**TO STUDY THE STRENGTH CHARACTERISTICS OF HIGH STRENGTH CONCRETE USING IRON SLAG AS PARTIAL REPLACEMENT OF CEMENT**

***In partial fulfillment for the award of the degree***

***Of***

**Masters of Technology**

**In**

**CIVIL ENGINEERING**


**Under The Guidance of**

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# CERTIFICATE

This is to certify that the declaration statement made by myself is correct to the best of my knowledge and belief. The Thesis Project ***"Partial Replacement of Cement with Iron Slag in High Strength Concrete)"*** is based on the technology / tool learnt and is fit for the submission and partial fulfillment of the conditions for the award of Masters of technology in Civil Engineering from Lovely Professional University, Phagwara.

| | |
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# ABSTRACT

The report introduces the studies and experiments done on the High Strength Concrete (HSC). Concrete is basically a mixture of cement, fine aggregates, coarse aggregates and water. Now a days, development of infrastructure are only possible with the help of concrete because concrete is needed in every type of construction like industries, buildings, highways and bridges. Due to increase in the construction, it leads to the utilization of large quantity of concrete. In any construction work, our main should be on strength as well as it should be economical. So, to increase the strength and performance of concrete, admixtures can be used but on the other side, the cost of concrete increases. So, to meet our requirements, some experiments and investigation are done.

In the present study, the main focus is on evaluating the mechanical properties of high strength concrete, prepared by partial replacement of cement with iron slag powder. Another reason to replace cement is that production of cement emits large amount of carbon dioxide gas into the atmosphere which leads to global warming. Hence, to reduce the use of cement, replacement of cement is to be done with iron slag powder, so that the strength and performance of concrete increases. For replacement, iron Slag is used because its specific gravity is almost similar to the cement. Iron slag also acts as a binding material in the concrete and economical to use. There is less heat of hydration in case of iron slag powder.

The cement has been replaced by weight with iron slag powder at different percentages like 6%, 9%, 12%, 18%, 24%, 36% and 48%. It is observed that optimum compressive strength is obtained at 12% replacement of cement with iron slag powder i.e. Hence iron slag powder can be used as one of the alternative material for cement but up to the certain limit only.

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| | |
|---|---|
| HSC | High Performance Concrete |
| $CO_2$ | Carbon-dioxide |
| CaO | Calcium Oxide |
| GGBS | Ground Granulated Blast Furnace Slag |
| OPC | Ordinary Portland Cement |
| $m^2/kg$ | metre square per kilo gram |
| min. | minute |
| hr | hour |
| $N/mm^2$ | Newton per millimetre square |
| % | Percentage |
| mm | millimetre |
| IS | Indian Standard |
| m | metre |
| WPC | White Portland Cement |
| ASTM | American Society for Testing and Materials |
| MgSO4 | Magnesium Sulphate |
| CTM | Compression Testing Machine |
| gm | kilogram |
| P | Standard Consistency |
| KN | Kilo newton |
| N | Newton |
| MPa | Mega Pascal |
| Sr.No. | Serial Number |
| ml | Milliliter |
| dia. | diameter |
| rpm | revolutions per minute |
| s | Standard Deviation |
| $kg/m^3$ | Kilogram per metre cube |
| $m^3$ | metre cube |
| kg | Kilogram |
| F.A | Fine Aggregate |

| | |
|---|---|
| C.A | Coarse Aggregate |
| R.C.C | Reinforced Cement Concrete |
| W/C | Water Cement Ratio |
| H.W | High Workable |
| M.W | Medium Workable |
| L.W | Low Workable |

# CHAPTER 1

# INTRODUCTION

## 1.1 High Strength Concrete

High strength concrete (HSC) may be defined as concrete with a specified characteristic cube strength between 50 and 100 MPa, although higher strengths have been achieved and used. In the 1970's, any concrete mixtures that showed 40 MPa or more compressive strength at 28-days were designed as high-strength concrete. Later, 50-100 MPa concrete mixtures were commercially developed.

**Table 1.1 Typical classification of strength**

| | |
|---|---|
| Normal Strength | 20-50 Mpa |
| High Strength | 50-100 Mpa |
| Ultra High Strength | 100-150 Mpa |
| Especial | >150 Mpa |

The main applications for HSC in-situ concrete construction are in offshore structures, columns for tall buildings, long-span bridges and other highway structures. For example the bridge constructed in Joigny used concrete with 60 MPa instead of concrete with 35 MPa. By using 60 MPa instead of 35 MPa the volume of concrete is reduced by 30%. PETRONAS Towers in Kuala Lumpur (Malaysia) which is about 450 m high used 40-80 MPa concrete.

The properties of a high-strength concrete-mix with a compressive strength of more than 40 MPa are greatly influenced by the properties of aggregates in addition to that of the water-cement ratio. To achieve high strength, it is necessary to use lowest possible water-cement ratio, which invariably affects the workability of the mix and necessitates the use of special vibration techniques for proper compaction. In the present state of art, a concrete with a desired 28 day compressive strength of up to 70 MPa can be made with suitably proportioning the ingredients using normal vibration techniques for compacting the concrete mix. The methods and technology for producing high strength concrete are not substantially different from those required for normal strength concrete. The target water/cement ratio should be in the range 0.30–0.36 or even lower.

The terms "High performance concrete" and "High strength concrete" are often taken to mean the same thing. However, as indicated, "High performance" strictly relates to a concrete that has been designed to have good specific characteristics.

## 1.2 Blast Furnace Iron Slag

Blast furnaces slag is a solid waste discharged in large quantities by the iron and steel industry in India. The re-cycling of these slag will become an important measure for the environmental protection. Iron and steel are basic materials that underpin modern civilization, and due to many years of research the slag that is generated as a by-product in iron and steel production is now in use as a material in its own right in various sectors. Slag enjoys stable quality and proper-ties that are difficult to obtain from natural materials and in the 21st century is gaining increasing attention as an environ-mentally friendly material from the perspectives of resource saving, energy conservation and CO2 reduction. The primary constituents of slag are lime (CaO) and silica (SiO2). Portland cement also contains these constituents. The primary constituent of slag is soluble in water and exhibits an alkalinity like that of cement or concrete. And as it is removed at high temperatures of 1,200°C and greater, it contains no organic matter whatsoever. Ground Granulated Blast furnace slag (GGBS) is a by-product for manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. Here the molten slag is produced which is instantaneously tapped and quenched by water. This rapid quenching of molten slag facilitates formation of “Granulated slag”. Ground Granulated Blast furnace Slag (GGBS) is processed from Granulated slag. If slag is properly processed then it develops hydraulic property and it can effectively be used as a pozzolanic material. However, if slag is slowly air cooled then it is hydraulically inert and such crystallized slag cannot be used as pozzolanic material. Though the use of GGBS in the form of Portland slag cement is not uncommon in India, experience of using GGBS as partial replacement of cement in concrete in India is scanty. GGBS essentially consists of silicates and alumina silicates of calcium and other bases that are developed in a molten condition simultaneously with iron in a blast furnace. The chemical composition of oxides in GGBS is similar to that of Portland cement but the proportion varies.

This report deals with the use of the blast furnace slag powder as a partial replacement of OPC and its effect on strength of cement concrete mix.

## 1.3 Objective Of Research

In the present study, the effect of addition of different percentages of Iron slag in concrete on mechanical properties and durability of concrete are examined. In all concrete mixes (except control mix) till 48 percent iron slag is added at replacement of cement by weight. The objectives of the work are as under.

1) To study the effect of addition of Iron slag on compressive strength of concrete.

2) To study the effect of addition of Iron slag on splitting tensile strength of concrete

3). To study the effect of addition of Iron slag on Flexural strength of concrete

4) To study the effect of addition of Iron slag on curing of concrete in MgSo4

## 1.4 Orientation Of Thesis

The thesis report consists of Six chapters:

Chapter 1- Provides introduction about High strength concrete and Iron slag, their properties, applications etc.

Chapter 2- Deals with the study of various researchers on Iron slag and HSC and their effect on different mechanical as well as durability properties.

Chapter 3- Deals with the scope and objectives of the study.

Chapter 4- Details the scheme of experimentation, materials used and variables involved. Information about concrete mix designs is also illustrated in this chapter.

Chapter 5- Presents the results, and their analysis for the strength properties such as compressive strength, splitting tensile strength, and durability property such as curing of concrete cubes in $MgSO_4$.

Chapter 6- Summarizes and concludes the findings of the study. Few recommendations for further studies are also discussed

## 1.5 Summary

This chapter discussed about the (i) HSC, properties, applications of Iron slag in civil engineering work, (iii) objective of thesis and (iv) orientation of thesis.

# CHAPTER 2

## REVIEW OF LITERATURE

### 2.1 Preliminary Remarks

Slag is a by-product generated during manufacturing of pig iron and steel. It is produced by action of various fluxes upon gangue materials within the iron ore during the process of pig iron manufacturing in blast furnace and steel manufacturing in steel melting shop. Primarily, the slag consists of calcium, magnesium, manganese and aluminum silicates in various combinations. The cooling process of slag is responsible mainly for generating different types of slags required for various end-use consumers. Although the chemical composition of slag may remain unchanged, physical properties vary widely with the changing process of cooling. The primary constituent of slag is soluble in water and exhibits an alkalinity like that of cement or concrete. And as it is removed at high temperatures of 1,200°C and greater, it contains no organic matter whatsoever. Ground Granulated Blast furnace slag (GGBS) is a by-product for manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. Here the molten slag is produced which is instantaneously tapped and quenched by water. This rapid quenching of molten slag facilitates formation of “Granulated slag”. Ground Granulated Blast furnace Slag (GGBS) is processed from Granulated slag. If slag is properly processed then it develops hydraulic property and it can effectively be used as a pozzolanic material. However, if slag is slowly air cooled then it is hydraulically inert and such crystallized slag cannot be used as pozzolanic material. Though the use of GGBS in the form of Portland slag cement is not uncommon in India, experience of using GGBS as partial replacement of cement in concrete in India is scanty. GGBS essentially consists of silicates and alumina silicates of calcium and other bases that are developed in a molten condition simultaneously with iron in a blast furnace. The chemical composition of oxides in GGBS is similar to that of Portland cement but the proportion varies.

## 2.2 Mechanical Properties

### 2.2.1 Compressive strength

**Khajuria et al. (2014)** investigated the compressive strength of concrete. Test specimen of standard size 150*150*150mm with varying percentage at 0,10,20,30 of iron slag as partial replacement of fine sand to check the compressive strength developed in concrete at 7,28,56 days respectively. In which cement has used OPC 43 grade and the properties of cement is given below in table no. 2.5 and water cement ratio was 0.5

**Table 2.1 Experimental properties of cement (Khajuria et al.,2014)**

| Sr No. | Characteristics | Values obtained experimentally |
|---|---|---|
| 1 | Specific gravity | 3.12 |
| 2 | Standard consistency, percent | 29 |
| 3 | Initial setting time, minutes | 155 |
| 4 | Final setting time, minutes | 337 |
| 5 | Compressive strength<br>3 days<br>7 days<br>28 days | <br>23.8 N/mm²<br>35.3 N/mm²<br>46.7 N/mm² |

**Table 2.2 Compressive strength of concrete mixes of specimen size 150*150*150 with iron slag (Khajuria et al. ,2014)**

| Mix | compressive strength (N/mm²) | | | Average compressive strength (N/mm²) | | |
|---|---|---|---|---|---|---|
| | 7 days | 28 days | 56 days | 7 days | 28 days | 56 days |
| CM | 20.58 | 25.79 | 32.55 | 19.75 | 26.09 | 32.05 |
| | 20.54 | 26.12 | 33.87 | | | |
| | 18.13 | 26.36 | 29.74 | | | |
| 10% | 27.7 | 37.88 | 45.87 | 25.02 | 39.33 | 46.06 |
| | 24.25 | 39.68 | 45.06 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 23.13 | 40.44 | 46.60 | | | |
| 20% | 35.21 | 51.86 | 59.15 | 33.52 | 49.90 | 57.07 |
| | 31.65 | 49.55 | 54.31 | | | |
| | 33.71 | 48.31 | 57.77 | | | |
| 30% | 45.15 | 56.40 | 57.55 | 44.44 | 55.68 | 60.21 |
| | 41.84 | 57.37 | 62.13 | | | |
| | 46.35 | 53.28 | 60.97 | | | |

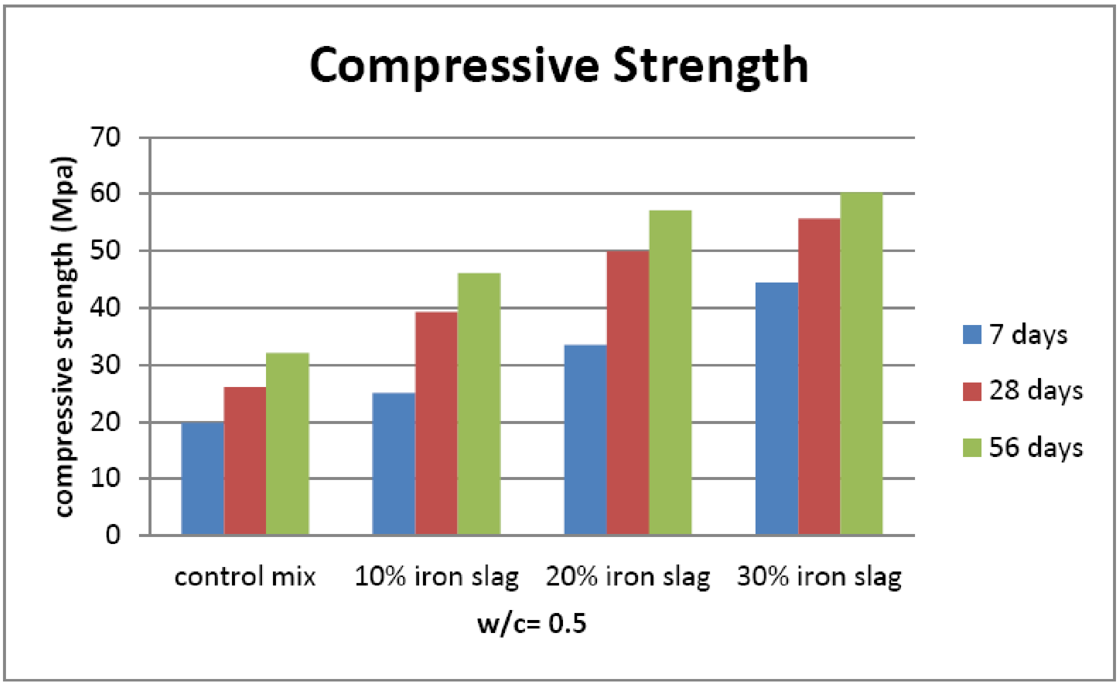



**Fig 2.1 Compressive strength of iron slag concrete (Khajuria et al. ,2014)**

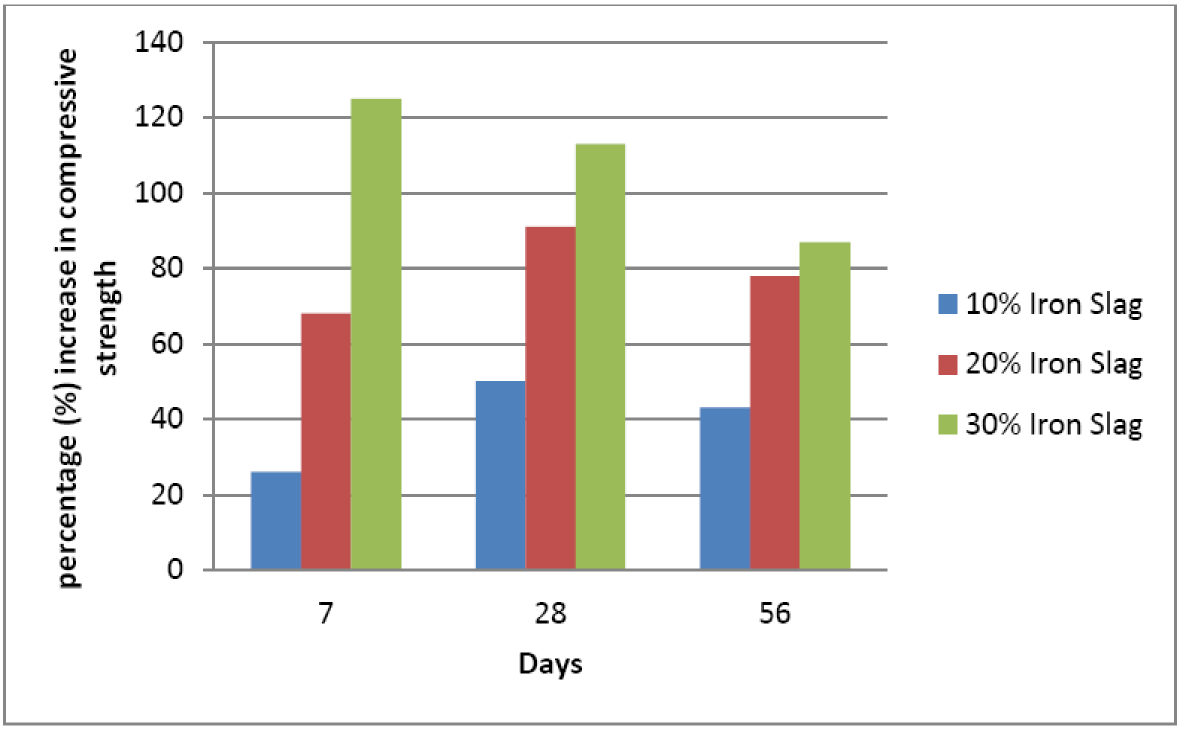



**Fig 2.2 Percentage increase in compressive strength of iron slag concrete (Khajuria et al. ,2014)**

After this investigation it is observed that after adding 10% iron slag in the mix, there was an increase of 26% after 7 days, 50% increase after 28 days and 43% increase after 56 days as compared to the control mix. By adding 20% and 30% iron slag , there was large amount of increase in percentage i.e. 68%, 91%, 78% and 125%, 113% , 87% after 7, 28 and 56 days respectively. The result is as shown in the table 2.6

**Arivalagan (2014)** Investigated the compressive strength of concrete. The compressive strength was founded at 7, 28 days .the specimens were casted according to IS: 516-1959. In which cement is used OPC 43 grade with specific gravity 3.11 Locally available river sand conforming to Grading zone II of IS: 383 1970 . The mix ratio used 1:1.6:2.907:0.41 which gave good result compared to control mix.

**Table 2.3 Mix proportions of concrete with various proportions of GGBS replacing cement in M35 grade concrete (Arivalagan ,2014)**

| Mix proptions | Controlled concrete | 20% GGBS | 30% GGBS | 40% GGBS |
|---|---|---|---|---|
| W/C ratio | 0.41 | 0.41 | 0.41 | 0.41 |

| | | | | |
|---|---|---|---|---|
| GGBS content | | 20 | 30 | 40 |
| GGBS content (wt) | | 0.8 | 1.2 Kg | 1.6 Kg |
| Cement content | 4 Kg | 3.2 Kg | 2.8 Kg | 2.8 Kg |
| Sand content | 5.186 Kg | 5.186 Kg | 5.186 Kg | 5.186 Kg |
| Sand content with bulking | 6.979 Kg | 6.979 Kg | 6.979 Kg | 6.979 Kg |
| Course aggregate | 10.216 Kg | 10.216 Kg | 10.216 Kg | 10.216 Kg |
| Water content | 2.00 Kg | 1.942 Kg | 1.948 Kg | 2.006 Kg |

**Table 2.4 Compressive strength at 7, 28 day with various proportions of GGBS replacing cement in M35 grade concrete (Arivalagan ,2014)**

| Type of concrete | Compressive strength at 7 days | Compressive strength at 28 days |
|---|---|---|
| Control concrete | 24.32 | 35.68 |
| 20% GGBS | 20.45 | 36.00 |
| 30% GGBS | 19.56 | 33.77 |
| 40% GGBS | 18.67 | 31.11 |

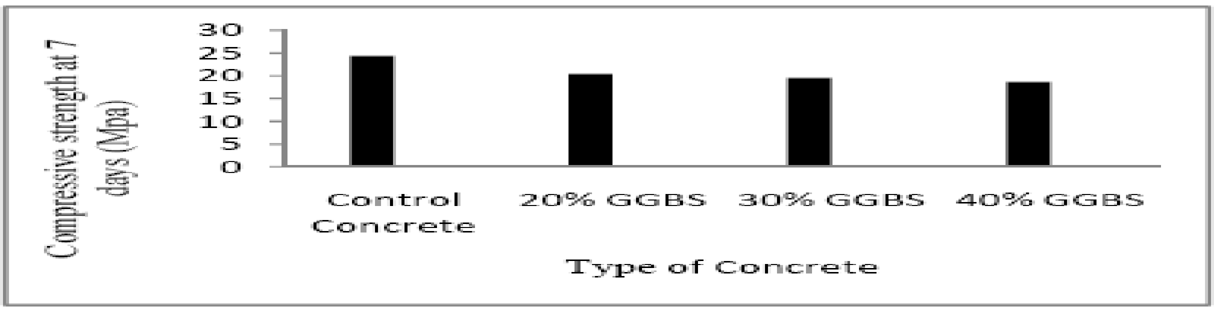


**Fig 2.3 Compressive strength at 7 days (Arivalagan ,2014)**

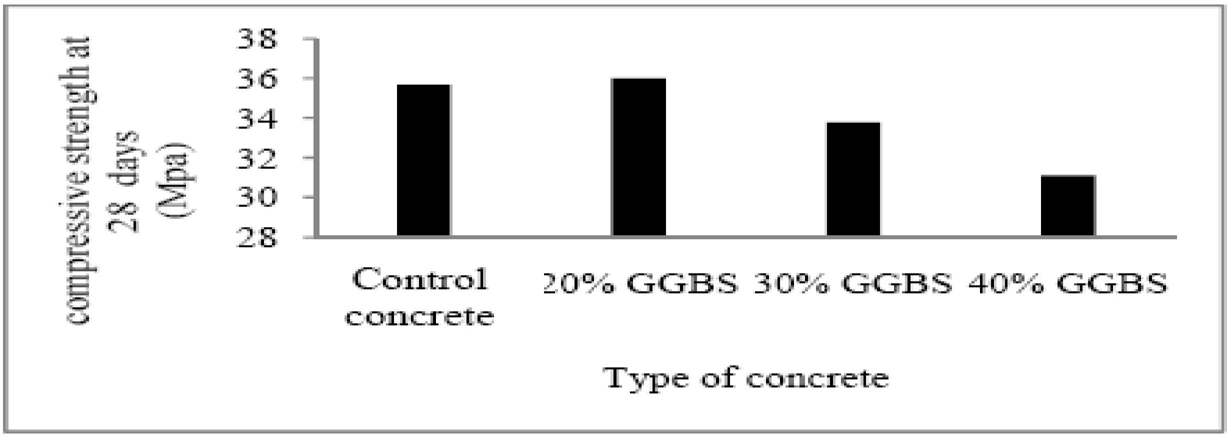



**Fig 2.4- Compressive strength at 28 days (MPa) (Arivalaga ,2014)**

Based on the experimental investigation, the following conclusions can be drawn: In this investigation it is observed that GGBS-based concretes have achieved an increase in strength for 20% replacement of cement at the age of 28 days. Increasing strength is due to filler effect of GGBS. The degree of workability of concrete was normal with the addition of GGBS up to 40% replacement level for M35 grade concrete. From the above experimental results, it is proved that GGBS can be used as an alternative material for cement, reducing cement consumption and reducing the cost of construction. Use of industrial waste products saves the environment and conserves natural resources

**Kaur et al. (2011)** Investigated compressive strength of concrete at different temperature. This paper deals with the mechanical properties of concrete made with ground granulated blast furnace slag (GGBFS) subjected to temperatures up to 350 _C. For this purpose, normal concrete having compressive strength of 34 MPa was designed using GGBFS as partial replacement of cement. Cylindrical specimens (150 · 300 mm) were made and subjected to temperatures of 100, 200 and 350 _C. Measurements were taken for mass loss, compressive strength, splitting tensile strength, and modulus of elasticity. This investigation developed some important data on the properties of concrete exposed to elevated temperatures up to 350 _C. In which OPC 53 grade cement has used and the properties of cement are given in Table no-2.7.

**Table 2.5 Experimental properties of cement (Kaur et al.,2011)**

| Sr No. | Characteristics | Values obtained experimentally |
|---|---|---|
| 1 | Specific gravity | 3.10 |
| 2 | Standard consistency, percent | 34 |
| 3 | Initial setting time, minutes | 48 |
| 4 | Final setting time, minutes | 240 |
| 5 | Compressive strength<br>3 days<br>7 days<br>28 days | <br>15.9 N/mm²<br>21.9 N/mm²<br>34.5 N/mm² |

**Table 2.6 Mix proportions of concrete with various proportions of GGBS replacing cement (Kaur et al.,2011)**

| Mix proptions | M-0 | M-1 | M-2 | M-3 |
|---|---|---|---|---|
| Cement content ($Kg/m^3$) | 450 | 360 | 270 | 180 |
| GGBFS ($Kg/m^3$) | 0 | 90 | 180 | 270 |
| Sand content ($Kg/m^3$) | 482 | 482 | 482 | 482 |
| Plasticizer ($1/m^3$) | 4.95 | 4.95 | 4.95 | 4.95 |
| Course aggregate ($Kg/m^3$) | 1040 | 1040 | 1040 | 1040 |
| Water content ($1/m^3$) | 203 | 203 | 203 | 203 |

| | | | | |
|---|---|---|---|---|
| Slump (mm) | 100 | 90 | 85 | 75 |

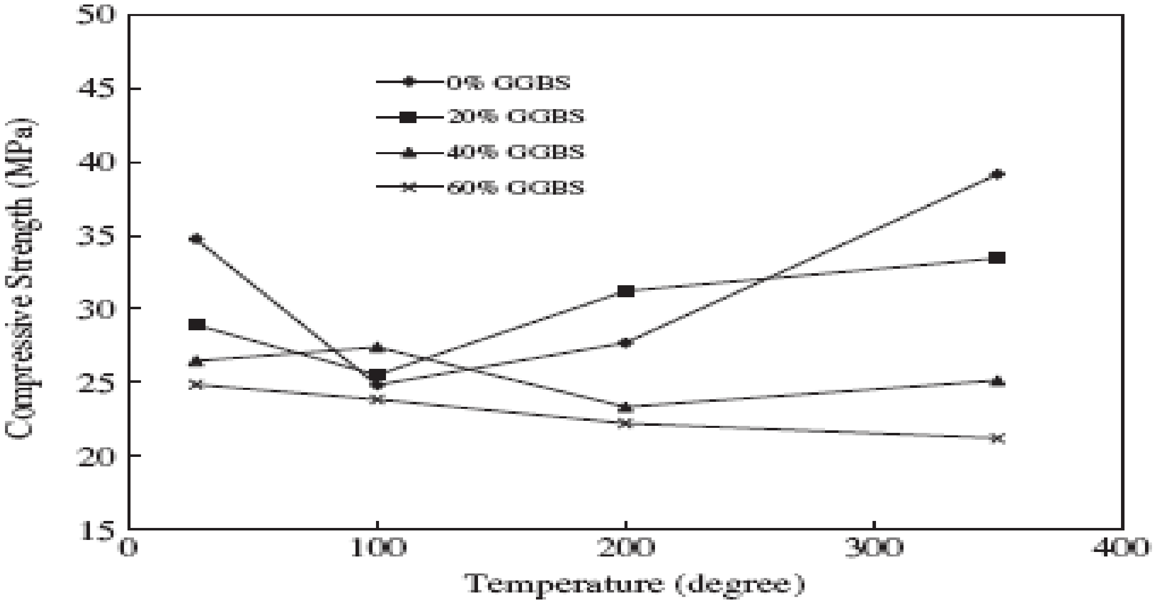



**Fig 2.5 Effect of temperature on the compressive strength of concrete at 28 days (Kaur et al.,2011)**

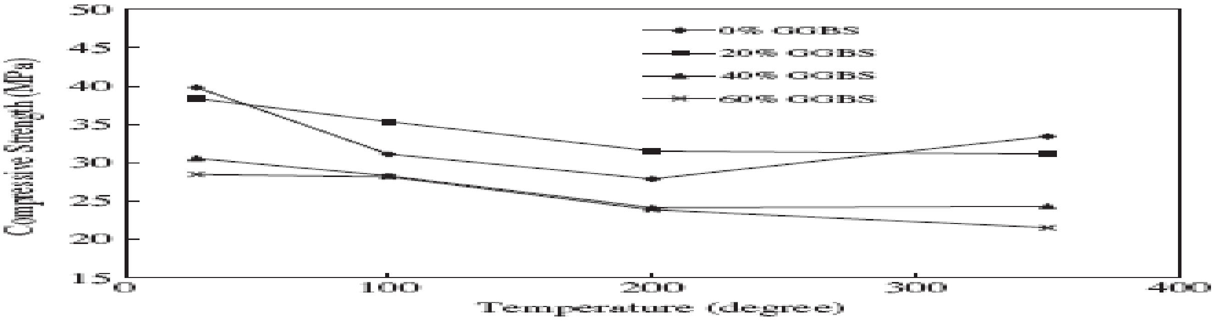



**Fig 2.6- Effect of temperature on the compressive strength of concrete at 56 days (Kaur et al.,2011)**

The result was evident that the compressive strength of concrete mixture increase with decrease in GGBS and vice-versa at normal temperature (27 degree C). Concrete containing 20%, 40% and 60% GGBS having compressive strength 16.8%, 23.8% and 28.5% lower than the control concrete mixture. The results shown in the fig 2.8 and 2.9

**Ismail and Hashmi et al. (2007)** Investigated the flexural strength with 10%,15% and 20% waste iron slag at curing period 3,7,14and 28 days .In which 87 prisms were casted to check the flexural strength of concrete and Type 1 OPC cement was used in which physical properties of the cement is discussed below in table.

**Table 2.7 Experimental properties of cement (Ismail and Hashmi et al.,2007)**

| Sr No. | Characteristics | Values obtained experimentally |
|---|---|---|
| 1 | Specific gravity | 3.12 |
| 2 | Standard consistency, percent | 34 |
| 3 | Initial setting time, minutes | 3.20 |
| 4 | Final setting time, Hours | 4.15 |
| 5 | Compressive strength<br>3 days<br>7 days | <br>24.96 N/mm²<br>30.80 N/mm² |

**Table 2.8 Increment (+) and decrement (-) (%) in compressive strength of waste iron slag concrete mix (Ismail and Hashmi et al.,2007)**

| % waste iron aggregate | Compressive strength 3 days | Compressive strength 7 days | Compressive strength 14 days | Compressive strength 28 days |
|---|---|---|---|---|
| 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10 | 8.20 | 11.43 | -6.60 | -1.08 |
| 15 | 15.20 | 14.90 | 2.97 | 12.95 |
| 20 | 22.60 | 15.90 | -0.46 | 17.40 |

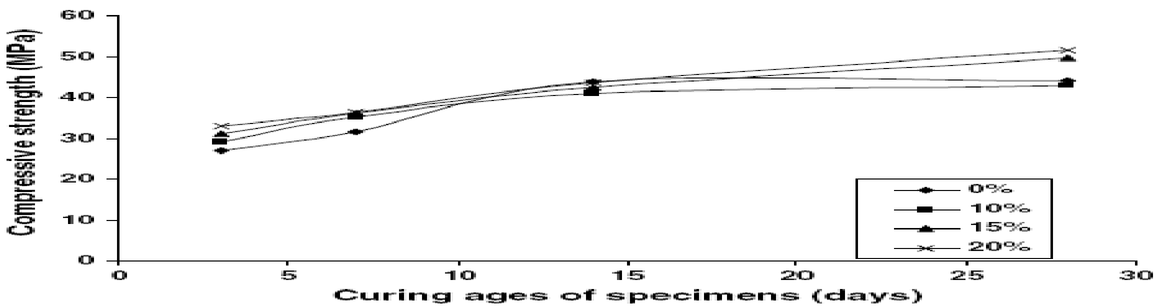



**Fig 2.7 Compressive strength of waste iron slag concrete mix (Ismail and Hashmi et al. ,2007)**

The test perform was slump test, compressive strength and flexural strength. The curing period was 3,7,14 and 28 days for testing compressive strength of waste iron slag .With 20% waste iron slag have highest compressive strength of 51.64MPa at curing of 28 days which was 17.4% more than reference specimen

**Dubey et al. (2007)** studied the compressive strength of concrete with blast furnace slag powder as partial replacement of cement 5 to 30%. Compressive strength of blast furnace slag concrete with different dosage of slag was studied as a partial replacement of cement. Test was conducted to check the strength developed in cement concrete mix, contain various percentage of iron slag powder and test at 7, 14, 28 days respectively. Standard size cubes were made 150mmx150mmx150mm and Cement used: OPC 43 grade ,W/ c Ratio: 0.5% Cement: Fine Aggregate: coarse aggregate proportion used: 1: 1.67:3.2

**Table 2.9 Mix specification for 1m³ concrete (Dubey et al.,2007)**

| particulars | Plain | 5%BFSP | 10%BFSP | 15%BFSP | 20%BFSP | 25%BFSP | 30%BFSP |
|---|---|---|---|---|---|---|---|
| Cement in Kg/m³ | 380 | 361 | 342 | 323 | 304 | 285 | 266 |
| Sand in Kg/m³ | 635 | 635 | 635 | 635 | 635 | 635 | 635 |
| C.A in Kg/m³ | 1216 | 1216 | 1216 | 1216 | 1216 | 1216 | 1216 |
| Blast | 0 | 19 | 38 | 57 | 76 | 95 | 114 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| furnace slag in kg/m³ | | | | | | | |
| Water in Kg/m³ | 190 | 190 | 190 | 190 | 190 | 190 | 190 |

**Table 2.10 Compressive strength test result in N/mm$^2$ (Dubey et al.,2007)**

| Mix description | Plain | 5 BFSP | 10 BFSP | 15 BFSP | 20 BFSP | 25 BFSP | 30 BFSP |
|---|---|---|---|---|---|---|---|
| % replaced | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
| 7 Days | 21.03 | 20.74 | 20.44 | 19.85 | 18.07 | 16.88 | 15.40 |
| 14 Days | 23.70 | 22.81 | 22.66 | 22.36 | 19.55 | 18.51 | 16.74 |
| 28 Days | 26.9 | 25.00 | 24.59 | 24.29 | 20.88 | 20.74 | 18.81 |

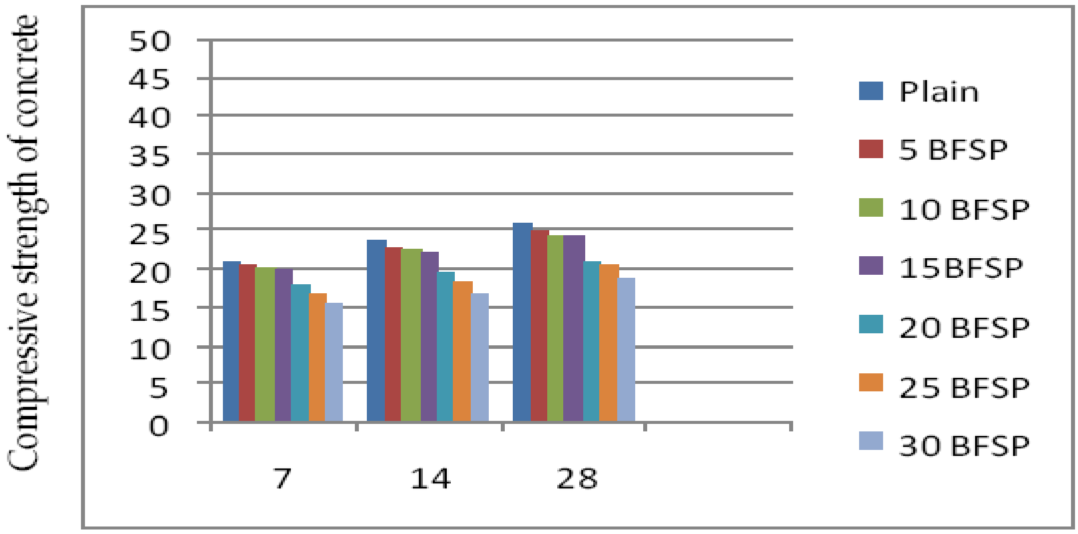


**Fig 2.8 Compressive strength of concrete with replacement of cement by iron slag at 7, 14, 28 days (Dubey et al. , 2007)**

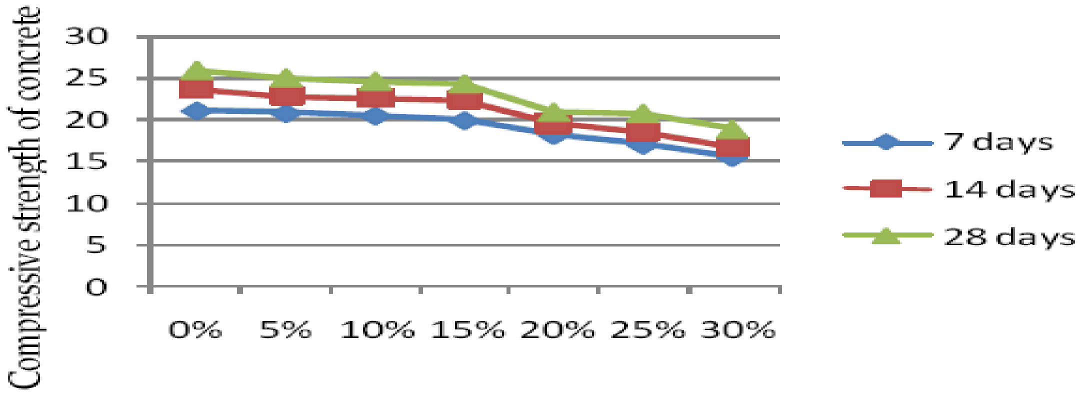



**Fig 2.9 Percentage of iron slag (Dubey et al. , 2007)**

The variation of compressive strength of concrete mix with different proportion of blast furnace slag powder as partial re- placement of cement is shown in fig2.1 and fig2.2 It was observed that 7 days, 14 days and 28 days compressive strength on 30% replacement of cement reduces about 30% that is from 21.03 N/mm2 to 15.40N/mm2, 23.70 N/mm2to 16.74 N/mm2.and 26.9 N/mm2to18.81 N/mm2 respectively. From study it can be con- cluded that as the % of BFSP increase, the strength tends to de- crease.

### 2.2.2 Split tensile strength

**Khajuria et al. (2014)** investigated the split tensile strength of concrete with varying percentage at 0,10,20,30 of iron slag as partial replacement of fine sand to check the compressive strength developed in concrete at 7,28,56 days respectively. In which cement has used OPC 43 grade and the properties of cement is given below in table no. 2.5 and water cement ratio was 0.5.

**Table 2.11 Experimental properties of cement (Khajuria et al.,2014)**

| Sr No. | Characteristics | Values obtained experimentally |
|---|---|---|

| | | |
|---|---|---|
| 1 | Specific gravity | 3.12 |
| 2 | Standard consistency, percent | 29 |
| 3 | Initial setting time, minutes | 155 |
| 4 | Final setting time, minutes | 337 |
| 5 | Compressive strength<br>3 days<br>7 days<br>28 days | <br>23.8 N/mm²<br>35.3 N/mm²<br>46.7 N/mm² |

**Table 2.12 Splitting tensile strength of concrete mix with iron slag (Khajuria et al. ,2014)**

| Mix | Splitting tensile strength ($N/mm^2$) | | | Average splitting tensile strength ($N/mm^2$) | | |
|---|---|---|---|---|---|---|
| | 7 days | 28 days | 56 days | 7 days | 28 days | 56 days |
| CM | 1.24 | 2.38 | 2.35 | 1.45 | 2.27 | 2.41 |
| | 1.40 | 2.17 | 2.46 | | | |
| | 1.70 | 2.28 | 2.42 | | | |
| 10% | 1.90 | 2.53 | 2.60 | 1.80 | 2.48 | 3.03 |
| | 1.80 | 2.46 | 3.45 | | | |
| | 1.99 | 2.47 | 3.04 | | | |
| 20% | 1.97 | 2.68 | 3.45 | 2.00 | 2.72 | 3.52 |
| | 2.04 | 2.77 | 3.57 | | | |
| | 2.01 | 2.72 | 3.55 | | | |
| 30% | 2.02 | 2.82 | 3.55 | 2.04 | 2.85 | 3.13 |
| | 2.06 | 2.85 | 2.64 | | | |
| | 2.04 | 2.89 | 3.20 | | | |

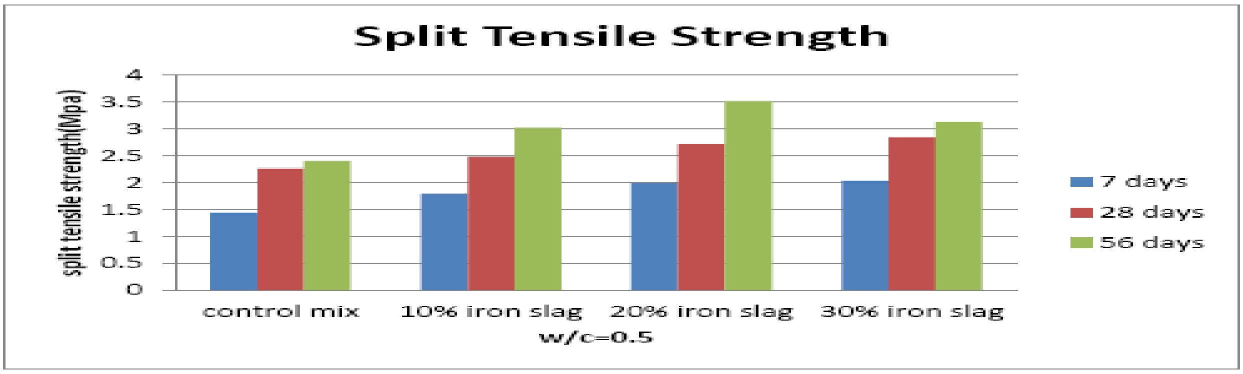



**Fig 2.10- Split tensile strength of iron slag concrete (Khajuria et al. ,2014)**

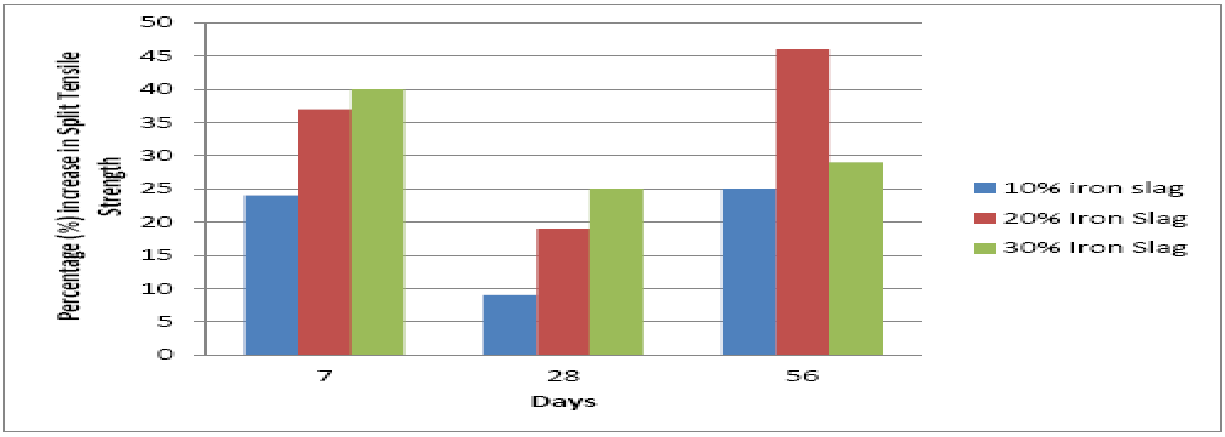



**Fig 2.11 Percentage increase in split tensile strength of iron slag concrete (Khajuria et al. ,2014)**

After investigation of spilt tensile strength. The split tensile strength was increase with increase in percentage of iron slag. After adding 10%,20% and 30% iron slag in concrete mix there was increase of 24%,9% and 25% at 10% ,37%,19% and 46% at 20% and 40%,25%,29% at 30% increase after 7,28 and 56 days respectively.

**Arivalagan (2014)** Investigated the split tensile strength of concrete. The compressive strength was founded at 7, 28 days .the specimens were casted according to IS: 516-1959. In which cement is used OPC 43 grade with specific gravity 3.11 Locally available river sand conforming to Grading zone II of IS: 383 1970. The mix ratio used 1:1.6:2.907:0.41 which gave good result compared to control mix.

**Table 2.13 Mix proportions of concrete with various proportions of GGBS replacing cement in M35 grade concrete (Arivalaga ,2014)**

| Mix proptions | Controlled cocrete | 20% GGBS | 30% GGBS | 40% GGBS |
|---|---|---|---|---|
| W/C ratio | 0.41 | 0.41 | 0.41 | 0.41 |
| GGBS content | | 20 | 30 | 40 |
| GGBS content (wt) | | 0.8 | 1.2 Kg | 1.6 Kg |
| Cement content | 4 Kg | 3.2 Kg | 2.8 Kg | 2.8 Kg |
| Sand content | 5.186 Kg | 5.186 Kg | 5.186 Kg | 5.186 Kg |
| Sand content with bulking | 6.979 Kg | 6.979 Kg | 6.979 Kg | 6.979 Kg |
| Course aggregate | 10.216 Kg | 10.216 Kg | 10.216 Kg | 10.216 Kg |
| Water content | 2.00 Kg | 1.942 Kg | 1.948 Kg | 2.006 Kg |

**Table 2.14 Split tensile strength (Arivalagan, 2014)**

| Type of concrete and mix proportions | Days of curing | Split tensile strength ($N/mm^2$) |
|---|---|---|
| Control concrete | 7 | 4.95 |
| M35-20 | 7 | 4.87 |
| M35-30 | 7 | 4.78 |
| M35-40 | 7 | 4.70 |
| Control concrete | 28 | 5.15 |
| M35-20 | 28 | 5.13 |
| M35-30 | 28 | 5.02 |
| M35-40 | 28 | 4.98 |

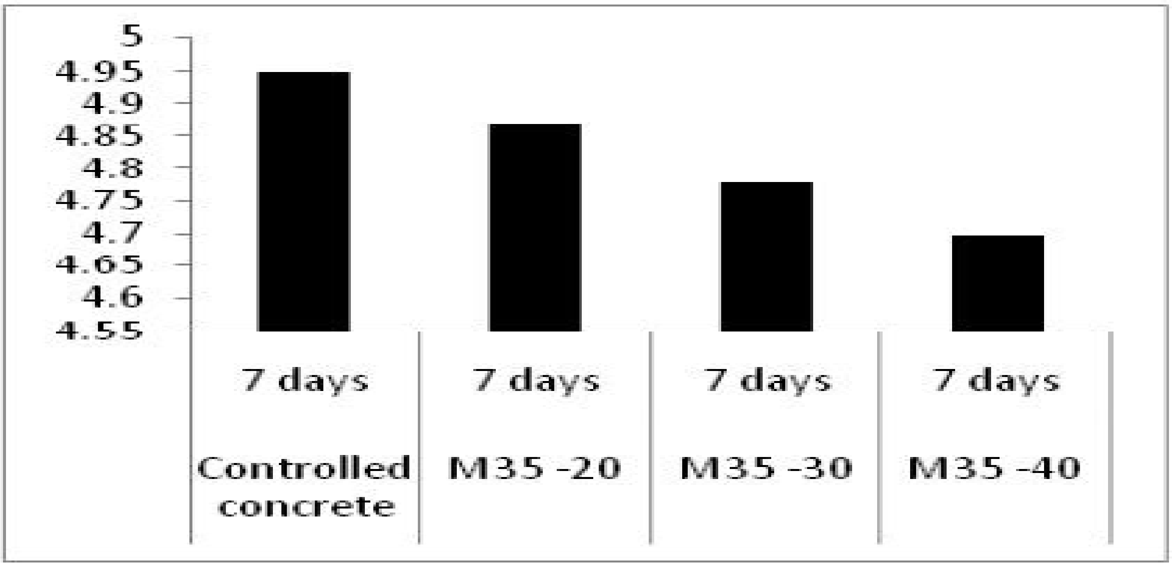



**Fig 2.12 Split tensile strength at 7 days Arivalagan, 2014)**

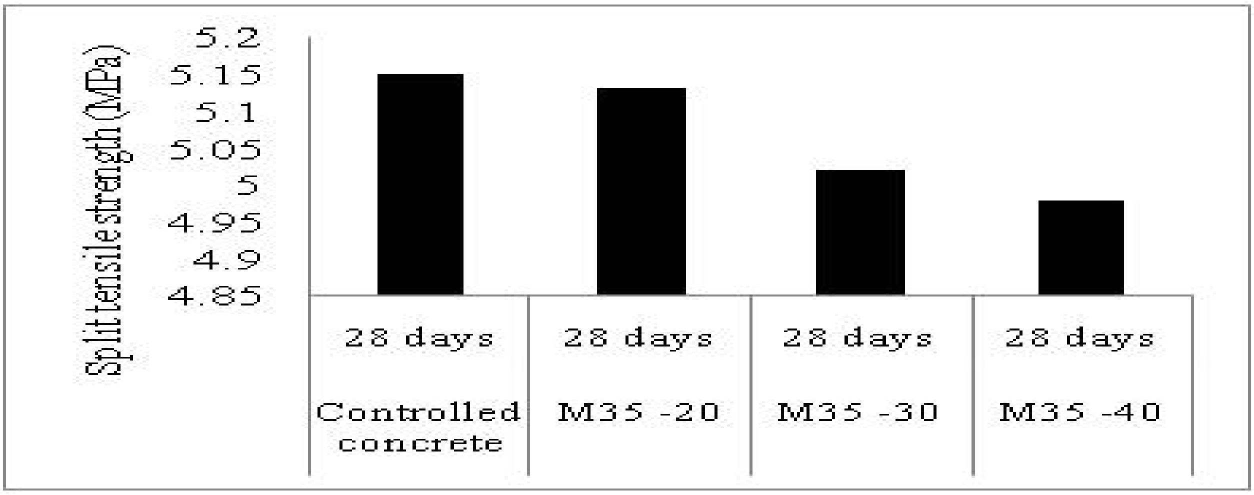



**Fig 2.13 Split tensile strength at 28 days (Arivalagan, 2014)**

After investigation, it is observed that concrete with the GGBS as a replacement material in concrete. The split tensile test was tested according to the IS: 5816-1976 .The split tensile strength of 5.20 N/mm$^2$ was achieved by 20% replacement of cement. The result shown in the table 2.11.

**Kaur and Siddique et al., (2011)** Investigated split tensile strength of concrete at different temperature. This paper deals with the mechanical properties of concrete made with ground granulated blast furnace slag (GGBFS) subjected to temperatures up to 350 _C. For this purpose, normal concrete having compressive strength of 34 MPa was designed using

GGBFS as partial replacement of cement. Cylindrical specimens (150 · 300 mm) were made and subjected to temperatures of 100, 200 and 350 _C. Measurements were taken for mass loss, compressive strength, splitting tensile strength, and modulus of elasticity. This investigation developed some important data on the properties of concrete exposed to elevated temperatures up to 350 _C. In which OPC 53 grade cement has used and the properties of cement.

**Table 2.15 Experimental properties of cement (Kaur et al. ,2011)**

| Sr No. | Characteristics | Values obtained experimentally |
|---|---|---|
| 1 | Specific gravity | 3.10 |
| 2 | Standard consistency, percent | 34 |
| 3 | Initial setting time, minutes | 48 |
| 4 | Final setting time, minutes | 240 |
| 5 | Compressive strength<br>3 days<br>7 days<br>28 days | <br>15.9 N/mm²<br>21.9 N/mm²<br>34.5 N/mm² |

**Table 2.16 Mix proportions of concrete with various proportions of GGBS replacing cement (Kaur et al. ,2011)**

| Mix proptions | M-0 | M-1 | M-2 | M-3 |
|---|---|---|---|---|
| Cement content (Kg/m³) | 450 | 360 | 270 | 180 |
| GGBFS (Kg/m³) | 0 | 90 | 180 | 270 |

| | | | | |
|---|---|---|---|---|
| Sand content (Kg/m³) | 482 | 482 | 482 | 482 |
| Plasticizer (1/m³) | 4.95 | 4.95 | 4.95 | 4.95 |
| Course aggregate (Kg/m³) | 1040 | 1040 | 1040 | 1040 |
| Water content (1/m³) | 203 | 203 | 203 | 203 |
| Slump (mm) | 100 | 90 | 85 | 75 |

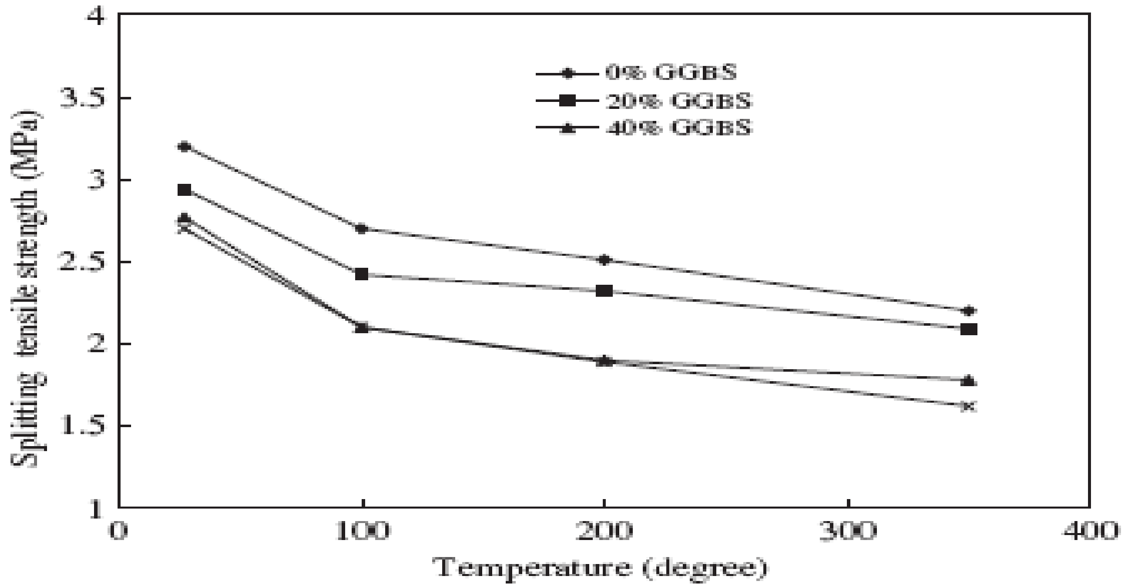



**Fig 2.14 Effect on temperature on the splitting tensile strength of concrete at 28 days (Kaur and Siddique et al., 2011)**

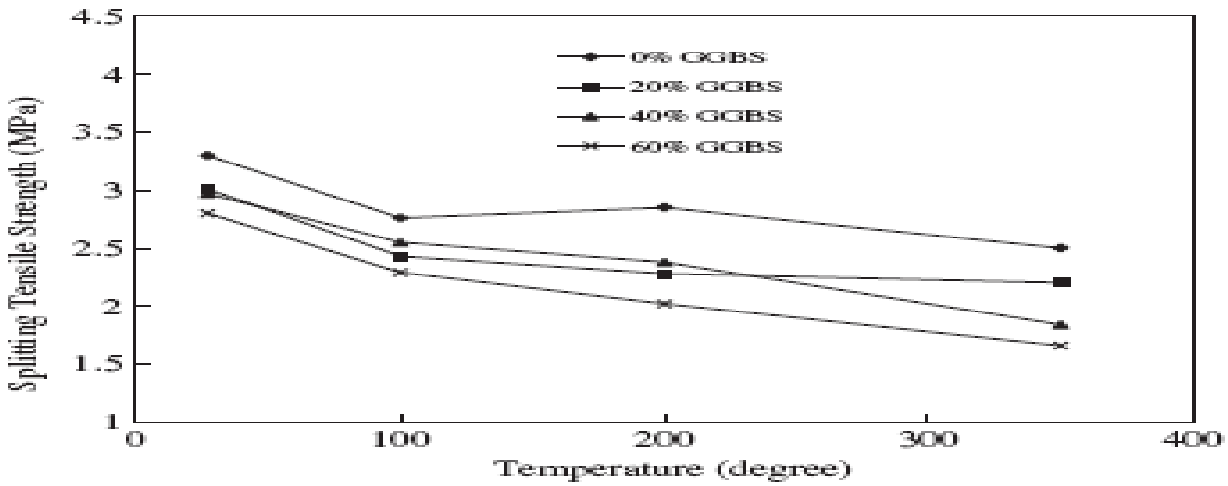



**Fig 2.15 Effect on temperature on the splitting tensile strength of concrete at 56 days (Kaur and Siddique et al., 2011)**

After Investigation it is observed that the split tensile strength of concrete at room temperature (27 degree C) decreased with increase in GGBFS. At 20%, 40% and 60% GGBFS the splitting tensile strength of concrete was 17.4%, 8.2% and 15.6% lower than the control (3.20MPa) at room temperature respectively.

### 2.2.3 Flexural strength

**Arivalagm, (2014**) Investigated the Flexural strength of concrete. The compressive strength was founded at 7, 28 days .the specimens were casted according to IS: 516-1959. In which cement is used OPC 43 grade with specific gravity 3.11 Locally available river sand conforming to Grading zone II of IS: 383 1970 . The mix ratio used 1:1.6:2.907:0.41 which give good result compared to control mix.

**Table 2.17 Mix proportions of concrete with various proportions of GGBS replacing cement in M35 grade concrete (Arivalaga ,2014)**

| Mix proptions | Controlled concrete | 20% GGBS | 30% GGBS | 40% GGBS |
|---|---|---|---|---|
| W/C ratio | 0.41 | 0.41 | 0.41 | 0.41 |
| GGBS content | | 20 | 30 | 40 |
| GGBS content (wt) | | 0.8 | 1.2 Kg | 1.6 Kg |
| Cement content | 4 Kg | 3.2 Kg | 2.8 Kg | 2.8 Kg |
| Sand content | 5.186 Kg | 5.186 Kg | 5.186 Kg | 5.186 Kg |

| | | | | |
|---|---|---|---|---|
| Sand content with bulking | 6.979 Kg | 6.979 Kg | 6.979 Kg | 6.979 Kg |
| Course aggregate | 10.216 Kg | 10.216 Kg | 10.216 Kg | 10.216 Kg |
| Water content | 2.00 Kg | 1.942 Kg | 1.948 Kg | 2.006 Kg |

**Table 2.18 Flexural strength of concrete (Arivalaga ,2014)**

| Type of concrete and mix proportions | Days of curing | flexural strength (N/mm$^2$) |
|---|---|---|
| Control concrete | 7 | 5.15 |
| M35-20 | 7 | 4.97 |
| M35-30 | 7 | 4.85 |
| M35-40 | 7 | 4.80 |
| Control concrete | 28 | 5.27 |
| M35-20 | 28 | 5.32 |
| M35-30 | 28 | 5.23 |
| M35-40 | 28 | 5.19 |

After investigation the flexural strength with different percentage of GGBFS find at 7 and 28 days. The flexural strength was 5.32 N/mm2 with 20% replacement. The result shown in the table.

**Ismail and Hashmi et al. , (2007)** Investigated the flexural strength with 10%,15% and 20% waste iron slag at curing period 3,7,14and 28 days .In which 87 prisms were casted to check the flexural strength of concrete and Type 1 OPC cement was used in which physical properties of the cement is discussed below in table.

**Table No 2.19 Experimental properties of cement (Ismail and Hashmi et al.,2007)**

| Sr No. | Characteristics | Values obtained experimentally |
|---|---|---|
| 1 | Specific gravity | 3.12 |
| 2 | Standard consistency, percent | 34 |
| 3 | Initial setting time, minutes | 3.20 |
| 4 | Final setting time, Hours | 4.15 |
| 5 | Compressive strength<br>3 days<br>7 days | <br>24.96 $N/mm^2$<br>30.80 $N/mm^2$ |

**Table 2.20 Increment (+) and decrement (-) (%) in flexural strength of waste iron slag concrete mix (Ismail and Hashmi et al. ,2007)**

| % waste iron aggregate | Flexural strength 3 days | Flexural strength 7 days | Flexural strength 14 days | Flexural strength 28 days |
|---|---|---|---|---|
| 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10 | 12.10 | 21.31 | 10.00 | 22.77 |
| 15 | 26.90 | 26.69 | 10.72 | 23.79 |
| 20 | 37.98 | 28.34 | 11.6 | 27.86 |

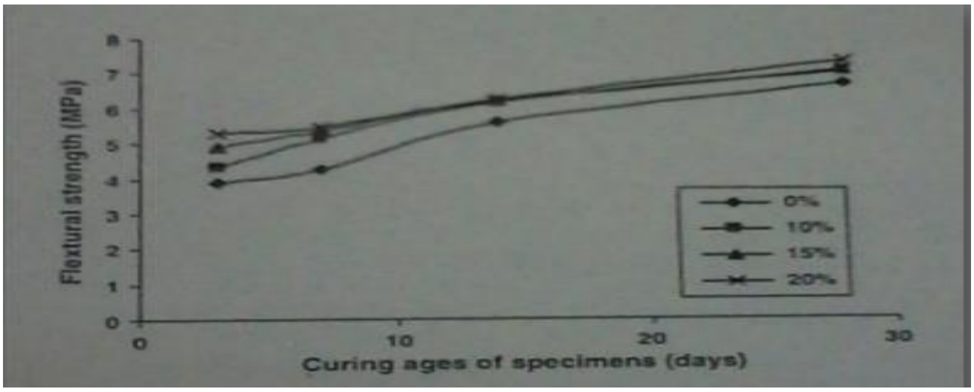



**Fig 2.16 Flexural strength of waste iron slag concrete mixes (Ismail and Hashmi et al. ,2007)**

The flexural strengths of the waste iron concrete mixes at all curing periods tend to increase above the reference concrete mixes with an increasing ration of iron waste slag the highest flexural strength was obtained at 20% of waste iron slag specimen i.e. 27.89% higher than the reference concrete mix at curing of 28 days. The result confirm that reuse of solid waste materials offers an approach to solving the pollution problem that arise from an accumulation of waste.

## 2.3 Durability Characteristics

### 2.3.1 Sulphate Resistance

**Khajuria et al.,(2014)** investigated the compressive strength of concrete. Test specimen of standard size 150*150*150mm with varying percentage at 0,10,20,30 of iron slag as partial replacement of fine sand to check the compressive strength developed in concrete at 7,28,56 days respectively. In which cement has used OPC 43 grade and the properties of cement is given below in table no. 2.5 and water cement ratio was 0.5.

**Table 2.21 Experimental properties of cement (Khajuria et al.,2014)**

| Sr No. | Characteristics | Values obtained experimentally |
|---|---|---|
| 1 | Specific gravity | 3.12 |
| 2 | Standard consistency, percent | 29 |
| 3 | Initial setting time, minutes | 155 |
| 4 | Final setting time, minutes | 337 |
| 5 | Compressive strength<br>3 days<br>7 days<br>28 days | <br>23.8 N/mm²<br>35.3 N/mm²<br>46.7 N/mm² |

**Table 2.22 Compressive strength of concrete mixes after immersion in 50g/l of $MgSo_4$ solution (Khajuria et al.,2014)**

| MIX | 7 days compressive strength | | 28 days compressive strength | | 56 days compressive strength | |
|---|---|---|---|---|---|---|
| | Control (28 days) | Immersed | Control (28 days) | Immersed | Control (28 days) | Immersed |
| 10% | 39.33 | 48.09 | 39.33 | 50.40 | 39.33 | 53.09 |
| 20% | 49.90 | 40.42 | 49.90 | 42.84 | 49.90 | 43.24 |
| 30% | 55.68 | 35.08 | 55.68 | 38.50 | 55.68 | 40.43 |

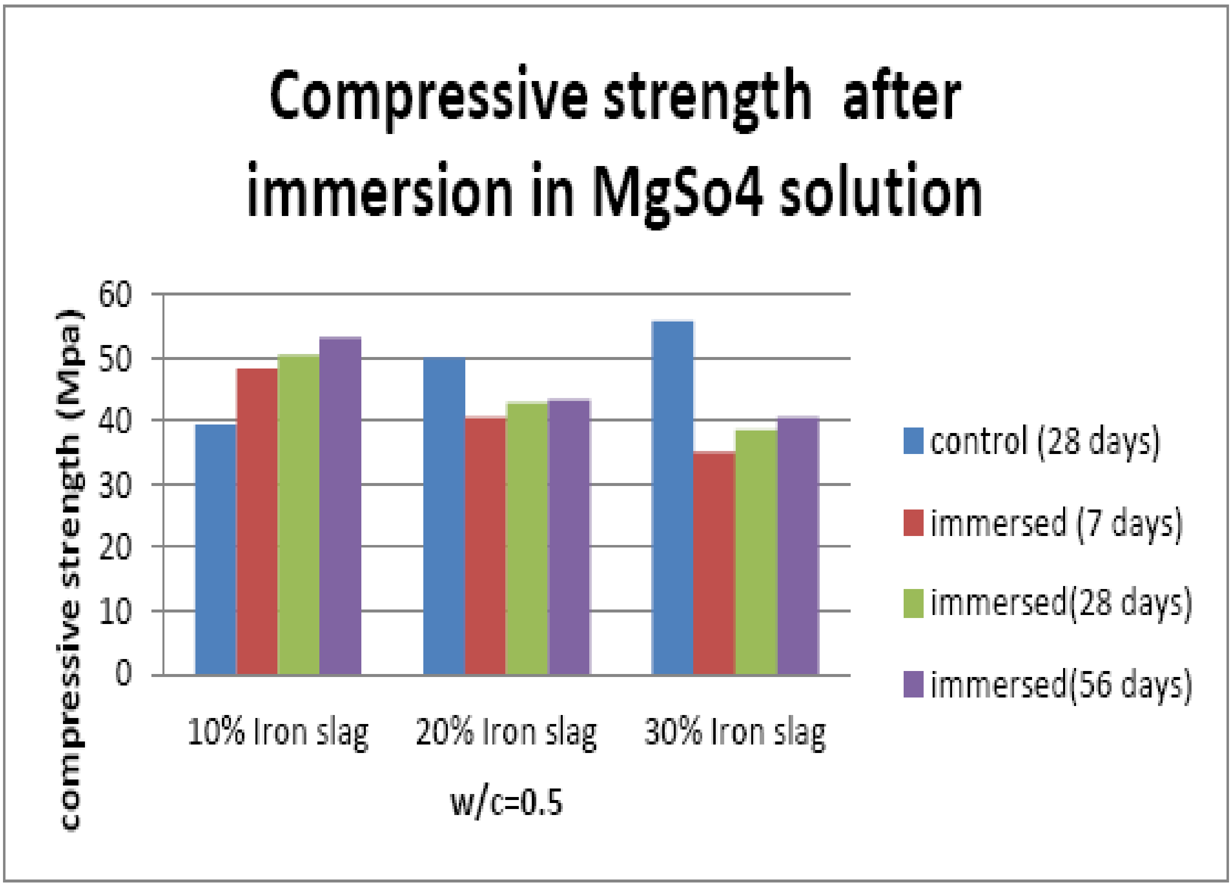



**Fig 2.17- Compressive strength after immersion in $MgSO_4$ solution (Khajuria et al.,2014)**

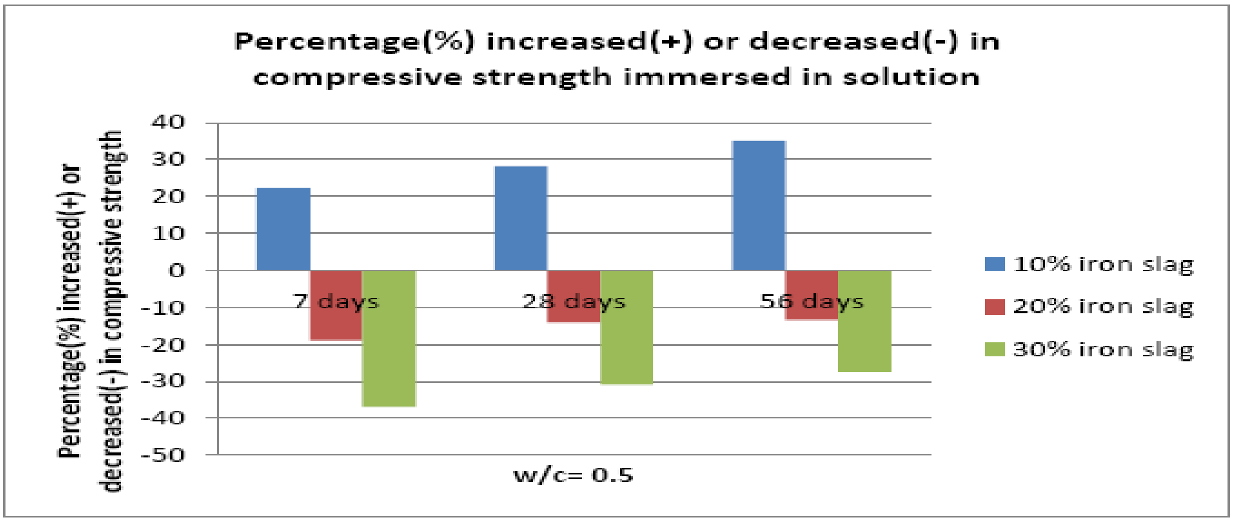



**Fig 2.18- Percentage increased (+) or decreased (-) in compressive strength after immersion in $MgSo_4$ solution as compressive strength of specimens cured in normal water at same ages (Khajuria et al.,2014)**

After investigation of the resistance to sulphate attack of concrete. The test was conducted using cube of 150*150*150mm in size. The cubes was casted and cured for 28 days if the immersed in solution for long period then the strength reduce so proper investigation has to be done. The compressive strength of 10% iron slag specimens immersed in 50g/l $MgSo_4$ solution gives more strength than other values immersed in water for 7, 28,and 56 days. With increase in percentage of iron slag then there was decrease in compressive strength of specimen cured at same ages.

**Veiga et al. (2012)** Investigated the sulphate resistance of a white Portland cement. The amount of granulated blast-furnace slag was 0%, 50% and 70% as a partial cement replacement. The performance was monitored by exposing the prepared mortar specimen to a 5% sodium sulphate solution for 2 years according to ASTM C1012/04. The use of slag was beneficial in both cements and an increase in its percentage increased in sulphate resistance. After 24 months of exposure to a sodium sulphate , it resist to sodium sulphate attack more than Portland cement because of lower value of CH content of WPC hydrate paste. White Portland cement having better resistance to sulphate attack than grey Portland cement that's why it could have been a complementary effect between slag and limestone used as filler in WPC.

Strength Portland cement (PC) were also used. The results showed the benefits of slag in both cements, and an increase in its percentage increased sulfate resistance. Chemical activation reduced the expansion compared to those mixtures without it. For long-term exposure, all of the WPC blends showed less expansion than the corresponding blends with PC. A microstructure analysis identified ettringite and gypsum as the main degradation products .Physical properties of cement are given below

**Table 2.23- Experimental properties of cement (Veiga et al.,2012)**

| Sr No. | Characteristics | Portland cement | White Portland cement |
|---|---|---|---|
| 1 | Specific gravity | 3.11 | 2.97 |
| 2 | Standard consistency, percent | 29 | 32 |
| 3 | Initial setting time, minutes | 125 | 100 |
| 4 | Final setting time, minutes | NA | NA |
| 5 | Compressive strength<br>3 days<br>7 days<br>28 days | <br>25.7 N/mm²<br>29.4 N/mm²<br>42.9 N/mm² | <br>35.1 N/mm²<br>41.2N/mm²<br>49.7N/mm² |

After the investigation the sulfate resistance of a white Portland cement (WPC) containing 0%, 50% or 70% granulated blast-furnace slag as a partial cement replacement was investigated. The use of Na2SO4 as a chemical activator in the 50% slag blend was also studied. The performance of the blended cements was monitored by exposing the prepared mortar specimens to a 5% Na2SO4 solution for 2 years according to ASTM C1012/04 and using TG/DTA, DRX and SEM/EDX analyses of the paste samples. The same blends composed a high early.

## 2.4 Summary

Literature on the utilization of Iron slag is not extensive. Only few studies have been reported on their use to evaluate mechanical as well as durability properties. Therefore, the present study put some contribution to the literature for the same.

# CHAPTER 3
# SCOPE AND OBJECTIVE OF THE STUDY

## 3.1 Scope Of Study

High-Strength concrete of grade M50 had been taken for experimental work. The cement was replaced by iron slag in proportions of 6%, 9%, 12%, 18%, 24%, 36% and 48%. Then we casted cubes, cylinders and beams in all proportions of partial replacement of cement along with the control specimen i.e., concrete specimens with zero replacement of cement and tried to investigate the impact of using Iron Slag as partial replacement of cement over the concrete's mechanical properties.

## 3.2 Objectives Of The Study

Concrete used in certain condition require good abrasion and erosion resistance and also high strength capability. These basic needs are related to mechanical properties of concrete. Our main objective of this project is to investigate the mechanical properties i.e., compressive strength, splitting tensile strength and Flexural strength of concrete at different replacement levels of cement with iron slag for the selected grade of concrete by comparing to the concrete with no iron slag i.e. the Control. Ultimately we are trying to investigate if we can produce a high strength concrete which is also waste managing, eco-friendly and economic.

# CHAPTER: 4
## EXPERIMENTAL PROGARM

## 4.1 General

The aim of the experimental program is to compare the properties of concrete made with Iron slag and varying percentages of iron slag incorporated in concrete. The basic tests carried out on concrete samples are discussed in this chapter, followed by a brief description about mix design and curing procedure adopted. At the end, the various tests conducted on the specimens are discussed.

## 4.2 Materials

For the entire experimental program, following materials were used.

### 4.2.1 Cement

Ordinary Portland Cement (OPC) grade 43 (Shree Ultra Tech) was used and tested confirming IS: 8112-1989. Test results were given in table 5.1

**Table 4.1 Physical Properties of Ordinary Portland Cement**

| Sr No. | Characteristics | Values obtained experimentally |
|---|---|---|
| 1 | Specific gravity | 3.11 |
| 2 | Standard consistency, percent | 33.8 |
| 3 | Initial setting time, minutes | 35 |
| 4 | Final setting time, Hours | 8 |
| 5 | Compressive strength (Mpa)<br>3 days<br>7 days<br>28 days | <br>22.9 N/mm²<br>30.9 N/mm²<br>42.5 N/mm² |
| 6 | Fineness (%) | 3.75 |

### 4.2.2 Fine Aggregate

Locally available natural sand with 4.75mm maximum size was used as fine aggregate. The physical properties and sieve analysis are given in Tables 4.2 and Table 4.3 respectively.

**Table 4.2 Physical Properties of Fine Aggregates**

| Sr No. | Characteristics | Values obtained experimentally |
|---|---|---|
| 1 | Type | Natural sand |
| 2 | Specific Gravity | 2.51 |
| 3 | Fineness Modulus | 2.55 |
| 4 | Grading zone | III |

**Table 4.3 Sieve Analysis of Fine Aggregates**

| S.no. | Sieve size | Weight retained (Grams) | Percentage retained (%) | Percentage Passing (%) | Cumulative percentage retained (%) |
|---|---|---|---|---|---|
| 1 | 4.75 | 5 | 0.50 | 99.50 | 0.50 |
| 2 | 2.36 | 59 | 5.90 | 93.60 | 6.40 |
| 3 | 1.18 | 136 | 13.60 | 80.00 | 20.00 |
| 4 | 600 | 243 | 24.30 | 55.70 | 44.30 |
| 5 | 300 | 415 | 41.50 | 14.20 | 85.80 |
| 6 | 150 | 122 | 12.20 | 2.00 | 98.00 |
| 7 | Pan | 20 | 2.00 | - | - |
| | | | | | $\Sigma F = 255$ |

Fineness modulus = $\Sigma F/100 = 2.55$

### 4.2.3 Course Aggregate

**Table 4.4 Physical Properties of Coarse Aggregates**

| Sr No. | Properties | Values obtained experimentally |
|---|---|---|
| 1 | Maximum size (mm) | 20 |
| 2 | Specific Gravity<br>10 mm<br>20 mm | <br>2.53<br>2.66 |
| 3 | Total Water Absorption (%) | 1.76 |
| 4 | Fineness Modulus | 7.68 |

**Table 4.5 Sieve Analysis of Coarse Aggregates**

| S.no. | Sieve Size | Weight retained (Grams) | Percentage retained (%) | Percentage Passing (%) | Cumulative percentage retained (%) |
|---|---|---|---|---|---|
| 1 | 20 | 0 | 0 | 100 | 0 |
| 2 | 12.5 | 2.81 | 72.88 | 27.11 | 72.83 |
| 3 | 10 | 0.67 | 22.48 | 4.63 | 95.36 |
| 4 | 4.75 | 0.13 | 4.63 | 0.01 | 99.99 |
| | | | | | $\Sigma$C= 268.18 |

Fineness Modulus = ($\Sigma$C+500)/100 = 7.68

**Table 4.6 Flakiness and Elongation Indices of Coarse Aggregates**

| Sr.no | Passing through IS Sieve (mm) | Retained on IS sieve (mm) | Thickness Gauge size (mm) | Mass of aggregate passing through thickness gauge (gm) | Length gauge size (mm) | Mass of aggregate retained on length gauge(gm) |
|---|---|---|---|---|---|---|
| 1. | 63 | 50 | 33.90 | 0 | - | 0 |
| 2 | 50 | 40 | 27 | 0 | 81.0 | 0 |
| 3. | 40 | 31.5 | 19.5 | 0 | 58.5 | 0 |
| 4. | 31.5 | 25 | 16.95 | 0 | - | 0 |
| 5. | 25 | 20 | 13.5 | 30 | 40.5 | 0 |
| 6. | 20 | 16 | 10.80 | 45 | 32.4 | 20 |
| 7. | 16 | 12.5 | 8.55 | 235 | 25.6 | 875 |
| 8. | 12.5 | 10 | 6.75 | 75 | 20.2 | 320 |
| 9. | 10 | 6.3 | 4.89 | 55 | 14.7 | 205 |
| | | | ∑W=W2= | 440 | ∑W=W4= | 1420 |

Weight of aggregate taken initially for flakiness index=W1gm=5000gm

Weight of aggregate taken initially for Elongation index=W3gm=5000gm

Flakiness Index = 8.8%

Elongation Index= 28.4%

**Table 4.7 Impact Value Of Aggregates**

| Trial No. | Quantity of aggregate of 10mm-12.5mm size (gm) | Quantity of sample passing 2.36 IS sieve | % passing |
|---|---|---|---|
| 1 | 690 | 40.23 | 5.83 |
| 2 | 700 | 40.30 | 5.75 |
| 3 | 685 | 39.90 | 5.82 |

Result: The Average Impact value of aggregate is = (5.83+5.75+5.82)/3

=5.8% $<$30%

#### 4.2.4 Iron Slag

Iron slag produced from iron ore factory Industrial Area Ludhiana and the Specific gravity of Iron Slag is calculated 3.53.

#### 4.2.5 Water

Generally, water that is suitable for drinking is satisfactory for use in concrete. Water from lakes and streams that contain marine life also usually is suitable. When water is obtained from sources mentioned above, no sampling is necessary. When it is supposed that water may contain sewage, mine water, or wastes from industrial plants or canneries, it should not be used in concrete unless tests indicate that it is satisfactory. In the present experimental program , potable tap water is used for casting.

#### 4.2.6 Admixture

The admixture used in this Mix is **Master Glenium sky 8777** is super plasticizer. The admixture used in the Mix is **Master Glenium sky 8777** is super plasticizer based on second generation polycarboxylic ether polymers, developed using Nano-technology. The product has been primarily developed for applications in high performance ready-mix concrete to facilitate total performance control. It is free of chloride and low alkali and is compatible with all types of cements.

#### 4.2.7 Design Of Concrete Mix

Concrete mix design is the way by which we choose the different constituents used in the concrete and determining the their amount and by taking care about the economy and various properties of the concrete like workability ,slump value , durability ,strength criteria etc. As we are not able to decide the mix proportion of the concrete correctly so we need to use various design methods. The material which is used is not fixed in amount. Tests which are conducted in the laboratory are not enough to decide the mix design. In order to decide the proper mix design firstly we should have the proper knowledge about the various properties of material which is used in the concrete and about the factors which affects the properties. Designing the mix design is also an art of civil engineer. Only the person who is expert and have authentic knowledge can do the proper design mix and find out the demerits the given mix design or the design which is already designed by other person. There are so many methods by which we can prepare the mix design but we need to select the appropriate one which satisfy all the conditions as per the requirements. Different mix design has the different amount of ingredients used, so with the change in the Mix the quantities of the material also changes.

In Our project we have designed the M50 grade of concrete as per the IS: 10262-2009, Concrete Mix Proportioning – Guidelines. So quantity of ingredients will differ in this mix design.

We worked on the High Performance Concrete by replacing the cement with Iron Slag by taking its different proportions. We also used the admixture in order to improve the workability and strength of the concrete in this. The mix design for M50 grade using the admixture provided here is for reference only. Actual site conditions vary and thus it should be adjusted as per the location and other factors.

**1. Parameter of Mix design M-50**

i. Grade Designation = M-50
ii. Type of cement = O.P.C-43 grade
iii. Brand of cement = A.C.C
iv. Admixture Used = Master Glenium Sky 8777
v. Fine Aggregate = Zone IV

**2. Specific Gravity**

i. Cement = 3.15
ii. Fine Aggregate = 2.61
iii. Coarse Aggregate(20mm) = 2.65
iv. Coarse Aggregate(10mm) = 2.66

Minimum cement used (As per Contract) = 400kg/$m^3$

Maximum Water Cement ratio (As per Contract) = 0.45

Now, hence Increasing Cement, Water, Admixtures by 2.5 % for the trial

Cement= 412*1.025=422 kg

Water = 144*1.025= 147.6 kg

Fine aggregate =621kg/$m^3$

Coarse Aggregate 20mm= 706kg

10mm=578kg

Admixture = 1.2 % by weight of Cement

Water: Cement: Fine Aggregate: Coarse Aggregate

0.36:1:1.472:3.043 (F.A=621 kg/$m^3$; C.A= 1284 kg/$m^3$)

**Table 4.8 Mix Proportion**

| Unit of Batch | Cement (Kg) | Fine Aggregate (Kg) | Course Aggregate (Kg) | | Water |
|---|---|---|---|---|---|
| | | | 10 mm | 20 mm | |
| Cubic meter content | 422 | 621 | 578 | 706 | 180 |
| Ratio of Ingredients | 1 | 1.472 | 1.369 | 1.673 | 0.36 |

**Table 4.9 Quantity of material used in $m^3$**

| Sr. No. | Items/Material | Material for 1 m^3 |
|---|---|---|
| 1 | Cement | 500kg |
| 2 | Water | 180kg/190kg |
| 3 | W/C ratio | 36 %/38% |
| 4 | Sand | 665kg |
| 5 | 10mm Aggregate | 513kg |
| 6 | 20mm Aggregate | 470kg |
| 7 | Admixture | 5kg |

**Table 4.10 Quantity of the material used at different % of Iron Slag**

| Sr.No. | Items | 0% | 6% | 9% | 12% | 18% | 24% | 36% | 48% |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Cement | 50kg | 47kg | 45.5kg | 44kg | 41kg | 38 kg | 32 kg | 26 kg |
| 2 | Iron Slag | - | 3kg | 4.5kg | 6 kg | 9kg | 12 kg | 18 kg | 24 kg |
| 3 | Water | 18 kg | 18kg | 18kg | 18 kg | 18kg | 18 kg | 18 kg | 18 kg |
| 4 | W/C Ratio | 36% | 36% | 36% | 36% | 36% | 36% | 38% | 38% |
| 5 | F.A | 66.5 kg | 66.5kg | 66.5kg | 66.5 kg | 66.5kg | 66.5 kg | 66.5 kg | 66.5 kg |
| 6 | 10mm (C.A) | 51 kg | 51kg | 51kg | 51 kg | 51kg | 51 kg | 51 kg | 51 kg |
| 7 | 20mm (C.A) | 47 kg | 47kg | 47kg | 47 kg | 47kg | 47 kg | 47 kg | 47 kg |
| 8 | Admixture | 0.25 kg | 0.25kg | 0.25kg | 0.25 kg | 0.25kg | 0.25 kg | 0.25 kg | 0.25 kg |
| 9 | Total Weight | 232.75 kg | 232.75 kg | 232.75 kg | 232.75 kg | 232.75 kg | 232.75 kg | 232.75 kg | 232.75 kg |

#### 4.2.8 Casting of specimens

All the specimens were casted referring to the mix proportions mentioned in table 4.8 and table 4.10. For these mix proportions, required quantities were weighed. Under this article, casting of specimens for different properties is mentioned.

#### 4.2.9 Specimens for Compressive Strength

150x150x150 mm sized cube specimens were prepared for compressive strength. The materials required were weighed according to the mix proportion. Cement, Iron slag, fine aggregates and coarse aggregates were dry mixed first to have a uniform color. After that 50% of the total water required was added to the mix to have thorough mixing for 3-4 minutes. Then 40% of the water was added with addition of iron slag to the mix. Remaining 10% of water was sprinkled on the above mix and it was thoroughly mixed in the mixer. The oiled samples were then filled with the mix prepared and then filled molds were put on the vibrating table for their proper mixing. Immediately after casting cubes, the specimens were covered with gunny bags to prevent water evaporation. Six identical cubes were casted. Out of six, three were tested after 7 days and rest after 28 days of curing.

#### 4.2.10 Specimens for Split Tensile Strength

300x150 mm sized cylinders specimens were prepared for split tensile strength. The materials required were weighed according to the mix proportion. Cement, Iron slag, fine aggregates and coarse aggregates were dry mixed first to have a uniform color. After that 50% of the total water required was added to the mix to have thorough mixing for 3-4 minutes. Then 40% of the water was added with addition of Iron slag to the mix. Remaining 10% of water was sprinkled on the above mix and it was thoroughly mixed in the mixer. The oiled samples were then filled with the mix prepared and then filled molds were put on the vibrating table for their proper mixing. Immediately after casting cubes, the specimens were covered with gunny bags to prevent water evaporation. Six identical cubes were casted. Out of six, three were tested after 7 days and rest after 28 days of curing.

#### 4.2.11 Specimens for Flexural Strength

100x100x500 mm sized cylinders specimens were prepared for split tensile strength. The materials required were weighed according to the mix proportion. Cement, Iron slag, fine aggregates and coarse aggregates were dry mixed first to have a uniform color. After that 50% of the total water required was added to the mix to have thorough mixing for 3-4 minutes. Then 40% of the water was added with addition of Iron slag to the mix. Remaining 10% of water was sprinkled on the above mix and it was thoroughly mixed in the mixer. The oiled samples were then filled with the mix prepared and then filled molds were put on the vibrating table for their proper mixing. Immediately after casting cubes, the specimens were covered with gunny bags to prevent water evaporation. Six identical cubes were casted. Out of six, three were tested after 7 days and rest after 28 days of curing.

## 4.3 TESTING OF SPECIMENS

After casting, specimens were tested after 7 and 28 days of curing. Under this article, the procedure followed for testing of specimens is mentioned for evaluating various properties like compressive strength, splitting tensile strength, Flexural Strength and durability of concrete.

#### 4.3.1 Mechanical Properties

#### 4.3.1.1 Compressive Strength

Specimens were demould after 24 hours of casting. Then they were poured in curing tank for the predefined time. At the age of testing, specimens were taken out of the tank and allowed surface drying for 10-15 minutes. Specimens were tested in Compression Testing Machine (CTM) at the load rate of 5 kN/sec specified as per IS: 516-1959. CTM has the capacity of 5000kN. The failure load was then evaluated.

**Fig. 5.1 Setup for Compressive Strength**

### 4.3.1.2 Split Tensile Strength

The Tensile Strength is obtained indirectly by placing the concrete cylinder to a compressive force acting horizontally. After applying the load, the failure occurs along the vertical axis due to the tension developed in transverse direction.

Since the concrete has low tensile strength which ranges from 8 to 12% of its compressive Strength.

$\sigma\ t = 2P/\pi DL$

Where P= load applied

D=Diameter of the cylinder

L= Height of the cylinder

$\sigma t$ =Tensile Strength of concrete ($N/mm^2$)

**Fig. 5.2 Setup for Split Tensile Strength**

#### 4.3.1.3 Flexural Strength Test

The flexural strength test is obtained for the beams which are casted in the lab. of Standard size and placed under four point loading set up in CTM. After applying the load, the beam produces a pure bending zone with constant bending moment and zero shears in the middle of the span.If the fracture occurs within the middle of the span then the flexural strength is given by the formula

$$\sigma c=3PL/4bd^2$$

Where, P=load in N

L=Span between two supports in mm

b = width of the beam

d= depth of the beam

If the fracture occurs outside the middle third of the beam , but within the 5% of the span length in that case the flexural strength is given by the formula

$$\sigma c=3Pa/bd^2$$

Where, P=load in N

a= distance between section of fracture and the nearest support in mm.

b=width of the beam

d=depth of the beam

However, if the fracture occur more than 5% of the outside the middle third, the test results are discarded.


**Fig. 5.3 Setup for Flexural Strength**

## 4.4 Summary

In this chapter various properties like specific gravity, moisture content, etc. were evaluated for the components of concrete. Ingredients of grade mix were evaluated, and according to mix proportion, materials were weighed. According to the mix prepared, specimens were casted to evaluate mechanical properties (compressive strength, splitting tensile strength and flexural strength) and durability property for the concrete mixes.

# CHAPTER 5
## RESULTS AND DISCUSSIONS

## 5.1 General

In this chapter the parameters studied on the control and concrete made with replacement of iron slag with cement are discussed. These parameters are Compressive strength, Split Tensile Strength, Flexural Strength Test and slump test are discussed and comparisons between the various concrete mixes are represented.

## 5.2 Slump Test

**Table 5.1 Material taken for every Slump test**

| | % of Iron Slag | 0% | 6% | 9% | 12% | 18% | 24% | 36% | 48% |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Cement | 3.54kg | 3.32 kg | 3.22 kg | 3.1152kg | 2.90kg | 2.690kg | 2.2656kg | 1.840kg |
| 2 | Iron Slag | - | 0.212kg | 0.318kg | 0.4248kg | 0.63kg | 0.849kg | 1.2744kg | 1.699kg |
| 3 | F.A | 4.28kg | 4.28kg | 4.28kg | 4.28kg | 4.28kg | 4.28kg | 4.28kg | 4.28kg |
| 4 | C.A | 6.63kg | 6.63kg | 6.63kg | 6.63kg | 6.63kg | 6.63kg | 6.63kg | 6.63kg |
| 5 | Water | 1.275kg | 1.275kg | 1.27kg | 1.275kg | 1.275kg | 1.275kg | 1.3452 | 1.3452 |
| 6 | W/C | (36%) | (36%) | (36%) | (36%) | (36%) | (36%) | (38%) | (38%) |
| 6 | Admixture | 0.017kg (.5%) | 0.017kg (.5%) | 0.017kg (0.5%) | 0.017kg (.5%) | 0.017kg (.5%) | 0.017kg (.5%) | 0.017kg (.5%) | 0.017kg (.5%) |

**Table 5.2 Slump Value at different Percentage of replacement**

| Water Content | Replacement | Slump value |
|---|---|---|
| 36% | 0% | 87mm |
| 36% | 6% | 92mm |
| 36% | 9% | 89mm |
| 36% | 12% | 120mm |
| 36% | 18% | 88mm |
| 36% | 24% | 73mm |
| 38% | 36% | 87mm |
| 38% | 48% | 79mm |

## 5.3 Compaction Factor Test

**Fig.5.1 Compaction factor Test**

Compaction Factor = weight of partially compacted concrete/ weight of fully compacted concrete

**Table 5.3 Relation of slump values and compaction factor**

| Workability | Slump in mm | Compaction factor |
|---|---|---|
| Very stiff | - | 0.70 |
| Stiff | 0 to 25 | 0.75 |
| Stiff plastic | 25 to 50 | 0.85 |
| Plastic | 75 to 100 | 0.90 |
| Flowing | 150 to 175 | 0.95 |

i. Weight of partial compacted concrete and cylinder W3 kg.

| Serial No. | % Replacement | W2-W1 kg |
|---|---|---|
| 1 | 0% | 11.37 |
| 2 | 6% | 11.38 |
| 3 | 9% | 11.30 |
| 4 | 12% | 11.23 |
| 5 | 18% | 11.10 |
| 6 | 24% | 11.01 |
| 7 | 36% | 10.89 |
| 8 | 48% | 10.81 |

ii. Weight /mass of fully compacted concrete W3 kg.

| Serial No. | % Replacement | W3=W2-W1 kg |
|---|---|---|
| 1 | 0% | 11.97 |
| 2 | 6% | 11.97 |
| 3 | 9% | 11.94 |
| 4 | 12% | 11.91 |
| 5 | 18% | 11.88 |
| 6 | 24% | 11.82 |
| 7 | 36% | 11.79 |
| 8 | 48% | 11.72 |

**Table 5.4 Compaction factor values**

| Serial No. | % Replacement | Compaction factor= W2-W1/W3-W1 |
|---|---|---|
| 1 | 0% | 0.95 (High Workable) |
| 2 | 6% | 0.9507(High Workable) |
| 3 | 9% | 0.9464(High Workable) |
| 4 | 12% | 0.943(High Workable) |
| 5 | 18% | 0.9343(Medium Workable) |
| 6 | 24% | 0.9314(Medium Workable) |
| 7 | 36% | 0.924(Low Workable) |
| 8 | 48% | 0.9224(Low Workable) |

## 5.4 Flow Test

**Table 5.5 Flow test values**

| S. No. | Replacement | Dia. Of Flow concrete (cm) | Flow Percentage(%) |
|---|---|---|---|
| 1 | 0% | 48.6 | (48.6-25)*100/25=94.4(H.W) |
| 2 | 6% | 48.8 | 95.2 (H.W) |
| 3 | 9% | 46.7 | 86.8 (M.W) |
| 4 | 12% | 43.7 | 74.8 (M.W) |
| 5 | 18% | 42.4 | 69.6 (M.W) |
| 6 | 24% | 39.8 | 59.2 (M.W) |
| 7 | 36% | 36.1 | 44.4 (L.W) |
| 8 | 48% | 32.3 | 29.2(L.W) |

## 5.5 Tests on Hardened Concrete

### 5.5.1 Compressive Strength Test

It is conducted to check the strength of given concrete. The specimen of given concrete is made and put under the load per unit area of cross-section in uniaxial compression under given rate of loading. It is expressed in N/mm2 .Here we have done the test by making the cube of standard size i.e. 150mmX150mmX150mm. The concrete were made according to design mix by replacing cement by iron slag powder 0%, 6%,9%,12%,18%, 24% , 36% and 48%. Concrete were filled in cube and left for initial setting. After 24 hours, the cubes were opened and specimens were placed for curing. The curing of specimen was done for 7 and 28 days. Then, the specimens were tested in CTM (Compression testing machine).

i. The result shows the grade of concrete.

Compressive Strength= P/A

Where P= Load coming on the cube

A=cross-sectional area

**Table 5.6 Compressive Strength of Cubes.**

| Replacement with Iron Slag | Compressive Strength after 7 days(MPa) | Average(MPa) | Compressive Strength after 28 days(MPa) | Average(MPa) |
|---|---|---|---|---|
| 0% | 52.41 | 52.7 | 59.52 | 58.21 |
| | 53.32 | | 56.74 | |
| | 52.37 | | 58.37 | |
| 6% | 52.9 | 53.56 | 58.81 | 59.48 |
| | 53.7 | | 57.74 | |
| | 54.1 | | 61.9 | |
| 9% | 52.68 | 53.04 | 57.61 | 58.75 |
| | 54.44 | | 58.43 | |
| | 52.01 | | 60.21 | |
| 12% | 44.438 | 44.567 | 51.23 | 51.91 |
| | 44.65 | | 51.71 | |
| | 44.613 | | 52.80 | |
| 18% | 43.32 | 43.68 | 48.41 | 47.99 |

| | | | | |
|---|---|---|---|---|
| | 43.72 | | 48.36 | |
| | 44.01 | | 47.22 | |
| 24% | 42.79 | 43.056 | 46.8 | 46.77 |
| | 42.95 | | 46.661 | |
| | 43.43 | | 46.87 | |
| 36% | 37.36 | 37.65 | 41.452 | 42.144 |
| | 38.38 | | 42.11 | |
| | 37.22 | | 42.87 | |
| 48% | 26.216 | 27.138 | 33.723 | 34.718 |
| | 27.89 | | 35.061 | |
| | 27.31 | | 35.37 | |

Case I: After 7 days

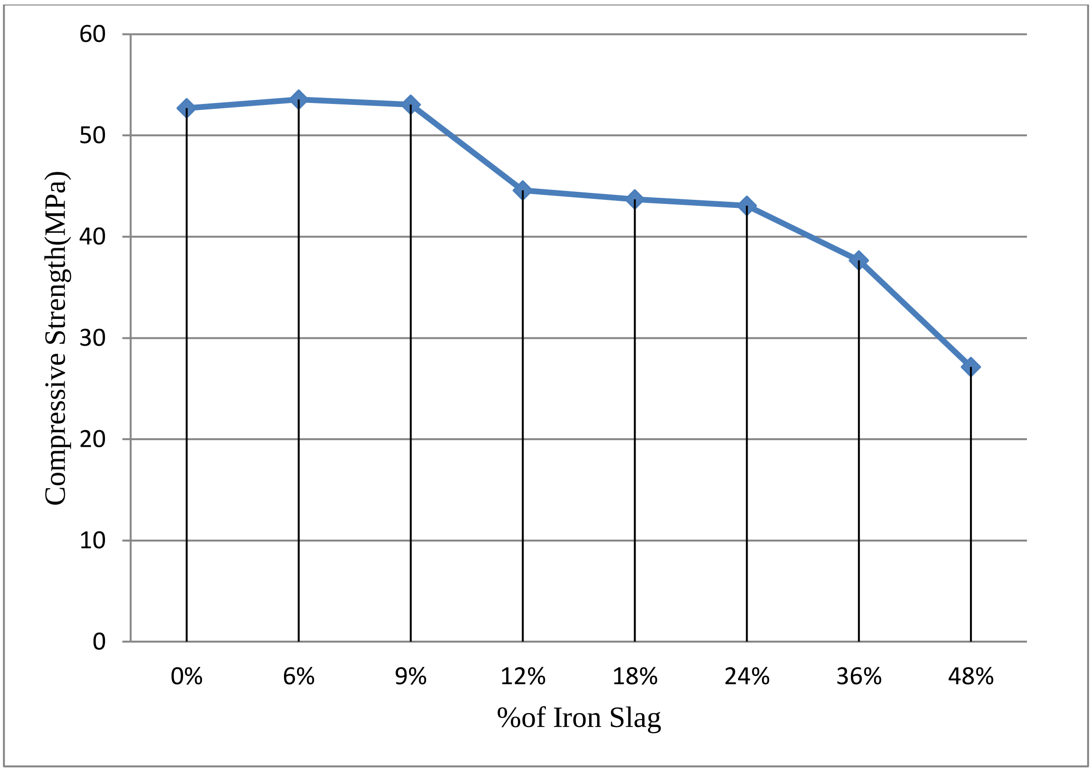



**Fig.5.2 Variation of Compressive Strength with increase in % of Iron Slag after 7 days.**

Case II: After 28 days

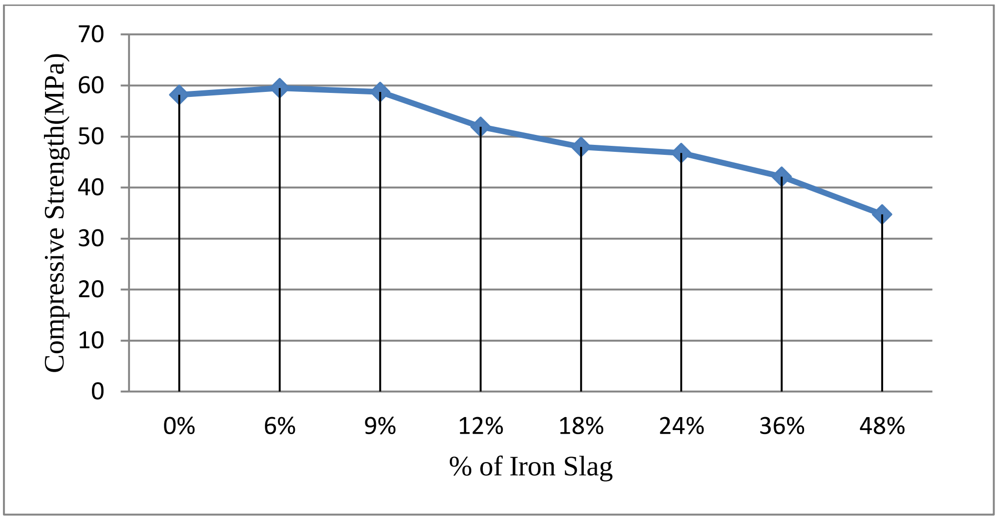



**Fig.5.3 Variation of Compressive Strength with increase in % of Iron Slag after 28 days**

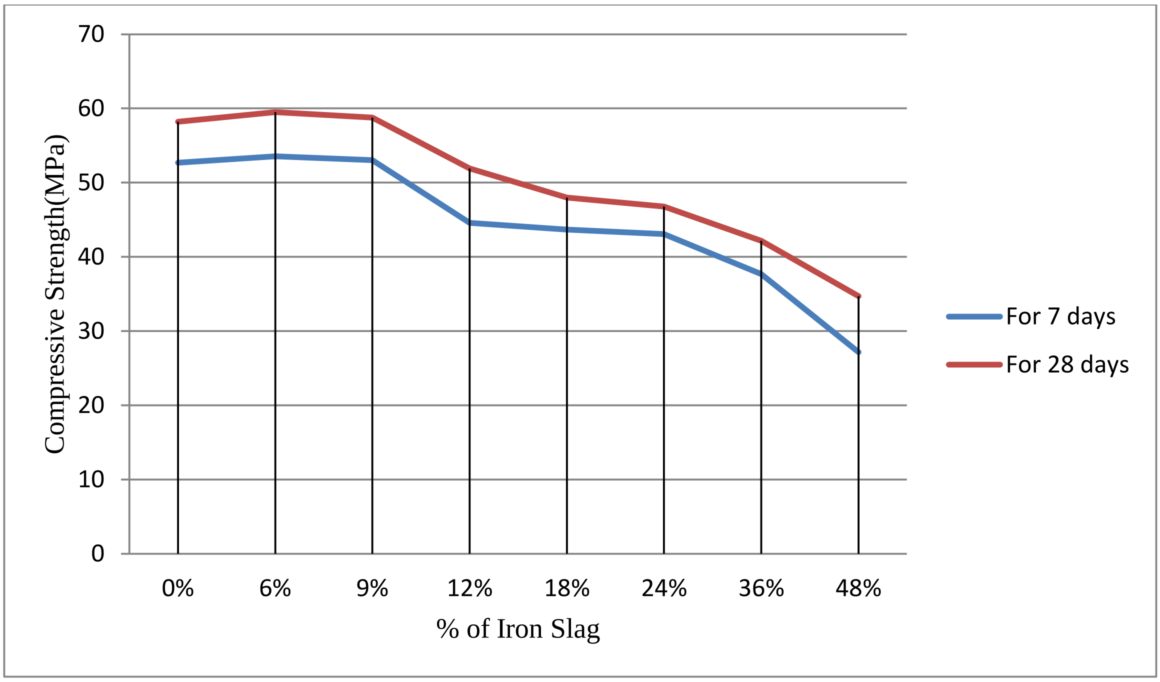
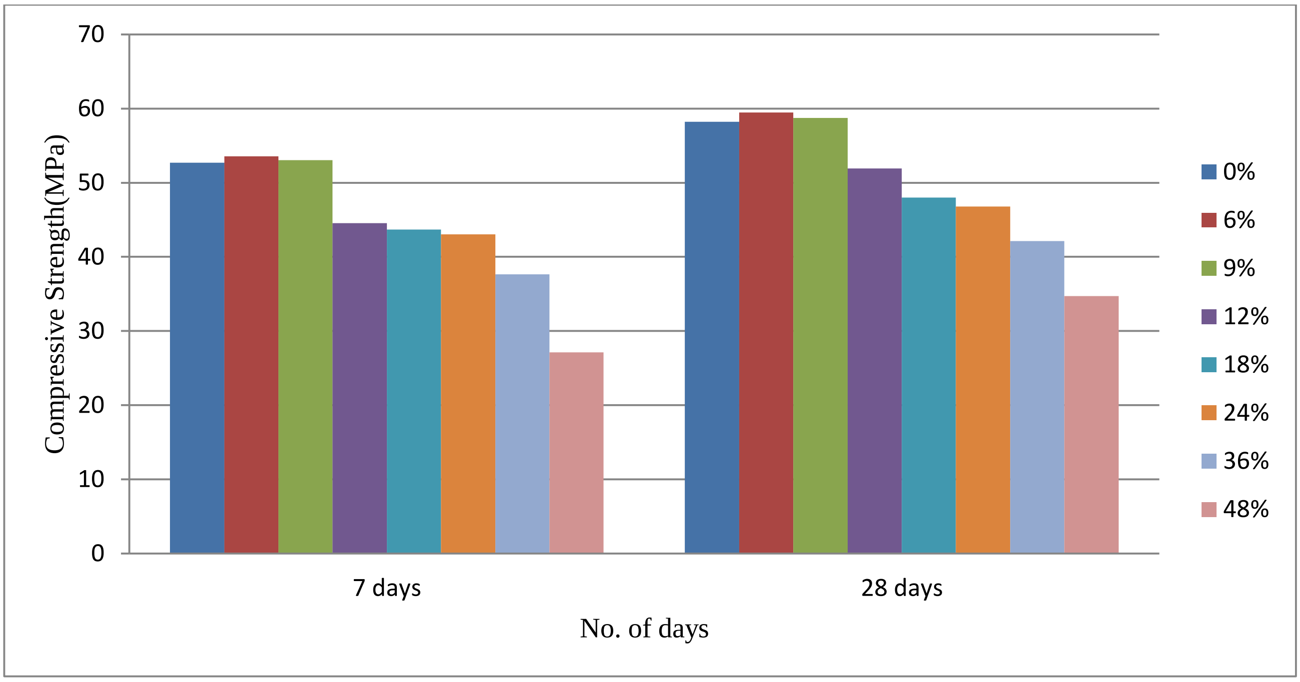



**Fig.5.4 Comparison of Compressive Strength obtained at 7 days and 28 days**

From the graphs above, it is clearly observed that at first the compressive strength of concrete increases with the increase in the percentage of Iron Slag powder mixed in the concrete but , after some percentage , the strength starts decreasing. At 7 days, the normal concrete attains its characteristics strength of 52.7MPa which is more than the 50MPa. But when we see the characteristic strength of concrete after 28 days, the concrete with 0%,6%,9% and 12%

replacement have 58.21MPa , 59.48MPa , 58.75MPa and 51.91MPa which is more than 50MPa. Hence the concrete with 0%, 6%, 9% and 12% replacement can be used for M50 grade. The concrete with 18% of replacement with Iron Slag powder have 4.02% lesser strength when compare to compressive strength of M50 grade. So, these types of concrete are not desirable for work as M50 grade of concrete.

**Fig.5.5 Bar graph showing variation of Compressive Strength with increase in % of Iron Slag after 7 days and 28 days.**




## 5.5.2 Split Tensile Strength

The Tensile Strength is obtained indirectly by placing the concrete cylinder to a compressive force acting horizontally. After applying the load, the failure occurs along the vertical axis due to the tension developed in transverse direction.

Since the concrete has low tensile strength which ranges from 8 to 12% of its compressive Strength.

$$\sigma_t = 2P/\pi DL$$

Where P= load applied

D=Diameter of the cylinder

L= Height of the cylinder

σt =Tensile Strength of concrete ($N/mm^2$)

**Table 5.7 Tensile Strength of the cylinder**

| Replacement with Iron Slag | Tensile Strength after 7 days(MPa) | Average (MPa) | Tensile Strength after 28 days(MPa) | Average(MPa) |
|---|---|---|---|---|
| 0% | 4.41 | 4.39 | 5.45 | 5.68 |
| | 4.49 | | 5.83 | |
| | 4.27 | | 5.77 | |
| 6% | 4.40 | 4.38 | 5.63 | 5.67 |
| | 4.42 | | 5.76 | |
| | 4.32 | | 5.62 | |
| 9% | 4.35 | 4.353 | 5.34 | 5.26 |
| | 4.38 | | 5.20 | |
| | 4.33 | | 5.24 | |
| 12% | 4.285 | 4.309 | 5.01 | 5.11 |
| | 4.387 | | 5.13 | |
| | 4.256 | | 5.19 | |
| 18% | 4.24 | 4.17 | 4.75 | 4.789 |
| | 4.26 | | 4.758 | |
| | 4.01 | | 4.86 | |
| 24% | 4.161 | 4.168 | 4.573 | 4.571 |
| | 4.22 | | 4.53 | |
| | 4.124 | | 4.61 | |
| 36% | 3.32 | 3.37 | 4.08 | 4.07 |
| | 3.38 | | 3.98 | |
| | 3.41 | | 4.15 | |
| 48% | 3.01 | 3.07 | 3.60 | 3.667 |
| | 3.13 | | 3.72 | |
| | 3.08 | | 3.681 | |

Case I: After 7 days

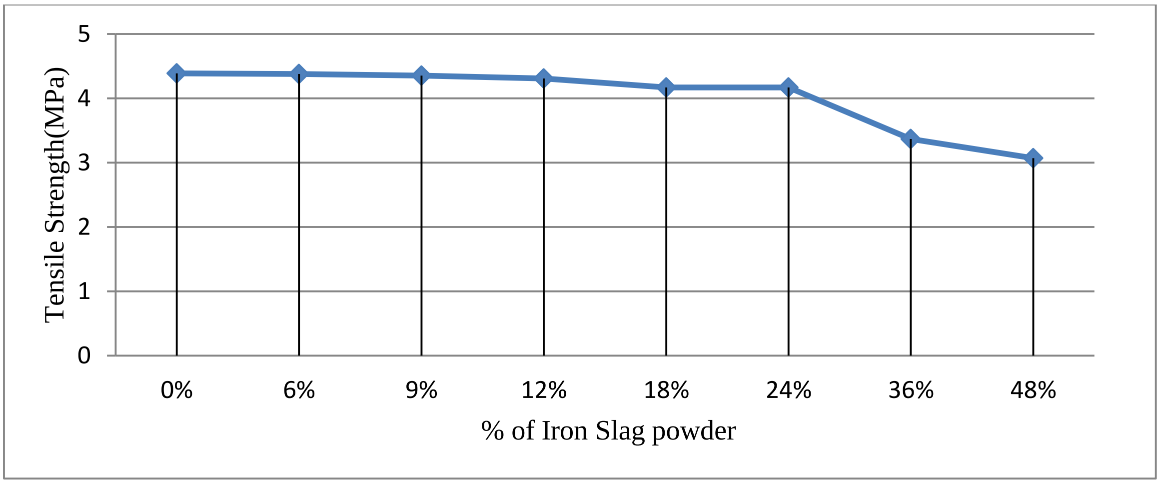



**Fig.5.6 Variation of Tensile Strength with increase in % of Iron Slag after 7 days**

Case II: After 28 days

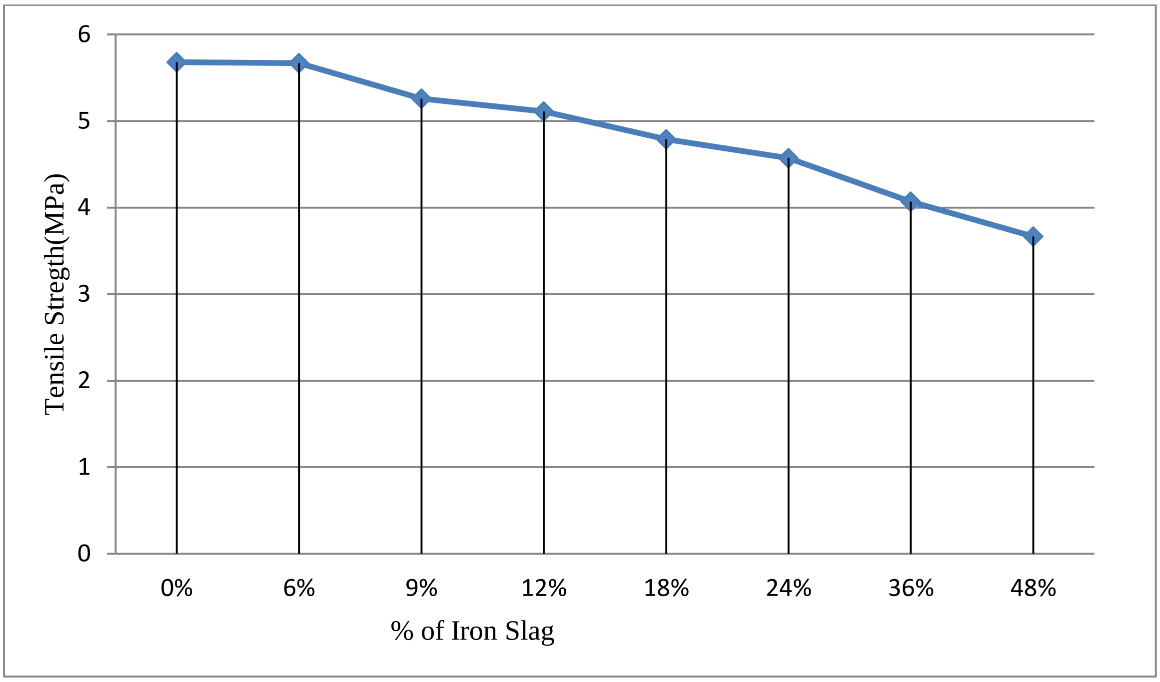



**Fig.5.7 Variation of Tensile Strength with increase in % of Iron Slag after 28 days**

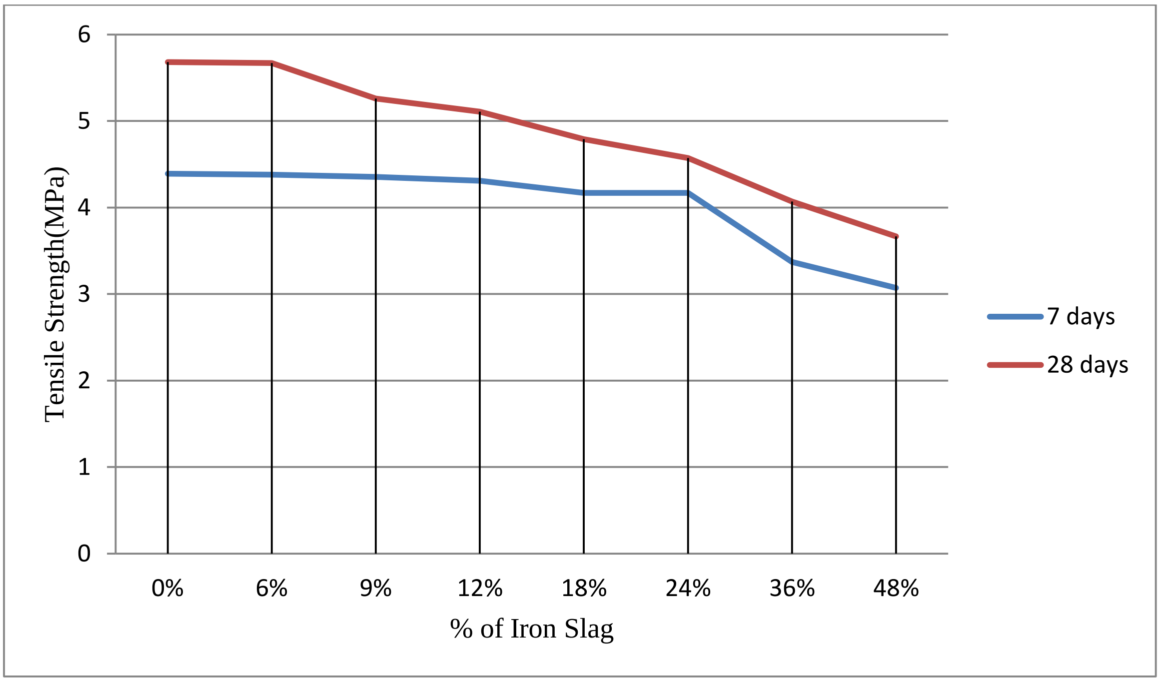



**Fig.5.8 Comparison of Tensile Strength obtained at 7 days and 28 days**

As the above graph shows that the tensile strength of concrete decreases with the increase in the percentage of Iron Slag powder replaced in the concrete. The value of tensile strength should be more than 5 MPa for M50 grade. After 7 days, the tensile strength of normal concrete is 4.39 MPa which is 12.2% less than desired tensile strength and hence can be used for work. But after 28 days, the concrete with 0% and 12% replacement hence more than 5MPa and hence can be used for M50 grade.The concrete with 24% of replacement with Iron Slag powder have 8.58% lesser tensile strength when compared with desired tensile strength of cylinder for M50 grade. So, the replacement after 24% gives lesser strength which are undesirable for work.

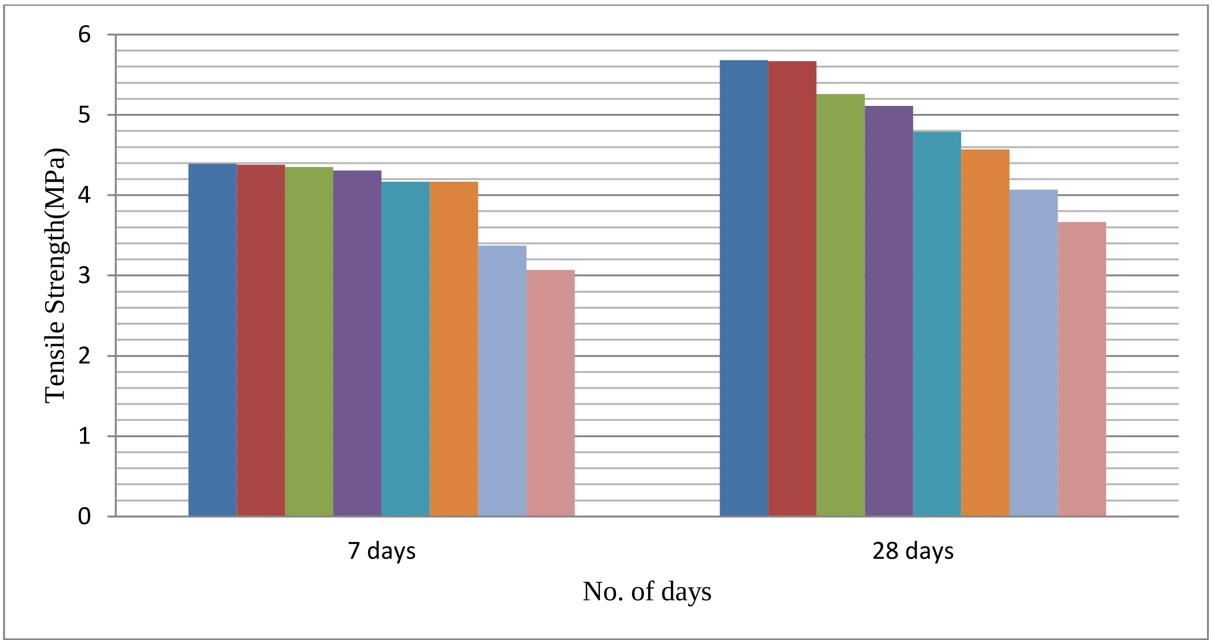



**Fig.5.9 Bar graph showing the variation of Tensile Strength with increase in % of Iron Slag after 7 days and 28 days.**

### 5.5.3 Flexural Strength Test

The flexural strength test is obtained for the beams which are casted in the lab. of Standard size and placed under four point loading set up in CTM.After applying the load, the beam produces a pure bending zone with constant bending moment and zero shears in the middle of the span. If the fracture occurs within the middle of the span then the flexural strength is given by the formula

$\sigma c=3PL/4bd^2$

Where, P=load in N

L=Span between two supports in mm

b = width of the beam

d= depth of the beam

i. If the fracture occurs outside the middle third of the beam , but within the 5% of the span length in that case the flexural strength is given by the formula

$\sigma c=3Pa/bd^2$

Where, P=load in N

a= distance between section of fracture and the nearest support in mm.

b=width of the beam

ii. However, if the fracture occur more than 5% of the outside the middle third, the test results are discarded.

**Table 5.8 Flexural Strength of beams**

| Replacement with Iron Slag | Flexural Strength after 7 days(MPa) | Average (MPa) | Flexural Strength after 28 days(MPa) | Average(MPa) |
|---|---|---|---|---|
| 0% | 6.15 | 6.186 | 7.65 | 7.303 |
| | 6.22 | | 6.78 | |
| | 6.19 | | 7.48 | |
| 6% | 6.29 | 6.268 | 7.73 | 7.877 |
| | 6.27 | | 7.8 | |
| | 6.245 | | 8.1 | |
| 9% | 6.33 | 6.387 | 8.24 | 8.28 |
| | 6.39 | | 8.45 | |
| | 6.44 | | 8.17 | |
| 12% | 6.39 | 6.5 | 8.97 | 9.05 |
| | 6.66 | | 9.09 | |
| | 6.45 | | 9.11 | |
| 18% | 6.24 | 6.28 | 8.76 | 8.79 |
| | 6.32 | | 8.79 | |
| | 6.28 | | 8.82 | |
| 24% | 5.79 | 5.953 | 8.55 | 8.556 |
| | 6.15 | | 8.67 | |
| | 5.92 | | 8.45 | |
| 36% | 5.19 | 5.24 | 6.38 | 6.343 |
| | 5.32 | | 6.19 | |
| | 5.21 | | 6.46 | |
| 48% | 4.71 | 4.74 | 5.98 | 5.85 |
| | 4.84 | | 5.82 | |
| | 4.69 | | 5.75 | |

Case I: After 7 days

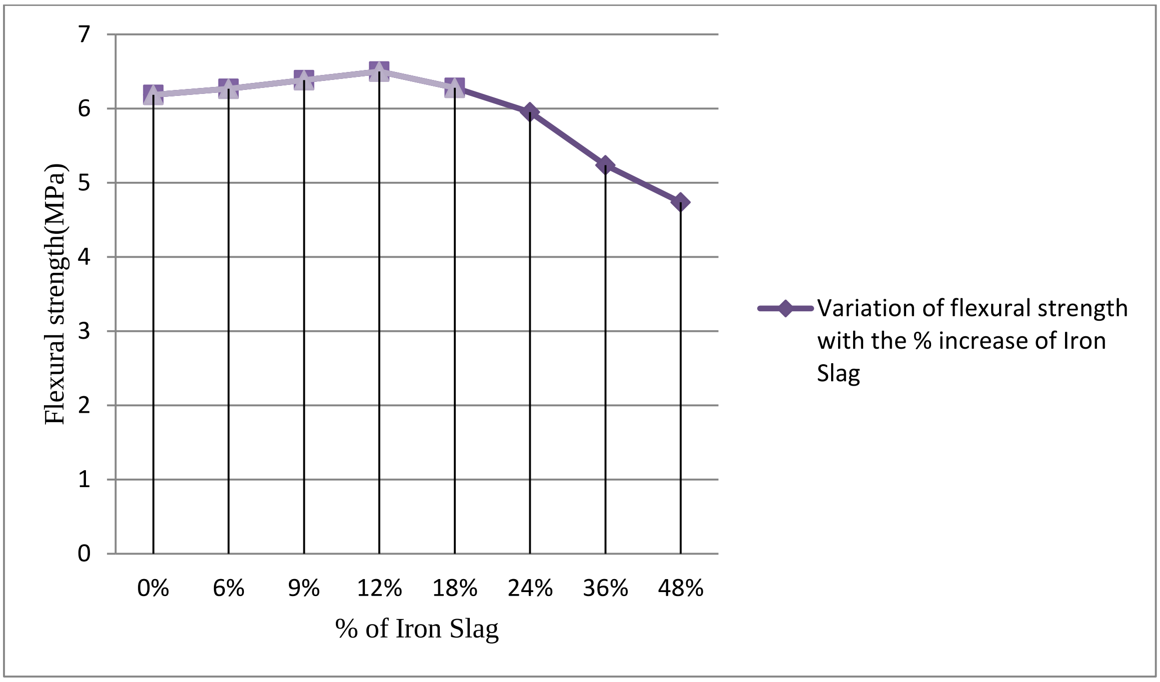



**Fig.5.10 Variation of Flexural Strength with increase in % of Iron Slag**

Case II: After 28 days


**Fig.5.11 Variation of Flexural Strength with increase in % of Iron Slag after 28 days**

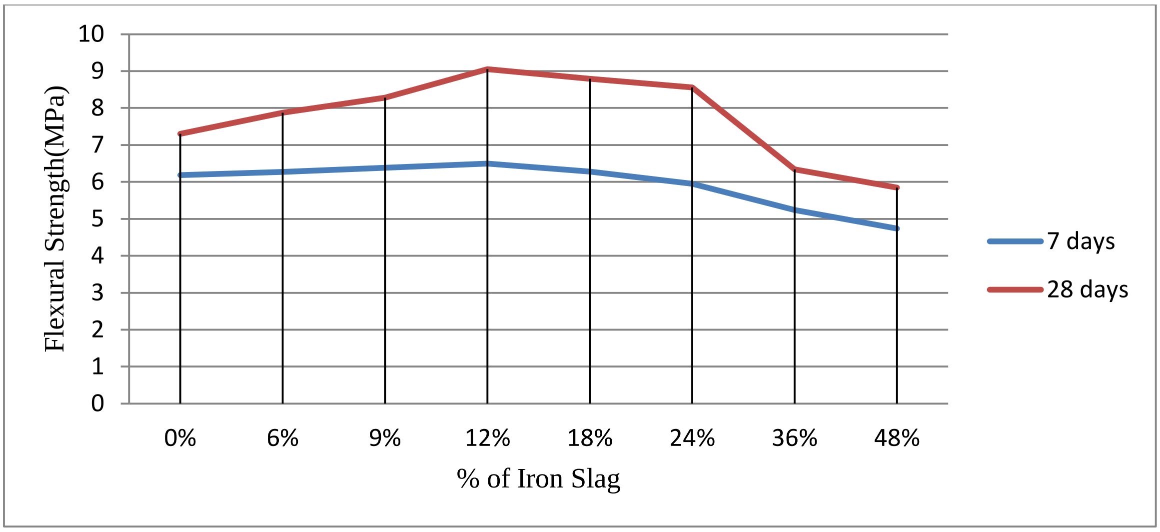



**Fig.5.12 Comparison of Flexural Strength obtained after curing of 7 days and 28 days.**

As the results for the flexural strength of beam are discussed with the graph which clearly depicts that the value of flexural strength increases first when we replaces the 12% of cement with iron slag powder. But after 12% of replacement, the graph decreases which means that the flexural strength of the beam goes on decreasing when we replace cement more than 12% with iron slag powder. The value of flexural strength of the beam should be more than 7MPa for M50 grade of concrete. After 28 days, the value of flexural strength of beam is more than 7 MPa in the case of 0%, 12%, and 24% of replacement of cement with iron slag. After 7days, the flexural strength of the beam are 88.3%,92.8%,85.04% for 0%,12%,and 24% respectively, which are more than 70% in each case. So, the concrete having replacement till 24% can be used for the work.

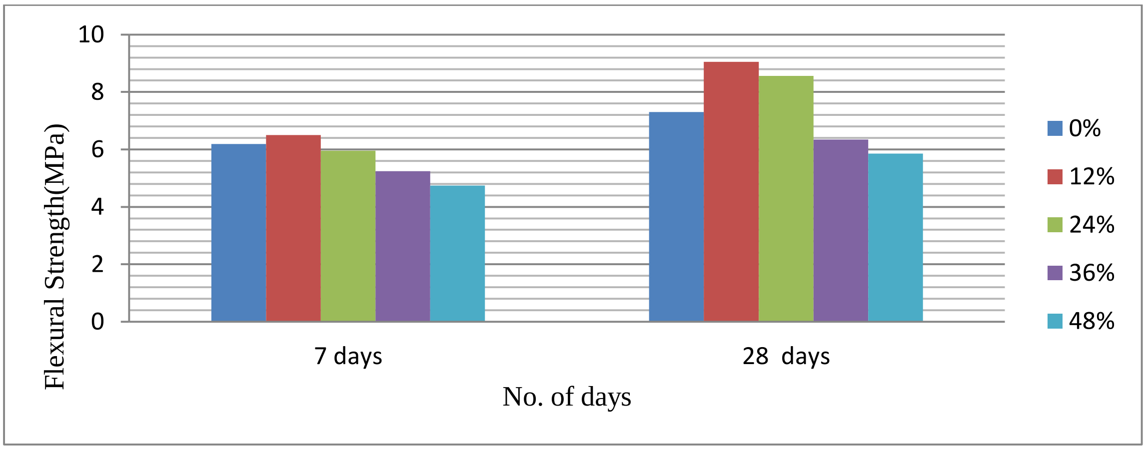



**Fig.5.13 Bar graph showing the variation of Flexural Strength with increase in % of Iron Slag after 7 days and 28 days.**

### 5.5.4 Sulphate Attack Test

The main purpose of conducting sulphate attack test is to determine the resistance ability of concrete in long term. The tests are conducted only for cube. For every replacement of cement with iron slag i.e. at 12%, 24%, 36% and 48% we casted one extra cube for doing sulphate attack test. Now the specimen is cured for 7 days and 28days by immersing the cubes in the solution of $MgSO_4$ (Magnesium Sulphate).The curing tank contains 50g/l $MgSO_4$ solution.

After the curing of 7days and 28 days, the specimens are tested in the CTM in the same way as we did other tests. Then the results are compared with the result of a specimen which are cured in normal water for 7 days and 28days respectively.

**Table 5.14 Compressive Strength of cubes when immersed in $MgSO_4$ solution.**

| Replacement of cement with Iron Slag | 7 days | 7days | 28 days | 28 days |
|---|---|---|---|---|
| | Cured in Water (MPa) | Cured in $MgSO_4$ (MPa) | Cured in Water (MPa) | Cured in $MgSO_4$ (MPa) |
| 0% | 52.7 | 56.61 | 58.21 | 60.86 |
| 12% | 44.567 | 48.871 | 51.91 | 52.71 |
| 24% | 43.056 | 40.34 | 46.77 | 41.724 |
| 36% | 37.65 | 33.235 | 42.144 | 36.674 |
| 48% | 27.138 | 20.19 | 34.718 | 28.072 |

Case I: After 7 days

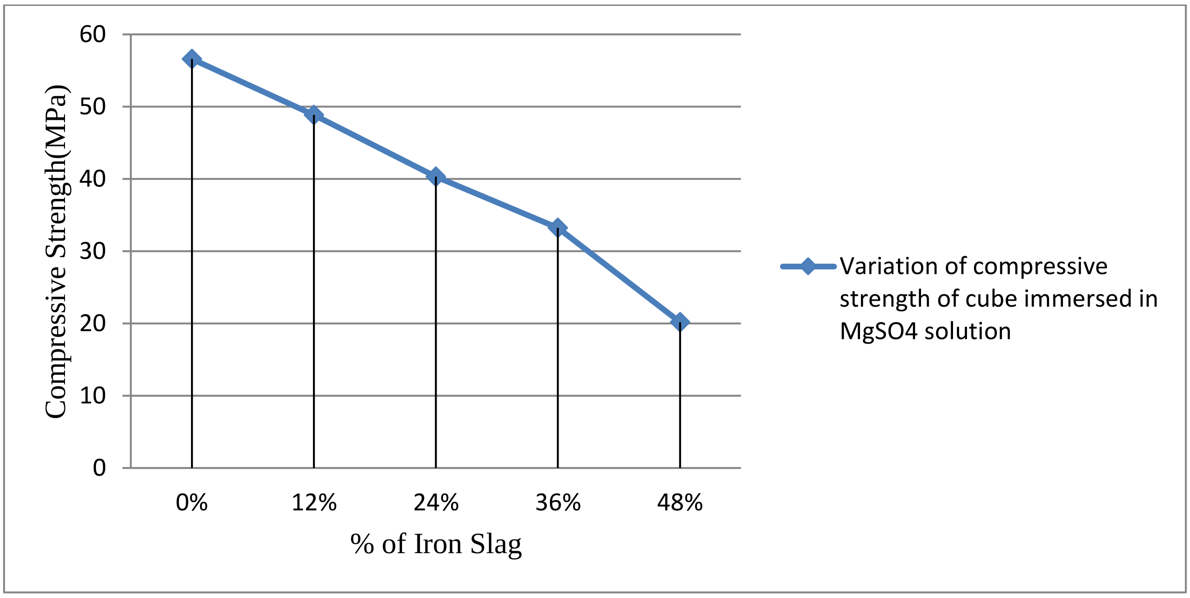



**Fig.5.14 Variation of Compressive Strength with increase in % of Iron Slag after 7 days when immersed in MgSO4 Solution**

When the comparison between the compressive strength of cube immersed in water and the cube immersed in MgSO4 solution is done, the following results are:

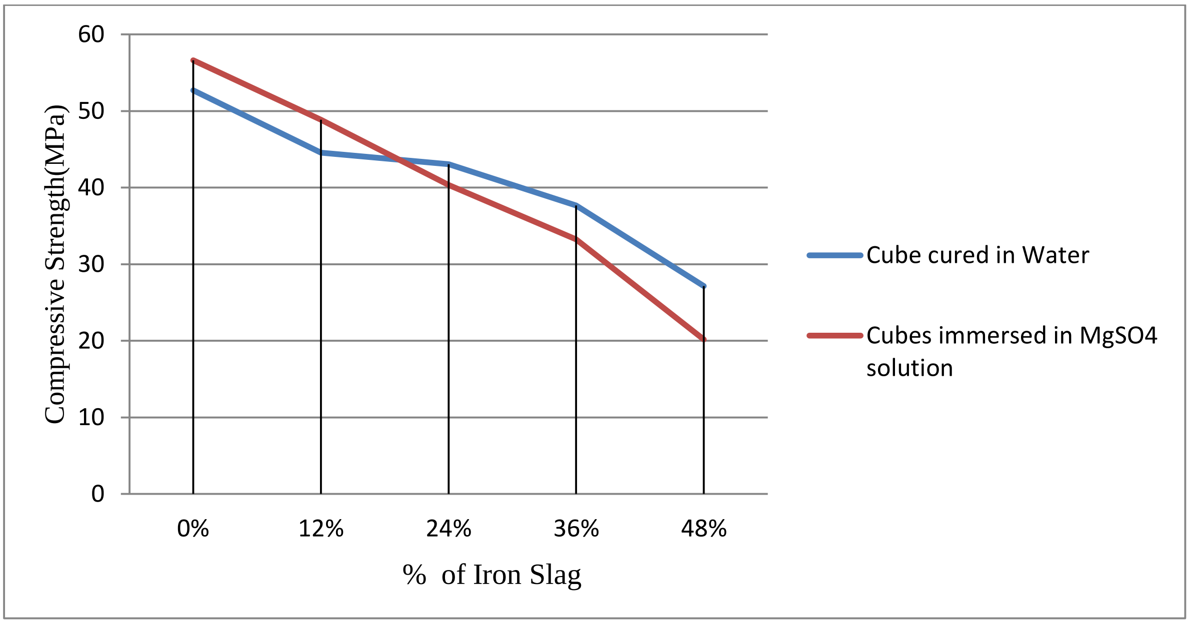



**Fig.5.15 The comparison between the compressive strength of cube immersed in water and the cube immersed in MgSO4 solution.**

From the above graph , it is clearly observed that the compressive strength of the cube goes on decreasing when we replaces the cement with Iron Slag powder even after curing it by MgSO4 solution.

Case II: After 28 days

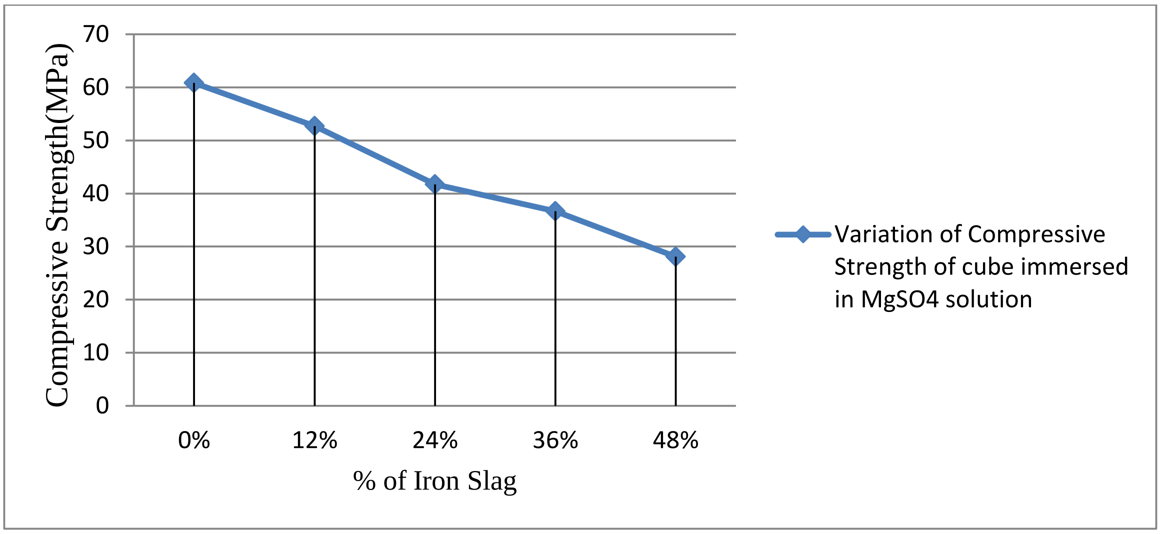



**Fig.5.16 Variation of Compressive Strength with increase in % of Iron Slag after 28 days when immersed in MgSO4 Solution.**

When the comparison between the compressive strength of cube immersed in water and the cube immersed in MgSO4 solution is done, the following results are:

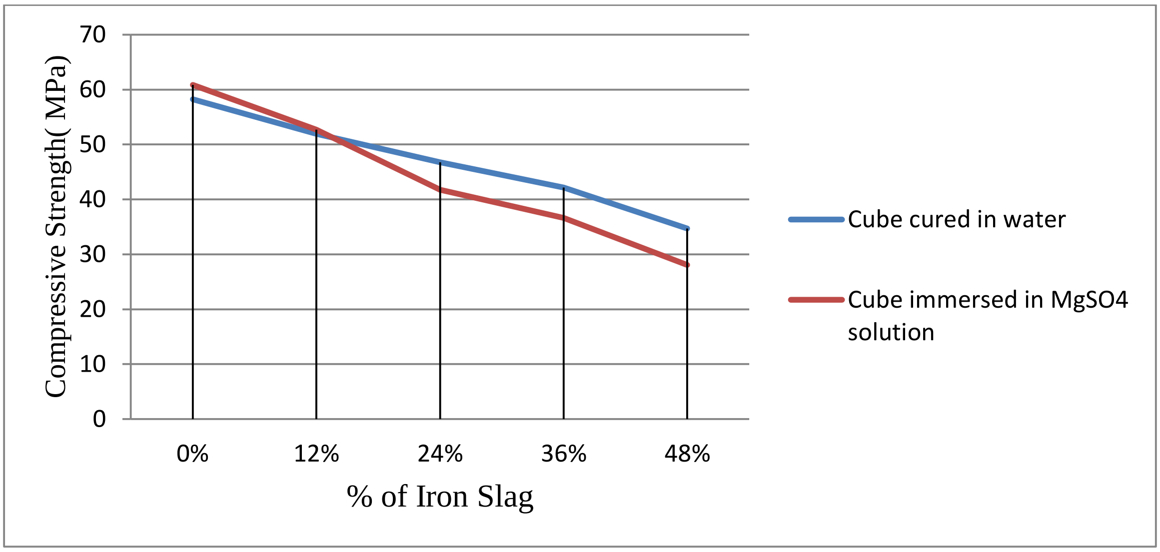



**Fig.5.17 The comparison between the compressive strength of cube immersed in water and the cube immersed in MgSO4 solution after 28 days.**

When we immersed the cube for curing in $MgSO_4$ solution then the compressive strength of cube increases for O% and 12% replacement whereas, the strength goes on decreasing for later replacement.

# CHAPTER 6
# CONCLUSIONS

## 6.1 General

The present study concluded the effect of addition of Iron slag on strength and durability properties of concrete mixes prepared by adding Iron slag in replacement with cement by weight and in which iron slag varying percentages (6,12,18,24,36,48 %) of (cement + iron slag) by weight. On the basis of the results from the present study, following conclusions were drawn.

## 6.2 Conclusions

i. The material used in the experiments is good and workable.

ii. The admixture used in the experiments gave the great impact on the strength of concrete.

iii. The Specific gravity of Iron Slag powder is near about the specific gravity of the cement so the Iron Slag powder is used by replacing the cement at various percentages.

iv. While testing the split tensile strength of the cylinder, it is observed that cylinder fails along its diameter vertically.

v. While testing the flexural strength of the beam it is seen that beam failed in between the loading span between its two supports and hence formula that we used is $3PL/4bd^2$.

vi. It is observed while experiment that the compressive strength of concrete increases at 6% of replacement of cement with iron slag but for 9 and 12 % of replacement, the strength decreases as compared to 6% and again when we increases the replacement, the strength goes on decreasing.

vii. The optimum compressive strength is obtained at 12% of replacement of cement with iron slag powder.

viii. The compressive strength of the cube after curing for 28 days, came more than 50 MPa in case of 0%,6%,9% and 12% replacement of cement with Iron Slag powder but for 18% replacement it has 4.02% lesser strength than the desired strength. So, it can be concluded that up to 12% replacement of cement with Iron Slag powder can be done.

ix. The tensile strength of cylinder after curing it for 28days, came more than 5MPa in case of 0% and 12% replacement of cement with Iron Slag powder but for 24% replacement, it has 8.58%lesser strength than desired tensile strength i.e. 5MPa. So, it can be concluded that up to 12% of replacement of cement with Iron Slag powder can be done.

x. In case of flexural strength of beam, the replacement of cement with Iron Slag powder can be done up to 24%.

xi. The flexural strength increases initially as the replacement of cement with Iron Slag increases, but after 12%, the strength decreases.

xii. While doing the Sulphate attack test it is concluded that compressive strength of cube goes on decreasing as replacement of cement with Iron Slag increases.

xiii. As the replacement of the cement with Iron Slag powder increases, the binding property of concrete goes on decreasing.

xiv. The workability of concrete also decreases when we are replacing the cement with Iron Slag powder.

xv. Hence, Iron Slag powder can be used as one of the alternative material for the cement but up to the certain limits only.

## 6.3 Scope of the Study

We have performed the experimental investigation to check the strength and performance of design mix concrete i.e. M50 grade at various replacement of cement with Iron Slag powder.

Various tests performed in the laboratory are compressive strength, split tensile strength, flexural strength and Sulphate attack by curing the specimen at 7 days and 28 days. Due to the lack of time, we were not able to test the specimen by doing further curing i.e. at 56 days and 128 days. The strength may vary by doing further curing. The effect of temperature on the specimen was not performed due to lack of various instrument and machine. It is known that iron slag may be one of the best replacement of cement as it increases the strength without affecting the environment. We can also perform tests for chlorination, carbonation, permeability and hydration. We can also check how iron slag helps in leach beds.

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