomite) are charged into blast furnace along with coke for fuel. The coke is combusted to produce carbon monoxide, which reduces iron ore into molten iron product. Fluxing agents separate impurities and slag was produced during separation of molten steel. Slag is a nonmetallic inert waste by product primarily consists of silicates, alumina silicates and calcium-alumina silicates. The molten slag which absorb much of the sulfur from the charge comprises about 20 percent by mass of iron production. As the aggregate can significantly control the properties of concrete, the properties of the aggregates have a great importance (Beshert al., 2003) and (Maslehudinet al.,2002) have indicated that the durability of steel slag cement concrete was better than the same for crushed limestone aggregate.

### *Steel Slag Wastewater Treatment*

- Removes over 80% Phosphorous from pollutions sources
- Reduces Suspended Solids
- Slag Barriers Reduce Dairy Farm Non-Point Source Runoff
- Increases pH of water
- Can be used as an Agricultural Soil Amendment/Lime Source

### *Steel Slag for Portland cement Manufacturing*

- Calcined Steel Slag – Reduces $CO_2$
- For Every Ton of Portland Cement Clinker Manufactured 1 Ton of $CO_2$ is

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emitted
•For Every Ton of Slag Used to Replace Natural Raw Materials No Additional $CO_2$ is emitted
• Saves Natural Resources

**6. Super Plasticizer (Tec Mix 550)**

***Key Benefits and Features***

1. Enhanced water reduction properties resulting in improved workability and greatly porosity of concrete.
2. Significantly reduces segregation and bleeding of concrete mix.
3. Helps produce concrete of high early strength and also increases the ultimate compressive strength.
4. An extremely useful admixture for pre-cast concrete.
5. Improve the final texture of concrete.
6. Gentle on reinforcements does not cause corrosion of reinforcements.
7. Does not contain chlorides-safe for use in pre-stressed concrete.
8. Superior dispersion of concrete particles results in production of a cohesive concrete mix with reduce segregation.

***Usage***

- Ideal as an admixture for high volume concreting for floor, walls or foundations.
- Ideal for production of high strength concrete with reduced permeability by reducing the water content.
- Improve workability makes tec mix 550 suited for concreting in areas with congested reinforcement
- Ideal for sloped roof concreting and roof slabs with complicated geometry like domes, shells and flooded plate.
- High workability concrete can be produced at site optimized mix dosages with tec mix 550.
- Can be used for producing pump able concrete at site

## II. EXPERIMENTAL PROGRAMME

**1. Scope And Objectives**

***Scope of the Work***

The scope of the present work includes the study of the following topics:

- Characterization of steel slag.
- Mix design for M40 grade concrete with various replacement levels of steel slag.
- Study on properties of fresh and hardened concrete with the replacement of coarse aggregate by various proportion of steel slag.
- Durability studies on concrete for the optimum replacement level of steel slag.
- -+Studies on micro structural properties of concrete with steel slag.
- Experimental and analytical studies on structural behavior of concrete with steel slag.

**2. Objective of Using Steel Slag:**

- To minimize the waste.
- To generate revenue.
- To minimize volumes accumulating and taking up space in a dumping yard.
- To reduce the costs of storage and disposal.
- To satisfy the customer demand for products for which coarse are a by- product.
- To achieve sustainability.
- To ensure landscape restoration.
- To reduce the extraction of natural coarse aggregate.

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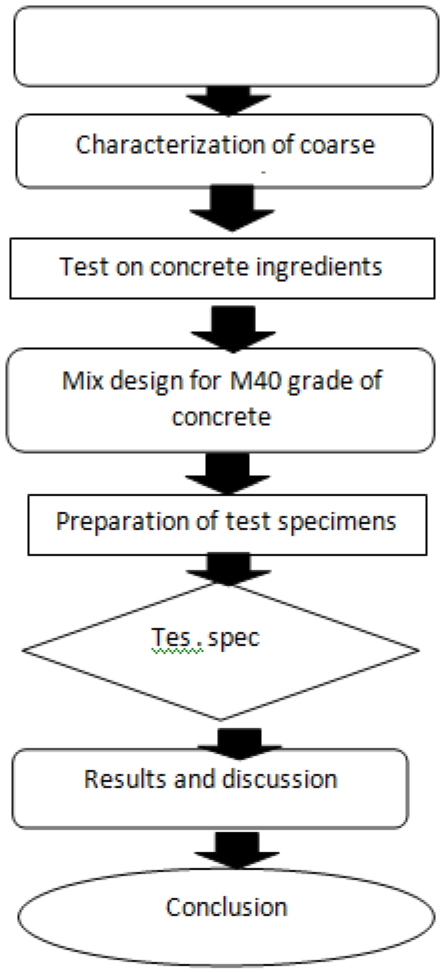
## 3. Methodology

The methodology is shown in fig 3.1. The flow chart step-by-step procedure of the present thesis work




## 4. Mix Proportion

***Mix Design For M40 Grade Of Concrete***

Design specification for proportioning:
Grade of designation = M40
Types of cement = OPC 53 Grade
Types of chemical admixtures = SP(550 Tec Mix)
Maximum nominal size of aggregate = 20mm
Maximum water- cement ratio = 0.45
Workability = 100mm(slump)
Exposure condition = sever
Degree of supervision = good
Maximum cement content = 450Kg/$m^3$

***Test data of materials***

Specific gravity of cement = 3.15
Specific gravity of coarse aggregate = 2.72
Specific gravity of fine aggregate = 2.62
Water absorption
Coarse aggregate = 0.6%
Fine aggregate = 1%
Sieve analysis
Coarse aggregate = 6.86
Fine aggregate = 3.10

***Target Mean Strength: M40***

Use of Indian standards IS456-2000& IS 10262-2009,

fck = fck+1.65S
= 40+ 1.65x5
= 48.25N/mm$^2$

***Selection of water cement ratio***

From is IS 456-2000, table5,
Maximum W/C ratio for M40 Grade concrete = 0.45
SELECTION OF WATER CONTENT:
From is IS 10262-2009, table2,
Maximum water content =186liters for 100mm slump
Estimation of water content for 100mm slump
= 186+ (6/100) x186
= 197liters/m3
Arrived using Super Plasticizers = (10/100) x 19
= 19.7liter/m3
Required water content = 197 – 19.7
= 177.3
=158liter/m3

***Calculation of cement content***

Maximum W/C ratio for M40 Grade concrete = 0.45
W/C = 0.40
Cementitious material content = (177.3/0.40)
= 443.25Kg/m3

***Proportion Of Volumes Of Coarse Aggregate And Fine Aggregate Content***

From is 10262-2009 table: 3 Coarse {20mm size} and fine aggregate {zone II} for water-cement ratio of 0.50= 0.64.
For W/C ratio of 0.40= 0.66
Therefore volume coarse aggregate = 0.66
Volume of fine aggregate content = 0.34

***Mix Calculations***

The mix calculations per unit volume of concrete shall be follows:

1. Volume of concrete =1 m$^3$
2. Volume of cement=$\frac{\text{mass of cement}}{\text{specific gravity of cement}} \times \frac{1}{1000}$

$=\frac{443.25}{3.15} \times \frac{1}{1000}$
= 0.140 m$^3$

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3. Volume of water $= \frac{\text{mass of water}}{\text{specific gravity of water}} \times \frac{1}{1000}$
   $= \frac{177.3}{1} \times \frac{1}{1000}$
   = 0.1773kg/m$^3$
4. Volume of chemical $= \frac{\text{mass of chemi admixtures}}{\text{specific gy of admixtures}} * \frac{1}{1000}$
   Admixtures = 7.9/1.2 *1/1000
   = 0.0066 m$^3$
5. Volume of all in aggregates
   =(1-(0.140+0.1773+0.0066))
   = 0.676 m$^3$
6. Mass of course = e$\times$ $volme\ of C.A \times 1000$
   aggregates = 0.676*0.66*2.72*1000
   = 1213.73 kg
7. Mass of fine= e$\times$volume of f.a $\times$ s.g of f.a $\times$ **1000**
   aggregates = 0.676 *0.34*2.66*1000
   = 611.46 Kg

**Mix ratio**

| Cement content | Fine aggregate | Coarse aggregate | water |
|---|---|---|---|
| 443.25kg/m$^3$ | 611.46kg/m$^3$ | 1213.73kg/m$^3$ | 153.26lit/m$^3$ |
| 1 | 1.37 | 2.73 | 0.40 |

## III. RESULT AND DISCUSSION

### 1. Compressive Strenght

The compressive strength of steel slag with coarse aggregate table 3.4 shows the variation of compressive strength with different percentage of replacement of steel slag content of 0% (i.e., 100% natural coarse aggregate), 20%, 30%, and 40% for 7 days, 28 days. The average compressive strength of M40 grade concrete cubes are also given in the below tables.

The compression test on concrete cubes for conventional concrete cube after 7and 28 days curing period are given in table 3.1 and 3.2.

*Table No.3.1 Compressive Strength of Conventional Concrete Cubes for 7 days.*

| Sl. No | Sizeof specimen | Ultimate load (KN) | Compressive strength (N/mm$^2$) | Average Compressive strength (N/mm$^2$) |
|---|---|---|---|---|
| 1. | 150x150 x150 | 730 | 32.45 | 33.13 |
| 2. | 150X150 x150 | 713 | 31.69 | |
| 3. | 150x150 x150 | 793 | 35.26 | |

*Table No.3.2 Compressive Strength of Conventional Concrete Cubes for 28days.*

| Sl. No | Sizeof specimen | Ultimate load (KN) | Compressive strength (N/mm$^2$) | Average Compressive strength (N/mm$^2$) |
|---|---|---|---|---|
| 1. | 150x150 x150 | 1172 | 52.13 | 49.98 |
| 2. | 150X150 x150 | 1085 | 48.23 | |
| 3. | 150x150 x150 | 1115 | 49.58 | |

The compression test on concrete cubes for 10% replacement of steel slag at 7and 28 days of curing period are given in table 3.3 and 3.4

*Table No.3.3 Compressive Strength of 10% replacement for 7 days.*

| Sl. No | Size of specimen | Ultimate load (KN) | Compressive strength (N/mm$^2$) | Average Compressive strength (N/mm$^2$) |
|---|---|---|---|---|
| 1. | 150x150 x150 | 859 | 38.21 | 35.03 |
| 2. | 150X150 x150 | 844 | 37.54 | |
| 3. | 150x150 x150 | 793 | 29.32 | |

*Table No.3.4 Compressive Strength of 10% replacement for 28 days.*

| Sl. No | Size of specimen | Ultimate load (KN) | Compressive strength (N/mm$^2$) | Average Compressive strength (N/mm$^2$) |
|---|---|---|---|---|
| 1. | 150x150 x150 | 1121 | 54.28 | 52.62 |
| 2. | 150X150 x150 | 1175 | 52.26 | |
| 3. | 150x150 x150 | 1155 | 51.34 | |

The compression test on concrete cubes for 20% replacement of steel slag at 7and 28 days of curing period are given in table 3.5 and 3.6

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*Table No3.5 Compressive Strength of 20% replacement for 7 days.*

| Sl. No | Size of specimen | Ultimate load (KN) | Compressive strength (N/mm$^2$) | Average Compressive strength (N/mm$^2$) |
|---|---|---|---|---|
| 1. | 150x150 x150 | 866 | 38.25 | 38.86 |
| 2. | 150X150 x150 | 870 | 38.69 | |
| 3. | 150x150 x150 | 892 | 39.65 | |

*Table No.3.6 Compressive Strength of 20% replacement 28 days.*

| Sl. No | Size of specimen | Ultimate load (KN) | Compressive strength (N/mm$^2$) | Average Compressive strength (N/mm$^2$) |
|---|---|---|---|---|
| 1. | 150x150 x150 | 1333 | 59.25 | 56.52 |
| 2. | 150X150 x150 | 1279 | 56.85 | |
| 3. | 150x150 x150 | 1203 | 53.48 | |

The compression test on concrete cubes for 30% replacement of steel slag at 7, 28 days of curing period are given in table 4.7. And 4.8.

*Table No.3.7 Compressive Strength of 30% replacement 7 days.*

| Sl. No | Size of specimen | Ultimate load (KN) | Compressive strength (N/mm$^2$) | Average Compressive strength (N/mm$^2$) |
|---|---|---|---|---|
| 1. | 150x150 x150 | 885 | 39.34 | 40.53 |
| 2. | 150X150 x150 | 866 | 38.52 | |
| 3. | 150x150 x150 | 984 | 43.74 | |

*Table No.3.8 Compressive Strength of 30% replacement 28 days.*

| Sl. No | Size of specimen | Ultimate load (KN) | Compressive strength (N/mm$^2$) | Average Compressive strength (N/mm$^2$) |
|---|---|---|---|---|
| 1. | 150x150 x150 | 1359 | 60.41 | 59.01 |
| 2. | 150X150 x150 | 1344 | 59.74 | |
| 3. | 150x150 x150 | 1280 | 56.89 | |

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The compression test on concrete cubes for 40% replacement of steel slag at 7and 28 days of curing period are given in table 4.9 and 4.10.

*Table No.3.9 Compressive Strength of 40% replacement 7 days.*

| Sl. No | Sizeof specimen | Ultimate load (KN) | Compressive strength (N/mm$^2$) | Average Compressive strength (N/mm$^2$) |
|---|---|---|---|---|
| 1. | 150x150 x150 | 672 | 29.87\ | 31.11 |
| 2. | 150X150 x150 | 643 | 28.60 | |
| 3. | 150x150 x150 | 784 | 34.86 | |

*Table No.3.10 Compressive Strength of 40% replacement for 7 days.*

| Sl. No | Sizeof specimen | Ultimate load (KN) | Compressive strength (N/mm$^2$) | Average Compressive strength (N/mm$^2$) |
|---|---|---|---|---|
| 1. | 150x150 x150 | 1180 | 52.46 | 48.70 |
| 2. | 150X150 x150 | 1043 | 46.37 | |
| 3. | 150x150 x150 | 1063 | 47.28 | |

*Table 3.11 the average compressive strength of M40 graded concrete cubes 7 days 28 days of curing period*.

| Sl. No | Type of mix | 7 days | 28 days |
|---|---|---|---|
| 1. | Conventional concrete | 33.13 (N/mm$^2$) | 49.98(N/mm$^2$) |
| 2. | 10% | 35.03(N/mm$^2$) | 52.62(N/mm$^2$) |
| 3. | 20% | 38.86(N/mm$^2$) | 56.52(N/mm$^2$) |
| 4. | 30% | 40.53(N/mm$^2$) | 59.01(N/mm$^2$) |
| 5. | 40% | 31.11(N/mm$^2$) | 48.70(N/mm$^2$) |

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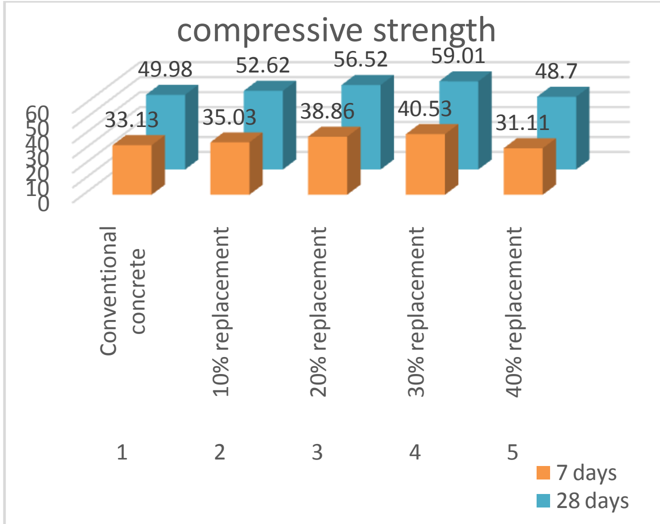


*Fig. 3.1 Compressive Strength of cube.*

**2. Flexural Strength Results**

The flexural strength on concrete prism for conventional, 10% replacement, 20% replacement, 30% replacement, 40% replacement at 7 days and 28 days are given below tables.

The flexural strength of conventional concrete prism at 7 days and 28 days.

*Table 3.12 Flexural strength of conventional concrete prism for 7 days.*

| Sl.no | Dimension of the beam in mm | Load in (N) | Flexural strength, for in N/mm$^2$ | Average stress in N/mm$^2$ |
|---|---|---|---|---|
| 1. | 500x100x100 | 10000 | 3.91 | |
| 2. | 500x100x100 | 10500 | 4.28 | 4.18 |
| 3. | 500x100x100 | 11000 | 4.36 | |

*Table 3.13 Flexural strength of conventional concrete prism for 28 days.*

| Sl.no | Dimension of the beam in mm | Load in (N) | Flexural strength, for in N/mm$^2$ | Average stress in N/mm$^2$ |
|---|---|---|---|---|
| 1. | 500x100x100 | 12500 | 4.86 | |
| 2. | 500x100x100 | 12000 | 4.71 | 4.97 |
| 3. | 500x100x100 | 13000 | 5.23 | |

**The flexural strength of 10% replacementat 7 days and 28 days.**

*Table 3.14 Flexural strength of 10% replacement for 7days.*

| Sl.no | Dimension of the beam in mm | Load in (N) | Flexural strength, for in N/mm$^2$ | Average stress in N/mm$^2$ |
|---|---|---|---|---|
| 1. | 500x100x100 | 11500 | 3.91 | 4.31 |
| 2. | 500x100x100 | 10000 | 4.28 | |
| 3. | 500x100x100 | 12500 | 4.36 | |

*Table 3.15 Flexural strength of10% replacementfor 28 days.*

| Sl.no | Dimension of the beam in mm | Load in (N) | Flexural strength, for in N/mm$^2$ | Average stress in N/mm$^2$ |
|---|---|---|---|---|
| 1. | 500x100x100 | 13500 | 5.21 | 5.21 |
| 2. | 500x100x100 | 13500 | 5.03 | |
| 3. | 500x100x100 | 14000 | 5.52 | |

**The flexural strength of 20% replacementat 7 days and 28 days.**

*Table 3.16 Flexural strength of 20% replacement for 7 days.*

| Sl.no | Dimension of the beam in mm | Load in (N) | Flexural strength, for in N/mm$^2$ | Average stress in N/mm$^2$ |
|---|---|---|---|---|
| 1. | 500x100x100 | 12500 | 4.99 | 4.73 |
| 2. | 500x100x100 | 10700 | 4.28 | |
| 3. | 500x100x100 | 11200 | 4.36 | |

*Table 3.17 Flexural strength of 20% replacementfor 28 days.*

| Sl.no | Dimension of the beam in mm | Load in (N) | Flexural strength, for in N/mm$^2$ | Average stress in N/mm$^2$ |
|---|---|---|---|---|
| 1. | 500x100x100 | 12500 | 5.40 | 5.46 |
| 2. | 500x100x100 | 12500 | 5.32 | |
| 3. | 500x100x100 | 13500 | 5.75 | |

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The flexural strength of 30% replacement at 7 days and 28 days.

*Table 3.18 Flexural strength of 30% replacement for 7 days.*

| Sl.no | Dimension of the beam in mm | Load in (N) | Flexural strength, for in $N/mm^2$ | Average stress in $N/mm^2$ |
|---|---|---|---|---|
| 1. | 500x100x100 | 12000 | 4.71 | 4.92 |
| 2. | 500x100x100 | 12500 | 4.94 | |
| 3. | 500x100x100 | 13500 | 5.39 | |

*Table 3.19 Flexural strength of 30% replacement for 28 days.*

| Sl.no | Dimension of the beam in mm | Load in (N) | Flexural strength, for in $N/mm^2$ | Average stress in $N/mm^2$ |
|---|---|---|---|---|
| 1. | 500x100x100 | 13500 | 5.94 | 5.84 |
| 2. | 500x100x100 | 13000 | 5.61 | |
| 3. | 500x100x100 | 14500 | 6.29 | |

The flexural strength of 40% replacement at 7 days and 28 days.

*Table 3.20 Flexural strength of 40% replacement for 7 days.*

| Sl.no | Dimension of the beam in mm | Load in (N) | Flexural strength, for in $N/mm^2$ | Average stress in $N/mm^2$ |
|---|---|---|---|---|
| 1. | 500x100x100 | 11500 | 4.61 | 4.34 |
| 2. | 500x100x100 | 11000 | 4.25 | |
| 3. | 500x100x100 | 10500 | 4.16 | |

*Table 3.21 Flexural strength of 40% replacement for 28 days.*

| Sl.no | Dimension of the beam in mm | Load in (N) | Flexural strength, for in $N/mm^2$ | Average stress in $N/mm^2$ |
|---|---|---|---|---|
| 1. | 500x100x100 | 12500 | 4.59 | 4.85 |
| 2. | 500x100x100 | 12000 | 4.39 | |
| 3. | 500x100x100 | 13500 | 4.79 | |

*Table 3.22 The average flexural strength graded concrete cubes 7 days, 28 days of curing period.*

| Sl. No | Type of mix | 7 days | 28 days |
|---|---|---|---|
| 1. | Conventional concrete | 4.18 | 4.97 |
| 2. | 10% | 4.31 | 5.21 |
| 3. | 20% | 4.73 | 5.46 |

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| | | | |
|---|---|---|---|
| 4. | 30% | 4.92 | 5.84 |
| 5. | 40% | 4.34 | 4.85 |

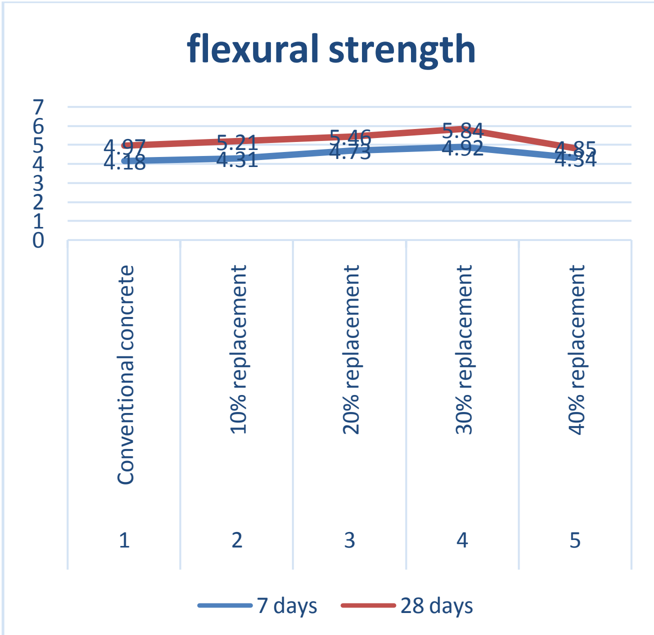


*Fig. 3.2 Flexural Strength of prism*

*Table 3.23 Rabid Chloride Penetration Results*

| **Sl.no** | **Time in Minute** | **Con (mA)** | **C10 (mA)** | **C20 (mA)** | **C30 (mA)** | **C40 (mA)** |
|---|---|---|---|---|---|---|
| 1 | 0 | 4 | 7 | 5 | 4 | 6 |
| 2 | 30 | 6 | 6 | 6 | 5 | 9 |
| 3 | 60 | 5 | 5 | 6 | 4 | 8 |
| 4 | 90 | 7 | 9 | 7 | 5 | 6 |
| 5 | 120 | 8 | 10 | 8 | 4 | 10 |
| 6 | 150 | 8 | 9 | 8 | 6 | 9 |
| 7 | 180 | 8 | 10 | 8 | 5 | 10 |
| 8 | 210 | 8 | 10 | 8 | 5 | 10 |
| 9 | 240 | 6 | 9 | 8 | 5 | 9 |
| 10 | 270 | 7 | 12 | 8 | 6 | 10 |
| 11 | 300 | 8 | 12 | 8 | 6 | 12 |
| 12 | 330 | 8 | 12 | 7 | 7 | 12 |
| 13 | 360 | 8 | 12 | 8 | 7 | 12 |

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*Table 3.24 Chloride Penetration Results*

| Sl.no | Mix designation | Coulombs | Chloride Penetration |
|---|---|---|---|
| 1 | CON | 140.6 | Very Low |
| 2 | S10 | 175.8 | Very Low |
| 3 | S20 | 150.17 | Very Low |
| 4 | S30 | 143.7 | Very Low |
| 5 | S40 | 167.3 | Very Low |

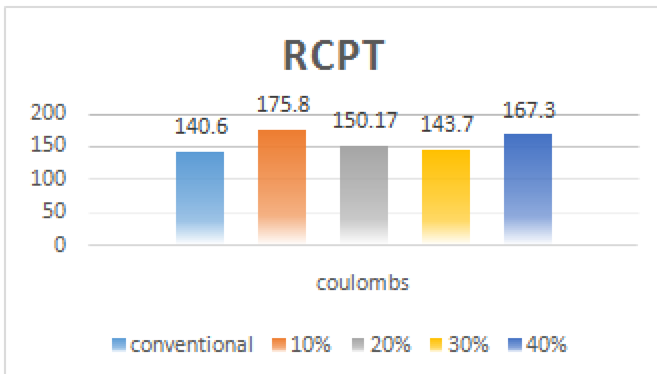


*Fig.3.3 Chloride penetration test*

## IV. CONCLUSION

In this work an attempt was made to replace fine aggregate by steel slag partially, various parameters such as Compressive strength, E for concrete, flexural strength, rapid chloride penetration and sorptivity were experimentally investigated for proportions such as 20%, 30%,40% & 50% and the following conclusions were made and was listed below,

- The compressive strength when compared with control mix for 10% replacement was 10.5% higher similarly for 20% it was 11.7%, for 30% it was 12.2% and for 40% it was 9.3%, Among these various replacement 30% steel slag gives maximum strength, so 30% replacement was optimum for compressive strength.
- The flexural strength when compared with control mix gave better results for all replacements except for 40% steel slag replacement. For 10% replacement it was 10.2% higher than control mix similarly for 20% it was 10.9% and for 30% it was 11.7% but for 40% replacement it was 9.7% lower than control mix, so 30% replacement was optimum for flexural strength.
- From stress strain graph the modulus of elasticity for various replacement were found and compared with conventional concrete. For 10% replacement it was 1.16% higher than control mix for 20% it was 1.19% for 30% it was 1.25% and for 40% it was 1.09% lower than control mix. Thus indicates that 30% replacement gave higher modulus of elasticity
- The RCPT has gained wide acceptance as a relatively easy and quick test method. The use of steel slag and proper curing will significantly reduce the chloride permeability, particularly at concrete ages past 28 days and this longer time to achieve the desired qualities should not be overlooked. If the limitations inherent to RCPT are understood, this test can be used for a wide range of applications, testing and quality control purposes. All replacements including control mix gave low chloride ion permeability, but 30% replacement gave very low chloride ion permeability.
- The water absorption of conventional concrete was found to be 0.855, for 10% it was 0.983, for 20% it was 0.914, for 30% it was 0.764 and for 40% it was 0.869.

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