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# AN INVESTIGATION OF MECHANICAL BEHAVIOUR OF CONCRETE BY PARTIALLY REPLACING SAND WITH CUPOLA SLAG AND OPC WITH FLY ASH

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**Abstract**— Due to growing environmental awareness, as well as stricter regulations on managing industrial waste, the world is increasingly turning to researching properties of industrial waste and finding solutions on using its valuable component parts so that those might be used as secondary raw material in other industrial branches. Besides that the reduction in the sources of natural sand and the requirement for reduction in the cost of concrete production has resulted in the increased need to identify substitute material to sand as fine aggregates in the production of concretes especially in Concrete. One of the major environmental issues is the large quantity of waste industrial waste resulting from the industrial sector which is deposited in domestic waste and in landfills, this is harmful to human. Considering the specificity of physical and chemical properties of metallurgical slags and a series of possibilities for their use in other industrial branches and in the field of civil constructions, this paper demonstrates the possibilities of using cupola slag as partial replacement of sand in concrete. In this present study cupola Slag is used to replace fine aggregates from 0% to 50% and fly ashis used to replace OPC from 0% to 35%. Concrete cubes, cylinders and beams were cast and their compressive strengths, tensile strength and flexural strength respectively evaluated at 7, 14 and 28 days.

**Index Terms**— River sand, Cupola Slag, Cement, Fly Ash, Compressive Strength, Split Tensile Test, Flexural Test

## 1 INTRODUCTION

Cupola Slag 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 making in blast furnace and steel manufacturing in steel melting shop. Primarily, the slag consists of calcium, magnesium, manganese and aluminium silicates in various combinations. In current years, growing thoughtfulness of environmental issues in our society had an impact in improved utilization of slag. The chemical composition of cupola slag are shown in table 1

**Table 1 Chemical composition of Cupola Slag (by XRF method)**

| Sr No. | Elements | Test Results(%) |
|---|---|---|
| 1 | $Al_2O_3$ | 09.50 |
| 2 | MnO | 02.90 |
| 3 | $SiO_2$ | 45.00 |
| 4 | MgO | 02.35 |
| 5 | $TiO_2$ | 01.00 |
| 6 | CaO | 14.25 |
| 7 | $Fe_2O_3$ | 23.50 |
| 8 | $Cr_2O_3$ | 00.30 |
| 9 | $Na_2O_3$ | 00.50 |

**Fig 1 Cupola Slag**

Inspite of various technologies growing for utilization of Fly Ash in concrete in India is yet low. It is promising that utilization rate will be inceased if large quantity of Fly Ash are incorporated in concrete mixes. This research was directed toward studying effects of Fly Ash on properties of concrete.

**Table 2 Chemical composition of Fly Ash (C type) (by XRF method)**

| Sr No. | Elements | Test Results(%) |
|---|---|---|
| 1 | $Al_2O_3$ | 17.50 |
| 2 | CaO | 26.10 |
| 3 | $SiO_2$ | 35.40 |
| 4 | MgO | 04.60 |
| 5 | $Fe_2O_3$ | 05.30 |
| 6 | $SO_3$ | 02.80 |


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### 1.1 Objective

- To establish alternative for sand and cement.
- To obtain the optimum dosage of cupola slag with fly ash.
- To study the impacts of partially replace with cupola slag with sand and fly ash with cement.
- Study of strength of concrete at the ages of 7 days and 28 days by partially replacing of sand and cement with cupola slag and fly ash respectively.

## 2 Literature Review

From referred literatures, one can conclude that waste cupola slag can be used in concrete by replacing sand partially or fully. Moreover around 15% - 25% replacement gives better result in compressive and other mechanical tests than conventional mixes. So we can use slag as a partially or fully replaced with fine aggregate as well as coarse aggregate. For Fly Ash, it can be used in concrete as a partially replacement of OPC with 25% - 35%. As far as research is concerns 30% relacemt gives highest compressive test so it can be used.

Authors decided to make mix design of M20 by partially replacing river sand and OPC with cupola slag and Fly ash(C type) respectively. Replacements are 15% for River sand(zone II) and 30% for OPC.



## 3 Initial Tests on oncrete ingredients

### 3.1 Test on OPC

The property of cement typically measured in any laboratory includes normal consistency, setting time, soundness, fineness and compressive strength of mortar. Normal consistency is an empirical that indicates the minimum water required to produce a certain level of fluidity in the cement paste.

**Table 3 Physical Properties of Cement**

| Sr No | particulars | Test results | Specifiction in IS 12269-2013 |
|---|---|---|---|
| 1 | Specific Gravity | 3.15 | |
| 2 | Fineness | $299 m^2/kg$ | $225 m^2/kg$ |
| 3 | Consistency | 28% | 26%-32% |
| 4 | Initial setting Time | 142 min | Min 30 min |
| 5 | Final Setting time | 190 min | Max 600min |
| 6 | Comp. Strength | 38MPa(3 days) | Min 27MPa |
| 7 | Soundness | 3 mm | Max 10mm |

**Table 4 Chemical Properties of Cement**

| Sr No | Particulars | Test Results | Specification in IS 12269-2013 |
|---|---|---|---|
| 1 | Manesia (%by mass) | 2.84 | Max 6.00 |
| 2 | Ratio of Alumina to iron oxides | 1.32 | Min 0.66 |
| 3 | In soluble Residue (% by mass) | 1.84 | Max 4.00 |
| 4 | Lime saturation factor CaO- 0.7SO3 | 0.91 | 0.8 - 1.02 |
| 5 | Total Loss on Ignition (%) | 1.80 | Max 4.00 |
| 6 | Chlorides (%) | 0..18 | Max 0.10 |
| 7 | Sulphuric anhydride (% by mass) | 2.76 | Max 3.50 |

**(Source: Given by Ultratech cement provider)**

### 3.2 Test on River Sand (zone II)

**Table 5 Physical Properties of River Sand**

| Sr no | Characteristics | Value |
|---|---|---|
| 1 | Speciic gravity | 2.59 |
| 2 | Bulk Density | 1.3 |
| 3 | Fineness modulus | 2.618 |
| 4 | Water absorptions | 0.89 |
| 5 | Silt Content | 7.04 |
| 6 | Bulking of sand | 1.82 |

### 3.3 Test on Coarse aggregate

**Table 6 Physical Properties of Coarse aggregate**

| Sr No | Tests | Tests Results | Specification in IS 2386-1963 |
|---|---|---|---|
| 1 | Specific gravity | 2.73 | |
| 2 | Fineness Modulus | 6.95% | Max 10% |
| 3 | Elongation Index | 43.85% | Max 45% |
| 4 | Flakiness Index | 11.92% | Max 30% |
| 5 | Crusing Value | 21% | Max 30% |

### 3.4 Water

A potable water is generally considered satisfactory for mixing and curing of concrete. Water is free from any detrimental contaminants and was good potable quality. Water from lakes and streams that contain marine life also usually is suitable.

### 3.5 Cupola slag

**Table 7 Physical Properties of cupola**

| Sr No | characteristics | Test Results |
|---|---|---|
| 1 | Specific gravity | 1.88 |
| 2 | Bulk Density | 1.64 |
| 3 | Fineness Modulus | 2.10 |
| 4 | Water absoptions | 1.38 |
| 5 | Silt content | 5.263 |

## 4 Methodology

Ordinary Portland cement of 53 grade with specific gravity 3.15 was used in making the concrete. The fine aggregate used was sand of zone II and its specific gravity was 2.59. Course aggregates used in experimentation were 20m and down size and their specific gravity was found to be 2.72. The specific gravity of fly ash is found to be

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2.1. Mix proportion used for M20 concrete (control concrete) was 1:1.47:2.94 with w/c = 0.50 (IS 10262:2009).

**Fig 2 Compression test**

**Table 8 5 cubes quantities with M20 concrete mix in cupola replacements**

| Sr No | Cupola Replacements (%) | OPC (kg) | Sand (kg) | Cupola (kg) | Coarse Aggregate (kg) | Grit (kg) |
|---|---|---|---|---|---|---|
| 1 | 0 | 9.71 | 14.27 | 0 | 17.12 | 11.42 |
| 2 | 3 | 9.71 | 13.84 | 0.428 | 17.12 | 11.42 |
| 3 | 6 | 9.71 | 13.41 | 0.8562 | 17.12 | 11.42 |
| 4 | 9 | 9.71 | 12.98 | 1.2842 | 17.12 | 11.42 |
| 5 | 12 | 9.71 | 12.55 | 1.7124 | 17.12 | 11.42 |
| 6 | 15 | 9.71 | 12.12 | 2.1405 | 17.12 | 11.42 |
| 7 | 18 | 9.71 | 11.70 | 2.5686 | 17.12 | 11.42 |
| 8 | 21 | 9.71 | 11.27 | 2.995 | 17.12 | 11.42 |
| 9 | 30 | 9.71 | 9.989 | 4.281 | 17.12 | 11.42 |
| 10 | 40 | 9.71 | 8.562 | 5.708 | 17.12 | 11.42 |
| 11 | 50 | 9.71 | 7.135 | 7.135 | 17.12 | 11.42 |

**Table 9 Compressive Strength at 7 and 28 days**

| Sr No | Cupola Replacements (%) | Compressive strength 7days (MPa) | Compressive strength 28 days (MPa) |
|---|---|---|---|
| 1 | 0 | 13.49 | 20.76 |
| 2 | 3 | 09.81 | 15.45 |
| 3 | 6 | 13.539 | 21.089 |
| 4 | 9 | 14.188 | 21.662 |
| 5 | 12 | 14.26 | 23.009 |
| 6 | 15 | 18.64 | 28.68 |
| 7 | 18 | 15.427 | 24.142 |
| 8 | 21 | 15.21 | 23.769 |
| 9 | 30 | 15.646 | 23.493 |
| 10 | 40 | 14.85 | 23.351 |
| 11 | 50 | 13.99 | 22.938 |

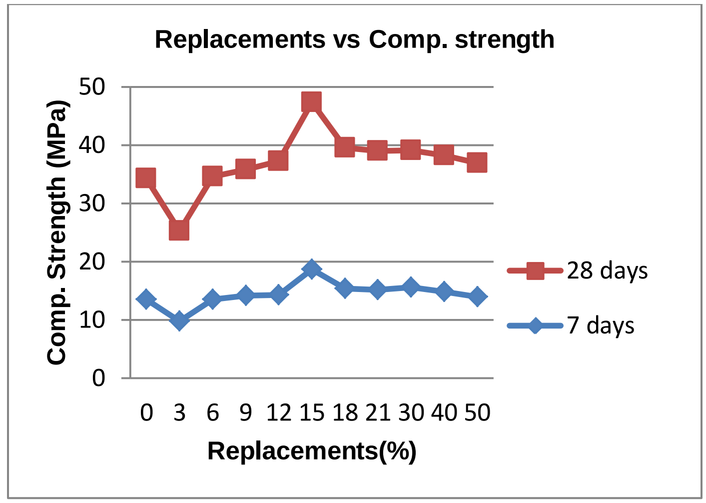


**Fig 3 Compressive Strength of Cubes at 7 and 28 days**

**Table 10 5 cubes quantities with M20 concrete mix in fly ash replacements**

| Sr No | Fly ash (%) | OPC | Fly ash | sand | cupola | Coarse Aggregate | Grit |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 9.71 | 0 | 12.13 | 2.14 | 17.124 | 11.42 |
| 2 | 7 | 9.03 | 0.68 | 12.13 | 2.14 | 17.124 | 11.42 |
| 3 | 14 | 8.35 | 1.36 | 12.13 | 2.14 | 17.124 | 11.42 |
| 4 | 21 | 7.67 | 2.04 | 12.13 | 2.14 | 17.124 | 11.42 |
| 5 | 28 | 6.99 | 2.72 | 12.13 | 2.14 | 17.124 | 11.42 |
| 6 | 30 | 6.80 | 2.91 | 12.13 | 2.14 | 17.124 | 11.42 |
| 7 | 35 | 6.31 | 3.40 | 12.13 | 2.14 | 17.124 | 11.42 |

**Table 11 Compressive Strength at 7 and 28 days (fly ash contains cube result in accelerated curing tank)**

| Sr No | Fly ash replacements | Comp strength 7days (MPa) | Comp strength 7days (MPa) |
|---|---|---|---|
| 1 | 0 | 13.49 | 20.76 |
| 2 | 7 | 10.94 | 17.64 |
| 3 | 14 | 11.7 | 18.36 |
| 4 | 21 | 13.29 | 20.62 |
| 5 | 28 | 14.58 | 22.78 |
| 6 | 30 | 16.5 | 24.80 |
| 7 | 35 | 15.14 | 23.12 |

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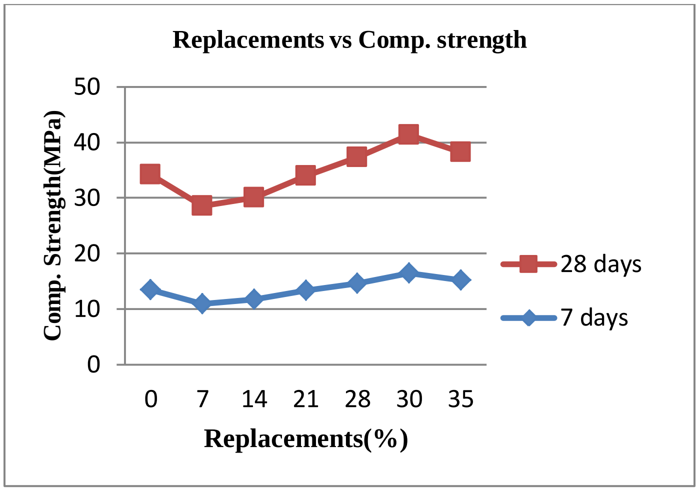


Fig 4 **Compressive Strength of Cubes at 7 and 28 days**

**Table 11 Compressive test at 7,14 and28 days**

| | Compressive strength 7 days(MPa) | Compressive strength 14 days(MPa) | Compressive strength 28 days(MPa) |
|---|---|---|---|
| **Control mix M20** | 13.49 | 17.68 | 20.76 |
| **Concrete mix M20** | 18.37 | 24.39 | 29.12 |

**(Concrete mix M20 means it has 15% cupola slag and 30% flyash)**

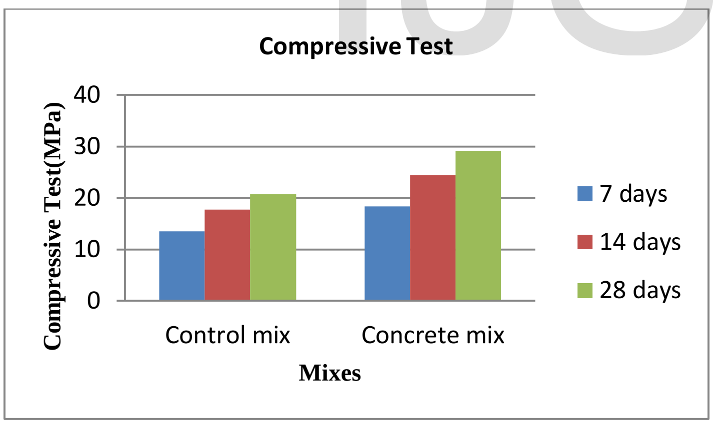


**Fig 5 Compressive Strength in MPa at 7 14 and 28 days**

**Table 12 Flexural tensile test at 7,14 and28 days**

| | Flexural strength 7 days(MPa) | Flexural strength 14 days(MPa) | Flexural strength 28 days(MPa) |
|---|---|---|---|
| **Control mix M20** | 2.49 | 2.80 | 2.87 |
| **Concrete mix M20** | 3.12 | 3.32 | 3.57 |

**Fig 6 Flexural Test**

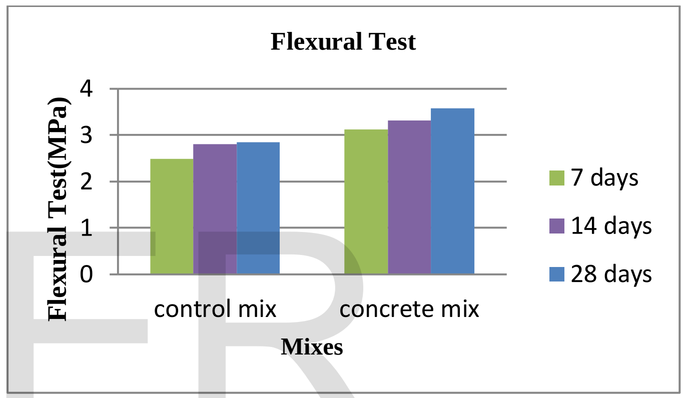


**Fig 7 Flexural Strength in MPa at 7 14 and 28 days**

**Table 13 Split Tensile Test at 7, 14 and 28 Days**

| | Tensile strength 7 days(MPa) | Tensile strength 14 days(MPa) | Tensile strength 28 days(MPa) |
|---|---|---|---|
| **Control mix M20** | 2.57 | 2.94 | 3.19 |
| **Concrete mix M20** | 3.21 | 3.47 | 3.86 |

**Fig 8 Split Tensile Test**

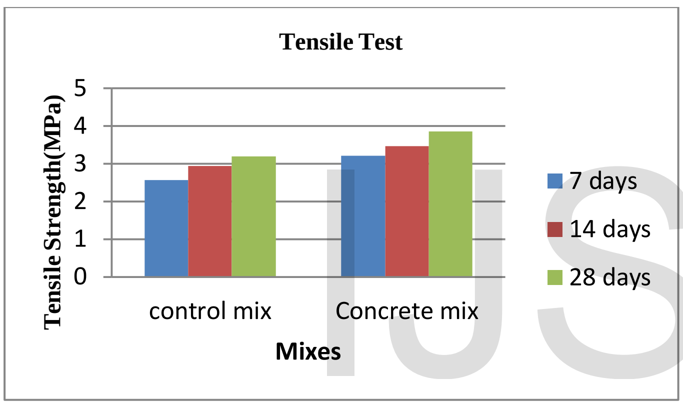


**Fig 9 Flexural test at 7, 14 and 28 days**

## 5 Discussion and Results

As the exploitation of the nature and natural materials had increased exponentially, new thoughts of recycling the wastes is the only way to preserve the nature. The above results are at par with the studies of conventional materials readily available in market. Results of investigation reveal that it is feasible to replace natural sand by cupola slag and opc with fly ash to achieve strength, economy and to achieve problem of waste disposal.

## Conclusions

An experimental study was conducted to study the effect of cupola slag in concrete when used as partial replacement for sand and OPC with fly ash. The following conclusions were drawn from the experimental studies for M20 grade of concrete.

- The maximum value of compressive strength obtained is 28.68MPa for M20 grade of concrete respectively when the fine aggregate is replaced by 15% cupola slag.
- Partially replacements of sand and OPC to15% cupola and 30% flyash respectively give maximum compressive strength and its value is 29.12 MPa at 28 days.
- Partially replacements give higher Flexural strength and it is 3.57MPa which is higher than contrl mix Flexural strength 2.87 MPa.
- Besides compressive strength and Flexural strength, it also gives best Tensile strength 3.86 MPa while contrl mix gives 3.19 MPa which is low.
- From the present study it is found that cupola slag when used as fine aggregate perform better. The reason may be due to its mineralogical composition and size of crystals.

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