A

Thesis Report

On

Optimization of Industrial Wastes as Partial Replacement in Production of Concrete

Submitted in partial fulfillment of the requirement

for the award of degree of

Master of Engineering

IN

PRODUCTION & INDUSTRIAL ENGINEERING

Submitted By:

RAVNEET SINGH

Roll No. 801082026

Under the Guidance of

Mr. Anirbhan Bhattacharaya	Dr. Maneek Kumar
Assistant Pofessor	Professor & Head
MED	CED
Thapar University, Patiala	Thapar University, Patiala

DEPARTMENT OF MECHANICAL ENGINEERING

THAPAR UNIVERSITY

PATIALA-147004, INDIA,

CERTIFICATE

It is Certified that this Thesis Report entitled **"Optimization Of Industrial Wastes As Partial Replacement In Production Of Concrete"** submitted by **Mr. Ravneet Singh,** in the partial fulfilment of the requirement, for the award of **Master Of Engineering (Production And Industrial Engineering)** Degree of **Thapar University, Patiala** is a record of student's own study carried under my supervision. This report is of desired standard and has not been submitted in any other University or Institute for the award of the degree.

Dated: 16/7/12
Place: Patiala

Ravneet Singh
(Ravneet Singh)

This is to certify that above declaration made by the student concerned is correct to the best of my knowledge and belief.

Anirban Bhattacharya
Mr. Anirban Bhattacharya
Assistant Professor
(MED)
Thapar University, Patiala

Maneek 16/7/12
Dr. Maneek Kumar
Profeesor & Head
(CED)
Thapar University, Patiala

Countersigned By:-

Dr. S.K. Mohapatra
Dean of Academic Affairs
Thapar University, Patiala

Dr. Ajay Batish
Head of ME Department
Thapar University, Patiala

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Ravneet Singh

Ravneet Singh

801082026

ABSTRACT

In the present world the production of cement is highly costly and significantly affects the environment. The CO_2 emissions has increased manifold over the last decade or so leading to global warming. Thus, it is the need of the how to control the usage of cement so that its production can be reduced for optimal usage. The present study has been done to find the optimal usage of industrial by products fly ash of class F, silica fume and rice husk ash to be used as a substitutes to cement.

The present study has been done to study the effects of different input parameters like mix by - product percentage used as a binder, type of concrete, mix percentage of coarse aggregate of two type 10mm and 20mm and curing days on output response namely compressive strength of concrete cube of size (150mm×150mm×150mm).

The effect of various parameters on output responses have been analysed using ANOVA and followed by the optimization of process parameters. Main effects have been plotted to determine the optimal design for each output parameter.

NOMENCLATURE

SF	:	Silica Fume
FA	:	Fly Ash
RHA	:	Rice Husk Ash
Dof	:	Degree of freedom
ANNOVA	:	Analysis of Variance
DOE	:	Design of experiment
SEM	:	Screening Electron Microscopy
MPa	:	Mega Pascal

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CHAPTER – 1

INTRODUCTION

1.1 GENERAL

In the today's world concrete plays an important role in the construction works like dams, buildings, roads etc. It is made when cement and other additives or aggregates are mixed. These additives are either natural or artificial, but the constant use of natural additives has lead to exhausting of this very important source. Thus the use of alternative aggregate is a natural step towards solving part of the depletion of natural aggregate, and the alternative aggregate processed from waste materials would appear to be an even more good solution. The search of the alternative material for concrete-making started much before more than half a century. The main objective of the reuse of material is to minimize the impact of human activities on the environment and the planet. Use of inorganic industrial by products in concrete-making will lead to sustainable concrete design. The industrial as well as other wastes such as copper slag, oil palm shells, wood waste ash, fly ash, granite sludge, cement kilns dust, steel chips, silica fume, rice husk ash etc. were used in concrete to improve the properties of concrete and to reduce the cost.

1.2 INDUSTRIAL WASTES

Industrial wastes are a huge source of pollution. The pollutants produced are extremely harmful to people and the environment. Many industries use freshwater as a source to carry away harmful chemicals and waste away from the plant and dump them into rivers, lakes and oceans.

This waste carries many harmful pollutants with them such as asbestos, lead, mercury, nitrates, phosphates, oils, sulphur, petrochemicals and dangerous salts. These pollutants are a great threat to all living beings.

Waste is an unavoidable by-product of most human activity. Economic development and rising living standards in the Asian and Pacific Region have led to increases in the quantity and complexity of generated waste, whilst industrial diversification and the provision of expanded health-care facilities have added substantial quantities of industrial hazardous waste and biomedical waste into the waste stream with potentially severe environmental and human health consequences.

1.2.1The industrial waste products

The industrial waste products which have been used for this project work have different process of formation and have different properties. The brief introduction to the industrial waste products used in the present work is presented below:-

(1) Fly Ash

Fly ash is one of the residues generated in combustion, and comprises fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipments before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace, in this case jointly known as **coal ash**. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO),

Toxic constituents depend upon the specific coal bed makeup, but may include one or more of the following elements or substances in quantities from trace amounts to several percent These quantities may includes :arsenic, beryllium, boron, cadmium, chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium

In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now require that it be captured prior to release. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43 percent is recycled, often used to supplement Portland cement in concrete production.

In some cases, such as the burning of solid waste to create electricity ("resource recovery" facilities a.k.a. waste-to-energy facilities), the fly ash may contain higher levels of contaminants than the bottom ash and mixing the fly and bottom ash together brings the proportional levels of contaminants within the range to qualify as nonhazardous waste in a given state, whereas, unmixed, the fly ash would be within the range to qualify as hazardous waste [26]

(2) Silica Fume

Microsilica or silica fume commonly called as a by-product in the manufacture of silicon and ferrosilicon, from a procedure that involves the reduction of high purity quartz with coal at a temperature of 3300°F (1816°C) in an electric arc furnace. Consisting in excess of 85% of amorphous non-crystalline silica (SiO2), microsilica is collected as the tiny particulate matter present in the emissions from this combustion process, a material that would otherwise have to be land filled. Individual microsilica particles are spherical in shape and measure about 3.937 micro inch (0.1 μm) in diameter, i.e., they are about 100 to 150 times smaller than Portland cement particles. The bulk density of microsilica is in the range of 150 to 250 kg/m^3 and its specific surface area is in the order of 20,000 to 23,000 m^2/kg.

Microsilica added to fresh concrete reacts with the calcium hydroxide produced during the hydration of Portland cement to produce increased amounts of calcium silicate hydrate. This results in a much stronger bond between the cement paste and the coarse aggregate, thereby leading to increased compressive strength. Moreover, the additional calcium silicate hydrates produced are much more resistant to chemical attack than the weaker calcium hydroxide. Another beneficial mechanism operative when microsilica is used derives from the fineness of its particles and is referred to as the micro-filler effect. Filling of voids in the matrix leads to a much denser pore structure, and “reduces the number and size of capillaries that would enable contaminants to infiltrate the concrete”

The combined action of microsilica as a pozzolana and as a filler, results in concrete that can be of very high strength and durability. No more than thirty years ago, 6,000 psi (41.37 x 106 N/m^2) concrete was considered to be high strength; using microsilica, compressive strengths of up to 20,000 psi (137.90 x 106 N/m^2) are reported in the literature. Similarly, the modulus of elasticity and the flexural strength at 28 days are also higher than in ordinary Portland cement concrete.

Improvements in durability and in scaling resistance result from greatly reduced fluid permeability and ionic diffusivity and the concomitant increased resistance to penetration by chloride ions, most notably present in deicing or marine salts. Microsilica concrete can also exhibit very good freeze-thaw durability provided the air entrained is controlled. Reduction in the alkalinity of the pore solution and in the diffusion of alkali ions and water lead to a decrease in expansion and in alkali-aggregate reactivity. High early strengths and resistance to abrasion are additional benefit.

Micro silica used in concrete is available in three forms: water slurry, dry uncompacted powder, and dry densified (compacted) powder. The micro silica content of the slurry form is about 50% by weight, the remainder being water. While used commercially in this from, slurried micro silica can be difficult to handle in ready-mix plants without special equipment. On the other hand, handling of the uncompacted powder poses a potential health risk, since it may be breathed in by construction personnel. Because of handling problems with both uncompacted and slurried microsilica, compacted or densified microsilica is preferred. Dry compacted microsilica is believed to have the same performance characteristics as the uncompacted material. At typical densities of 640.8 kg/m^3, its handling qualities approach those of Portland cement, whose density is usually around 1505.88 kg/m^3, The bulk density of uncompacted microsilica is typically 240.30 kg/m^3, Compacted microsilica is virtually free of dust and lumps, flows readily in pneumatic lines or along bucket elevators, and can be stored in ordinary cement silos or transported in bulk cement tankers [7]

(3) Rice Husk Ash

Rice Husk is one of the waste materials in the rice growing regions. This not only makes the purposeful utilization of agricultural waste but it will also reduce the consumption of energy used in the production of cement. Therefore Rice Husk is an agro based product which can be used as a substitute of cement without sacrificing the strength and durability.

Generally the Rice Husk Ash is used while burning the raw clay bricks in the Brick Kilns. Till recently it is also used in Hotels for cooking but now it is replaced by LPG Gas. Since Rice Husk has negligible protein content, it is not useful for animal feeding. Rice Husk Ash is obtained from burning of Rice Husk, which is the by-product of rice milling. It is estimated that 1,000 kg of rice grain produce 200 kg of Rice Husk; after Rice Husk is burnt, about 20 percent of the Rice Husk or 40 kg would become RHA and contains as much as 80-85% silica which is highly reactive, depending upon the temperature of incineration. Due to relative high water demand, the lime Rice Husk Ash cement developed lower compressive strengths.

However, the strength characteristics are considered adequate for general masonry work. Portland Rice Husk Ash cements containing upto 50% ash by weight showed compressive strengths which were considerably higher than the control Portland cements even at early ages of

3 and 7 days. The cements containing Rice Husk Ash possess excellent resistance to dilute organic and mineral acids. The water demand for normal consistency tends to increase with increasing Ash content of the blended cements. However, this can be corrected by application of certain water reducing admixtures. The investigations as outlined above point towards encouraging trend. Normally fly Ash may be used for partially replacing cement to the extent of about 25% of cement. Reactions that take place in the preparation of Rice Husk Ash concrete are; Silicon burnt in the presence of Oxygen gives Silica [15]

1.3 CONCRETE

Concrete is a composite construction material, composed of cement and other cementitious materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of gravel or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water and chemical admixtures.

Concrete solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a robust stone-like material.

1.3.1 Compositions

There are many types of concrete available, created by varying the proportions of the main ingredients below. In this way or by substitution for the cemetitious and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties.

The *mix design* depends on the type of structure being built, how the concrete will be mixed and delivered and how it will be placed to form this structure.

1.3.2 Cement

Portland cement is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar and plaster. It consists of a mixture of oxides of calcium, silicon and aluminium. Portland cement and similar materials are made by heating limestone (a source of calcium) with clay and grinding this product (called *clinker*) with a source of sulfate (most commonly gypsum).

1.3.3 Water

Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it and allows it to flow more freely.

Less water in the cement paste will yield a stronger, more durable concrete; more water will give a free-flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure.

Hydration involves many different reactions, often occurring at the same time. As the reactions proceed, the products of the cement hydration process gradually bond together the individual sand and gravel particles and other components of the concrete, to form a solid mass.

1.3.4 Reactions

Chemical notation: $C_3S + H \rightarrow C\text{-}S\text{-}H + CH$

Standard notation: $Ca_3SiO_5 + H_2O \rightarrow (CaO)\cdot(SiO_2)\cdot(H_2O)(gel) + Ca(OH)_2$

Balanced: $2Ca_3SiO_5 + 7H_2O \rightarrow 3(CaO)\cdot 2(SiO_2)\cdot 4(H_2O)(gel) + 3Ca(OH)_2$

1.3.5 Aggregates

Fine and coarse aggregates make up the bulk of a concrete mixture. sand, natural gravel and crushed stone are used mainly for this purpose. Recycled aggregates (from construction, demolition and excavation waste) are increasingly used as partial replacements of natural aggregates, while a number of manufactured aggregates, including air-cooled blast furnace slag and bottom ash are also permitted.

Decorative stones such as quartzite, small river stones or crushed glass are sometimes added to the surface of concrete for a decorative "exposed aggregate" finish, popular among landscape designers.

1.3.6 Reinforcement

Concrete is strong in compression, as the aggregate efficiently carries the compression load. However, it is weak in tension as the cement holding the aggregate in place can crack, allowing the structure to fail. Reinforced concrete solves these problems by adding either steel reinforced bars, steel fibers, glass fiber, or plastic fiber to carry tensile load. Thereafter the concrete is reinforced to withstand the tensile loads upon it.

1.3.7 Chemical Admixtures

Chemical *admixtures* are materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes. In normal use, admixture dosages are less than 5% by mass of cement and are added to the concrete at the time of batching/mixing. The common types of admixtures are as follows.

- **Accelerators** speed up the hydration (hardening) of the concrete. Typical materials used are $CaCl_2$, $NaNO_3$. However, use of chlorides may cause corrosion in steel reinforcing and is prohibited in some countries, so that nitrates may be favored.
- **Retarders** slow the hydration of concrete and are used in large or difficult pours where partial setting before the pour is complete is undesirable. Typical retarders are Sugar, Sucrose, glucose, citric acid.
- **Air entrainment** adds and entrains tiny air bubbles in the concrete, which will reduce damage during freeze thaw cycles, thereby increasing the concrete's durability. However, entrained air entails a trade off with strength, as each 1% of air may result in 5% decrease in compressive strength.
- **Plasticizers** increase the workability of plastic or "fresh" concrete, allowing it be placed more easily, with less consolidating effort. A typical plasticizer is lignosulfonate. Plasticizers can be used to reduce the water content of a concrete while maintaining workability and are sometimes called *water-reducers* due to this use. Such treatment improves its strength and durability
- **Pigments** can be used to change the color of concrete, for aesthetics.
- **Corrosion inhibitors** are used to minimize the corrosion of steel and steel bars in concrete.

1.3.8 Mixing of concrete

Thorough mixing is essential for the production of uniform, high quality concrete. For this reason equipment and methods should be capable of effectively mixing concrete materials containing the largest specified aggregate to produce *uniform mixtures* of the lowest slump practical for the work.

Separate paste mixing has shown that the mixing of cement and water into a paste before combining these materials with aggregates can increase the compressive strength of the resulting concrete. The paste is generally mixed in a *high-speed*, shear-type mixer at a (water to cement ratio) of 0.30 to 0.45 by mass. The cement paste premix may include admixtures such as accelerators or retarders, super plasticizers, pigments, or silica fumes. The premixed paste is then blended with aggregates and any remaining batch water and final mixing is completed in conventional concrete mixing equipment.

1.4 CEMENT & ITS TYPES

The cement is a binder, a substance that sets and hardens independently, and can bind other materials together. The word "cement" traces to the Romans who used the term *opus caementicium* to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick additives that were added to the burnt lime to obtain a hydraulic binder were later referred to as cementum, cimentum, cäment and cement.Cement used in construction is characterized as hydraulic or non-hydraulic.

Hydraulic cements (*e.g.*, Portland cement) harden because of hydration, chemical reactions that occur independently of the mixture's water content; they can harden even underwater or when constantly exposed to wet weather. The chemical reaction that results when the anhydrous cement powder is mixed with water produces hydrates that are not water-soluble.

Non-hydraulic cements (*e.g.*, lime and gypsumplaster) must be kept dry in order to retain their strength.The most important use of cement is the production of mortar and concrete—the bonding of natural or artificial aggregates to form a strong building material that is durable in the face of normal environmental effects.

Concrete should not be confused with cement, because the term *cement* refers to the material used to bind the aggregate materials of concrete. Concrete is a combination of a cement and aggregate.

Modern cement

Modern hydraulic cements began to be developed from the start of the Industrial Revolution (around 1800), driven by three main needs:

- Hydraulic cement renders for finishing brick buildings in wet climates.
- Hydraulic mortars for masonry construction of harbor works, etc., in contact with sea water.
- Development of strong concretes.

1.4.1 Types of Cement

(i) Portland cement

Cement is made by heating limestone (calcium carbonate) with small quantities of other materials (such as clay) to 1450 °C in a kiln, in a process known as calcinations, whereby a molecule of carbon dioxide is liberated from the calcium carbonate to form calcium oxide, or quicklime, which is then blended with the other materials that have been included in the mix. The resulting hard substance, called 'clinker', is then ground with a small amount of gypsum into a powder to make 'Ordinary Portland Cement.

Portland cement is a basic ingredient of concrete, mortar and most non-specialty grout. The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. As a construction material, concrete can be cast in almost any shape desired, and once hardened, can become a structural (load bearing) element. Portland cement may be grey or white.

(ii) Portland blast furnace cement contains up to 70 % ground granulated blast furnace slag, with the rest Portland clinker and a little gypsum. All compositions produce high ultimate strength, but as slag content is increased, early strength is reduced, while sulphate resistance increases and heat evolution diminishes. Used as an economic alternative to Portland sulfate-resisting and low-heat cements.

(iii) Portland fly ash cement contains up to 30 % fly ash. The fly ash is pozzolanic, so that ultimate strength is maintained. Because fly ash addition allows a lower concrete water content, early strength can also be maintained. Where good quality cheap fly ash is available, this can be an economic alternative to ordinary Portland cement.

(iv) Portland pozzolan cement includes fly ash cement, since fly ash is a pozzolan, but also includes cements made from other natural or artificial pozzolans. In countries where volcanic ashes are available (e.g. Italy, Chile, Mexico, the Philippines) these cements are often the most common form in use.

(v) Portland silica fumes cement. Addition of silica fume can yield exceptionally high strengths, and cements containing 5–20 % silica fume are occasionally produced. However, silica fume is more usually added to Portland cement at the concrete mixer.

(vi) Expansive cements contain, in addition to Portland clinker, expansive clinkers (usually sulfoaluminate clinkers), and are designed to offset the effects of drying shrinkage that is normally encountered with hydraulic cements. This allows large floor slabs (up to 60 m square) to be prepared without contraction joints.

(vii) White blended cements may be made using white clinker and white supplementary materials such as high-purity metakaolin.

(viii)Coloured cements are used for decorative purposes. In some standards, the addition of pigments to produce "colored Portland cement" is allowed. In other standards (e.g. ASTM), pigments are not allowed constituents of Portland cement, and colored cements are sold as "blended hydraulic cements".

(ix) Very finely ground cements are made from mixtures of cement with sand or with slag or other pozzolan type minerals that are extremely finely ground together. Such cements can have the same physical characteristics as normal cement but with 50% less cement particularly due to their increased surface area for the chemical reaction. Even with intensive grinding they can use up to 50% less energy to fabricate than ordinary Portland cements.

1.4.2 Non-Portland hydraulic cements

(i) Pozzolan-lime cements. Mixtures of ground pozzolan and lime are the cements used by the Romans, and can be found in Roman structures still standing (e.g. the Pantheon in Rome). They develop strength slowly, but their ultimate strength can be very high. The hydration products that produce strength are essentially the same as those produced by Portland cement.

(ii) Slag-lime cements. Ground granulated blast furnace slag is not hydraulic on its own, but is "activated" by addition of alkalis, most economically using lime. They are similar to pozzolan lime cements in their properties. Only granulated slag (i.e. water-quenched, glassy slag) is effective as a cement component.

(iii)Supersulfated cements. These contain about 80% ground granulated blast furnace slag, 15 % gypsum or anhydrite and a little Portland clinker or lime as an activator. They produce strength by formation of ettringite, with strength growth similar to a slow Portland cement. They exhibit good resistance to aggressive agents, including sulphate

(iv) Natural cements correspond to certain cements of the pre-Portland era, produced by burning argillaceous lime stones at moderate temperatures. The level of clay components in the limestone (around 30–35 %) is such that large amounts of belite (the low-early strength, high-late strength mineral in Portland cement) are formed without the formation of excessive amounts of free lime. As with any natural material, such cements have highly variable properties.

(v) Geopolymer cements are made from mixtures of water-soluble alkali metal silicates and aluminosilicate mineral powders such as fly ash andmetakaolin.

1.4.3 The Setting of Cement

Cement sets when mixed with water by way of a complex series of hydration chemical reactions still only partly understood. The different constituents slowly hydrate and crystallise while the interlocking of their crystals gives to cement its strength. After the initial setting, immersion in warm water will speed up setting. In Portland cement, gypsum is added as a compound preventing cement flash setting. The time it takes for cement to set varies; and can take anywhere from twenty minutes for initial set, to twenty-four hours, or more, for final set.

1.4 AIM AND SCOPE OF THE PRESENT INVESTIGATION

In the present work, various industrial by-products have been used as a partial replacement of cement. As we are aware, the production of cement is a very energy intensive process, it leads to production of CO_2 gas which is very harmful for life on this planet. The present study aims to reduce the quantity of cement by using the different industrial by products with improved or same compressive strength. The study has been carried out using the design experimental methodology to optimize various parameter/ factors that affects compressive strength.

1.5 ORGANIZATION OF THESIS

Chapter – 1 deals with basic introduction to industrials wastes, types of industrial wastes products, cement, compositions, reactions types of aggregates, chemical admixtures, mixing of concrete, properties of concrete, type of cements ,setting of cement

Chapter – 2 on literature review presents work done by various researches in the field of industrials waste materials like silica fume, rice husk ash and fly ash.

Chapter – 3 details the scheme of experimentation, materials used, concrete mixes cast parameters, techniques adopted for the casting.

Chapter – 4 details of mix design procedures and steps and evaluation of concrete mixes as per IS- 10262 – 2009.

Chapter – 5 details of results observed by ANOVA and optimal design consideration for each orthogonal array.

Chapter – 6 details of conclusions and recommendations

Chapter – 2
LITERATURE REVIEW

2.1 GENERAL

A large work has been done on the industrial wastes use as a replacement of cement as a binder. In this chapter select few research paper related to by – products like silica fume, rice husk ash, fly ash of F class used in this present work, We are broadly classified all the paper to different category, i.e. paper related to material related to silica fumes, rice husk ash , fly ash and the design of experiment.

2.2 SILICA FUME

Thomas [1] et al:

The results from laboratory studies on the durability of concrete that contains three different blends of portland cement, silica fume, and a wide range of fly ashes. Previous work has shown that high CaO fly ashes are generally less effective in controlling alkali silica reactivity and sulfate attack compared with Class F or low lime fly ashes. In this study it was shown that replacement levels of up to 60% were required to control expansion due to alkali silica reactivity with some fly ashes. The combinations of relatively small levels of silica fume (3 to 6%) and moderate levels of high CaO fly ash (20 to 30%) were very effective in reducing expansion due to alkali silica reactivity and also produced a high level of sulphate resistance. Concretes made with these proportions generally show good fresh and hardened properties since the combination of silica fume and fly ash is somewhat significant. For some proprtions fly ash appears to compensate for some of the workability problems often associated with the use of higher levels of silica fume, whereas the silica fume appears to compensate for the relatively low early strength of fly ash concrete. Diffusion testing indicates that concrete produced with three cementitious blends has a very large resistance to the penetration of chloride ions. Furthermore, these data indicate that the diffusivity of the concrete that contains three blends continues to decrease with time. The reductions are very significant and have a considerable effect on the predicted service life of reinforced concrete elements exposed to chloride environments.

Prokopski and Langier [2]

Prokopski and Langier have studied the effect of water/cement ratio and silica fume addition on the fracture toughness and structure of fractured surfaces of concrete. The results of the fracture toughness shows that concretes made from natural gravel aggregate, with water /cement ratio (W/C = 0.33, 0.43, 0.53 and 0.63), with or without silica fume. The values of the stress intensity factor (K), the critical values of crack tip opening displacement (CTOD) have to be determined. The examination results for profile roughness parameter and fractal dimension of concrete specimen fractures obtained in fracture toughness tests were performed. The highest values of the stress intensity factor, were obtained by concretes with the lowest water /cement ratio, W/C=0.33 when both with and without silica fume addition. This was obtained by considerably lower porosity of the aggregate plus cement paste transition zone as observed in micro structural examinations, which had in this case a compact structure with a small number of structural defects. Cracks, upon reaching the critical force PQ, ran through the coarse aggregate grains, and the obtained fractures were flat in character.

Ding and Li [3]

Ding and Li studied the effects of Metakaolin and Silica Fume on Properties of fresh & hardened Concrete. Metakaolin is a relatively new admixture for concrete. It is similar to silica fume in pozzolanic reactivity, but is lower in cost. The effects of metakaolin and silica fume on various properties of concrete were found and compared all the data in this study. There were seven concretes cubes were cast with water/binder ratio of 0.35 with 0, 5, 10, and 15% cement replaced by either metakaolin or silica fume. The concretes were tested for slump test, compressive strength, free shrinkage and chloride diffusivity by bonding. Metakaolin-modified concrete showed a better workability results than silica fume-modified concrete. If the replacement level was increased, the compressive strength of the metakaolin-modified concrete increased at all ages similarly to that of the silica fume-modified concrete. Both silica fume & Metakaolin free drying shrinkage and restrained the shrinkage cracking width. However, the cracking time was earlier for the metakaolin modified concrete & silica fume modified concrete . The two admixtures also greatly reduced the chloride diffusivity of the concrete.

Atis[4] et al.

Atis et al reports a part of an ongoing laboratory research investigation in which the compressive strength of silica fume concrete is studied under dry and wet curing conditions. The total of 48 concretes, including Portland cement concrete and silica fume concrete, were produced with four different water–cement ratios (0.3, 0.4, 0.5, 0.6), three different cement proportion (350, 400, 450 kg/m^3) and three partial silica fume replacement ratios (10%, 15%, 20%). A hyperplastisizer was introduced in concrete at various quantities to provide and keep a constant workability. Three cubic samples produced from fresh concrete were demoulded after a day; then, these cubes were cured at 27 ± 2 ˚C with 65% relative humidity, and three other cubic samples were cured at 27 ± 2 ˚C with 100% RH until the samples were used for compressive strength for 28 days of curing time. The comparison was made between silica fume & PPC on the basis of their compressive strength. Silica fume concretes were also compared among themselves like silica fume replacement ratio (10%,15%,20%). The compressive strength studied shows that silica fume concrete cured at 65% RH was influenced more than that of Portland cement concrete. It was observed that the compressive strength of silica fume concrete cured at 65% RH was show 13% lower than that of silica fume concrete cured at 100% RH. As the increase in the water–cementitious material ratios increased makes the concrete more sensitive to dry curing conditions. The influence of dry curing conditions on silica fume concrete was marked as the replacement ratio of silica fume increased.

Wong and Razak [5]

Wong and Razak have studied the concept of efficiency can be used for comparing the relative performance of various pozzolans when incorporated into concrete. The alternative method for find out the efficiency factor k of a pozzolanic material has been used. The method involves the Abram's strength–W/C ratio rule, calculates efficiency in terms of relative strength and cementitious materials content. The advantage of this method is that only two mixtures are required to determine the k factor of a specific mixture. The investigation of laboratory on silica fume and metakaolin concrete found that the computed efficiency factors varied with pozzolan type, replacement level and age. At 28 days, the k values ranged from 1.6 to 2.3 for MK and 2.1 to 3.1 for SF mixtures, while at 180 days, the k values varied from 1.8 to 4.0 for MK and 2.4 to 3.3 for SF mixtures. Generally, the k factors increased with age but decrease with higher pozzolanic content. The change in W/CM ratio from 0.33 to 0.27 did not significantly affect the resultant efficiency factor.

Holland [6]

Holland presented the detailed information of silica fume by the silica fume user manual is intended to provide practical information for everyone who actually deals with silica fume and silica fume concrete. It provides the basic information explaining what silica fume is and how it is used in concrete. Explain the primary uses of silica fume in concrete. It also provides the recommendations for given silica fume and silica fume concrete and also given the information on proportioning concrete containing silica fume for different applications.also shows the effects on health when working with silica fume & presents recommendations for personal protection.

Deshini [7]

Deshini research explores the effect of densification of microsilica on the mechanical and other engineering properties of concrete used on Ohio Department of Transportation projects. American Society for Testing and Materials (ASTM) C 1240 requires wet-sieved microsilica to pass the sieve No. 325 with no more than 10% retained. Densified microsilica samples submitted to ODOT sometimes do not meet this specification, since the sieving process may not be able to break the bonds formed due to densification. During this study sieve No.325 tests on three microsilica types (undensified, densified, and abused by prolonged exposure to moisture) were performed at the ODOT laboratory, but none of the materials tested were found to conform to the ASTM fineness specification. The compressive and flexural strengths of concretes mixed with each of the three microsilica types exceeded those envisaged by ODOT Item 499.03 Concrete-General: Proportioning. As expected from the first experiences the undensified microsilica concrete yielded higher values than its densified and abused microsilica counterparts at all ages, but this advantage was rather limited.

Friede and Bernd [8]

Friede and Bernd proposed the characteristics of micro silica or silica fume as an additive. Microsilica, or silica fume is an amorphous type of silica dust mostly collected in baghouse filters as by-product of the silicon and ferro-silicon production. The important physical and chemical properties of microsilica and uses those results for an evaluation of microsilica from a Health Safety and Environment standpoint.

Microsilica consists of spherical particles with an average particle size of 150 nm and a specific surface area of typically 20 m^2/g. The chemical and physical properties of this inorganic product are different as compared to other amorphous and crystalline silica polymorphs. Approximately 500.000 MT of microsilica are sold to the building industry world-wide and are used in fibre cement, concrete, oil-well drilling, refractories, and even in polymers.

Shadizadeh [9] et al.

Shadizadeh et al proposed that the Silica fume is a by-product of silicon metal or ferrosilicon alloys in smelters using electric arc furnaces. Silica fume consists of 85% to 95% amorphous silicon dioxide (SiO_2). Each particle of silica fume is spherical with average diameter 0.15-0.3 μm or 100 times finer than cement particle. Silica fume particles are water wet and absorb excess water in cement slurry when cement slurry is introduced to water. Silica fume dried the cement slurry, so rheological properties are controlled by dispersants. In this paper review, optimal level of silica fume and other additives for preparing 90 pcf cement slurry for liner cementing in one Iranian oilfield is determined. The different factors and properties slurry formulation are slurry density, rheological properties, fluid loss, free water, thickening time of cement slurry, and compressive strength and permeability of set cement. At the end of based on experimental results, the preferable slurry compositions are selected. This preferable slurry composition used for cementing of oil and gas wells where moderate and light weight cement density is needed.

2.3 RICE HUSK ASH

Cisse and Laquerbe [10]

Cisse and Laquerbe have studied the mechanical properties of filler sandcretes with rice husk ash. To capitalize on the local materials of agricultural and industrial wastes, residual fines from crushing process, sands from dunes, rise husk ash and residues of industrial and agricultural wastes have been used as additions in sandcretes. The mechanical resistance of sandcrete blocks obtained when ungrounded ash (and notably the grounded ash) is added reveals that there is an increase in performance of mortar blocks. In addition, the use of ungrounded rice husk ash enables production of a lightweight sandcrete with insulating properties, at a reduced cost.

Ganesan [11] et al.

Ganesan et al estimates the optimum level of replacement of rice husk ash with cementitious material. The rice husk ash (RHA) prepared from the boiler burnt husk residue of a particular rice mill has been evaluated for optimal level of replacement as blending component in cement. The physical, chemical and mineralogical characteristics of RHA were first analyzed or observed. The properties of concrete investigated include compressive strength, splitting tensile strength, water absorption, sorptivity, total charge-passed derived from rapid chloride permeability test and rate of chloride ion penetration in terms of diffusion coefficient. This particular RHA consists of 87% of silica, mainly in amorphous form and has an average specific surface area of 36.47 m^2/g. Test results shows that up to 30% of Rice husk ash could be advantageously blended with cement without adversely affecting the strength and permeability properties of concrete. From this study there is the linear relationship that exists among water sorptivty, chloride penetration and chloride diffusion

Givi [12] et al.

Givi et al performed the research on the compressive strength, water permeability and workability of concrete by partial replacement of cement with rice husk ash. Two types of rice husk ash with average particle size of 5 micron and 95 micron and with four different contents of (5,10,15& 20) percentage by weight were used. Replacement of cement up to maximum of 15% and 20% respectively by 95 and 5 lm rice husk ash, produces concrete with improved strength. The ultimate strength of concrete was gained at 10% of cement replacement by ultra fine rice husk ash particles. The percentage, velocity and coefficient of water absorption significantly decreased with 10% cement replacement by ultra fine rice husk ash. Moreover, the workability of fresh concrete was remarkably improved by increasing the content of rice husk ash especially in the case of coarser size. It is observed that partial replacement of cement with rice husk ash improves the compressive strength and workability of concrete and decreases its water permeability. In addition, decreasing rice husk ash average particle size shows the positive effect on the compressive strength and water permeability of hardened concrete but indicates bad effect on the workability of fresh concrete.

Zain [13] et al.

Zain et al have represented that Rice husk ash (RHA), having high silica content, can be produced from rice husk using appropriate combustion technique for use in concrete as a supplementary cementitious material. The production process of RHA from rice husk and the quality of RHA produced using rudimentary furnace of the National University of Malaysia. Three combustion methods and two grinding methods were used to investigate physical characteristics and chemical properties of RHA produced. Combustion temperature distribution of the furnace, ash particle size, silica crystallization phase and chemical content of the produced RHA were studied using X-ray diffraction (XRD) analysis and scanning electron microscopy (SEM). From the investigation, it was observed that combustion period, chilling duration, and grinding process and duration are important in obtaining RHA of standard fineness and quality. In addition, air ducts in the furnace are very useful in order to supply air for proper burning of rice husk.

Memon [14] et al.

Memon et al represented that the Self Compacting Concrete is defined by two primary properties: Deformability and Segregation resistance. Deformability or flowability is the ability of Self Compacting Concrete to flow or deform under its own weight. Segregation resistance or stability is the ability to remain homogeneous while doing so. Higher water range reducing admixtures are used to produce the sufficient deformability. At the same time period segregation resistance is conformed which is accomplished either by introducing a chemical viscosity modifying admixture or by increasing the amount of fines in the concrete. These viscosity modifying admixtures are very costly and they also increase the cost of SCC. Therefore, for producing low cost SCC, it is prudent to look at the alternates to help reducing the SSC cost. This research work is aimed at evaluating the usage of Rice Husk Ash (RHA) as viscosity modifying agent in SCC, and also studied the relative costs of the materials used in SCC. In this research, the main variables are the proportion of RHA, dosage of superplasticizer for flowability and water/binder ratio. The other parameters kept constant like the amount of cement, water, fine and coarse aggregate contents. Test results substantiate the feasibility to develop low cost SCC using RHA. In the first state of concrete, the different mixes of concrete have slump flow in the range of 595–795 mm, L-box ratio ranging from 0 to 1 and flow time ranging from 2.2 to 29.3 s.

Out of nine mixes, four mixes were found to satisfy the requirements suggested by European federation of national trade associations representing producers and applicators of specialist building products guide for making SCC. The compressive strengths of SCC mixes with RHA were comparable to the control concrete. Cost analysis showed that the cost of ingredients of specific SCC mix is 42.47% less than that of control concrete.

Kishore [15] et al.

This Kishore et al performed the research that the mechanical properties of high strength concrete with different replacement levels of ordinary Portland cement by Rice Husk Ash. The standard cubes (150×150×150) mm, cylinders (150dia×300height) mm and prisms (100×100×500) mm were casted. In all 144 cubes with M40 and M50 grade mix cases were casted and tested. The strength effect of High-strength concrete of different amounts of replacement of cement viz., 0%, 5%, 10%, 15% with Rice Husk Ash of both the grades were compared with that of the high-strength concrete without Rice Husk Ash. The compressive strength at 7, 28 and 56 days have been obtained. The results of the mechanical properties of the rice husk ash at 28 days have shown quite good and interesting results. The optimum level of replacement of rice husk ash found to be 10% in both the grades of the concrete.

2.4 FLY ASH

Nez [16] et al.

Nez et al studied the set of alkali-activated and thermally cured fly ash samples enabled the authors to develop a descriptive model for the microstructure of fly ash-based cementitious material. The microstructure of most fly ash particles (perfect spheres) not only makes microscopic research highly productive but also helps in the formulation of hypothesis explaining the fly ash activation over time through a series of consecutive steps that can be successfully fitted to real situations.

Yang [17] et al.

Yang et al develops the high-performance fiber reinforced cementitious composites (HPFRCC), taking into account environmental sustainability considerations. Engineered cementitious composites (ECC), a unique member of HPFRCC featuring high tensile ductility with ultra-high volumes of fly ash (HVFA) replacement level up to 85% by weight of cement, The micromechanics is applied in many aspects of the material design process, This study also emphasis the effect of fly ash content on altering material microstructure and mechanical properties. Experimental results show that HVFA ECCs, while incorporating high volumes of recycled fly ash, can retain a long-term tensile ductility of approximately 2 to 3%. Significantly, both the crack width and free drying shrinkage are decreased with an increase of the fly ash amount, which may advantages in the long-term durability of HVFA ECC structures. Micromechanics analysis indicates that the increase frictional bond in HVFA ECCs is responsible for the tight crack width. In addition, HVFA ECCs show a robustness improvement by achieving more saturated multiple cracking when reducing environmental impact through the use of industrial waste stream material instead of cement.

Christy and Tensing [18]

Christy and Tensing proposed that the cement mortar of mix proportion 1 : 3,1 : 4.5, 1:6 cement mortar in which cement is partially replacement with class F ash as 0%, 10%, 20%, 25% and 30% by weight proportion of cement. Higher the mix, higher the compressive strength has been obtained even with partial replacement of fly ash with cement test results shows the significant improvement in the strength improvement in the strength properties of mortar with fly ash as partial replacement with fine aggregate and with the cement.

Mehta [19]

Mehta presented the theory and construction practice with concrete mixtures containing more than 50% fly ash by mass proportion of the cementitious material. The different methods are discussed by which the incorporation of high volume of fly ash in concrete reduces the water demand, improves the workability, minimizes cracking due to thermal and drying shrinkage, and enhances durability to reinforcement corrosion, sulfate attack, and alkali-silica expansion. For countries like India and China, this technology can play a significant role in meeting the high demand for infrastructure in a sustainable manner.

Kumar [20]

Kumar proposed that the best way to dispose any waste material like fly ash is to use it in the construction material. In developed countries electrostatic precipitators collects fly ash, with greater fineness and it shows good pozzolonic activity. So fly ash can be used as partial replacement of cement. The effective utilization of fly ash in any field is possible only when the study of physical, chemical and mineralogical properties of the particular fly ash available is done. The properties will vary from plant to plant. The fly ash procured from Raichur thermal power station in Karnataka in the present work. The concrete mix was prepared using IS 10262:2009. Compressive strength studies were planned to correlate the effect of the different characteristics of supplementary cementitious materials for various mix proportion for different replacement levels. Fly ash of Class F and Ground granulated blast furnace slag (GGBS) are used as partial replacement of cement at various levels. Supplementary cementitious materials are replaced for various levels from 10 to 70 % for constant workability of 100 mm slump and also varying superplasticiser dosage. Durability of concrete is observed against resistance to acid attack for various concentrations.

Nail and Sivasundaram [21]

Nail and Sivasundaram investigated the performance of structural grade concrete incorporating high volumes of low calcium fly ash. Two different ASTM Class F fly ashes were used. A Portland cement concrete, designed to have 28-day compressive strength of 41 MPa, was used in this investigation as a control concrete. Concrete mixes were also designed to have fly ash having replacement based on total cement weight in the range of 0 - 60% by weight. Water to cementitious ratio was maintained approximately constant and the sutable superplasticizer is used to achieve the constant workability. Concrete was tested for compressive strength, splitting tensile strength, and modulus of elasticity in accordance with ASTM test methods. Compressive strength and splitting tensile strength of concrete were determined at ages 1, 7, and 28 days whereas modulus of elasticity was determined at 7 and 28 days.High replacement of cement by fly ash in concrete can caused decrease in compressive strength, splitting tensile strength, and modulus of elasticity within the experimental range.

2.5 OTHERS CEMENTITIOUS MATERIALS

Chan and Ji [22]

Chan and Ji proposed that Zeolite, a type of natural pozzolanic material, has been used in producing blended cement and concrete in China. In this study the evaluation of the effectiveness of zeolite increasing the performance of concrete in comparison with silica fume and pulverized fuel ash (PFA). In the first series of experiments, zeolite, silica fume, and PFA were all used to replace 5%, 10%, 15% and 30% of cement by weight in concrete with water to total cementitious material ratio (W/(C + P)) kept at 0.28. The observation that zeolite decreased bleeding and increased marginally the viscosity of concrete without significantly compromising the slump. And at 15% replacement level, it resulted in 14% increase in concrete strength at 28-day compared with the control concrete. The test results also showed that there existed an optimum replacement level for zeolite to efect a decrease in initial surface absorption and in chloride diffusion of concrete. The test results of the second series of experiments where zeolite, silica fume and PFA were in turn used to replace 10% of cement in concretes with W/(C + P) in the range of 0.27 to 0.45 appeared that zeolite performed better than PFA but was inferior to silica fume in terms of increasing strength, decreasing initial surface absorption and chloride diffusion. It was further found that when W/(C + P) was greater than 0.45, the strength of the concretes incorporating zeolite or PFA (by direct replacement) was lower than that of the control concrete. The micro-structural study on concrete with zeolite shows that the soluble SiO2 and Al2O3 could react with Ca(OH)2 to produce C±S±H which densified the concrete matrix. Pozzolanic effect of zeolite improved the microstructure of hardened cement paste and reduced the content of the harmful large pores, hence made concrete more impervious.

Torkittikul and Chaipanich [23]

Torkittikul and Chaipanich investigated the feasibility of using ceramic waste and fly ash to produce mortar and concrete. Ceramic waste fragments obtained from local industry were crushed and sieved to produce fine aggregates. The measured concrete properties demonstrate that while workability was reduced with increasing ceramic waste content for PCC and fly ash concrete, the workability of the fly ash concrete with 100% ceramic waste as fine aggregate sufficient, Portland cement control concrete with 100% ceramic waste where close to zero slump was measured. The compressive strength of ceramic waste concrete was found to increase with ceramic waste content and optimum level at 50% for the control concrete, dropping when the ceramic waste content was increased beyond 50%. However, the compressive strength in the fly ash concrete increased with increasing ceramic waste content upto 100%. The benefits of using ceramic waste as fine aggregate in concrete containing fly ash were therefore verified.

Nochaiya [24] et al.

Nochaiya et al proposed that the normal consistency, setting time, workability and compressive strength results of Portland cement–fly ash–silica fume systems. The observation show that water requirement for normal consistency was found to increase with increasing SF content while a decrease in initial setting time was found. Workability, measured in term of slump, was decrease with silica fume content. However, it must be noted that the reduction in the slump values, the workability of Portland cement–fly ash–silica fume concrete in most cases remained higher than that of the Portland cement control concrete. The utilization of silica fume with fly ash was found to increase the compressive strength of concrete at early ages (pre 28 days) up to 145%. with the highest strength obtained when silica fume was used at 10 wt%. The scanning electron micrographs show that utilization of fly ash with silica fume resulted in a much denser microstructure, thereby leading to an increase in compressive strength.

Chapter – 3
EXPERIMENTAL PROGRAM AND TEST RESULTS

3.1 GENERAL

The experimental plan has been designed to generate compressive strength data for concrete with and without mineral admixture. The concrete mixes have been proportioned for the different values of parameters, which affect the compressive strength of the concrete. The range of values of parameters involved are given in Table 3.1

The coarse aggregates used in the study have been divided into two zones based on the percentage passing through the two consecutive sieves. The aggregates used in this study were 20mm and 10mm in size and used in different proportions according to the mix design. The zone types are given in Table 3.4 and 3.5

The fine aggregate used in this study was riverbed sand of zone III which is decided based upon the percentage passing though the 600µm sieves. The sieve analysis results are in the Table 3.2

3.2 CONCRETE MIX PORPORTIONS

The proportions for the various concrete mixes have been obtained by varying the water – cement ratio, water content , cement content ,type of concrete and percentage replacement of cement by fly ash, silica fume and rice husk ash. The physical and chemical properties of these by – products like fly ash, rice husk ash and silica fumes are given in the tables. IS method as per IS 10262-2009 of mix design was used for determining the proportions. Adjustments due to variations in the specific gravity, water absorption etc. were also incorporated in the design.

3.3 MATERIALS

Same sets of materials have been used throughout for casting of cubes for the mix proportions tabulated in Table3.1. Relevant compressive tests in accordance with the Indian Standard codes of practice were conducted to determine the physical properties of the materials used in the study .The details of the materials along with their properties have been presented in subsequent sections.

3.3.1 Cement

Although all materials that go into concrete mix are essential, cement is very often the most important because it is usually the delicate link in the chain. The function of the cement is first of all to bind the sand and stone together and second to fill up the voids in between sand and stone particles to form a compact mass. Although it constitutes only about 20percent of the volume of concrete mix. It is the active portion of binding medium and is the only scientifically controlled ingredient of concrete. Any variation in its quantity affects the compressive strength of the concrete mix.

Portland Pozzolana cement of 43 grade conforming to IS : 1489-1991 (Part I)has been used .The cement content has been varied from 375 to 425 kg/m³ in the present study and mixes have been proportioned corresponding to cement contents of 375, 397.7, 414.63 kg/m³. Cement of same brand was obtained from local market and was stored in an airtight silo.Tests were conducted for each batch of cement procured. The physical properties of cement is shown in Table 3.12

3.3.2 Aggregates

The aggregate is the matrix or principal structure consisting of relatively inert and coarse particles. The aggregate is used primarily for the purpose of providing bulk to the concrete. The most important function of fine aggregates is to assist in producing a workable and a uniform concrete mix. The fine aggregate also assists the cement paste to hold the coarse aggregate particles in suspension. This action promotes plasticity in the concrete mix and prevents segregation of paste and coarse aggregate during its transportation. The aggregates provide about 75 percent of the body of the concrete and hence their influence is extremely important. The properties of these particles greatly affect the performance of the concrete.

a)Fine Aggregates

IS: 383 – 1970 define those fine aggregate, as those passing 4.75mm IS sieve. The fine aggregate is often termed as a sand size aggregate given in Table 3.2. Locally available riverbed sand was used in the present study. The sand is first sieved through4.75mm, to remove any bigger particle than 4.75mm The properties of the same are given in the Table 3.3 The sand conforms to grading zone-III

The fine aggregate used was washed and removed of any slit or dirt. The fine aggregate was then used for casting of cubes for each type of concrete mix.

b) Coarse Aggregates

The coarse aggregate is defined as that retained on 4.75 mm IS sieve or retained on BIS test sieve no.480. To increase the density of the resulting concrete mix, the coarse aggregate is frequently used in two or more sizes. Two types of aggregates with different sizes have been used in the present study. The details of the same are as below:

CA-I Aggregate passing 20mm sieve and retained on 10mm sieve.

CA-II Aggregate passing 10mm sieve and retained on 4.75mm sieve.

The properties of these aggregates have been listed in Tables 3.4 and 3.5. The percentage contributions from each type of aggregates have been varied and two zones have been considered for proportioning of the concrete mix.

The aggregate were tested as per Indian standard specifications IS : 383 – 1970.

3.3.3 Fly Ash

Fly ash is a byproduct of the combustion of pulverized coal in thermal power plants. It is removed by the dust collectors as a fine particles residue from the combustion gases before they are discharged into the atmosphere. Fly ash particles are typically spherical, ranging in diameter from less than 1 up to 150µm. More than 85 percent of most fly ashes comprise of chemical compounds and glasses formed from the elements silicon, aluminum, iron, calcium and magnesium.

The addition of fly ash in concrete mix affects all aspects of concrete properties. As a part of composite that forms the concrete mass,fly ash acts in part as fine aggregate and in part as a cementitious component. In recent years there has been a recognition that fly ashes differ in significant and definable terms, reflecting their composition and to some extent, their origin. Canadian and American specifications recognize two general classes of fly ash: Class C, normally produced from lignite or sub bituminous coals; and Class F produced from bituminous coals.

Class C ashes differ from class F ashes principally in often having a capacity for self hardening in the absence of cement. Also Class C ashes have high levels of calcium content(containing 15 to 35 per cent CaO) as compared to Class F ashes (containing less than 10 per cent CaO).

The physical and chemical properties of the fly ash given in Tables 3.6 and 3.7 used in the present study (procured from Guru Gobind Singh Super Thermal Plant , Ropar with the help of Pollution Control Board,Patiala). The fly ash used in this study is a low calcium class F and it conforms to the requirements of IS 3812 – 1981.

3.3.4 Silica Fume

Microsilica is obtained as a by-product in the manufacture of silicon and ferrosilicon, from a procedure that involves the reduction of high purity quartz with coal at a temperature of 3300°F (1816°C) in an electric arc furnace. Consisting in excess of 85% of amorphous non-crystalline silica (SiO_2), microsilica is collected as the tiny particulate matter present in the emissions from this combustion process, a material that would otherwise have to be landfilled. Individual microsilica particles are spherical in shape and measure about 3.937 micro inch (0.1 μm) in diameter, i.e., they are about 100 to 150 times smaller than Portland cement particles. The bulk density of microsilica is in the range of 10 to 15 pcf (150 to 250 kg/m3), and its specific surface area is on the order of 10,000 to 13,000 yd^2/lb (20,000 to 23,000 m^2/kg).

The primary chemical properties of silica fume given in Table 3.9 .Following is a discussion of each of these properties. Note that the major chemical properties are included in the standard specifications for microsilica/silica fume. This term simply means that microsilica/silica fume is not a crystalline material. A crystalline material will not dissolve in concrete, which must occur before the material can react. Don't forget that there is a crystalline material in concrete that is chemically similar to microsilica/silica fume. That material is sand. While sand is essentially silicon dioxide (SiO_2), it does not react because of its crystalline nature. Silicon dioxide (SiO_2). This is the reactive material in microsilica/silica fume. Trace elements. There may be additional materials formed as trace elements in the microsilica/silica fume based upon the metal being produced in the smelter from which the fume was recovered. Usually, these materials have no impact on the performance of microsilica/silica fume in concrete. Standard specifications may put limits on some of the materials in this category.

The Microsilica/silica fume particles are extremely small, with more than 95% of the particles being less than 1 μm (one micrometer). Particle size is extremely important for both the physical and chemical contributions (discussed below)of microsilica/silica fume in concrete. A photograph of portland cement grains and microsilica/silica fume particles is shown in Fig3.3.

Bulk density is just another term for unit weight. The bulk density of the as-produced fume depends upon the metal being made in the furnace and upon how the furnace is operated. Because the bulk density of the as-produced microsilica/silica fume is usually very low, it is not very economical to transport it for long distances. Specific gravity is a relative number that tells how microsilica/silica fume compares to water, which has a specific gravity of 1.00. Microsilica/silica fume has a specific gravity of about 2.2, which is somewhat lighter than portland cement, which has a specific gravity of 3.15. Thus, adding microsilica/silica fume to a concrete mixture will not "densify" the concrete in terms of increasing the density of the concrete. These physical properties shown in table 3.8

Microsilica added to fresh concrete reacts with the calcium hydroxide produced during the hydration of Portland cement to produce increased amounts of calcium silicate hydrate. This results in a much stronger bond between the cement paste and the coarse aggregate, thereby leading to increased compressive strength. Moreover, the additional calcium silicate hydrates produced are much more resistant to chemical attack than the weaker calcium hydroxide. Another beneficial mechanism operative when microsilica is used derives from the fineness of its particles and is referred to as the micro-filler effect. Filling of voids in the matrix leads to a much denser pore structure, and "reduces the number and size of capillaries that would enable contaminants to infiltrate the concrete".

The combined action of microsilica as a pozzolan and as a filler, results in concrete that can be of very high strength and durability. No more than thirty years ago, 6,000 psi (41.37 x 106 N/m^2) concrete was considered to be high strength; using microsilica, compressive strengths of up to 20,000 psi (137.90 x 106 N/m^2) are reported in the literature. Similarly, the modulus of elasticity and the flexural strength at 28 days are also higher than in ordinary Portland cement concrete . Improvements in durability and in scaling resistance result from greatly reduced fluid Permeability and ionic diffusivity and the concomitant increased resistance to penetration by chloride ions, most notably present in deicing or marine salts. Microsilica concrete can also exhibit very good freeze-thaw durability provided the air entrained is controlled. Reduction in the alkalinity of the pore solution and in the diffusion of alkali ions and water lead to a decrease in expansion and in alkali-aggregate reactivity. High early strengths and resistance to abrasion are additional benefits. Microsilica used in concrete is available in three forms: water slurry, dry

uncompacted powder, and dry densified (compacted) powder. The microsilica content of the slurry form is about 50% by weight, the remainder being water. While used commercially in this from, slurried microsilica can be difficult to handle in ready-mix plants without special equipment. On the other hand, handling of the uncompacted powder poses a potential health risk, since it may be breathed in by construction personnel. Because of handling problems with both uncompacted and slurried microsilica, compacted or densified microsilica is preferred. Dry compacted microsilica is believed to have the same performance characteristics as the uncompacted material. At typical densities of 40 pcf (640.8 kg/m^3), its handling qualities approach those of Portland cement, whose density is usually around 94 pcf (1505.88 kg/m^3). The bulk density of uncompacted microsilica is typically 15 pcf (240.30 kg/m^3). Compacted microsilica is virtually free of dust and lumps, flows readily in pneumatic lines or along bucket elevators, and can be stored in ordinary cement silos or transported in bulk cement tankers[7].

In this present study the silica fume is procured from KGR Agro Fusion Pvt. Ltd (Ludiana).

3.3.5 Rice Husk Ash

Rice Husk is one of the waste materials in the rice growing regions. This not only makes the purposeful utilization of agricultural waste but it will also reduce the consumption of energy used in the production of cement. Therefore Rice Husk is an agro based product which can be used as a substitute of cement without sacrificing the strength and durability.

Generally the Rice Husk Ash is used while burning the raw clay bricks in the Brick Kilns. Till recently it is also used in Hotels for cooking but now it is replaced by LPG Gas. Since Rice Husk has negligibleprotein content, it is not useful for animal feeding. Rice Husk Ash is obtained from burning of Rice Husk, Which is the by-product of rice milling. It is estimated that 1,000 kg of rice grain produce 200 kg of Rice Husk; after Rice Husk is burnt, about 20 percent of the Rice Husk or 40 kg would become RHA. Rice Husk Ash contains as much as 80-85% silica which is highly reactive, depending upon the temperature of incineration. Due to relative high water demand, the lime Rice Husk Ash cement developed lower Compressive strengths. However, the strength characteristics are considered adequate for general masonry work. Portland Rice Husk Ash cements containing up to 50% Ash by weight showed compressive strengths which were considerably higher than the control Portland cements even at early ages of 3 and 7 days. The cements containing Rice Husk Ash possess excellent resistance to dilute organic and mineral acids. The water demand for normal consistency tends to increase with increasing Ash content of the blended cements. However, this can be corrected by application of certain water reducing admixtures. The investigations as outlined above point towards encouraging trend. Normally fly Ash may be used for partially replacing cement to the extent of about 25% of cement. Reactions that take place in the preparation of Rice Husk Ash concrete are; Silicon burnt in the presence of oxygen gives Silica. The physical and chemical properties RHA is given the Table3.10 and Table 3.11

$$\mathbf{Si + O_2 \text{ -------- } SiO_2}$$

$$\mathbf{C_3S\ (Cement) + H_2O \text{ ----------- } CSH + Ca\ (OH)_2}$$

The highly reactive silica reacts with Calcium hydroxide released during the hydration of cement, resulting in the formation of Calcium Silicates responsible for strength.

$$\mathbf{SiO_2 + Ca\ (OH)_2 \text{ ----------- } CSH + SiO_2}$$

Rice Husk Ash when mixed with Ordinary Portland Cement even upto 70%, replacement gives high compressive strength as early as at 3 days. The investigations conducted on Portland Rice Husk Ash cements up to 50% of ash showed higher compressive strength than the control Portland cement even at as early as 3 days. in a concrete mixture, when 30% Rice Husk Ash by weight of the total cementing material was present, the 7 days and the 28 days compressive strengths were higher and the adiabatic temperature rise was 1.800 F lower than the control concrete. The reaction product of lime and silicate from Rice Husk Ash and showed that it is Calcium Silicate Hydrate (C-S-H) which accounts for the strength of lime Rice Husk Ash cements. It was also observed that there is reduction in strength up to 40% replacement by Rice Husk Ash in the manufacture of sandcrete blocks. SEM images of rice husk ash are shown in fig 3.1 and fig. 3.2

3.4 CASTING OF SPECIMENS

Cubes of 150mm size were cast for each of the two different mix designs defines as per the L18 array of the design of the experiment. These cubes were tested at 7 days, 14days and 28 days of curing period. For all these mix proportions, required quantities of materials were weighted. Cement, fine aggregates and coarse aggregates were mixed dry to get a uniform colour. The byproducts fly ash, rice husk ash and silica fume are used as a replacement of binder in an optimum percentage in the combination of pairs and care was taken to have a uniform desperation upon the other ingredients. Water was added at the end and mixing was done till a uniform and homogenous mix was achieved. The mix produced was first tested for workability and then the cubes were casted.

All the moulds were properly oiled and tightened before casting the specimens. To facilitate proper and uniform compaction, a vibration table with a fixed revolutions per minute was used for the purpose. The specimens were removed from the moulds after 24 hours and then cured in a water till the date of testing.

3.5 CURING OF SPECIMENS

The curing of the specimens was done in a curing tank designed to keep the temperature and relative humidity as per desired standards. The tank used had heating elements, thermostats and pumps (for circulation of water) were installed to keep the temperature of water at 27^0C.the temperature of water in the tank was kept within the range for the entire period of curing.

3.6 TESTING OF SPECIMENS

The specimens, after the fixed curing period 7days, 14 days and 28 days were tested for compressive strength on an automatic compression testing machine (3000kN capacity). A uniform pace rate of 5.25kN/sec was maintained throughout the testing of each specimen. It consists RS – 485 to RS- 232 convertor which converts data transmitted by the digital head to a form recognized by the computer. The unit comprises of loading unit and pumping unit and a hydraulic jack is fixed to the base.

Specifications of automatic compression testing machine

1. AIMIL Ltd. India
2. 3000 KN capacity
3. Serial no. 09149
4. CAT no. AIM -320E-FA

3.7 RESULTS OF COMPRESSIVE STRENGTH TESTING

The result of the compressive strength obtained from the automatic compression testing machine is in the form of force (kN). Actually this is the force at which the cube or specimen become ruptures or breaks. The strength of cube is calculated by the relation of force upon area.

$$\mathbf{S = (F/A) \times 1000}$$

S = strength of the cube/specimen (N/mm^2)

F = force at which a cube/ specimen rupture (KN)

A = area of cube (mm^2)

There are three cubes of for the same trial for the better results obtained with negligible variation in the results. The average value of the three cubes is taken for the strength. The size of specimen or cube was (150mm × 150mm× 150mm). The compressive strength was carried out as per IS 516: 1979 at the end of 7 days, 14 days and 28 days of curing

Table 3.1 Range of values of various parameters

Percentage replacement of cement by fly ash	20 and 30 per cent
Percentage replacement of cement by silica fume	5 and 10 per cent
Percentage replacement of cement by rice husk ash	20 and 30 per cent
Water-cementitious ratio	0.41- 0.48
Cementitious content	375 – 415 kg/m^3
Water content	170 – 180 kg/m^3

Table 3.2 Sieve analysis of sand

Weight of sample taken = 2 kg

IS sieve size	Weight retained, grams	Percentage retained	Cumulative percentage retained	Percentage passing
4.75 mm	24.0	1.2	1.2	98.8
2.36 mm	90.0	4.5	5.7	94.3
1.18 mm	212.0	10.6	16.3	83.7
600 micron	238.0	11.9	28.2	71.8
300 micron	670.0	33.5	61.7	38.3
150 micron	690.0	34.5	96.2	3.8
Pan	76.0	3.8	ΣC = 2.093	………

Total of cumulative %age retained = 209.3

Fineness modulus of fine aggregate = 209.3/100 = 2.093

Table3.3 Physical Properties of fine aggregates

S.No.	Property	Observed values
1.	Unit mass (compact)	1.672 kg/m^3
2.	Unit mass(loose)	1.56 kg/m^3
3.	Specific gravity (dry)	2.50
4.	Percentage voids(compact)	33.4 percent
5.	Percentage voids (loose)	37.7 percent
6.	Percentage absorption	0.5 percent

Table 3.4 Properties of coarse aggregate type CA-I(20mm)

S.No.	Property	Observed values
1.	Unit mass (compact)	1.51 kg/m^3
2.	Unit mass (loose)	1.35 kg/m^3
3.	Specific gravity (saturated surface dry)	2.62
4.	Percentage voids (compact)	41.2 per cent
5.	Percentage voids (loose)	48.6 per cent
6.	Percentage absorption	1.8 per cent

Table 3.5 properties of coarse aggregate type CA – II(10mm)

S.No.	Property	Observed values
1.	Unit mass (compact)	1.45 kg/m^2
2.	Unit mass (loose)	1.32 kg/m^2
3.	Specific gravity (saturated surface dry)	2.56
4.	Percentage voids (compact)	43.7 per cent
5.	Percentage voids (loose)	48.7 per cent
6.	Percentage absorption	1.18 per cent

Table 3.6 Physical properties of fly ash

S.No.	Property	Observed values
1.	Colour	Grey (blackish)
2.	Lime reactivity – average compressive strength at blaine 3389 cm^2/gm	47.87 kg/cm^2
3.	Specific gravity	1.99

Table 3.7 Chemical properties of Fly Ash

S. No.	Constituent	Percent by weight
1.	Loss on ignition(%)	4.52
2.	Silica (SiO_2)	54.80
3.	Aluminium oxide (Al_2O_3)	29.56
4.	Iron oxide (Fe_2O_3)	5.18
5.	Calcium oxide (CaO)	1.48
6.	Magnesium oxide (MgO)	1.45
7.	Sulphur trioxide (SO_3)	0.17
8.	Sodium oxide (Na_2O)	1.42
9.	Insoluble residue(%)	99.55

Table 3.8 Physical properties of Silica Fume

S.No.	Property	Values
1.	Particle size (typically)	< 1 μm
2.	Bulk denity (densified)	480 to 720 kg/m^3
3.	Specific gravity	2.2
4.	Colour in bulk	Light gray
5.	Colour in slurry	Black

Table 3.9 Chemical properties of Silica Fume

S. No.	Constituent	Percent by weight
1.	Carbon	0.6 – 1.5
2.	Silica (SiO_2)	85 – 95
3.	Aluminium oxide (Al_2O_3)	0.5 – 1.7
4.	Iron oxide (Fe_2O_3)	0.4 – 2
5.	Calcium oxide (CaO)	2 – 2.3
6.	Magnesium oxide (MgO)	0.1 – 1.5

Table 3.10 The physical properties of Rice Husk Ash

S.No.	Properties	Values
1.	Bulk density(loose)	0.40 g/cm^3
2.	Bulk density(dense)	0.49 g/cm^3
3.	Specific gravity	2.4
4.	Colour	Black

Table 3.11 The chemical properties of Rice Husk Ash

S. No.	Constituent	Percent by weight
1.	Loss on ignition(%)	14.26
2.	Silica (SiO_2)	79.84
3.	Aluminium oxide (Al_2O_3)	0.14
4.	Iron oxide (Fe_2O_3)	1.16
5.	Calcium oxide (CaO)	0.55
6.	Magnesium oxide (MgO)	0.19
7.	Sulphur trioxide (SO_3)	……..
8.	Sodium oxide (Na_2O)	0.08
9.	Potassium oxide (K_2O)	2.90
10.	Managenese oxide	0.07
11.	Carbon (C)	7.75
12.	Titanium oxide (TiO_2)	0.01
13.	Phosphorous oxide (P_2O_3)	0.80

Table 3.12 Physical properties of Cement

S.No.	Characteristics	Value obtained in Laboratory	Value as per IS-1489 (part -1) 1991
1.	Specific gravity	3.10	3.15
2.	Fineness(% retained on90µm Sieve)	1	<10
3.	Standard consistency (%)	34	----
4.	Initial setting time (min)	130	30(min.)
5.	Final setting time (min)	240	600(max.)
6.	Compressive strength (N/mm^2)	3 days = 16.22 7 days = 22.31 28 days = 33.50	16.00 22.00 33.00

3.8 SEM IMAGES OF MATERIALS

Rice husk ash

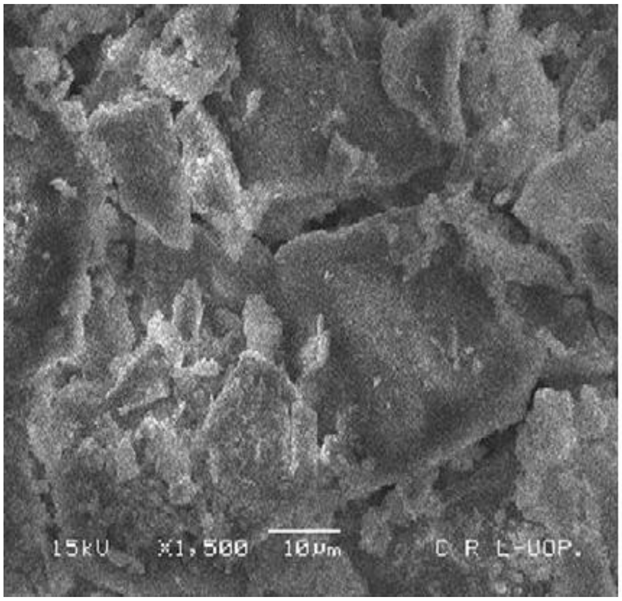


Fig 3.1 Raw rice husk ash without sieving. [14]

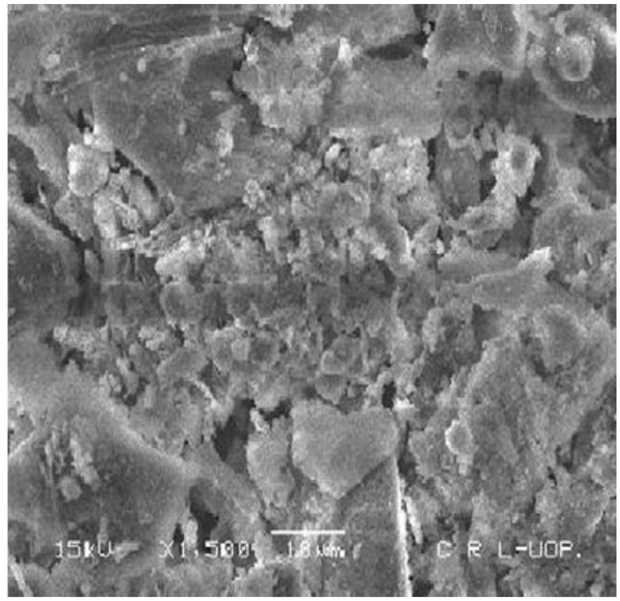


Fig 3.2 Rice husk ash with 150 μm sieving

Portland cement & silica fume

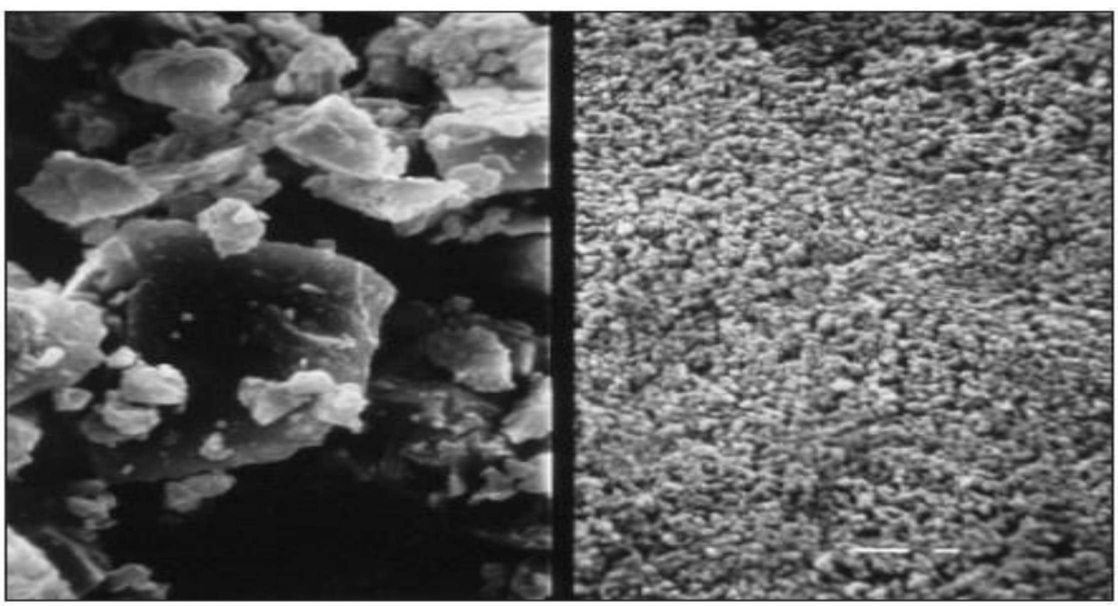


Fig 3.3 Left image of Portland cement and right image of silica fume on the same magnification on SEM [25]

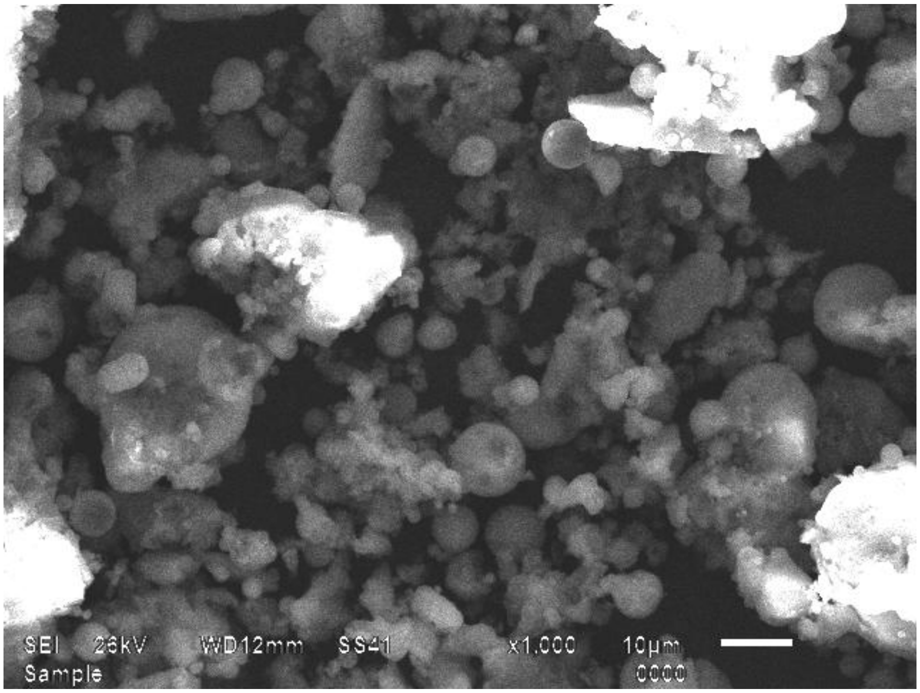


Fig. 3.4 SEM image of fly ash on zoom x1,000

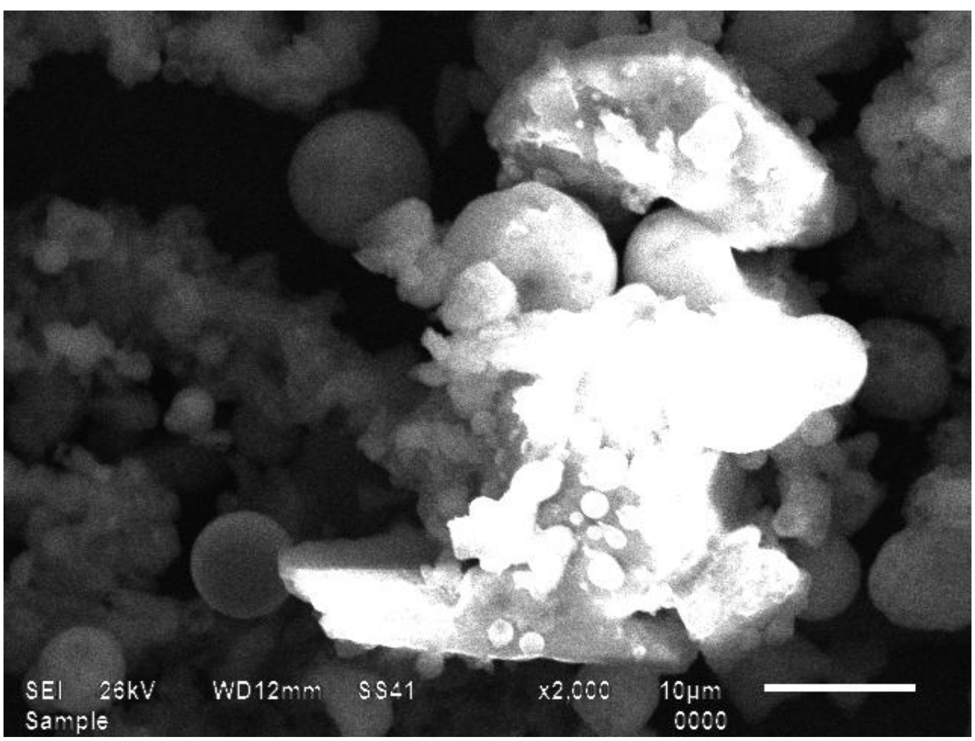


Fig 3.5 SEM image of flyash on zoom x2,000

Chapter – 4
CONCRETE MIX DESIGN PROCEDURES

4.1 GENERAL

The mix design procedures for concrete mixes have been presented in this chapter. Initially based upon the properties of material being used a control with and without mineral admixtures is designed.

4.2 PROCEDURE FOR PROPORTIONING OF CONCRETE MIXES

The process of selecting suitable ingredients for concrete and determining their relative amounts with the objective of producing concrete of required strength, durability and workability as economically as possible is termed mix design. According to IS 456 – 2000 the mix proportions shall be selected to ensure workability of fresh concrete and when hardened, it shall have the required strength, durability and the surface finish.

Thus the proportioning of ingredients of concrete is governed by the required performance of concrete in two states, viz. plastic and hardened state. If the plastic concrete is not workable, it cannot be properly placed and compacted. The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, viz. quality and quantity of cement, water and aggregates; batching and mixing ; placing, compaction and curing. The cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer.

With advent of high-rise buildings and pre-stressed concrete, use of higher grades of concrete is becoming more common. Even the revised IS 456-2000 advocates use of higher grade of concrete for more severe conditions of exposure, for durability considerations. With advent of new generation admixtures, it is possible to achieve higher grades of concrete with high workability levels economically. Use of mineral admixtures like fly ash, slag, metakaolin and silica fume have revolutionized the concrete technology by increasing strength and durability of concrete by many folds.

4.3 MIX DESIGN FOR THE CONCRETE

4.3.1. Advantages of Mix design

Mix design aims to achieve good quality concrete at site economically.

I. Quality concrete means

- Better strength
- Better imperviousness and durability
- Dense and homogeneous concrete

II. Economy

a) Economy in cement consumption

It is possible to save up to 15% of cement for M20 grade of concrete with the help of concrete mix design. In fact higher the grade of concrete more are the savings. Lower cement content also results in lower heat of hydration and hence reduces shrinkage cracks.

b) Best use of available materials:

Site conditions often restrict the quality and quantity of ingredient materials. Concrete mix design offers a lot of flexibility on type of aggregates to be used in mix design. Mix design can give an economical solution based on the available materials if they meet the basic IS requirements. This can lead to saving in transportation costs from longer distances.

c) Other properties:

Mix design can help us to achieve form finishes, high early strengths for early deshuttering, concrete with better flexural strengths, concrete with pumpability and concrete with lower densities. [27]

4.3.2. What is mix design?

Concrete is an extremely versatile building material because, it can be designed for strength ranging from M10 (10Mpa) to M100 (100 Mpa) and workability ranging from 0 mm slump to 150mm slump. In all these cases the basic ingredients of concrete are the same, but it is their relative proportioning that makes the difference.

Basic Ingredients of Concrete: -

1. Cement – It is the basic binding material in concrete

2. Water – It hydrates cement and also makes concrete Workable

3. Coarse Aggregate – It is the basic building component of concrete.

4. Fine Aggregate – Along with cement paste it forms mortar grout and fills the voids in the coarse aggregates.

5. Admixtures – They enhance certain properties of concrete e.g. gain of strength, workability, setting properties, imperviousness etc.

4.3.3. Information required for concrete mix design [27]

The site engineer should give following information while giving material for mix design to the mix design laboratory: -

a) Grade of concrete (the characteristic strength)

b) Workability requirement in terms of slump

c) Other properties (if required): -

i. Retardation of initial set (to avoid cold joints in case of longer leads or for ready mix concrete)

ii. Slump retention (in case of ready mix concrete)

iii. Pumpability (In case of ready mix concrete)

iv. Acceleration of strength (for precast members or where early deshuttering is desired)

v. Flexural strength (normally required for concrete pavements)

d) Ascertain whether condition of exposure to concrete is mild, moderate severe or very severe. Proper investigation of soil should be done to ascertain presence of sulphates & chlorides, in case of doubt.

e) What is the degree of control at site? Following factors indicate degree of control at site: -

i. Batching – weight batching / volume batching.

ii. Type of aggregates – whether mixed graded aggregate will be used or 20mm, 10mm aggregates will be used separately.

iii. Testing of concrete – whether casting & testing of concrete cubes will be done regularly at site.

iv. Source of aggregate – whether sources of sand and aggregate will be standardised or likely to change frequently.

v. Supervision – whether qualified staff will be present to supervise concreting work and make necessary corrections e.g. correction for moisture in sand and changes in material properties.

4.4 STEP –BY STEP PROCEDURE FOR PROPORTIONING CONCRETE MIX

1. Characteristics of aggregates

The first step is to determine the properties of available coarse and fine aggregates. The maximum nominal size and zone of coarse aggregates and grading zone of fine aggregate based upon percentage of material passing 600 micron sieve, needs to determined.

2. Determination of target means compressive strength of concrete

This depends upon the confidence level or reliability index, age of curing and degree of quality control expected at site.

Depending upon the curing period chosen viz. 7days, 14days and 28days,the target mean compressive strength shall be calculated by the desired strength by the factor k. These factors take into account the quality control investigated at the site and the number of results that can fall below the desired strength at site.

Target mean strength = Characteristic strength + K × s

K= Himsworth Coefficient is taken as 1.65 for 5 % probability of failure.

s = Standard deviation depending upon the quality control

The values of s are given in IS 10262 for fair, good and very good degree of control. However, IS 456-2000 has given revised values of 's' to be considered for mix design. Better the degree of control lesser is the value of s and lower is the target mean strength. In other words, the 'margin' kept over characteristic strength is more for fair degree of control to that of good degree of control.

Say for M30 grade of concrete, K=1.65 (for 5% failure) and Standard Deviation = 5 N / mm^2.

Target Mean Strength = 30 + 1.65 × 5 = 38.25 N/mm^2

3. Determine the curve of cement based on its strength.

The strength of cement is determined either by conventional methods given in IS 4031-1988 (Part 6) or by accelerated curing reference mix method mentioned in IS 10262 – 1982. The cement is classified into various curves based on the strength of cement.

Curve	Strength of Cement (N/mm2)
A	31.9 to 36.8 N/mm2
B	36.8 to 41.7 N/mm2
C	41.7 to 46.6 N/mm2
D	46.6 to 51.5 N/mm2
E	51.5 to 56.4 N/mm2
F	56.4 to 61.3 N/mm2

After selecting the appropriate curve based on the strength of cement, water/cement ratio is interpolated for a given target mean strength.

4. **Determine water/cement ratio**

The relation between Target Mean Strength and water cement ratio for different cement curves is given in IS 10262 system. Once the cement curve is fixed, water/cement ratio required for achieving the target mean strength can be interpolated.

For Example

For F curve and target mean strength of 37 the water cement ratio is 0.48

For F curve and target mean strength of 38.25 the water cement ratio is 0.46

All the mix design methods follow same procedure up to this stage.

5. **Finding cement content**

Most of the mix design methods find cement content with following formula:

$$\text{Water/cement ratio} = \frac{\text{Weight of Water per m}^3}{\text{Weight of cement per m}^3}$$

$$\text{Weight of cement} = \frac{\text{Weight of Water per m}^3}{\text{Water/cement ratio}}$$

Weight of water required per m^3 also called as water demand.

Water demand depends on:

i. Required Workability of concrete: Higher the workability required greater is the water demand.

ii. Aggregate properties: Fineness and silt content of fine aggregate, size, shape and flakiness of coarse aggregate, type of aggregate e.g. crushed, uncrushed.

iii. Use of admixtures: Plasticizers will reduce the water demand [27]

4.5 CALCULATIONS FOR THE DIFFERENT TYPES OF CONCRETE

In this work there are different types of concrete have been used, these different types of concrete are M20, M25 and M30. The different calculations have been required for each of the concrete, and from these calculations the actual experimental data has been obtained for this work. These calculation are given below

4.5.1 Characteristics of materials required for concrete mix design

(i) Cement

(a)	Type of cement used	Portland PozzolanaCement
(b)	specific gravity of cement	3.14

(ii) Aggregates

(a)	Specific gravity	
	Coarse aggregate – 10mm	2.56
	Coarse aggregate – 20mm	2.62
(b)	Specific gravity	
	Fine aggregate (sand)	2.50
	Grading zone of sand	III

4.5.2 Evaluation of M20 as per IS: 10262:2009

For M20 concrete, with good control, the standard deviation is 4.0

Target strength = 20 + 1.65×4.0 = 26.6 MPa

Water - cement ratio (W/C) = 0.48

Water content for medium workability = 186 kg/m³

Adjusted mass water content = 180 kg/m³

Volume of coarse aggregate 0.64 m³

Adjustment due to any difference from reference conditions = 0.01/0.05 = 0.2×0.02 = 0.004

Adjusted volume of coarse aggregate value = 0.64 + 0.004 = 0.644 m^3

Volume of fine aggregate = 1- 0.644 =0.356 m^3

Cement content = W/0.48 = 180/0.48 = 375 kg/m^3

Volume of water content = 180/1000 = 0.180m^3

Volume of cement content = 375/3.14 = 119.42/1000 = .119 m^3

Vol. of total aggregates = 1-(vol. of water+ volume of cement) = 1 - (0.18+0.119)= 0.701 m^3

Mass of aggregates

CA(20mm) = 0.701×(0.644/2)×2.62×1000 = 591.39 kg/m^3

CA(10mm) = 0.701×(0.644/2)×2.57×1000 = 580.70 kg/m^3

Fine aggregate = 0.701×0.356×2.50×1000 = 623.89 kg/m^3

In the above calculated values mass of cement, mass of water, mass of coarse and fine aggregates are desirable for the preparation of the trial mix for M20

4.5.3 Evaluation of M25 as per IS: 10262:2009

For M20 concrete, with a good control, the standard deviation is 4.0

Target strength = 25 + 1.65×4.0 = 31.6 MPa

Water - cement ratio (W/C) = 0.44

Water content for medium workability = 180 kg/m^3

Adjusted mass water content = 175 kg/m^3

Volume of coarse aggregate 0.64 m^3

Adjustment due to any difference from reference conditions = 0.01/0.05 = 0.2×0.06 = 0.012

Adjusted volume of coarse aggregate value = 0.64 + 0.012 = 0.652 m^3

Volume of fine aggregate = 1- 0.652 =0.348 m^3

Cement content = W/0.48 = 180/0.48 = 397.7 kg/m^3

Volume of water content = 175/1000 = 0.175 m^3

Volume of cement content = 397.7/3.14 = 126.6/1000 = 0.1266 m³

Volume of total aggregates = 1-(vol. of water+ volume of cement) = 1 - (0.175+0.1266)= 0.6983 m³

Mass of aggregates

CA(20mm) = 0.6983×(0.652/2)×2.62×1000 = 596.51 kg/m³

CA(10mm) = 0.6983×(0.652/2)×2.57×1000 = 585.13 kg/m³

Fine aggregate = 0.6983×0.348×2.50×1000 = 607.60 kg/m³

In the above calculated values mass of cement, mass of water, mass of coarse and fine aggregates are desirable for the preparation of the trial mix for M25

4.5.4 Evaluation of M30 as per IS: 10262: 2009

For M20 concrete, with a very good control, the standard deviation is 5.0

Target strength = 25 + 1.65×5.0 = 38.25 MPa

Water - cement ratio (W/C) = 0.41

Water content for medium workability = 175 kg/m³

Adjusted mass water content = 170 kg/m³

Volume of coarse aggregate 0.64 m³

Adjustment due to any difference from reference conditions = 0.01/0.05 = 0.2×0.09 = 0.018

Adjusted volume of coarse aggregate value = 0.64 + 0.018 = 0.658 m³

Volume of fine aggregate = 1- 0.658 =0.342 m³

Cement content = W/0.48 = 170/0.41 = 414.63 kg/m³

Volume of water content = 170/1000 = 0.170 m³

Volume of cement content = 414.63/3.14 = 132.00/1000 = 0.132 m³

Vol. of total aggregates = 1-(vol. of water+ volume of cement) = 1 - (0.170+0.132)= 0.6979 m³

Mass of aggregates

CA(20mm) = 0.6979×(0.658/2)×2.62×1000 = 601.5 kg/m³

CA(10mm) = 0.6979×(0.658/2)×2.57×1000 = 590.09 kg/m³

Fine aggregate = 0.6979×0.342×2.50×1000 = 596.7 kg/m³

In the above calculated values mass of cement, mass of water, mass of coarse and fine aggregates are desirable for the preparation of the trial mix for M30. For all the three types of concrete M20, M25 and M30 the calculated values are given in table 4.1.

4.6 STANDARDISED THE MIX DESIGN

For the better results or to check the accuracy of design it was necessary to run trails. These three type of concrete are firstly tested by the formation of cubes on the trail bases and three trail run are preformed and each trial run contains six cubes So the total number of cubes are eighteen. Further Taguchi orthogonal array approach have been implemented on the by products used in this study. Also the trails have been prepared for the Taguchi analysis by using waste products like fly ash, silica fume and rice husk ash. Trails for Taguchi analysis have been listed out by using L18 array. For each trail the number of cubes were three and also the mass proportions for L18 array have been listed in Tables (4.7) and (4.8).

4.7 MIX DESIGN EXPERIMENT

The experimental plan was formulated considering four variables and three levels based on the Taguchi method. The responses to be studied are compressive strength. The first variable was binder mix percentage like (silica fume + fly ash) and having six levels. Second variable was type of concrete having three levels. Third variable was coarse aggregate percentage. Fourth variable was curing days. All variables are shown in the Table 4.5 with their levels. Using Taguchi’s orthogonal array, a total of 18 experiments were carried out. In the study of L 18 sets used separately and same are in Tables are 4.5 and 4.6 Only the type and percentage of binder in set I and set II all other variables remains same. There is no change in variable B, C and D. The analyses of the experimental data were carried out using MINITAB 16 software, which is especially used for DOE applications. The experimental observations were transformed into S/N ratios for measuring the quality characteristics. S/N ratio is defined as the ratio of the mean of the signal to the standard deviation of the noise. S/N ratios take into account the amount of variability in the response data and closeness of the average response to the target. The S/N ratio characteristics can be classified into three categories, viz., ‘smaller-the-better’, ‘larger-the-better’ and ‘nominal-the-best’ characteristic. The S/N ratios were calculated for strength of concrete using larger-the-better characteristic as per the procedure described below.

S/N = -10 log [MSD]

Where MSD = $1/n (\Sigma y^2)$

MSD = Mean Square Deviation

S/N = -10 log [$1/n (\Sigma y^2)$]

where y is the observed data (SR or TWR)

n is the number of observations.

The S/N ratios were calculated for strength of cubes using larger-the-better characteristic:

S/N = -10 log [MSD]

Where MSD = $1/n (\Sigma 1/y^2)$

S/N = -10 log [$1/n (\Sigma 1/y^2)$]

where y is the observed data (strength)

n is the number of observations.

Taguchi Technique DOE is a powerful analysis tool for modeling and analyzing the influence of multiple control factors on the performance output. DOE approach using Taguchi technique is devised for process optimization and identification of optimal combination of the factors for a given response. It provides a simple, efficient and systematic approach to optimize design for performance, quality and cost. Taguchi method is a powerful tool for designing high quality systems based on orthogonal arrays. Taguchi DOE method is used to evaluate the relative contribution of process and material parameters on the response. The Taguchi approach to experimentation provides an orderly way to collect, analyze and interpret data to satisfy the objectives of the study. Taguchi technique creates a standard orthogonal array to consider the effect of several factors on the target value and defines the plan of experiments. Experiments are designed and conducted to study the parameters that affect the response. Taguchi method employs a generic signal-to-noise (S/N) ratio to quantify the present variation. These S/N ratios are meant to be used as measures of the effect of noise factors on performance characteristics. Analysis of variance (ANOVA) is used to determine the design parameters or their interactions significantly influencing the response. ANOVA is a computational technique that quantitatively estimates the relative contribution of each control factor on the overall measured response and expresses it as a percentage. Actually the ANOVA is the technique that compute the result values so the detail about ANOVA in the next chapter.

Table 4.1 Trail mix proportions (Kg/m^3)

s.no.	**Type of concrete**	**Water**	**cement**	**fine aggregate**	**ca (20mm)**	**ca(10mm)**
1.	(M20)	180	375	623.89	591.39	580.10
2.	(M25)	175	397.70	607.60	596.51	585.13
3.	(M30)	170	414.63	596.70	601.5	590.09

Table 4.2Compressive strength of concrete mix for M20, M25 and M30

Concrete type	**M20**		**M25**		**M30**	
	7 days	**28 days**	**7 days**	**28 days**	**7 days**	**28 days**
Strength	21.05	30.46	22.15	33.80	25.45	44.25

Table 4.3 Variables of Taguchi orthogonal array

Levels	(A) Type of Binder with mix percentage %	(A) Type of binder with mix percentage%
	Set 1	**Set 2**
1.	SF(5)+FA(20)	SF(5)+FA(30)
2.	SF(10)+FA(30)	SF(10)+FA(20)
3.	FA(20)+RHA(20)	FA(20)+RHA(30)
4.	FA(30)+RHA(30)	FA(30)+RHA(20)
5.	SF(5)+RHA(20)	SF(5)+RHA(30)
6.	SF(10)+RHA(30)	SF(10)+RHA(20)

Levels	(B) Type of concrete
1.	M 20
2.	M 25
3.	M30

Levels	(C) type of coarse aggregate with mix percentage
1.	CA(20mm)=50%, 10mm=50%
2.	CA(20mm)=100%,10mm=0%
3.	CA(20mm)=0%,10mm=100%

Levels	(D) curing days
1.	7
2.	14
3.	28

Table4.4 Taguchi orthogonal array L 18 for set 1 and set 2

S.No.	A Binder mix percentage	B Type of concrete	C Coarse aggregate mix %age	D Curing days
1.	1	1	1	1
2.	1	2	2	2
3.	1	3	3	3
4.	2	1	1	2
5.	2	2	2	3
6.	2	3	3	1
7.	3	1	2	1
8.	3	2	3	2
9.	3	3	1	3
10.	4	1	3	3
11.	4	2	1	1
12.	4	3	2	2
13.	5	1	2	3
14.	5	2	3	1
15.	5	3	1	2
16.	6	1	3	2
17.	6	2	1	3
18.	6	3	2	1

Table 4.5 After fill the experimental values (set 1)

S.No.	Binder mix percentage	Grade of concrete	Percentage of course aggregates	Curing days
1.	SF(5%)+FA(20%)	M20	CA(20mm)=50%,10mm=50%	7 days
2.	SF(5%)+FA(20%)	M25	CA(20mm)=100%,10mm=0%	14 days
3.	SF(5%)+FA(20%)	M30	CA(20mm)=0%,10mm=100%	28 days
4.	SF(10%)+FA(30%)	M20	CA(20mm)=50%,10mm=50%	14 days
5.	SF(10%)+FA(30%)	M25	CA(20mm)=100%,10mm=0%	28days
6.	SF(10%)+FA(30%)	M30	CA(20mm)=0%,10mm=100%	7days
7.	FA(20%)+RHA(20%)	M20	CA(20mm)=100%,10mm=0%	7days
8.	FA(20%)+RHA(20%)	M25	CA(20mm)=0%,10mm=100%	14days
9.	FA(20%)+RHA(20%)	M30	CA(20mm)=50%,10mm=50%	28 days
10.	FA(30%)+RHA(30%)	M20	CA(20mm)=0%,10mm=100%	28days
11.	FA(30%)+RHA(30%)	M25	CA(20mm)=50%,10mm=50%	7days
12.	FA(30%)+RHA(30%)	M30	CA(20mm)=100%,10mm=0%	14days
13.	SF(5%)+RHA(20%)	M20	CA(20mm)=100%,10mm=0%	28days
14.	SF(5%)+RHA(20%)	M25	CA(20mm)=0%,10mm=100%	7days
15.	SF(5%)+RHA(20%)	M30	CA(20mm)=50%,10mm=50%	14days
16.	SF(10%)+RHA(30%)	M20	CA(20mm)=0%,10mm=100%	14days
17.	SF(10%)+RHA(30%)	M25	CA(20mm)=50%,10mm=50%	28days
18.	SF(10%)+RHA(30%)	M30	CA(20mm)=100%,10mm=0%	7days

Table 4.6 After the experimental values L 18 (set 2)

S.No.	A	B	C	D
	Binder mix percentage	**Type of concrete**	**Type of coarse aggregate**	**Curing days**
1.	SF(5%)+FA(30%)	M20	CA(20mm)=50%,10mm=50%	7 days
2.	SF(5%)+FA(30%)	M25	CA(20mm)=100%,10mm=0%	14 days
3.	SF(5%)+FA(30%)	M30	CA(20mm)=0%,10mm=100%	28 days
4.	SF(10%)+FA(20%)	M20	CA(20mm)=50%,10mm=50%	14 days
5.	SF(10%)+FA(20%)	M25	CA(20mm)=100%,10mm=0%	28days
6.	SF(10%)+FA(20%)	M30	CA(20mm)=0%,10mm=100%	7days
7.	FA(20%)+RHA(30%)	M20	CA(20mm)=100%,10mm=0%	7days
8.	FA(20%)+RHA(30%)	M25	CA(20mm)=0%,10mm=100%	14days
9.	FA(20%)+RHA(30%)	M30	CA(20mm)=50%, 10mm=50%	28 days
10.	FA(30%)+RHA(20%)	M20	CA(20mm)=100%,10mm=0%	28days
11.	FA(30%)+RHA(20%)	M25	CA(20mm)=50%, 10mm=50%	7days
12.	FA(30%)+RHA(20%)	M30	CA(20mm)=100%,10mm=0%	14days
13.	SF(5%)+RHA(30%)	M20	CA(20mm)=100%,10mm=0%	28days
14.	SF(5%)+RHA(30%)	M25	CA(20mm)=0%,10mm=100%	7days
15.	SF(5%)+RHA(30%)	M30	CA(20mm)=50%, 10mm=50%	14days
16.	SF(10%)+RHA(20%)	M20	CA(20mm)=0%,10mm=100%	14days
17.	SF(10%)+RHA(20%)	M25	CA(20mm)=50%, 10mm=50%	28days
18.	SF(10%)+RHA(20%)	M30	CA(20mm)=100%,10mm=0%	7days

Table 4.7 Trail mix proportions for the L18 array (set 1)

All values in kg/m^3

Trail	Water	Cement	CA(20mm)	CA(10mm)	Fine aggregate	Fly ash	Silica fume	Rice husk ash
1.	180	281.25	591.4	580	623.89	75	18.75	…
2.	175	298.27	1193.02	…	607.60	79.54	19.88	…
3	170	310	…	1180	596.67	82.92	20.73	…
4.	180	225	591.4	580.1	623.89	112.5	37.5	…
5.	175	238.62	1193.02	…	607.60	119.31	39.77	…
6.	170	248.77	…	1180	596.7	124.39	41.46	…
7.	180	225	1182.8	…	623.82	75	…	75
8.	175	238.62	…	1170.26	607.60	79.54	…	79.54
9.	170	248.77	601.5	590.09	596.7	82.92	…	82.92
10.	180	150	…	1160.2	623.89	112.5	…	112.5
11.	175	159	596.51	585.13	607.60	119.31	…	119.31
12.	170	165	1203	…	596.7	124.38	…	124.38
13.	180	181.25	1182.8	…	623.89	…	18.75	75
14.	175	298.27	…	1170.26	607.60	…	19.88	79.54
15.	170	310.97	601.5	590.09	596.7	…	20.73	82.92
16.	180	225	…	1160.2	623.89	…	37.5	112.5
17.	175	238.62	596.51	585.13	607.60	…	39.77	119.31
18.	170	248.77	1203	…	596.7	…	41.46	124.38

Table4.8 Trail mix proportion for L18 array (set 2)

All values in Kg/m^3

Trail	Water	Cement	CA(20mm)	CA(10mm)	Fine aggregate	Fly ash	Silica fume	Rice husk ash
1.	180	243.75	591.4	580	623.89	112.5	18.75	…
2.	175	258.50	1193.02	…	607.60	19.88	119.31	…
3	170	269.5	…	1180	596.67	20.73	124.38	…
4.	180	262.5	591.4	580.1	623.89	75	37.5	…
5.	175	278.39	1193.02	…	607.60	79.54	39.77	…
6.	170	290.24	…	1180	596.7	82.96	41.46	…
7.	180	187.5	1182.8	…	623.82	75	…	112.5
8.	175	198.85	…	1170.26	607.60	79.54	…	119.31
9.	170	207.3	601.5	590.09	596.7	82.92	…	124.38
10.	180	187.5	…	1160.2	623.89	112.5	…	75
11.	175	198.85	596.51	585.13	607.60	119.31	…	79.54
12.	170	207.3	1203	…	596.7	124.38	…	82.92
13.	180	243.75	1182.8	…	623.89	…	18.75	112.5
14.	175	258.5	…	1170.26	607.60	…	19.88	119.31
15.	170	269.50	601.5	590.09	596.7	…….	20.73	124.38
16.	180	262.5	…	1160.2	623.89	………	37.5	75
17.	175	278.39	596.51	585.13	607.60	………….	39.77	79.54
18.	170	290.24	1203	…	596.7	……….	41.46	82.92

Chapter – 5

RESULTS AND DISCUSSION

5.1 GENERAL

This chapter includes the details of the experimental work performed on industrial wastes products like fly ash of F class, silica fume and rice husk ash have been reused in the concrete as a replacement of binder(cement) . The objective of the experimentation is to study the effect of binder mix percentage, type of concrete, type of coarse aggregates with different percentage and days for curing on the compressive strength of concrete. Signal to noise ratio was determined and graphs are generated on the basis of experimental data. The obtained results are analyzed using MINITAB 16.

5.2 S/N RATIO ANALYSIS

The experimental was conducted as per orthogonal array L – 18 array was generated with the help of Minitab 16. The experiments have been carried out with two different L-18 sets like L – 18 (set 1) and L- 18(set 2). The main different between these two sets only the binder mix percentage (A) other variables remains constant which is shown in pervious chapter Table no. 4.3 for the mean compressive strength S/N ratio have been required is larger the best. The compressive strength of cubes was conducted by the compressive testing machine. In Table 5.2 and 5.9 analysis of compressive strength using S/N ratio gives the optimum compressive strength value of concrete.

5.3 RESULTS FOR COMPRESSIVE STRENGTH

The results for compressive strength for each L – 18 (set- 1) and (set –2) given in Table 5.2 and 5.9. For these two sets L -18(set 1) and L – 18(set 2) fifty six cubes were casted for each L -18 set. Three cubes required for each trail for the evaluation of better average compressive strength. The compressive testing machine gives the reading in the form of force (KN) and for obtain the strength value given formula is required

$$\text{Strength (MPa)} = \frac{Compre\ ssive\ \ force\ \ (KN)}{Area\ \ (150\times150)} \times 1000$$

After using above formula actual compressive strength was developed in MPa. The average compressive strength was calculated for each trail of array for both the sets. The data of average compressive strength or mean compressive strength have been introduced in the Minitab 16 software. Taguchi DOE method is used to evaluate the relative contribution of process and material parameters on the response. The Taguchi approach to experimentation provides an orderly way to collect, analyze and interpret data to satisfy the objectives of the study. Taguchi technique creates a standard orthogonal array to consider the effect of several factors on the target value and defines the plan of experiments. Experiments are designed and conducted to study the parameters that affect the response. Taguchi method employs a generic signal-to-noise (S/N) ratio to quantify the present variation. These S/N ratios are meant to be used as measures of the effect of noise factors on performance characteristics. Analysis of variance (ANOVA) is used to determine the design parameters or their interactions significantly influencing the response. ANOVA is a computational technique that quantitatively estimates the relative contribution of each control factor on the overall measured response and expresses it as a percentage. Through the ANOVA variance for means and variance of S/N ratio have been obtained for the significant or insignificant variables can be sort out result for the array set – 1 given by Table5.4 and result for the array set – 2 is given by 5.11

5.3.1. Influence of Parameters on strength

Strength of first type of type of binder is quite reasonable (Figure 5.1) but start decreased gradually when the high percentage of fly ash has been added with any of the combination with silica fume or with rice husk .fly ash combined with rice husk results the gradual decrease in the strength of concrete but when the combination of silica fume with rice husk ash gives very excellent result regard to strength. Type of concrete also shows the Increase in compressive strength but not at a very high rate. Mixed used of coarse aggregate of same proportion show reasonable compressive strength. But the use of totally a single type of coarse aggregate become decrease on compressive strength. The curing time greatly rise in the compressive strength because the concrete bonding become more strong after first seven days and shown in Table 5.5

5.3.2 Model analysis of compressive strength

The coefficients of model for S/N ratios for compressive strength are shown in Table 5.6 . The parameter R^2 describes the amount of variation observed in compressive strength is explained by the input factor. R^2 = 91.1% indicate that the model is able to predict the response with high accuracy. Adjust R^2 is a modified R^2 that has been adjusted for the number of terms in the model. If unnecessary terms are included in the model, R^2 artificially high, but adjusted R^2(=74.8%) may get smaller. The standard deviation of errors in the modeling, S= 1.628 Comparing the P-value to a commonly used α-level = 0.05, it is found that if the P-value is less than or equal to α, it can be concluded that the effect is significant, otherwise it is not significant.

5.3.3 Optimal design consideration (set 1)

Compressive strength

In this experiment analysis, the mean effect plot in Figure 5.2 is used to estimate the mean compressive strength with optimal design conditions. In Table 5.4 it is concluded that highest compressive strength was achieve when the type of concrete M30 and curing days time 28 days were selected. In S/N ratios highest compressive strength was found when type of concrete M30 and curing time 28days selected in the experimental trail .in some case, the same levels of the significant factors provide the higher average and reduced variability; hence nothing has to be compromised. In some case, the level of factors which improve the average and improve the uniformity may conflicts which mean compromise may have to be reached.

Estimating the mean

Compressive strength is a "Higher the better" type response. In this experiment analysis different experiment trials have been chosen to obtained satisfactory results. After conducting the experiments the optimum treatment condition with in the experiments determined on the basis of prescribed combination of factor levels is determined to one of those in the experiment.

Mean value of compressive strength is given by:

$$\mu_{B3,\,D3} = \overline{B3} + \overline{D3} - \overline{T} \quad = 23.758 + 25.927 - 20.38192 = 29.3030$$

$\overline{T}$ = Mean of seq. of SS.

Confidence interval around the estimation mean

The confidence interval signifies the maximum and minimum value between which the true average lies at some stated percentage of confidence. The estimate of the mean μ is only na point estimate based on the average of results obtained from the experiment statically it specify that there is 50 % chance of the true averages being greater than μ and 50% chance of the true average being less than μ.

Confidence interval around the estimated compressive strength

$$CI = \sqrt[2]{\frac{F\alpha,v1,v2\ Ve}{\eta eff}} = \text{where } F\alpha, v1, v2 = \text{F ratio}$$

α = risk (0.05)

Confidence = 1 - α

$v1$ = degree of freedom for mean which is always = 1

$v2$ = degree of freedom for error = Ve = 13

ηeff = N / 1+ dof = 18/1+2+2 = 3.6

$$CI = \sqrt[2]{\frac{0.05\times1\times13\times24.56}{3.6}} = 2.10475$$

Thus the confidence interval around the estimated mean of compressive strength is given by 29.3030 ± 2.10475 N/mm².

5.3.4 Parameters influence the compressive strength (set 2)

Strength of first type of type of binder is quite reasonable (Figure 5.3) but start decreased gradually when the high percentage of fly ash has been added with any of the combination with silica fume or with rice husk ash and fly ash combined with rice husk results the gradual decrease in the strength of concrete but when the combination of silica fume with high percentage of rice husk ash gives very steep bounce in the compressive strength of concrete. Type of concrete also shows the Increase in compressive strength but not at a very high rate.

Mixed used of coarse aggregate of same proportion show reasonable compressive strength. But the use of totally a single type of coarse aggregate become decrease on compressive strength. The curing time greatly rise in the compressive strength because the concrete bonding become more strong after first seven days and shown in table 5.12

5.3.5 Model analysis of compressive strength (set 2)

The coefficients of model for S/N ratios for compressive strength are shown in Table 5.13. The parameter R^2 describes the amount of variation observed in compressive strength is explained by the input factor. R^2 = 89.7% indicate that the model is able to predict the response with high accuracy. Adjust R^2 is a modified R^2 that has been adjusted for the number of terms in the model. If unnecessary terms are included in the model, R^2 artificially high, but adjusted R^2(=70.8%) may get smaller. The standard deviation of errors in the modeling, S= 2.083 Comparing the P-value to a commonly used α-level = 0.05, it is found that if the P-value is less than or equal to α, it can be concluded that the effect is significant, otherwise it is not significant.

5.3.6 Optimal design consideration (set 2)

Compressive strength

In this experiment analysis, the mean effect plot in Figure 5.3 is used to estimate the mean compressive strength with optimal design conditions. In Table 5.11 it is concluded that highest compressive strength was achieve when the binder mix of SF(5%)+RHA(30%) is used as a partial replacement of cement and curing days time 28 days were selected. In S/N ratios highest compressive strength was found when the binder mix percentage of SF (5%)+ RHA (30%) and curing days time 28days selected in the experimental trail. In some case, the same levels of the significant factors provide the higher average and reduced variability; hence nothing has to be compromised. In some case, the level of factors which improve the average and improve the uniformity may conflicts which mean compromise may have to be reached.

Estimating the mean

Compressive strength is a "Higher the better" type response. In this experiment analysis different experiment trials have been chosen to obtained satisfactory results. After conducting the experiments the optimum treatment condition with in the experiments determined on the basis of prescribed combination of factor levels is determined to one of those in the experiment.

Mean value of compressive strength is given by:

$\mu_{A5, D3} = \overline{A5} + \overline{D3} - \overline{T}$ = 31.7141 +25.1798 – 21.8232 = 35.070

$\overline{T}$ = Mean of seq. of SS.

Confidence interval around the estimation mean

The confidence interval signifies the maximum and minimum value between which the true average lies at some stated percentage of confidence. The estimate of the mean μ is only a point estimate based on the average of results obtained from the experiment statically it specify that there is 50 % chance of the true averages being greater than μ and 50% chance of the true average being less than μ.

Confidence interval around the estimated compressive strength

$$CI = \sqrt[2]{\frac{F\alpha,v1,v2\ Ve}{\eta eff}} = \text{where } F\alpha, v1, v2 = \text{F ratio}$$

$v1$ = degree of freedom for mean which is always = 1

$v2$ = degree of freedom for error = Ve = 10

ηeff = N / 1+ dof = 18/1+5+2 = 2.25

$$CI = \sqrt[2]{\frac{0.05\times1\times10\times14.892}{2.25}} = 1.819$$

Thus the confidence interval around the estimated mean of compressive strength is given by 35.070 ± 1.819 N/mm²

Table 5.1 L 18 Taguchi orthogonal array (set 1)

Trails	Binder mix percentage(A)	Type of concrete(B)	Coarse aggregate mix %age(C)	Curing days(D)
1.	SF(5%)+FA(20%)	M20	CA(20mm)=50%,10mm=50%	7 days
2.	SF(5%)+FA(20%)	M25	CA(20mm)=100%,10mm=0%	14days
3.	SF(5%)+FA(20%)	M30	CA(20mm)=0%,10mm=100%	28days
4.	SF(10%)+FA(30%)	M20	CA(20mm)=50%, 10mm=50%	14days
5.	SF(10%)+FA(30%)	M25	CA(20mm)=100%,10mm=0%	28days
6.	SF(10%)+FA(30%)	M30	CA(20mm)=0%,10mm=100%	7days
7.	FA(20%)+RHA(20%)	M20	CA(20mm)=100%,10mm=0%	7days
8.	FA(20%)+RHA(20%)	M25	CA(20mm)=0%,10mm=100%	14days
9.	FA(20%)+RHA(20%)	M30	CA(20mm)=50%, 10mm=50%	28 days
10.	FA(30%)+RHA(30%)	M20	CA(20mm)=0%,10mm=100%	28days
11.	FA(30%)+RHA(30%)	M25	CA(20mm)=50%, 10mm=50%	7days
12.	FA(30%)+RHA(30%)	M30	CA(20mm)=100%,10mm=0%	14days
13.	SF(5%)+RHA(20%)	M20	CA(20mm)=100%,10mm=0%	28days
14.	SF(5%)+RHA(20%)	M25	CA(20mm)=0%,10mm=100%	7days
15.	SF(5%)+RHA(20%)	M30	CA(20mm)=50%, 10mm=50%	14days
16.	SF(10%)+RHA(30%)	M20	CA(20mm)=0%,10mm=100%	14days
17.	SF(10%)+RHA(30%)	M25	CA(20mm)=50%, 10mm=50%	28days
18.	SF(10%)+RHA(30%)	M30	CA(20mm)=100%,10mm=0%	7days

Table 5.2 Result of compressive strength filling L 18 orthogonal array (set 1)

Trail no.	Compressive strength			Mean	S/N ratio
	1	**2**	**3**		
1	16.39556	15.95111	14.61333	15.65333	23.86051566
2	20.56444	20.30667	19.11111	19.99407	26.00460496
3	34.14667	31.19556	28.13333	31.15852	29.78995094
4	21.42222	19.20889	19.18667	19.93926	25.9598334
5	30.39556	29.67556	29.65333	29.90815	29.51407766
6	11.64	17.40889	16.05333	15.03407	23.13943403
7	9.284444	9.755556	7.875556	8.971852	18.94706541
8	21.17778	20.90667	17.66667	19.91704	25.89418721
9	26.53333	25.42667	26.67556	26.21185	28.363929
10	12.67556	15.11111	15.05778	14.28148	23.00634204
11	9.013333	8.817778	9.106667	8.979259	19.06245149
12	17.29778	17.87556	16.52	17.23111	24.71261139
13	18.93333	18.40444	20.11556	19.15111	25.62606505
14	20.46222	20.02667	19.61778	20.03556	26.03217139
15	25.99556	29.87556	23.65333	26.50815	28.3489857
16	17.55556	16.72889	19.04444	17.7763	24.95977433
17	34.49778	34.28889	35.56	34.78222	30.82385499
18	22.78667	20.49333	20.74667	21.34222	26.55588424

Table 5.3 ANOVA for means – Compressive strength (set – 1)

Source	DF	Seq. SS	Adj MS	F-test	P
Binder mix percentage(A)	5	230.83	46.17	4.30	0.052
Type of concrete(B)	2	177.06	88.53	8.24	0.019
Mix %age of coarse aggregate(C)	2	24.14	12.07	1.12	0.385
Curing days(D)	2	357.48	178.74	16.63	0.004
Residual error	6	64.48	10.75		
Total	17	853.99			
E pooled	13	319.4	24.56		

Table 5.4 Significant factors for compressive strength (Set 1)

Factors	Affecting mean		Affecting variation (S/N ratios)	
	contribution	Best level	contribution	Best level
Binder mix percentage(A)	Insignificant	……	insignificant	………
Type of concrete(B)	significant	M30	significant	M30
Mix percentage of coarse aggregate(C)	insignificant	……	insignificant	………
Curing days (D)	significant	28 days	significant	M30

Table 5.5 Response table for means –compressive strength (Set 1)

LEVEL	Binder mix percentage(A)	B Type of concrete(B)	Mix percentage of Coarse aggregate(C)	Curing days(D)
1	22.27	15.96	22.01	15.00
2	21.63	22.27	19.43	20.23
3	18.37	22.91	19.70	25.92
4	13.50			
5	21.90			
6	24.63			
Delta	11.14	6.95	2.58	10.91
Rank	1	3	4	2

Table 5.6: ANOVA for S/N ratios-compressive strength (Set 1)

Source	DF	Seq. SS	Adj MS	F-test	P
Binder mix percentage(A)	5	55.416	11.083	4.18	0.055
Type of concrete(B)	2	32.860	16.430	6.20	0.035
Mix percentage of Coarse aggregate(C)	2	2.176	1.088	0.41	0.681
Curing days(D)	2	72.107	36.054	13.61	0.006
Residual error	6	15.900	2.650		
Total	17	178.459			
S = 1.628 R-Sq = 91.1% R-Sq (adj) = 74.8%					

Table 5.7 Response for the S/N ratios (set 1)

LEVEL	Binder mix percentage(A)	Type of concrete(B)	Mix percentage of Coarse aggregate(C)	Curing days(D)
1	26.59	23.78	26.10	23.03
2	26.35	26.24	25.26	26.03
3	24.47	26.93	25.59	27.89
4	22.30			
5	26.72			
6	27.47			
Delta	5.17	3.15	0.84	4.86
Rank	1	3	4	2

Table 5.8 L 18 Taguchi orthogonal array (set 2)

Trails	binder mix percentage(A)	type of concrete(B)	mix %age of coarse aggregates(C)	curing days(D)
1	SF(5%)+FA(30%)	M20	CA(20mm)=50%,10mm=50%	7 days
2	SF(5%)+FA(30%)	M25	CA(20mm)=100%,10mm=0%	14 days
3	SF(5%)+FA(30%)	M30	CA(20mm)=0%,10mm=100%	28 days
4	SF(10%)+FA(20%)	M20	CA(20mm)=50%,10mm=50%	14 days
5	SF(10%)+FA(20%)	M25	CA(20mm)=100%,10mm=0%	28days
6	SF(10%)+FA(20%)	M30	CA(20mm)=0%,10mm=100%	7days
7	FA(20%)+RHA(30%)	M20	CA(20mm)=100%,10mm=0%	7days
8	FA(20%)+RHA(30%)	M25	CA(20mm)=0%,10mm=100%	14days
9	FA(20%)+RHA(30%)	M30	CA(20mm)=50%,10mm=50%	28 days
10	FA(30%)+RHA(20%)	M20	CA(20mm)=100%,10mm=0%	28days
11	FA(30%)+RHA(20%)	M25	CA(20mm)=50%,10mm=50%	7days
12	FA(30%)+RHA(20%)	M30	CA(20mm)=100%,10mm=0%	14days
13	SF(5%)+RHA(30%)	M20	CA(20mm)=100%,10mm=0%	28days
14	SF(5%)+RHA(30%)	M25	CA(20mm)=0%,10mm=100%	7days
15	SF(5%)+RHA(30%)	M30	CA(20mm)=50%,10mm=50%	14days
16	SF(10%)+RHA(20%)	M20	CA(20mm)=0%,10mm=100%	14days
17	SF(10%)+RHA(20%)	M25	CA(20mm)=50%,10mm=50%	28days
18	SF(10%)+RHA(20%)	M30	CA(20mm)=100%,10mm=0%	7days

Table 5.9 Result of compressive strength filling L 18 orthogonal array (set 2)

Trial no.	Compressive strength			Mean	S/N ratio
	1	2	3		
1.	14.69778	14.47111	13.73778	14.30222	23.10807
2	18.69778	19.14667	19.77333	19.20593	25.6687
3	25.89333	19.47111	25.91556	23.76	27.51693
4	17.87556	17.37778	18.70222	17.98519	25.0983
5	26.38222	32.44444	30.37778	29.73481	29.4653
6	15.93778	18.80444	18.59556	17.77926	24.99827
7	7.817778	7.871111	8.391111	8.026667	18.0907
8	14.16444	16.15556	17.13778	15.81926	23.98372
9	26.41333	25.38667	25.34222	25.71407	28.20342
10	20.58667	19.65333	20.03111	20.09037	26.05976
11	7.542222	8.173333	7.906667	7.874074	17.92399
12	11.94667	14.01778	13.16889	13.04444	22.30851
13	29.93333	27.79556	30.68444	29.47111	29.38793
14	31.04444	32.47556	32.03556	31.85185	30.06269
15	34.55111	33.28444	33.62222	33.81926	30.58328
16	25.58222	24.47556	24.65778	24.90519	27.9258
17	31.60444	35.89778	32.84889	33.45037	30.48802
18	25.72	26.17333	26.00889	25.96741	28.28857

Table 5.10 ANOVA for means – compressive strength (set 2)

Source	DF	Seq. SS	Adj MS	F-test	P
Binder mix percentage(A)	5	718.21	143.641	11.39	0.005
Type of concrete(B)	2	65.62	32.808	2.60	0.154
Mix percentage of coarse aggregate(C)	2	7.61	3.805	0.30	0.750
Curing days(D)	2	274.73	137.365	10.89	0.010
Residual error	6	75.69	12.615		
Total	17	1141.86			
E pooled	10	148.92	14.892		

Table 5.11 Significant factors for compressive strength (Set 2)

Factors	**Affecting mean**		**Affecting S/N ratio**	
	contribution	**Best level**	**Contribution**	**Best level**
Binder mix percentage(A)	Significant	Level5–(SF5%) +RHA(30%)	Significant	Level5–(SF5%) +RHA(30%)
Type of concrete(B)	Insignificant		Insignificant	
Mix percentage of coarse aggregate(C)	Insignificant		Insignificant	
Curing days (D)	Significant	Level 3 (M30)	Significant	Level 3(M30)

Table 5.12 Response for means – compressive strength (set 2)

Level	**Binder mix percentage(A)**	**Type of concrete (B)**	**Mix percentage of coarse aggregate (C)**	**Curing days(D)**
1.	19.09	19.13	22.19	17.63
2.	21.83	22.99	20.91	20.80
3.	16.52	23.35	22.37	27.04
4	13.67			
5.	31.71			
6.	28.11			
Delta	18.04	4.22	1.46	9.40
Rank	1	3	4	2

Table 5.13 Analysis of variance for S/N ratios (set 2)

Source	DF	Seq. SS	Adj SS	Adj MS	F-test	P
Binder mix percentage(A)	5	140.792	140.792	28.158	6.49	0.021
Type of concrete(B)	2	12.824	12.824	6.412	1.48	0.301
Mix percentage of coarse aggregate(C)	2	4.728	4.728	2.364	0.55	0.606
Curing days(D)	2	68.565	68.565	34.283	7.90	0.021
Residual error	6	26.024	26.024	4.337		
Total	17	252.932				
S = 2.083 R-Sq = 89.7% R-Sq (adj) = 70.8%						

Table 5.14 Response for S/N ratios (set 2)

Level	Binder mix percentage(A)	Type of concrete (B)	Mix percentage of coarse aggregate (C)	Curing days(D)
1.	25.43	24.95	25.90	23.75
2.	26.52	26.27	25.53	25.93
3.	23.43	26.98	26.76	28.52
4	22.10			
5.	30.01			
6.	28.90			
Delta	7.91	2.04	1.22	4.77
Rank	1	3	4	2

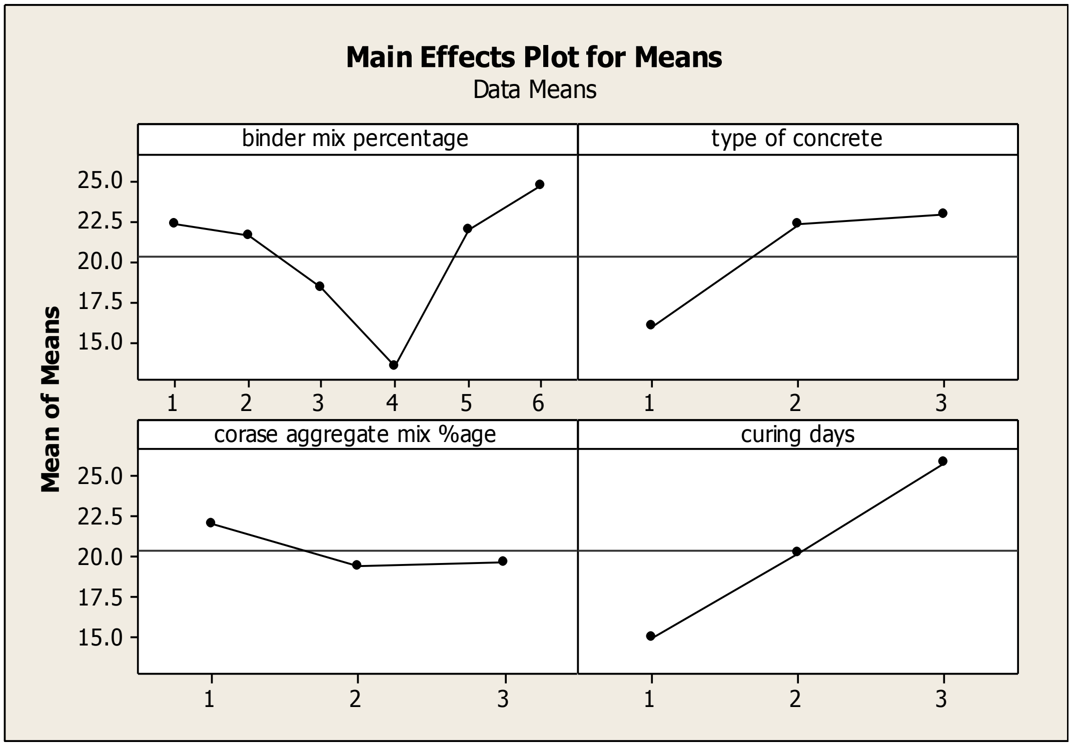


Figure 5.1: Main effects plot for Mean – compressive strength (set 1)

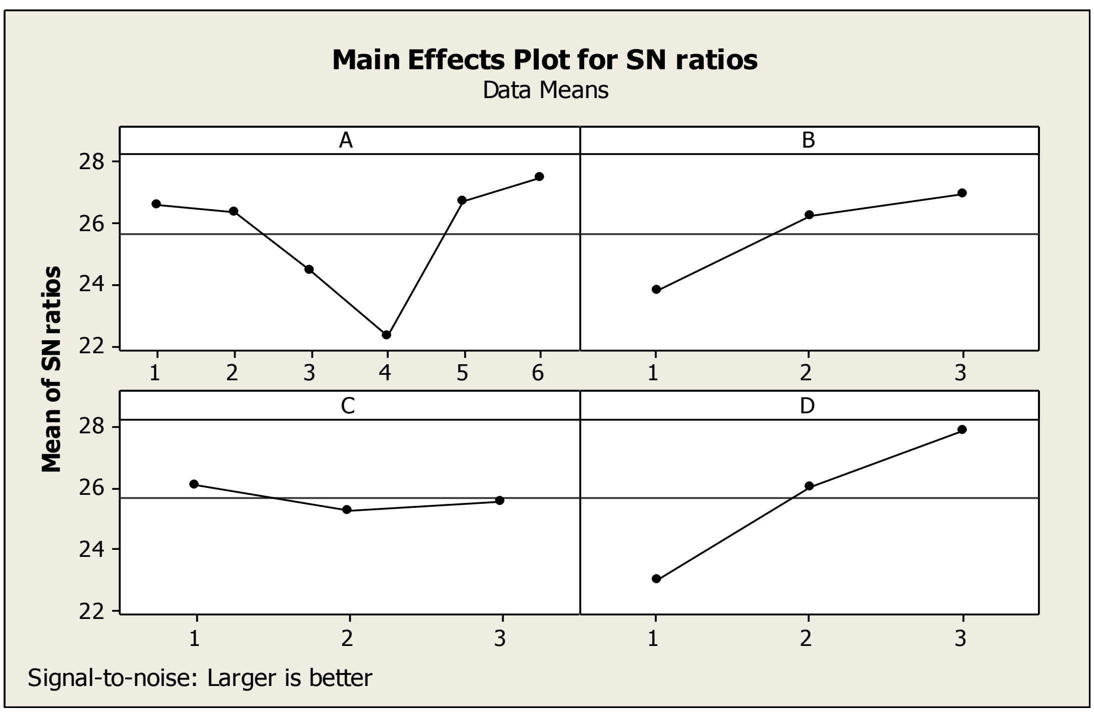
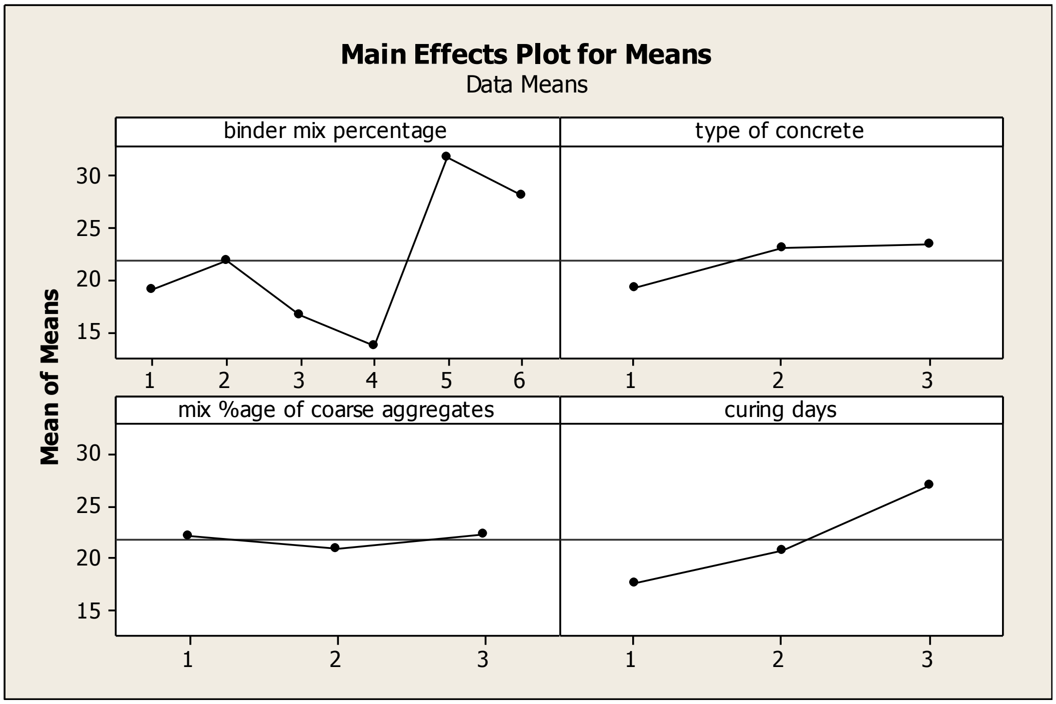
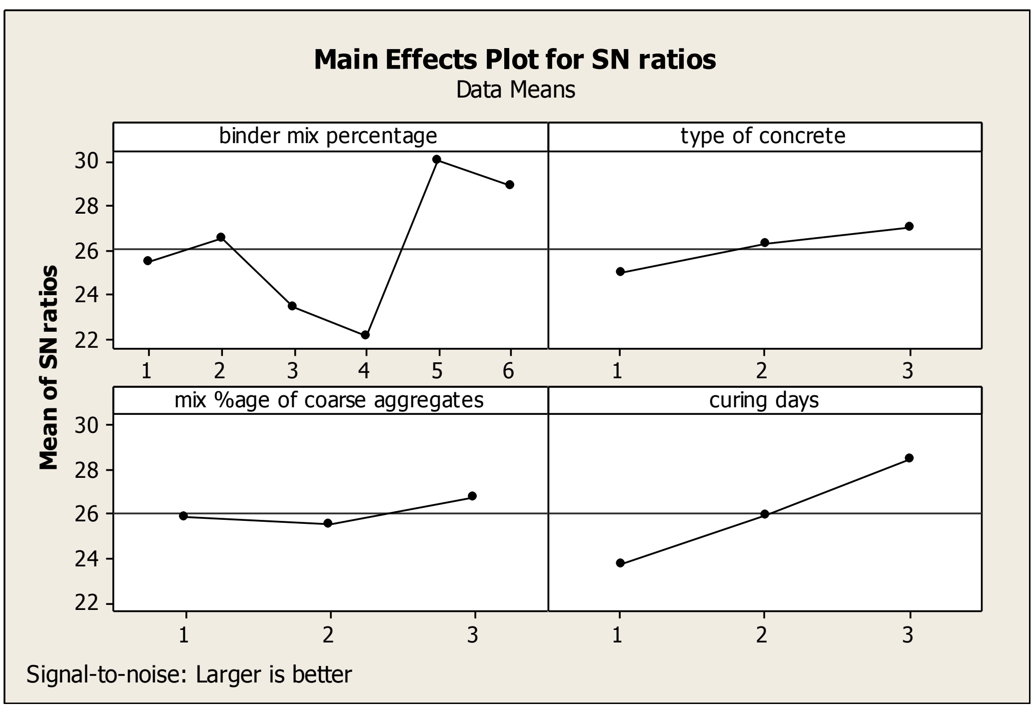


Figure 5.2 Main effects plots for SN ratios (set 1)



5.3 Main effects plot for mean for compressive strength (set 2)



Figures 5.4 main effects plot for SN ratios (set 2)

Chapter 6
CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The present study was carried out to study the effect of input parameters like water to cement ratio, by product percentage used as a binder, type of concrete like M20,M25 and M30,type of aggregates used and their different percentage and last one was the curing time on the output parameter compressive strength. Following conclusions were drawn from the present study.

1. The compressive strength is mainly affected by the product percentage used as replacement of cement and curing time.
2. Highest compressive strength was achieved when the combination of silica fume and rice husk ash are used as a replacement of binder with M30 type concrete for 28 days curing .
3. When curing time is taken as 7 days and a combination of silica fume (10%) and rice husk ash (30%) used as a binder, for M30 type of concrete, with coarse aggregate of size 20mm given the highest compressive strength for set1.
4. When curing time is taken 7days and a combination of silica fume(5%) and rice husk ash(30%) used as binder for M25 type of concrete with coarse aggregate of 10mm size only give the highest compressive strength for set 2
5. When curing time is taken as14 days and combination of silica fume(5%) and rice husk ash(20%) used as a binder for M30 type of concrete with coarse aggregate of 10mm size and 20mm both are give the highest compressive strength for set 1.
6. When curing time is taken as14 days and combination of silica fume(5%) and rice husk ash(30%) used as a binder for M25 type of concrete with coarse aggregate of 10mm and 20mm both are give the highest compressive strength for set 2.
7. When curing time is taken as28 days and combination of silica fume(10%) and rice husk ash(30%) used as binder for M25 type of concrete with coarse aggregate of 10mm and 20mm both are give the highest compressive strength for set 1.

8. When curing time is taken as 28 days and a combination of silica fume(10%) and rice husk ash(20%) used as a binder for M25 type of concrete with coarse aggregate of 10mm and 20mm give the highest compressive strength for set 2.

9. Finally it can be concluded that a combination of silica fume with rice husk ash gives the much higher compressive strength as compared to fly ash and rice husk combination which gives the least compressive strength. Thus, for grades of concrete up to M30 it is beneficial to use the above stated combination from strength perspective.

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