# Effect of Copper Slag And Fly Ash on High Strength Concrete

**Karanam Anil kumar[1], G. Kalyan (M.tech)[2]**
[2]Dept of Civil Engineering
[1]Assistant Professor, Dept of Civil Engineering
[1, 2] Akula Sree Ramulu college of engineering..

***Abstract-*** *Concrete is an extraordinary building material in the human history. It is no doubt that with the improvement of human civilization, concrete will continue to be a governing construction material in the future. Concrete is one of the necessary elements for structural work in the modern construction. In the decade, buildings around the world have become higher and so the structural strength demand for concrete is increased. Hence, they require high strength concrete.*

*In this present work, an experimental investigation was conducted to study the effect of using copper slag as a fine aggregate and the effect fly ash as partial replacement of cement on the properties high strength concrete. Totally ten concrete mixtures were prepared. Five mixes containing different proportions of copper slag ranging from 0% (for the control mix) to 75%.Five mixes containing fly ash as partial replacement of cement ranging from 6% to 30%(all 5 mixes contains 50% copper slag as sand replacements) . Concrete mixes were tested for workability, density, compressive strength, tensile strength, flexural strength and durability. The results indicate that there is a slight increase in the density of nearly 6% with the increase of copper slag content, whereas the workability increased with increase in copper slag percentage. Addition of up to 50% of copper slag as sand replacement yielded comparable strength with that of the control mix. However, further additions of copper slag caused reduction in the strength due to an increase of the free water content in the mix. Mix with 75% copper slag replacement gave the lowest compressive strength value of approximately 80 MPa, which is almost 4% more than the strength of the control mix. For this concrete containing 50% copper slag, fly ash is introduced in the concrete for better performance. Introduction of fly ash gave better results than concrete containing 50% copper slag.The strength has increased approximately 3% containing 18% fly ash and decreased with further replacements of cement with fly ash. Whereas, workability got increased with further increase in fly ash content. Therefore, it is recommended that 50% of copper slag can be used as replacement of sand and 18% fly ash can be used as replacement of cement in order to obtain high strength concrete with better performance with good strength and durability properties.*

## I. INTRODUCTION

**GENERAL** Concrete is a highly important building material in the human history. It is no doubt that with the improvement of human civilization, concrete will continue to be a governing construction material in the future. Concrete is probably the most widely used construction material in the world. It is only second to water as the most profoundly consumed substance with about six billion tons being produced every year. In 2011, about 3.8 billion tons of cement was produced worldwide, which can be translated to about 38 billion tons of cement-based products (from which concrete is the majority), assuming that cement constitutes 10% of their mass. Such a common application of concrete and other cement based materials is caused by a number of factors, including their worldwide availability, relatively low price, good mechanical properties and durability. Concrete having compressive strengths of 20-40 $N/mm^2$ has been usually used in constructions. With the demand for more advanced structural practices along with deterioration , long term poor performance of conventional concrete led to enhanced explorations for development of concrete which would tally on all the aspects that a new construction material is evaluated upon strength, workability, durability, affordability and will thus facilitate the construction of maintainable and cost-effective buildings with an extraordinary design moreover providing a material that will have long term better performance and reduced maintenance. The development of high performance concrete in this regard has been a great innovation in concrete technology. ACI defines High Performance Concrete as “Concrete having special features of performance and consistency requirements that are not always be achieved regularly using conventional ingredients and normal mixing, placing and curing practices”. Main factors for High Performance Concretes are strength, long term durability, serviceability as determined by crack and deflection control, along with response to long term environmental effects. High performance concretes (HPC) are those concretes which are having properties which satisfy the various performance standards. Generally, concretes with higher strengths and qualities superior to conventional concretes are called High performance concrete. Hence HPC can be considered as a logical improvement of cement concrete in which the constituents are proportioned and nominated to contribute efficiently to the different properties of cement concrete in fresh and also in hardened states. High strength concrete is mostly a form of HPC which has compressive strength higher than the conventional concrete. In HSC, reduced weight is essential where architectural concerns require smaller load carrying components. The use of HSC offers various advantages in the maintainable and economical design of structures and gives a direct savings in the concrete volume saved, savings in land costs in congested areas, decrease in form-work area and cost.

## II. CONCEPTS IN THE DESIGN OF HIGH STRENGTH CONCRETE

In order to achieve high strength including performance, the various important factors that govern the strength of concrete are as follows

- Properties of the cement paste
- Properties of the aggregate
- Different types of chemical and mineral admixtures that are to Be used
- Comparative proportions of the constituent materials to beUsed
- Paste –Aggregate interaction
- Mixing, Compaction and Curing
- Testing Procedures

All these factors need to be adjusted in order to achieve concrete with considerably high compressive strength for HPC.

## III. MATERIAL SELECTION FOR HSC

The main constituents of HPC are almost the same as that of conventional concrete. These are

i. Cement
ii. Fine aggregate
iii. Coarse aggregate
iv. Water
v. Mineral admixtures (fine filler and/or pozzolonic supplementary cementitious materials)
vi. Chemical admixtures (plasticizers, superplasticizers, retarders, air-entraining agents)

**Cement**

There are two essential requirements for any cement: (i) strength improvement with time and (ii) facilitating proper rheological features in fresh state.

**Coarse aggregate**

The main factors of coarse aggregate that effect the concrete performance are its shape, texture and the maximum nominal size. As the aggregate is usually stronger than the paste, its strength is not a important factor for conventional concrete. Though, the aggregate strength becomes essential in the case of HPC. Surface texture and mineralogy affects the bond between the aggregates and the paste and also the stress level at which micro cracking arises. The surface texture also affects the modulus of elasticity, the shape of the stress-strain curve and the compressive strength of concrete.

**Effect of Aggregate Type**

The essential strength of coarse aggregate is not an necessary factor if w/c falls within the range of 0.50 to 0.70 due to the fact that the cement-aggregate bond or the hydrated cement paste fails long before than aggregates do.

It is nevertheless, not true for very high strength concretes (VHSC) having very low water-cement ratio of 0.20 to 0.30. For such concretes, aggregates can undertake the weaker-link role and fail in the form of transgranular ruptures on the failure surface. Though, the aggregate minerals should be strong enough , unchanged, and fine grained in order to be appropriate for very HSC . Intra granular and inter granular fissures partially decomposed coarse-grained minerals, and the existence of cleavages and lamination planes tend to deteriorate the aggregate, and hence the ultimate strength of the concrete.

**Effect of Aggregate Size**

The use of larger maximum nominal size of aggregate affects the strength in numerous ways. First, since larger aggregates have less specific surface area and the aggregate-paste bond strength is less, the compressive strength of concrete is reduced. Secondly, for a given volume of concrete, using larger aggregate effects in a smaller volume of paste thus providing more restriction to volume changes of the paste. This may prompt additional stresses in the paste causing micro cracks prior to application of load, which may be a serious factor in very high strength (VHS) concretes. Hence, it is the general consent that smaller size aggregate should be used to produce high performance concrete

It is usually suggested that 10 to 12 mm is the appropriate maximum size of aggregates for making high strength concrete. However, satisfactory performance and economy can also be reached with 20 to 25 mm maximum size graded aggregates by appropriate proportioning with a mid or high-range water reducer, high volume blended cements, and coarse ground Portland cement.

**Mineral admixtures**

Mineral admixtures form a necessary part of the HPC mix. These are used for several purposes, depending upon their properties. More than the chemical composition, mineralogical and granulometric features govern the effect of mineral admixture's role in improving properties of concrete. The fly ash (FA), the ground granulated blast furnace slag (GGBS) and the silica fume (SF) has been used extensively as supplementary cementitious materials in HSC. These mineral admixtures, typically fly ash and silica fume decrease the permeability of concrete and chloride-ion penetration without much variation in the total porosity.

The pozzolanas also reacts with other alkalis such as sodium and potassium hydroxides existing in the cement paste. These reactions decreases permeability, additional alkalis present in the paste, decrease free water content, thus rise in the strength and increases the durability.
Fly ash is used as a partial replacement for cement in concrete and delivers very good Performance. Concrete is durable with continuous increase in compressive strength beyond 28 days. There is minute indication of carbonation, it has low to average permeability and good resistance to chloride-ion penetration. Chloride ion penetration rating of high volume fly ash (HVFA) concrete is less than 2000 coulombs, which indicate a very low permeability concrete. It remains to increase because many fly ash particles react very slowly, pushing the coulomb value lower and lower.

**<u>Chemical composition</u>**

The chemical compositions of mineral admixtures such as natural pozzolanas, fly ash, silica fume, rice husk ash, and metakaolin is presented in Table 1

**Table: 1 Typical oxide analysis of mineral admixtures**

| Mineral admixtures | Main oxides present | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | SiO | Al2 | FeO | C2 | Mg | SO | Alkali | LoI |
| Diatomaceous earth | 86 | 2.3 | 1.8 | | 0.6 | | 0.4 | 5.2 |
| Fly ash (coal) | 55 | 2.5 | 9.2 | 4.4 | 1.0 | 1.0 | 1.0 | 2.0 |
| Fly ash (lignite) | 44 | 21 | 3.8 | 12. | 3.1 | 7.0 | 7.8 | 0.82 |
| Blast furnace slag | 38 | 8 | 2 | 40 | 11 | 0.1 | 0.8 | 2.0 |
| Silica fume | 90 | 1.0 | 0.0 | 0.1 | 0.2 | 2.2 | 0.1 | 3.6 |
| Rice husk ash | 92 | 0.4 | 0.2 | 0.4 | 0.4 | 0.1 | 2.9 | 2.8 |

A look at this table tells that silica and alumina content vary widely. However, these chemical changes do not considerably effect the properties of concrete. Fly ashes usually contain less silica and more alumina when compared to natural pozzolanas. Both fly ash and blast furnace slag have high calcium and magnesium oxide content. Highly active admixtures like silica fume and rice husk ash contains high content of silica.

The ground, granulated blast furnace slag and rice husk ash have to be ground to the required fineness to attain pozzolanic action. Typically, particles less than 10µm in size contribute to early strength.Particles between 10 and 45 µm show strength gain up to 28 days.Particles larger than 45 µm contribute little to the strength.The slag is normally ground to fineness of 460-560 m2/kg. The typical surface area of micro silica is 12,000 m2/kg. This is because the particle size of silica fume is in the range of 0.01-0.45 µm.However, the rice husk ash is ground only to a fineness of 6-10µm because of the porous structure. The metakaolin is ground to a fineness of about 1-2 µm.

The pozzolanic material with large surface area exhibits tremendous reactivity. It imparts stability and cohesiveness to the mixture and prevents bleeding and also segregation. A summary of the Characteristics of various mineral admixtures is given in Table 2

| Type | Classification | Chemical composition | Particle characteristics |
|---|---|---|---|
| Ground granulated blast furnace slag (GGBS) | Cementitious and pozzolanic | Silicate glass containing calcium magnesium silicate | Unprocessed materials are grains like sand. These are ground to size < 45 µm (500 $m^2/kg$ Blaine) particles and |
| Calcium-rich fly ash | Cementitious and pozzulanic | Silicate glass containing mainly calcium, magnesium, aluminum alkides. Also contains $C_3A$, CaO, $C_2S$, $C_4A_3S$ traces unburnt carbon 1-2% | Powder consists of particles < 45 µm. However, 10-15% are more than 45 µm. Particles are solid spheres of 20 µm. surface is generally smooth. |
| Condensed silica fume | Highly active pozzolana | Pure silica of non-crystalline form | Extremely fine powder consisting of solid spheres of 0.1 µm average diameter, about 20 $m^2/kg$ su |
| Rice husk ash | Highly active pozzolana | Consists essentially of pure silica in non-crystalline form | Particles are <45 mm but have cellular and porous |
| Low-calcium fly ash | Cementitious and pozzolanic | Mostly silicate glass containing aluminium and iron and alkides, small quantities of quartz, hematite, etc. | Powder having particles of 15-30% > 45 µm. most particles are solid sphere. |
| Natural material | Natural pozzolana | Contains alumino silicate glass, natural pozzolanas containing quartz, | Particles are <45 µm and have rough texture. consists of crystalline silica, |
| Slowly cooled blast furnace slag, bottom ash, field burnt ri | Weak pozzolana | Consists of crystalline silicate material | Pulverized to fine powder, and ground materials have rough texture. |

## Superplasticizers or HRWR

The superplasticizers are widely used in HSCs with very low water- cementitious material ratios. In addition to deflocculation of cement grains and increase in the fluidity, the other phenomena that are likely to be present are the following

- **(a)** Induced electrostatic repulsion between particles
- **(b)** Distribution of cement grains and resulting the release of water trapped within cement flocks
- **(c)** Decrease of surface tension of water
- **(d)** Improvement of lubrication film between particles
- **(e)** Change in morphology of hydration products
- **(f)** Induced steric-hindrance preventing particle to particle contact

The key objectives for using superplasticizers are the following:

- **(i)** To produce very dense concrete and to provide very low permeability with sufficient resistance to freezing-hawing
- **(ii)** To reduce the effect of heat of hydration by lowering the cement content
- **(iii)** To make concrete with low air content and high workability to ensure high bond strength
- **(iv)** To lower the water-cement ratio in order to keep the influence of creep and shrinkage to a minimum
- **(v)** To create concrete of lowest porosity to protect it against external attacks

The following types of superplastisizers are used

- Naphthalene-based
- Melamine-based
- Lignosulfonates-based
- Polycarboxylate-based
- Combinations of above

## Superplastisizer Dosage

There is no a prior way of determining the required superplasticizer dosage. It must be determined by trial and error procedure. Basically, if strength is the primary criterion, then one should work with the lowest w/c ratio possible, and thus the highest superplasticizer dosage. However, if the rheological properties of the HPC are very important, then the highest w/c ratio possible consistent with the required strength should be used, with the superplasticizers dosage then adjusted to get the desired workability.

## Retarders

Retarders are generally recommended for HSC to minimize the slump loss problem.However, it is difficult to maintain compatibility between the retarder and the superplasticizer Therefore, the Retarders are recommended only as a last resort.The rheology is better controlled by the use of appropriate mineral admixture (supplementary cementing material) discussed before.

**Mix Proportion**

The main difference between mix designs of HPC and CC is the emphasis laid on performance aspect also (in fresh as well as hardened stages of concrete) besides strength, in case of HPC. Whereas in design of CC mixes, strength of concrete is an important criterion. By imposing the limitations on maximum water–cement ratio, minimum cement content,workability (slump, flow table, compaction factor, Vee-Bee consistency), etc , it is sought to assure performance of CC, rarely any specific tests are conducted to measure the durability aspects of CC, during the mix design. In HPC, however, besides strength, durability considerations are given supreme importance. To achieve high durability of HPC, the mix design of HPC should be based on the following considerations:

**i**) The water-binder (w/b) ratio should be as less as possible, preferably 0.3 and below
**ii**) The workability of concrete mix should be enough to obtain good compaction (use suitable chemical admixtures such as superplasticizer (SP)
**iii**) The transition zone between aggregate and cement paste should be strengthened (add fine fillers such as silica fume (SF)
**iv**) The microstructure of cement concrete should be made dense and impermeable (add pozzolanic materials such as fly ash (FA), ground granulated blast furnace slag powder (GGBFSP), Silica fume, etc.
**v**) Proper curing regime of concrete should be established (this is to overcome the problems associated with usual adoption of very low water content and high cement content in HPC mixes)

## IV. REPLACING MATERIALS USED IN THIS PROJECT

**Fine aggregates** is an essential constituent of concrete. The worldwide consumption of natural river sand is very high due to the wide use of concrete. The demand for natural river sand is reasonably high in developed countries due to infrastructural development. In this condition several developing countries are facing a scarcity in the supply of natural sand.

The unavailability of adequate quantity of river sand for production of cement concrete is affecting the development of the construction industry in many parts of the country. Thus, the construction activities in developing countries are facing a problem to find new materials to minimize the demand of river sand. In order to minimize the dependency on natural aggregates as the main source of aggregates in concrete, artificially made aggregates and artificial aggregates generated from industrial wastes provide an alternative for the construction industry.

**COPPER SLAG: Fine aggregates replacing material**

**Copper slag** is considered as one of the industrial by-product which could have a favorable future in construction industry as partial or full substitute of aggregates. It is a by-product obtained during the smelting and purifying of copper. Major constituents of a smelting charge are sulphides and oxides of iron and copper. The charge also comprises of oxides like calcium oxide, alumina, magnesia and mainly silica which are either present in the original concentrate or added as flux. Thus, copper-rich matte (sulphides) and copper slag (oxides) are formed as two different liquid phases.

**Supplementary Cementitious Material**

At present, harsh environmental – pollution controls and regulations have resulted in an increase in the manufacturing wastes and sub graded byproducts which can be used as SCMs slag etc. The use of SCM's in concrete constructions not only saves these materials to check the pollution but also to improve the properties of concrete in fresh and hardened states.

**FLY ASH: A Pozzalanic Supplementary Cementitious material**

Fly ash as shown in fig 1. is the ash precipitated electro-statically from the exhaust fumes of coal fired power station. It is an eco-friendly product. Its particles are spherical and are generally of higher fineness than cement, so that the silica is readily available for reaction. The Portland pozzolana cement makes concrete more impermeable and denser as compared to Portland cement. The long term strength of cement blended with fly ash (>25 %) is better compared to OPC. The fly ash converts $Ca(OH)_2$ into useful cementitious compounds, thereby increasing the properties of hardened concrete.

**SILICA FUME: It is also a type of pozzolanic material.**

Mineral additions which are also known as mineral admixtures which have been used with cements for many years. There are two types of materials non crystalline and crystalline. Micro silica or silica fume is extreme fine non crystalline material. Silica fume is produced in electric arc furnace as a by-product of the production of elemental silicon's or alloys containing silicon. It is normally a light black shaded powder to somewhat like Portland or some fly ashes silica fume is generally categorized as a supplementary cementations material. Silica fume or micro silica was initially viewed as cement replacement material and in some area it is usually used as replaced by much smaller quantity of silica fume may be used as pozzalanic admixtures. Admixture is characterized as a material other than cement, water and aggregate that is utilized as a ingredients of concrete and is added to the batch instantly before mixing or during mixing. Pozzalanic admixtures are siliceous or aluminous material which is themselves give practically no cementitious esteem yet will in finely isolated structure also they synthetically respond with calcium hydroxide and freed on hydration at conventional temperature to structure mixes having cementitious properties in the presence of water. In our experiment we are using micro silica as a artificial pozzolans. In this present study, adding 25% by wt of cement in concrete.

Fly ash

Copper slag

Silica fume

Fig 1 Replacing materials used in the Project.

**Scope of Research Work** The study has been under taken to investigate the effects of a specially processed form of "copper slag" on fresh, hardened and durability properties of concrete.

**Objective of the study** In this study, the effects of addition of copper slag as fine aggregate and fly ash as a mineral admixture on fresh, hardened and durability properties of concrete are investigated. The precise objectives of the study are as follows:-

- To study the fresh property (slump) of concrete.
- To study variation in density of concrete.
- To study the development of hardened property (compressive strength, split-tensile strength, flexural strength) of concrete containing copper slag as fine aggregate, Fly ash as partial replacement of ordinary portland cement (opc) at various curing ages.

## V. LITERATURE REVIEW

**Introduction** This chapter deals with the review of the existing literature on the use of copper slag and mineral additives in concrete. The most important investigations, related to the current investigation, are summarized and salient facts which seem to emerge from the research discussed. The discussion is generally confined to the durability and strength characteristics of concrete with copper slag and mineral admixtures such as silica fume and fly ash.

**Fresh concrete properties Khalifa S. Al-Jabri ,Makoto Hisada et al(2009)**, This research study was conducted to investigate the performance of high strength concrete (HSC) made with copper slag as a fine aggregate at constant workability.Six concrete mixtures were prepared with different proportions of copper slag at constant workability. The water content was adjusted in each mixture in order to achieve the same workability as that for the control mixture. The results indicated that the water demand reduced by almost 22% at 100% copper slag replacement compared to the control mixture. Mix proportion and water-to-cement (w/c) ratio for high performance concrete and the measured slump and reduction in water quantity (per mixture) for HSC at constant workability are presented in table 2.1(a) and 2.1(b). Effect of copper slag addition as sand replacement of the workability and strength of HSC is shown in fig 2

**Table 1** Mix proportion and water-to-cement (w/c) ratio for high performance concrete

| Mix proportions (kg/m³) | | | | | | w/c ratio | SP (l/m³) |
|---|---|---|---|---|---|---|---|
| Cement | Silica fume | Sand | 10 mm Agg. | 20 mm Agg. | Water | | |
| 400 | 44 | 710 | 1190 | - | 140 | 0.35 | 7.9 |

**Table 2** The measured slump and reduction in water quantity (per mixture) for HSC at constant workability.

| Mix no. | Mix type | Slump (mm) | w/c ratio | Water (kg) | Saving in water demand (%) |
|---|---|---|---|---|---|
| 1 | Control (100%S) | 26 | 0.35 | 10.5 | 0 |
| 2 | 70%S + 30%CS | 24 | 0.32 | 9.6 | 8.6 |
| 3 | 50%S + 50%CS | 26 | 0.31 | 9.4 | 10.5 |
| 4 | 30%S + 70%CS | 27 | 0.30 | 8.9 | 15.2 |
| 5 | 20%S + 80%CS | 28 | 0.29 | 8.7 | 17.1 |
| 6 | 100%CS | 27 | 0.27 | 8.2 | 21.8 |

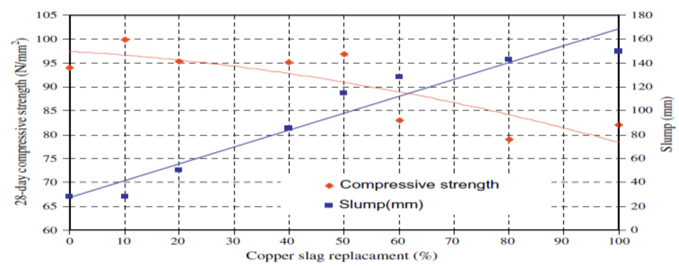


**FIG 2** Effect of copper slag addition as sand replacement on the workability and strength of HSC.

**Afaf Ghais, Duaa Ahmed et al (2014**), had reported that partial replacement of cement in engineering projects reduces the cost of construction with ecological benefits. The type and mix ratio affects the strength and workability of cement-concrete matrices. This research deals with the replacement of Class F fly ash with cement used in concrete. Replacement of 10% fly ash with cement improves the comprehensive strength of concrete in 28 days period, and the workability is increased by 53.8%.

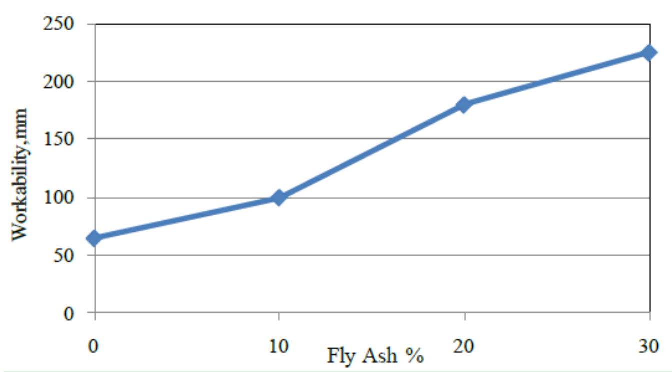


**FIG 3** Concrete workability with fly ash

**Summary**

This chapter include the application of High strength concrete and research work related to various properties such as fresh properties (Slump flow), hardened properties (compressive strength,split tensile strength, flexural strength), durability properties of concrete carried out by various researchers. In present study, experimental work has been done to study properties like workability, Mechanical properties.

**Gaps in Literature**

From the above literature, it was reviewed that researchers have studied copper slag properties and optimum dose as partial substitution of sand in high strength concrete. It was also reviewed that researchers have studied fly ash properties and optimum dose as partial substitution of cement in concrete. Thus, a need arises to study the combined use and effects of copper slag and fly ash on various properties of High strength concrete as partial replacement of fine aggregate and cement. Thus, the present study is carried out to address these gaps and provide the base for better understanding and improved usage of concrete.

## VI. EXPERIMENTAL PROGRAMME

**General** To achieve the objectives of the study, an extensive experimental programme was planned which included evaluation of slump, compressive strength, split tensile strength, flexural strength properties at various ages of concrete containing copper slag as sand replacement, fly ash as partial substitution of cement. This chapter outlines the experimental programme planned for this study in detail. The properties of the concrete making materials, concrete mix details, casting, curing, workability of concrete, details of tests performed on hardened concrete are presented.

**Test Programme**

The following test programme was planned to explore the fresh and strength properties of concrete:

- To obtain the physical properties of the concrete constituents i.e. ordinary Portland cement (OPC), sand, coarse aggregate and mineral admixtures used are as per relevant ACI and IS Codes of Practice.
- Obtaining the design mix for concrete.
- Testing the workability of concrete
- Casting and curing of specimens.
- Testing of specimens for compressive strength, split tensile strength and flexural strength.

Determining the effects of substitution of copper slag as fine aggregate and fly ash as partial replacement of cement with various percentages on fresh, hardened properties.

**Materials used** The properties of materials used in concrete were determined in laboratory as per relevant code of practice. Different materials used in the present study were cement, coarse aggregates, sand, copper slag, silica fume, fly ash and water. Results of the tests conducted to determine physical properties of materials are reported and discussed in this section. The materials in general conformed to the provision laid down in the relevant Indian Standard Codes. The materials used were having the following characteristics.

**Cement** is tested for its various properties as per IS 4031-1988 and found to be conforming to the requirements as per IS 12269-1987. The cement is tested for various properties.

**Specific gravity of cement** Specific Gravity is determined by measuring the weight of a cement sample and its volume by measuring the liquid displaced by the cement sample. The liquid, which is to be used, should be such that it does not have any chemical reaction with cement otherwise the volume would include that of products the reactions. Also the liquid, which is to be used, should be such that it does not have any physical reaction such as absorption with the cement.

The average Specific Gravity of the O.P.C is about 3.15. If a given sample of cement exhibits a value of Specific Gravity significantly different from 3.15, the quantity of the sample may be suspect of clays and such impurities for adulterates have been added to the cement the lower values of the Specific Gravity obtained likewise partly hydrated cement which can occurred due to prolonged storage under moist environment will also lead to lower values.

**Normal consistency of cement** is defined as that percentage water requirement of the cement paste the viscosity of which will be such that the Vicat plunger penetrates up to a point 5 to 7mm from the bottom of the Vicat'smould. When water is added to cement, the resulting paste starts stiffening and gaining strength simultaneously losing its consistency.

**Initial setting time and final setting time of cement**

The water requirement for making specimen for the determination of initial and final setting times and of tensile and compressive strength of cement sand mortars and for soundness tests depends upon the normal consistency of cement to be used. This normal consistency or water demand of cement depends upon the compound composition and fineness of the cement.

**Compressive strength of cement** of hardened cement bond is the most critical of every last one of properties. Strength tests are not made on perfect bond glue due to difficulties of excessive shrinkage and subsequent cracking of neat cement. Strength of cement is discovered by implication on cement sand mortar in particular extents. The standard ennore sand to be utilized with in the test shall conform to IS: 650-1966

Ordinary Portland Cement of 53 grade (Zuari) was used according to IS 12269 (1987)[86]. The chemical properties of the cement was obtained from the manufacturer are presented in the Table 3.

**Table 3** Physical Properties of Cement

| Particulars | Test result | Requirement as per IS:12269-1987 |
|---|---|---|
| **Chemical Composition** | | |
| % Silica($SiO_2$) | **19.79** | |
| % Alumina($Al_2O_3$) | **5.67** | |
| % Iron Oxide($Fe_2O_3$) | **4.68** | |
| % Lime(CaO) | **61.81** | |
| % Magnesia(MgO) | **0.84** | Not more Than 6.0% |
| % Sulphuric Anhydride ($SO_3$) | **2.48** | Max. 3.0% when $C_3A$>5.0 Max. 2.5% when $C_3A$<5.0 |
| % Chloride content | **0.003** | Max. 0.1% |
| Lime Saturation Factor CaO-$0.7SO_3/2.8SiO_2+1.2Al_2O_3+0.65 Fe_2O_3$ | **0.92** | 0.80 to 1.02 |
| Ratio of Alumina/Iron Oxide | **1.21** | Min. 0.66 |

**Fine aggregates SAND** is used as fine aggregate. The specific gravity and water absorption of the sand according to IS 2386 (Part III, 1963)[79] are 2.65 and 1% respectively and the fineness modulus of the sand was observed as 2.7. Grading of fine aggregate was done by sieve analysis according to IS 383 (1970)[75]

**Table 4** Sieve analysis of sand.

| S.NO | Sieve size (mm) | Weight retained | Percentage weight retained | Cumulative weight retained(F) | % passing (100-F) |
|---|---|---|---|---|---|
| 1 | 4.75 | 20 | 2 | 2 | 98 |
| 2 | 2.36 | 20 | 2 | 4 | 96 |
| 3 | 1.18 | 133 | 13.3 | 17.3 | 82.7 |
| 4 | 0.600 | 358 | 35.8 | 53.1 | 46.9 |
| 5 | 0.300 | 411 | 41.1 | 94.2 | 5.8 |
| 6 | 0.150 | 55 | 5.5 | 99.7 | 0.3 |
| 7 | Pan | 1 | 0.1 | 100 | 0 |

**COPPER SLAG** is used as fine aggregate. The specific gravity and water absorption of the sand according to IS 2386 (Part III, 1963)[79] are 3.51 and 0.18% respectively and the fineness modulus of the sand was observed as 2.53. Grading of copper slag was done by sieve analysis according to IS 383 (1970).

**Table 5** Sieve analysis of copper slag

| S.NO | sieve size (mm) | Weight retained | Percentage wt retained | Cumulative weight retained(F) | % passing (F) |
|---|---|---|---|---|---|
| 1 | 4.75 | 20 | 2 | 2 | 98 |
| 2 | 2.36 | 20 | 2 | 4 | 96 |
| 3 | 1.18 | 133 | 13.3 | 17.3 | 82.7 |
| 4 | 0.600 | 358 | 35.8 | 53.1 | 46.9 |
| 5 | 0.300 | 411 | 41.1 | 94.2 | 5.8 |
| 6 | 0.150 | 55 | 5.5 | 99.7 | 0.3 |
| 7 | Pan | 1 | 0.1 | 100 | 0 |

**Coarse aggregates** The material which is retained on 4.75 mm sieve is known as coarse aggregate. Locally available 10 mm coarse aggregates were used in this work conforming to IS: 383-1970, with properties as given in table 2.73, respectively. Sieve analysis of 10mm size coarse aggregates is as shown in table 6

Weight of sample taken = 2000 grams

**Table 6** Sieve analysis of 10mm coarse aggregates

| Sieve size (mm) | Retained weight (g) | % weight Retained | Cumulative % Retained (F) | Cumulative % Passing (100-F) |
|---|---|---|---|---|
| 20 | 0 | 0 | 0 | 100 |
| 16 | 0 | 0 | 0 | 100 |
| 12.5 | 20 | 1 | 1 | 99 |
| 10 | 236 | 11.8 | 12.8 | 87.2 |
| 4.75 | 1456 | 72.8 | 85.6 | 14.4 |
| 2.36 | 269 | 13.45 | 99.05 | 0.95 |

Fineness modulus of coarse aggregates **= 5.98**

**Table 7** Physical properties of 10mm coarse aggregates.

| Physical tests | Values |
|---|---|
| Specific gravity | 2.72 |
| Fineness modulus | 5.98 |
| Water Absorption (%) | 0.3 |
| Bulk density (compacted) ( $kg/m^3$) | 1453 |
| Bulk density (loose) ( $kg/m^3$) | 1649 |

**Fly ash**

Fly ash as shown in fig 5was obtained from 'Rayalaseema thermal power plant. The physical properties of fly ash are as shown in table 8.

**Table 8** Physical properties of Fly ash

| S.NO | Physical Properties | Test Results |
|---|---|---|
| 1 | Colour | Grey |
| 2 | Specific gravity | 2.2 |

**Silica fume**

**Physical properties of silica fume**

The primary properties of silica fume are discussed below

**Particle size**

Silica fume has the very small size particles, with more than 95 percent of the particles being less than one micrometer (1 µm). Particle size is extremely important for both physical and chemical contribution.

**Bulk density**

This simply shows the term for unit weight. The bulk density of the silica fume relies on the metal being made in the kind of heater and upon how the heater is worked due to the created silica fume is normally low it is not prudent to transport it for more distances.

**Specific gravity**

Specific gravity that tells how silica fume contrasts with water, which has a specific gravity of 1.0. This number is used in proportioning concrete silica fume has specific gravity of about 2.2 to 2.7, which is having somewhat less weight than Portland cement, which has specific gravity of 3.15. Thus adding silica fume to concrete mixture would have not "densify" the concrete in terms of increasing the density of concrete.

**Specific surface**

Specific surface area defined as the total area of given mass of concrete. Due to the silica fume particles are little, the surface area is higher. We well realize that water request increments for sand as the particles size get to be exceptionally more diminutive. The same thing is happen for silica fume. This is the reason it is important to utilize silica fume in mix with the water reducing admixture or super plasticizer. Brunauer Emmittt Teller (BET) and Nitrogen absorption methods are specialized methods which must be utilized to measure the specific surface of the silica fume..
Silica as shown in fig 7 was obtained from 'astraa chemicals'. The physical properties of silica fume are as shown in table 9

**Table 9** Physical properties of silica fume

| S.NO | Physical Properties | Test Results |
|---|---|---|
| 1 | Colour | white |
| 2 | Specific gravity | 2.63 |

**Super plasticizer**

A new generation of super plasticizers, based on polycarboxylate ether polymers allows the reduction of water content of up to 40%.

In order to increase the strength and also reduce the porosity (impermeability),i.e. to extend the durability and thus the life time of a concrete structure it is of utmost importance to keep the w/c as low as possible. Good mix design with a low w/c ratio must go in line with appropriate placing on the job site.

**Master Glenium SKY 8233** is an admixture of another era focused around adjusted poly-carboxylic ether. The product has been primarily developed where the highest durability and performance required, which is free of chloride and low alkali content. It is perfect with different varieties of cements
A severe over-dosage of Master Glenium SKY 8233 can result in the following:

1. Extension of initial and final set
2. Bleed/segregation of mix, quick loss of Workability
3. Increased plastic shrinkage

A slight overdosing may not adversely affect the ultimate strength of the concrete and can achieve higher strengths than normal concrete, provided it is properly compacted and cured

Master Glenium sky 8233 (BASF Company) as shown in fig 7 is used as high range water reducer (HRWR) SP. The properties of the chemical admixtures as obtained from the manufacturer are presented in the Table 10.

**Table 10** Properties of super plasticizer

| Chemical Admixture | Specific gravity | PH | Solid content (%) | Quantity in % by weight of cementitious materials | Main component |
|---|---|---|---|---|---|
| Master Glenium Sky 8233 | 1.08 | 5.0 | 35 | 0.5-1.5 | Polycarboxylate Ether |

**Water**

In general, for concrete production potable water is used. Waste water from industrial units, sewage and other polluted areas should not be used in concrete. If the quality of water is doubted, then it should be tested before its use


Cement


Sand


copper slag


Fly Ash

Super plasticizer

## VII. MIX COMPOSITION

The mix proportion chosen for this study is given in Table 11.Ten concrete mixtures with different proportions of copper slag ranging from 0% (for the control mix) to 75% and fly ash 6% to 30%were considered as shown in Table 11. The materials were mixed in a rotating pan. The overall mixing time was about 4 min. The mixes were compacted using vibrating table. The slump of the fresh concrete was determined .The specimens were demoulded after 24 h, cured in water and then tested at room temperature at the required age.

**Table 11**: Concrete Mix Composition(kg/m$^3$)

| Mix No. | Description | Cement | Water | Silica fume | Fly Ash | Sand | Copper slag | Coarse aggregates | Super plasticizer (l/m$^3$) |
|---|---|---|---|---|---|---|---|---|---|
| M0 | Control (100% S) | 520 | 130 | 52 | 0 | 613.89 | 0 | 1161.59 | 7.8 |
| M1 | 90% S + 10% C.S | 520 | 130 | 52 | 0 | 552.5 | 81.31 | 1161.59 | 7.8 |
| M2 | 75% S + 25% C.S | 520 | 130 | 52 | 0 | 460.41 | 203.27 | 1161.59 | 7.8 |
| M3 | 50% S + 50% C.S | 520 | 130 | 52 | 0 | 306.94 | 406.55 | 1161.59 | 7.8 |
| M4 | 25% S + 75% C.S | 520 | 130 | 52 | 0 | 163.47 | 609.85 | 1161.59 | 7.8 |
| M5 | 50% S + 50% C.S+ 6% F.A | 520 | 130 | 52 | 31.2 | 306.94 | 406.55 | 1161.59 | 7.8 |
| M6 | 50% S + 50% C.S+ 12% F.A | 520 | 130 | 52 | 62.41 | 306.94 | 406.55 | 1161.59 | 7.8 |
| M7 | 50% S + 50% C.S+ 18% F.A | 520 | 130 | 52 | 93.6 | 306.9 | 406.55 | 1161.59 | 7.8 |
| M8 | 50% S + 50% C.S+ 24% F.A | 520 | 130 | 52 | 124.8 | 306.9 | 406.55 | 1161.59 | 7.8 |
| M9 | 50% S + 50% C.S+ 30% F.A | 520 | 130 | 52 | 156 | 306.9 | 406.55 | 1161.59 | 7.8 |

**S-Sand, C.S-Copper slag, F.A-Fly ash**

**Casting and Curing of Specimens**

Cube specimens of size 100 mm x 100 mm x 100 mm were used for obtaining compressive strength of the various mixes. The casting of the specimens was done under laboratory conditions using standard equipment. Initially, the sand and cement were mixed systematically to get a uniform mix in dry condition indicated by the uniform colour and no concentration of either material was visible. Then, coarse aggregate added to this dry mix and turned over twice or thrice in dry state itself in a pan mixer for one minute fig 3.7.Then water was added slowly to get a uniform mix. Then mixing was continued for about one minute to get uniform mix. The moulds for casting the specimens were cleaned, brushed and oiled and placed on vibrating table .The homogenous concrete mix, already prepared was placed in the specimen moulds in two layers, each layer vibrated properly. The specimens were marked with their respective designations after 3 hours of setting and were allowed to set in the moulds for 24 hours .Subsequently the specimens were de-moulded and immersed in fresh water curing tank. Sufficient no. cubes of each batch were removed from water curing after 7, 28 days for compressive strength test.

**Fig: 4** Concrete Pan mixer used for mixing

**Test on fresh Concrete:**
**Slump test**

Workability is considered to be that property of concrete which indicates its ability to be mixed, handled, transported and most importantly, placed with a minimum loss of homogeneity. More precisely, it defines that it can be fully compacted with minimum energy input. There should be no sign of any segregation or bleeding in a workable concrete. The workability of all the mixes of concrete used in this work was controlled by conducting slump test. The variation of slump properties of concrete is shown in fig 4.1.

**Fig 5** slump cone test

**Test on hardened concrete:**

**Compressive strength**

Compressive strength tests were carried on 100mm×100mm×100mm cubes with compression testing machine as shown in fig 6. The compressive strength at a particular age was taken as average strength of 3 cube specimens. The cube specimens were casted and demoulded after 24 hours. All the specimens were tested on compression testing machine at constant loading rate as per IS: 516-1959. The results are tabulated in table 4.2 and fig 4.2

**Fig 6** Compressive strength test setup

**Split-Tensile strength**

Split-Tensile strength tests were carried on 100mm diameter and 200mm height cylinders with compression testing machine as shown in fig 7. The compressive strength at a particular age was taken as average strength of 2cylinder specimens. The cylinder specimens were casted at an average temperature of $24^0$ C and demoulded after 24 hours. All the specimens were tested on compression testing machine at constant loading rate of as per IS: 516-1959.The results are tabulated in table 4.2 and fig 4.3

**Fig** 7 Split tensile strength test setup

**Flexural strength**

Flexural strength tests were carried on 100mm×100mm×500mm beams with universal testing machine as shown in fig 8. The compressive strength at a particular age was taken as average strength of 2 cylinder specimens. The cylinder specimens were casted at an average temperature of $24^0$ C and demoulded after 24 hours. All the specimens were tested on compression testing machine at constant loading rate as per IS: 516-1959

Fig 8 flexural strength test setup

**Summary**

The test programme as planned to achieve the objectives of the present investigation, has been described in this chapter. The basic properties of the various ingredients of concrete such as cement, fine aggregate, coarse aggregate, copper slag, fly ash and water are presented. Concrete mix details along with method of casting and curing has been reported. The testing procedure for fresh and hardened properties of concrete is discussed in detail.

## VIII. RESULTS AND DISCUSSION

**General**

In this chapter, experimental investigations were carried out to study the influence of the copper slag and fly ash admixtures on the fresh properties (Slump), hardened properties (Compressive strength, Tensile strength, flexural strength) of concrete.

**Fresh properties of Concrete**

**Workability and density**

The effect of copper slag replacement as fine aggregates on the workability and density of high strength concrete is presented in Table 12 for different proportions of copper slag. The workability of concrete was considered based on the measured slump of fresh concrete. It is clear that the workability of concrete increases with the increase of copper slag content in concrete mixes. For the control mixture (i.e. Mix 1), the measured slump was 48 mm whereas for Mix 5, with 75% replacement of copper slag, the measured slump was 82mm. This increase in the workability with the increase of copper slag quantity is due to the low water absorption characteristics of copper slag and its glassy surface. However, it should be noted that mixes with high contents of copper slag (i.e. M4) showed signs of bleeding and segregation which can have disadvantageous effects on concrete performance. Also Table shows that there is general slight increase in the density of high strength concrete with the increase of copper slag quantity. The density of concrete was increased by almost 6%. This is mainly due to the higher specific gravity of copper slag which was 3.51 compared with sand which has a specific gravity of 2.65. And with the replacement of cement with fly ash also tends to increase in workability with a negligible increment in the density. Variation of slump is shown in the fig 9.

**Table 12** Fresh properties of different Concrete mixes

| Mix no. | Description | Slump (mm) | Density (kg/m3) |
|---|---|---|---|
| M0 | Control (100% S) | 48 | 2460 |
| M1 | 90% S + 10% C.S | 55 | 2470 |
| M2 | 75% S + 25% C.S | 66 | 2520 |
| M3 | 50% S + 50% C.S | 74 | 2550 |
| M4 | 25% S + 75% C.S | 82 | 2591 |
| M5 | 50% S + 50% C.S+ 6% F.A | 78 | 2525 |
| M6 | 50% S + 50% C.S+ 12% F.A | 86 | 2526 |
| M7 | 50% S + 50% C.S+ 18% F.A | 93 | 2526 |
| M8 | 50% S + 50% C.S+ 24% F.A | 97 | 2528 |
| M9 | 50% S + 50% C.S+ 30% F.A | 102 | 2526 |

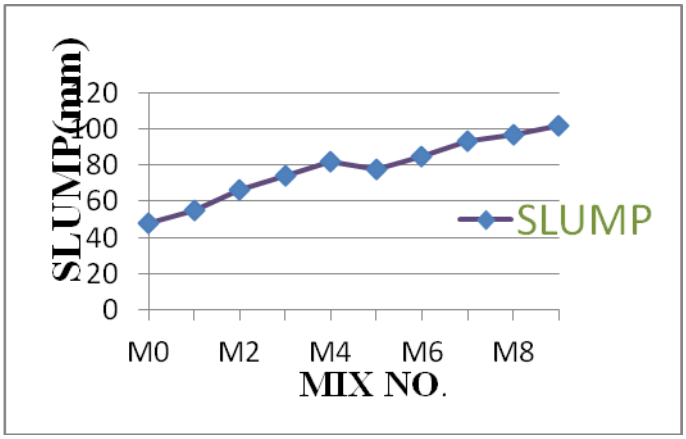


**Fig 9** variation of slump value with mixes

**Hardened properties**

**Strength properties** The results of the compressive strength tests conducted on concrete specimens of different mixes water cured at 7days and 28days are presented and discussed in this section. Addition of up to 50% of copper slag as sand replacement yielded comparable strength with that of the control mix. However, further additions of copper slag caused reduction in the strength due to an increase of the free water content in the mix. Whereas, replacement of cement with fly ash caused increment in strength up to 18% (including 50% copper slag). Mixtures (M4) with 75% copper slag replacement gave the less compressive strength value which was almost 7% lower than the strength of the HSC with 50% copper slag replacement. Mixtures with 24% and 30% fly ash (including 50% copper slag) gave lowest compressive strength value which was almost 2% lower than the strength of HSC without replacement of fly ash. It is recommended that 50 % of copper slag can be used as replacement of sand and 18% fly ash can be used as replacement of cement in order to obtain HPC with good properties. Split tensile strength and flexural strengths of the mixes also follows the same pattern as compressive strength. Optimum mix M7 has maximum split tensile strength and maximum flexural strength.

**Table-13**: Strength results of all mixes in water curing of 7-days and 28-days

| Mix No | Mix Propotions | Compressive Strength (MPa) | | Tensile Strength (MPa) | | Flexural Strength (MPa) | |
|---|---|---|---|---|---|---|---|
| | | 7 Days | 28 Days | 7 Days | 28 Days | 7 Days | 28 Days |
| M0 | Control (100% S) | 62.83 | 78.66 | 4.695 | 4.93 | 8.04 | 8.87 |
| M1 | 90% S + 10% C.S | 63.66 | 80.83 | 4.77 | 5.013 | 8.79 | 9.17 |
| M2 | 75% S + 25% C.S | 65.66 | 83.3 | 4.85 | 5.17 | 9.25 | 9.41 |
| M3 | 50% S + 50% C.S | 67.66 | 85.33 | 5.013 | 5.41 | 9.61 | 10.12 |
| M4 | 25% S + 75% C.S | 62.66 | 79.83 | 4.69 | 5.01 | 8.58 | 9.34 |
| M5 | 50% S + 50% C.S+ 6% F.A | 68.5 | 86.0 | 5.25 | 5.41 | 9.82 | 10.36 |
| M6 | 50% S + 50% C.S+ 12% F.A | 69.3 | 87.16 | 5.33 | 5.49 | 9.88 | 10.38 |
| M7 | 50% S + 50% C.S+ 18% F.A | 71.0 | 88.33 | 5.65 | 5.72 | 9.92 | 10.42 |
| M8 | 50% S + 50% C.S+ 24% F.A | 68.83 | 86.66 | 5.25 | 5.41 | 9.86 | 10.36 |
| M9 | 50% S + 50% C.S+ 30% F.A | 67.83 | 85.83 | 5.17 | 5.25 | 9.82 | 10.32 |

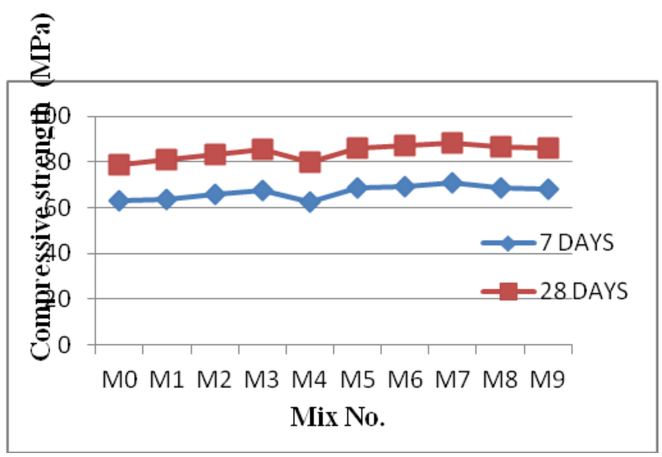


**Fig 10 : Variation of compressive strength with mixes**

## IX. CONCLUSIONS

From this study, it was concluded that copper slag as fine aggregate and fly ash as cement replacement material are advantageous in terms of fresh property parameters, mechanical properties. The following conclusions can be drawn based on the results of this work,

- The degree of workability improved with the addition of copper slag. This increase in the workability with the increase of copper slag quantity is due to the low water absorption characteristics of copper slag and its glassy surface. With the replacement of cement with fly ash also tends to increase in workability with a negligible variation in the density.

- Compared to the control mix, there was a slight increase in the high strength concrete density of nearly 6% with the increase of copper slag content
- Addition of up to 50% of copper slag as sand replacement yielded comparable strength with that of the control mix. However, further additions of copper slag caused reduction in the strength due to an increase of the free water content in the mix. Whereas, replacement of cement with fly ash caused increment in strength up to 18% (including 50% copper slag).
- Mixtures with 75% copper slag replacement gave the less compressive strength value which was almost 7% lower than the strength of the high strength concrete with 50% copper slag replacement.
- Mixtures with 24% and 30% fly ash (including 50% copper slag) gave lowest compressive strength value which was almost 2% lower than the strength of high strength concrete without replacement of fly ash.

## X. SCOPE FOR FUTURE STUDY

The following proposals are made for future study

- ➢ The present study can be extended to investigate other properties such as depth of penetration, ultra sonic pulse velocity, water absorption etc, with varying percentages of copper slag and fly ash.
- ➢ Durability aspects such as, Sulphate resistance, Alkali resistance, RCPT (Rapid Chloride Penetration Test), can also be investigated.

The superplasticizer content was kept constant in the present study; by varying the superplasticizer content, effect of water/powder ratio and compressive strength can be compared.

## REFERENCES

[1] ACI 211.4R-93(Reapproved 1998), Guide for Selecting Proportions for High-Strength Concrete with Portland Cement and Fly Ash

[2] Afaf Ghais, Duaa Ahmed, Ethar Siddig, Isra Elsadig, Samah Albager**, "**Performance of Concrete with Fly Ash" International Journal of Geosciences, 2014, 5, 1445-1450.

[3] IS: 12269-1987 "Specifications for 53-Grade Portland cement", Bureau of Indian Standards, New Delhi, India.

[4] IS 516:1959. Methods of tests for strength of concrete, New Delhi, India: Bureau of Indian Standard.

[5] Indian Standard code IS: 383-1970., "Specifications for coarse and fine aggregates from natural source of concrete", Bureau of Indian standards, New Delhi, India.