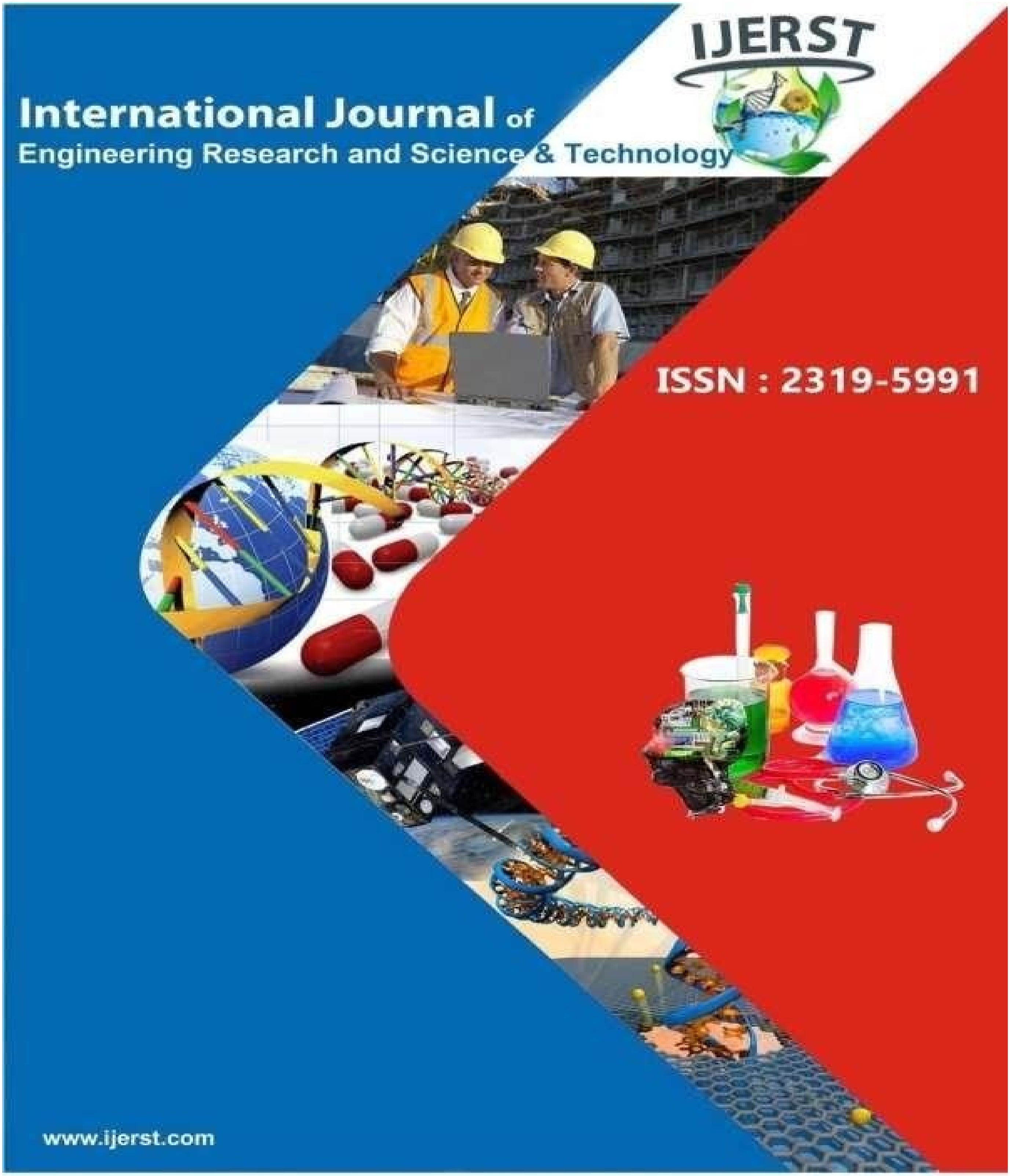

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International Journal of Engineering Research and Science & Technology

I ISSN 2319-5991 www.ijerst.com

Vol. 21, Issue 1, 2025

INVESTIGATION OF MECHANICAL PROPERTIES AND VARIATION OF THE PHYSICAL PROPERTIES OF CONCRETE USING INDUSTRIAL BY PRODUCTS

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ABSTRACT

The increasing demand for sustainable construction materials has driven research into the use of industrial by-products as partial replacements for conventional concrete ingredients. This study investigates the mechanical properties and variations in the physical characteristics of concrete incorporating industrial by-products such as fly ash, silica fume, Aluminium slag. A series of concrete mixes were prepared with varying proportions of these materials, and their effects on compressive strength and durability were evaluated. Additionally, key physical properties such as density, workability, and water absorption were analyzed. The results indicate that incorporating industrial by-products can enhance certain mechanical properties while influencing physical characteristics depending on the material type and replacement level. This study contributes to the development of eco-friendly and cost-effective concrete, promoting the utilization of industrial waste in sustainable construction practices.

Key words: Workability, Compressive strength, Water absorption.

I. INTRODUCTION

1.1 GENERAL

Sustainable construction mainly aims at reduction of negative environmental impact resulted by construction industry which is the largest consumer of natural resources. The total amount of by-products generated by the industries worldwide every year exceeds 1000 million tonnes. Over a period of time, waste management had become one of the most complex and challenging problem in the world which is affecting the environment. The rapid growth of industrialization gave birth to numerous kinds of waste by-products like Aluminium slag, fly ash, silica fume and slagswhich are by-products formed in smelting, and other metallurgical and combustion processes from impurities in the of storage. Always, construction industry had been at vanguard in consuming these waste products in large quantities.

1.1.1 ALUMINIUM SLAG DEFINED

Aluminium slag is a mixture of free metal and non metal substances (e.g., aluminium oxide and salts).Slags as well as salt slags (or: salt cakes) are residues from aluminium industry. Aluminium slag is formed during refining and by air-oxidation of the liquid metal during melting, holding and casting operations. It consists of a complex conglomerate, including metallic oxides (e.g.: Al_2O_3, $Al_2O_3 \cdot MgO$, $Al_2O_3 \cdot SiO_2$, $Al_2O_3 \cdot FeO$ etc.), nitrides (e.g.: AlN), chlorides (e.g.: $AlCl_3$, NaCl, KCl), fluorides (e.g.: CaF_2, NaF, AlF_3, Na_3AlF_6 etc.), carbides (e.g.: Al_4C_3), sulphides (e.g.: Al_2S_3), phosphides (e.g.: AlP), dirt and impurities apart from metallic aluminium (between 80-20%). The formation of slag and the amount of slag formed depend on different factors like type and quality of input material (e.g.: aluminium scraps in secondary industry) operating conditions and type of technology and furnace applied. Depending on different conditions during charging, melting, refining as well as skimming, the metal-content of slag may

International Journal of Engineering Research and Science & Technology
I ISSN 2319-5991 www.ijerst.com
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vary between 20-80% Al (average value: 60% Al). According to Organisation for Economic Co-operation and Development (OECD) definition, residues with more than 45% Al are called "skimmings" and materials containing less than 45% Al are called "slag". Slag may also be separated into "White Slag" from primary smelters without salt cover and "Black Slag" from secondary smelter with salt cover (e.g. Rotary Furnace or Tilting Rotary Furnace). Due to the properties of slag and salt slag (or salt cake), they are both included in the list of hazardous wastes (European Commission, 2000). [6]

Fig: .1 BlackAluminium slag

Fig: 2. Sieved Black Aluminium slag

1.1.2 SILICA FUME DEFINED

The American Concrete Institute (ACI) defines silica fume as "very fine non-crystalline silica produced in electric arc furnaces as a by-product of the productions of elemental silicon or alloys containing silicon" (ACI 116R). It is usually a graycoloured powder, somewhat similar to Portland cement or some fly ashes. Silica fume is usually categorized as a supplementary cementitious material. This term refers to materials that are used in concrete in Addition to portland cement. Silica fume is frequently referred to by other names:

- Condensed silica fume
- Micro-silica
- Volatilized silica

Silica fume is a by-product of producing silicon metal or ferrosilicon alloys in smelters using electric arc furnaces. These metals are used in many industrial applications to include Aluminium and steel production, computer chip fabrication, and productions of silicones, which are widely used in lubricants and sealants. While these are very valuable materials, the by-product silica fume is of more importance to the concrete industry.

Fig: 3 Silica Fume

Fig: 4 Silica Fume

1.1.3 FLY ASH DEFINED

The combustion of pulverized coal at high temperatures and pressures in power stations produces different types of ash. The 'fine' ash fraction is carried upwards with the flue gases and captured before reaching the atmosphere by highly efficient electro static

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ISSN 2319-5991 www.ijerst.com
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precipitators. This material is known as Pulverized Fuel Ash (PFA) or 'fly ash'. It is composed mainly of extremely fine, glassy spheres and looks similar to cement.

Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants, whereas bottom ash is removed from the bottom of the furnace. In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release. Depending upon the source and makeup of the coal being burned, the components of the fly ash produced vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO). Fly ash is commonly used to supplement Portland cement in concrete production, where it can bring both technological and economic benefits, and is increasingly finding use in the synthesis of geopolymers and zeolites.

Fig: 5 Dumped Fly Ash

1.2ENVIRONMENTAL IMPACTSOF ALUMINIUM SLAG, FLY ASH AND SILICA FUME

Aluminium slag which is a by-product of aluminium production is very harmful to the nature when exposed. Because,

- Slag is highly reactive when it comes into contact with water.
- Slag is a skin and eye irritant, when it comes into contact.
- Slag emits toxic chemicals and gases into the atmosphere.
- When deposited and stored in landfills, slag is hazardous to the environment by emitting fumes.
- Fly ash contains trace concentrations of heavy metals and other substances that are known to be detrimental to health in sufficient quantities. Potentially toxic trace elements in coal include arsenic, beryllium, cadmium, barium, chromium, copper, led, mercury, molybdenum, nickel, radium, selenium, thorium, uranium, vanadium, and zinc.
- Since coal contains trace levels of arsenic, barium, beryllium, boron, cadmium, chromium, thallium, selenium, molybdenum and mercury, its ash will continue to contain these traces and therefore cannot be dumped or stored where rainwater can leach the metals and move them to aquifers.
- Micro silica, or silica fume (CAS-no. 69012-64-2), is an amorphous type of silica dust mostly collected in bag house filters as by-product of the silicon and Ferro-silicon production.
- Micro silica consists of spherical particles with an average particle size of 150 nm and a specific surface area of typically $20m^2/g$. The chemical and physical properties of this inorganic product are different as compared to other amorphous and crystalline silica polymorphs. More than 500.000 MT of micro silica are sold to the building industry world-wide and are used in fibre cement, concrete, oil-well drilling, refractories, and even in polymers.
- Micro silica contains trace amounts of heavy metal oxides and organic deposits, which originate from natural raw materials. Since the concentration of these impurities is very low, micro silica complies with company policies and international regulations. Traces

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of crystalline silica in micro silica do not seem to represent a health risk, neither for silicosis nor for lung cancer, due to the low levels and the large particle size.

1.3 ECONOMIC MOTIVES

Recycling aluminium uses about 5% of the energy required to produce aluminium from bauxite, because the latter requires much electrical energy to electrolyze aluminium oxide into aluminium. Recycling results in significant cost savings over the production of primary new aluminium even when the cost of collection, separation and recycling are taken into account. Small percentage losses result in large losses, thus the flow of material is well monitored and accounted for financial accountability. It is understandable that metallic aluminium content in slag is of interest, as aluminium recovered had value to the enterprise.

When reviewing primary aluminium production, it can be noted that mitigating slag formation is the most direct means of making an impact to the bottom line. Degassing had been used, but this can only reduce 5% of slag and there is a cost associated with this step.

The other possibility is to convert slag recovery into a non-salt processing step. Recycling of Aluminium slag without salt fluxes and using plasma torches had been developed in France, however it is more cost-effective. It is estimated that the investment for a production unit would be 20 million dollars per year, which mean 661 dollars will be added to the cost of slag for each ton produced.

1.4 ADMIXTURES

Is code reminds us that chemical Admixtures are designed to enhance the properties of concrete in the plastic and hardened states, increase efficiency of cementitious material, and improve the economy of concrete mixtures. While concrete contractors are not required to have the same level of understanding of Admixtures as concrete producers, a refresher in some of the basic types of Admixtures and their benefits should simplify the contractor's job.

It is important to remember Admixtures don't include secondary cementitiousmaterials such as silica fume or other pozzolana, though they can bring similar benefits to concrete. The primary function of silica fume and other pozzolana is not their abilities to function as Admixtures. And, for the purpose of this article, pigments for colouring concretes have been omitted, even though ACI defines them as Admixtures. The following is a list of the major types of chemical Admixtures and a brief description of their use and possible compositions.

1.5 SCOPE OF THE PRESENT PROJECT

1. To access the effect of partial replacement of different waste materials on weight basis of OPC.
2. To examine the effect of these substances with different dosages like replacement of cement by weight in mortar cubes on short term and long term.
3. To find the strength of concrete cubes after conducting durability tests.
4. To identify the best combination of supplementary cementitious materials used with OPC in concrete, which will be most economy and nature friendly?

Today much energy is consumed to recover the Al from the slag; energy could be saved if the slag was diverted and utilized as an engineering material. There are two forms of slag – white slag and black slag. White slag is formed during the primary Al refining process, while black slag is formed during the secondary refining process, which uses relatively large amounts of Chloride salt fluxes.

Potential benefits:

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- Material related:

- ♦ Aluminium oxides from slag recycling comprise an alternative source toprimary material.
- ♦ Fly ash, silica fume are the by-products of the coal based industries and alloy industries.

- Economic:

- ♦ Aluminium smelters benefit by charging a gate fee for handlingand processing waste slag.
- ♦ Since fly ash and the silica fume are the industrial waste products,these are available at free of cost.
- ♦ The end products of the aluminium recycling process (aluminium ingots, powder metallurgy products) are considered as high value.

- Environmental

- ♦ Less waste is disposed of to landfill.
- ♦ In this study a concrete mix was developed using mineral Admixtures. The effect of cement replacement of 5, 10 and 20 % by Aluminium slag, fly ash, silicafume, by keeping the total Cementitious content i.e., cement plus Admixtures constant.
- ♦ CO_2 emission from the cement can be reduced by replacing the cement with these industrial wastes.

II. LITERATURE REVIEW

General:

In the literature, there are several studies to use these industrial waste residues in construction applications as the replacement of sand or cement, to produce concrete blocks, to manufacture aluminate cement or as filler in asphalt products, strength gain in concrete with the use of silica fume and fly ash. The results proved that the concrete products can be prepared by using the salt as the replacement of sand or cement without causing deleterious effects on concrete characteristics, and the calcium aluminate cement can be produced by using the salt cake as sources of CaO and Al_2O_3.

In this chapter, only literature concerning those aspects related to this particular research i.e. the mechanical and durability properties of hardened concrete incorporating fly ash, silica fume and Aluminium slag as a mineral Admixtures Added to concrete made with the Portland cement are discussed.

A.Go´mez1, N.B.Lima and J.A.Teno´rio(2008)carried a work on *"Quantitative analysis of Aluminium slag by the Rietveld method".*Aluminium white slag is a valuable material principally due to its high metallic aluminium content. The aim of this work is to develop a method for quantitative analysis of aluminium white slag with high accuracy. Initially, the material was separated into four granulometric fractions by means of screening. Two samples of each fraction were obtained, which were analyzed by means of X-ray fluorescence and energy dispersive spectroscopy in order to determine the elements present in the samples. The crystalline phades aluminium, corundum, spinel, defect spinel, diaoyudaoite, aluminium nitride, silicon and quartz low were identified by X-ray diffraction. The quantitative phade analysis was performed by fitting the X-ray diffraction profile with the Rietveld method using the GSAS software. The following quantitative results were found: 77.8% aluminium, 7.3% corundum, 2.6% spinel, 7.6% defect spinel, 1.8% diaoyudaoite, 2.9% aluminium nitride, and values not significant of quartz and silicon.

K.E.Lorber and H.Antrekowitsch (2009) carried a work on "Treatment and disposal of residues from Aluminium slag recovery". Basically, slag could be disposed on special types of hazardous waste landfills relatively safely, as long as water and moisture is strictly kept away. But due to insufficient base linear systems and inadequate surface capping of elder landfills, in reality pollution

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of ground water (e.g.: F-, Cl-, NH_4 +, CN-, high pH and electric conductivity values) and ambient air (e.g.: CH_4, H_2, NH_3) can be observed in many cases, when slag was land filled. Investigations done on a former industrial landfill for residues coming from a secondary aluminium plant, showed high concentrations (e.g.: >4 Vol% H_2, >7 Vol% CH_4, >2 Vol%, NH_3) of dangerous gases in soil air. It also turned out, that the pollution found in ground water (e.g. NH_4 +, F-, Cl-) did not result from percolation of precipitation water but from bottom – leaching of the landfill, caused by capillary diffusion. Top and bottom layer of the site are relatively wet and compacted, the space in between is filled up with dry, dust like slag material. This makes sense, because slag will immediately react with water according. For a 20 year old sample of slag material taken from a site-depth between 4-5m, the gas formation potential was determined over 21 days. As shown in Fig. 3, the sample was showing a linear development of degassing, with a rather constant gas formation potential of 8.4 N ml/kg DM per day.

B. Lipowska, J. Witek and K. Stec 2010, had done research work on "Aluminium slag-based insulating and exothermic materials for metallurgical industry", in the conducted investigations, Aluminium slag was a basic component of raw mixes used to obtain insulating and exothermic materials. Two types of slag were used: waste produced in the process of aluminium chips melting (slag A) and waste produced in the process of beverage can melting (slag B). Due to a potential reaction of the alloy with alkaline metal salts contained chiefly in the dust fraction, 0.5÷2 mm grain size distribution was applied. The chemical composition of these types of slag indicates that they differ chiefly in Al contents, both in a metallic and oxide form. Thermo-hardening resins were used as binders: solid novolak and liquid carbamide-formaldehyde resin. The material was obtained by filtrating the slurry. To this end, suitable amounts of selected raw materials and binder were used to prepare a water suspension, which was filtrated at the pressure of ca 0,1MPa. In the conducted investigations, the influence of the type of slag and binder as well the impact of the share of quartz sand and mineral wool on the material's basic properties was determined: apparent density and compression strength after drying and firing at 1450 C as well as refractoriness. The investigations were carried out for samples in a form of =h=50mm cylinders, moulded in the process of slurry filtration. It was found (Table 2) that the type of slag and binder used does not influence basic properties, i.e. Apparent density and compression strength of the obtained materials, both after binders hardening at 150^0 C and after their firing. Refractoriness of the examined materials reached 1570^0 C. Increasing the share of mineral wool from 10 to 15% (batch 3) reduced the material's refractoriness by 20^0 C. Moreover, investigations into thermal properties of the obtained materials were conducted in a device which allows determining the amounts of heat carried away or supplied in the measuring process. The results were recorded in a form of graphs showing the loss of heat of the examined material sample versus time. The result of heat loss measurement for the model sample made of technically pure $Al_2O_3$was assumed as the reference level. On the basis of the obtained dependencies, the duration of exothermic effect and FIV (Final Insulating Value) was determined – the loss of heat from an examined sample of material after measurement, i.e. after 45 min. Trials were carried out to test the possibility of using slag –waste formed in the production or recycling of aluminium – to obtain an insulating and exothermic material

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for riser head sleeves applied in the metallurgical industry. Properly composed raw mixes, among others containing slag, raw materials which are necessary in exothermic reactions and ensure a material with suitable mechanical and thermal properties, enabled obtaining a material characterized by good thermal properties as well as sufficient mechanical strength, both at the stage of installation and alloy casting. The trials conducted in semi-technical conditions, using prototype sleeves, revealed their good quality and effectiveness in the metallurgical process, comparable to the currently applied sleeves. The conducted tests confirmed the fact that the obtaining of an insulating-exothermic material may be one of the directions in the utilization of Aluminium slag, which being arduous waste for the environment is currently stored at dumping grounds.

III. MATERIALS AND METHODOLOGY

3.1 MATERIALS

3.1.1 Ordinary Portland Cement (53 grade):-

Cement may be described as a material with Adhesive and cohesive properties that make it capable of bonding, mineral fragments into a compact whole. Most cement used today is Portland cement. This is carefully proportioned and specially processed combination of lime, silica, iron oxide and alumina. It is usually manufactured from limestone mixed with shale, clay. Properly proportioned raw materials are pulverized into kilns where they are heated to a temperature of 1300 to 1500˚C. The clinker is cooled and ground to fine powder with Addition of about 3 to 5% of gypsum. The OPC (53 grade) used in the present work is of Anjanicement.The cement used in the casting of cubes and cylinders meets the following specifications as per IS 12269-1987.

QUALITY PARAMETERS

Table: 1 Fineness of Ordinary Portland cement

Trail No.	1	2	3
Weight in cement (g)	100	100	100
Quantity of Cement Retained (%)	6	7	6

Table: 2 Soundness of Ordinary Portland cement

Test physical requirement	AnjaniO.P.C 53 grade	IS 12269-1987
Lechatlier Method(mm)	1	<10

Table: 3 Normal Consistency of Ordinary Portland cement

Test physical requirement	AnjaniO.P.C 53 grade	IS 12269-1987
Normal Consistency (%)	34	Not Specified

Table: 4 Setting Time of Ordinary Portland cement

Test physical requirement	Anjani OPC 53 grade	IS 12269-1987
Initial setting time(min)	50	>30
Final setting time(min)	320	<600

3.1.2 Fine aggregate

Naturally available sand is used as fine aggregate in the present work. The most common constituent of sand is silica, usually in the form of quartz, which is chemical inert and hard. The sand is free from clayey matter, silt and organic impurities etc. Hence used as a fine aggregate in concrete. The size of sand is that passing through 4.75 and retained on 150 micron IS sieve. The specific gravity of Sand is taken as 2.62. Sand is tested for specific gravity, in accordance with IS: 2386-1963.

Table:5 Properties of fine aggregate

Sl. No	Properties	Unit	Results
1	Specific gravity	-	2.7
2	Bulking of sand	%	4
3	Partial size variation	mm	0.15 to 4.75

Table:6 Grain Size Distribution of Fine Aggregate

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Sieve Size	Weight Retained (gm)	Cumulative % Retained	Cumulative % Passing	Zone - Specifications as per IS:383-1970 for % Passing			
				I	II	III	IV
4.75 mm	12	1.2	98.8	90-100	90-100	90-100	95-100
2.36 mm	103	11.5	88.5	60-95	75-100	85-100	95-100
1.18 mm	316	43.1	56.9	30-70	55-90	75-100	90-100
600 µ	205.5	63.65	36.35	15-34	35-59	60-79	80-100
300 µ	296.5	93.3	6.7	5-20	8-30	12-40	15-50
150 µ	62	99.5	0.5	0-10	0-10	0-10	0-10
Pan	2	100	0	---	---	---	---

Fineness Modulus of Fine Aggregate=312.25/100=3.12

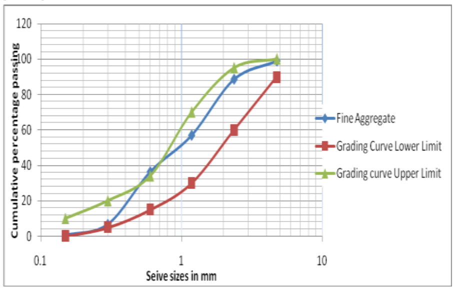

Fig :6. Particle Size Distribution of Fine Aggregate

3.1.3 Water

The water used for the study was free of acids, organic matter, suspended solids, alkalis and impurities which when present may have adverse effect on the strength of concrete.Water is an important ingredient of concrete, which not only actively participates in the hydration of cement but also contributes to the workability of fresh concrete. Cement is a mixture of complex compounds, the reaction of cement with water leads to its setting and hardening. All compounds present in the cement are anhydrous but when brought into contact with the water they get hydrolyzed, forming hydrated compounds. The two principal functions of water in a concrete mix are to effect hydration and improve workability. Too much of water causes a loss of strength by upsetting the water cement ratio. Water which is used in mixing the concrete must be clean and free from acids, alkalis, oils, and organic materials. Sea water is not suitable for use in making steel-reinforced concrete because of the risk of corrosion of the reinforcement, particularly in warm and humid environment. The locally available potable water, which is free from concentration of acid and organic substances, is used for mixing the concrete. The specific gravity of water is taken as 1.00.

3.1.4 FLY ASH

FLY ASH

Fly ash is a by- product of the combustion of pulverized coal in thermal power plants. A dust-collection system removes the fly ash, as a fine particulate residue, from combustion gases before they are discharged into the atmosphere (Figure1.4). The types and relative amounts of incombustible matter in the coal used determine the chemical composition of fly ash. More than 85% of most fly ashes is comprised of chemical compounds and glasses formed from the elements silicon, Aluminium, iron, calcium, and magnesium. Generally, fly ash from the combustion of subbituminous coals contains more calcium and less iron than fly ash from bituminous coal; also, fly ash from subbituminous coals contains very little unburned carbon. Plants that operate only intermittently (peak-loads stations) and that burn bituminous coals produce the largest percentage of unburned carbon. Fly-ash particles are typically spherical, ranging in diameter from <1 µm up to 150 µm. Fly ashes exhibit pozzolanic activity. The American Society for Testing and Materials (ASTM) (ASTM, 1975) defines a pozzolan as "a siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but which will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties." Fly ashes contain metastable alumina silicates that will react with calcium ions, in the presence of moisture, to form calcium silicate hydrates.

In recent years, it had become evident that fly ashes differ in significant and definable ways that reflect their combustion and, to

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some extent, their origin. The ASTM recognizes two general classes of fly ash:

• Class C, normally produced from lignite or sub bituminous coals

• Class F, normally produced from bituminous coals

Chemical Composition

In general, which contains more than 60% SiO_2, and 28% Al_2O_3 by mass and source of fly ash influence its mineralogical composition. Due to the rapid cooling of burned coal in the power plant, fly ashes consist of non-crystalline particles (≤90%), or glass and a small amount of crystalline material. Depending on the system of burning, some unburned coal may be collected with ash particles. In Addition to a substantial amount of glassy material, each fly ash may contain one or more of the four major crystalline phades: quartz, mullite, magnetite, and hematite. In subbituminous fly ashes, the crystalline phades may include C_3A, C_4A_3S, calcium sulphate, and alkali sulphates. Table 2.1 shows the chemical composition of some selected fly ashes. The reactivity of fly ashes is related to the non-crystallinephade or glass. The reasons for the high reactivity of high-calcium fly ashes may lie partially in the chemical composition of the glass.

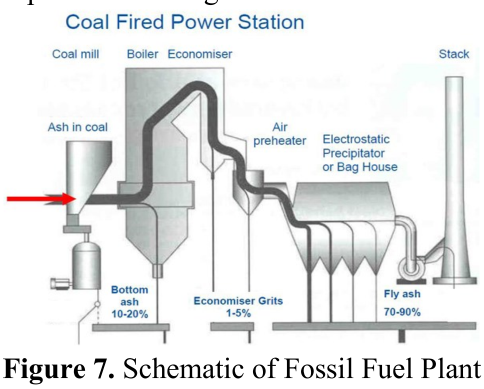

Figure 7. Schematic of Fossil Fuel Plant

Table 7 CHEMICAL PROPERTIES

Constituents	Percentage (%)
SiO_2	60.48
Al_2O_3	28.15
Fe_2O_3	4.52
CaO	1.71
K_2O	1.41
MgO	0.47
Na_2O	0.14
L.O.I	1.59

3.2 Compression strength test method:

It is the most common test conducted on hardened concrete as it is an easy test to perform and also most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The compressive test is carried out on specimens cubical in shape as shown in fig of the size 150mm x 150mm x 150mm.

Fig:8. Compaction by vibrator

Fig:9. Concrete Cube Specimens

The test is carried out in the following steps: First of all the mould preferably of cast iron,is used to prepare the specimen of size 150mm x 150mm x 150mm.During the placing of concrete in the moulds it is compacted with the tamping bar with not less than 35 strokes per layer. Then these moulds are placed on the vibrating table and are compacted until the specified condition is attained. After 24 hours the specimens are removed from the moulds and immediately submerged in clean fresh water. After 28 days the specimens are tested under the load in a compression testing machine.

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Fig: 10. Expansions of Concrete Cubes

From the above fig: 3.6, we can observe that there is expansion in concrete cubes with replacement of Aluminium slag. As the percentage of Aluminium slag increases, the expansion also increases because of formation of voids in concrete cubes.

Fig: 11. Compression Testing Machine.

IV. MIX DESIGN

4.1 MIX DESIGN FOR PRESENT INVESTIGATION:

In the present work the Indian standard method (IS METHOD) had been used to get proportions for normal strength concrete. The concrete mix design for M_{20} were carried out according to Indian standard recommendation method as per IS 10262-1982.

4.2 MIXTURE PROPORTIONING PROCEDURE

The basic steps involving in the Indian standard method of design of concrete can be summarized as follows

Steps 1: determination of target mean strength or field strength

Formula for calculating target means strength as follows

$F_t = f_{ck} + ks$

Where f_t = target mean compressive at 28 days

f_{ck}= characteristic compressive strength at 28 days

k = statically value depending upon the accepted portions of flow results and the number of tests.

S= Assumed standard deviation

Note: As per IS: 456-2000, the value of k is taken 1.65, assuming that characteristic strength is expected to fall not more than 5 percent of test results. And value of s is also taken from IS 456-2000 table. This is given for each grade of concrete. The value of s for M_{20} and M_{25} is 4Mpa and 5Mpa.

STEP2: WATER-CEMENT RATIO

The water-cement ratio is chosen from table no. IS: 456-2000(36). Which specify the minimum cement content, maximum water cement ratio and minimum grade of concrete for the different exposure conditions with normal maximum size aggregate is 20mm. The value selected is compared with available relations in SP: 23-1982(35). For the determination of w/c ratio for the target mean compressive strength at 28 days.

It is noted here that w/c ratio for the determined target mean compressive strength at 28 days gives lower value than specified maximum value in table of IS 456-2000.

STEP3: ESTIMATION OF REQURIED WATER

The approximate water content is selected from the table 35 and 38 of SP. 23-1982, applied for normal concrete mix, which considers the aggregate type (whether crushed or uncrushed), maximum size of the aggregate and required slumps as a measure of level of workability.

STEP4: ESTIMATION OF AIR CONTENT

The estimated entrapped air content is taken (2%) from table No. 41 of SP 23-1982, based on nominal maximum size of the aggregate.

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STEP5: DETERMINATION OF CEMENT CONTENT

The cement content is calculated from the selected w/c ratio and estimated water content. The cement content calculated is compared with the minimum required cement content as per the durability consideration as stipulated in the IS 456-2000. The greater of the two values is adopted. It is noted that the quantity Adopted is inclusive of the Addition of part supplementary cementitions material to OPC.

STEP 6: ESTIMATION OF PERCENTAGE OF SAND IN TOTAL AGGREGATE

The percentage of sand in total aggregate depends upon the grading of sand to be incorporated in the mix. The general guideline is obtained from the figure 45 of SP 23-1982(35).

This is based on maximum size of coarse aggregate and the required slump value targeted. It is to be noted that concrete with super plasticizers will have different percentage of sand than concrete without super plasticizers for the same w/c ratio. Apartfrom the guidelines given in the figure 45 of the SP: 23-1982(35) for the calculation of the percentage of sand in total aggregate percentages of fine aggregates is also seen in relation to the ratio of total fine contents (cement plus fly ash plus fine aggregate) to total coarse aggregate content per m^3 of mature. If it was not found in the specified range then the percentage is adjusted accordingly. The ratio of total fines to aggregate is a very important factor which influence the quality of concrete very much, varies with the W/C ratio of concrete for a given slump range values.

It is noted that the W/C ratio 0.5 was kept for the production of M_{20} concrete for slump range 80-120 mm in this project work.

V. RESULTS AND DISCUSSION

5.1 GENERAL

The results of the present investigation are presented both in tabular and graphical forms in order to facilitate the analysis, interpretation of the results is results obtained is based on the current knowledge available in the literature as well as on the nature of results obtained. The significance of the results is assessed with reference to the standards specified by the relevant IS codes.

1. The normal consistency of cement sample prepared with different replacement by 5%, 10% and 20% of Aluminium slag are compared with ordinary cement and also normal consistency of cement paste sample by partial replacement with constant Aluminium slag of 5% and different proportions of 10% and20% of silica fume and fly ash and at the same time another cement paste sample keeping Aluminium slag at 10% constant and different proportions of 10% and 20% of silica fume and fly ash.
2. Both the initial and final setting time of cement sample prepared with different replacement by 5%,10%,20% of Aluminium slag are compared with ordinary cement and also the initial and final setting time of cement paste sample by partial replacement with constant Aluminium slag of 5% and different proportions of 10% and 20% of silica fume and fly ash and at the same time another cement paste sample keeping Aluminium slag constant at 10% and different proportions of 10% and 20% of silica fume and fly ash. If the difference is less than 30 minutes, the change is considered to be insignificant and if it is more than 30 minutes, the change is considered to be significant.

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3. The sieve analysis of fine and coarse aggregate which is used for the present experimental work.
4. The average compressive strength of concrete of at least three cubes (150×150×150 mm) prepared with mineral Admixtures under consideration is compared with that of three cubes prepared with ordinary cement (for 3 days, 14 days, 28 days, 56 days and 90 days). If the difference in the strength is less than 10%, it is considered to be insignificant and if it is greater than 10%, it is considered to be significant.

5.2 NORMAL CONSISTENCY

5.2. 1Normal consistency of 100% cement

Table: 8 Normal consistency of 100% cement

S.No	Water percentage (%)	Depth not penetrated (mm)
1	28	36
2	30	32
3	32	14
4	34	6

Normal consistency of cement = 34%.

5.2.2Normal consistency of 80%cement +20% Aluminium slag

Table: 9 Normal consistency of 80% C + 20% AS

S.No	Water percentage (%)	Depth not penetrated (mm)
1	28	25
2	30	19
3	32	17
4	34	14
5	36	13
6	38	10

Normal consistency of 80% cement + 20% Aluminium slag = 38 %.

5.2.3Normal consistency90% cement + 10% Aluminium slag

Table: 10 Normal consistency of 90% C + 10%AS

S.No	Water percentage (%)	Depth not penetrated (mm)
1	28	40
2	30	40
3	32	21
4	34	10

Normal consistency of 90% cement + 10% Aluminium slag = 34%.

5.2.4.Normal consistency 95% cement + 5% Aluminium slag

Table: 11. Normal consistency of 95% C + 5% AS

S.No	Water percentage (%)	Depth not penetrated (mm)
1	28	39
2	30	23
3	32	11
4	34	6

Normal consistency of 95% cement + 5% Aluminium slag = 34%.

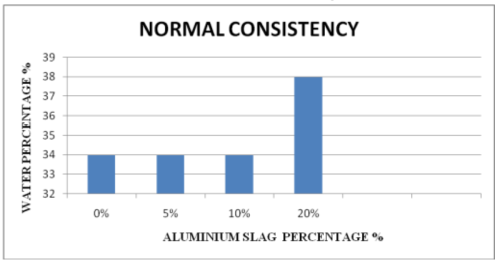

Fig: 12. Effect on Normal Consistency for different replacement of OPC with AS

5.3 RESULTS OF INITIAL AND FINAL SETTING TIME

5.3.1 Initial and final Setting time of cement with replacement of AS and FA.

The variations in the initial and final setting times of cement with Addition of fly ash and 5%Aluminium slag.

From table 5.4 it is observed that both the initial and final setting times got retarded andAccelerated by replacement of fly ash and Aluminium slag in the ordinary Portland cement.

Table 12:Initial and Final setting time values cement with replacement of fly ash and Aluminium slag.

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S.NO	Details of Material	Initial Setting Time (minutes)	Final Setting Time (minutes)
1	100% OPC +0%AS+ 0% FA	40	380
2	85% OPC +05%AS+ 10% FA	50	280
3	75% OPC +05%AS+20% FA	60	260

5.3.2 Initial and final Setting time of cement with replacement of Aluminium slag and silica fume

The variations in the initial and final setting times of cement with Addition of silica fume.

From table 5.4.1 it is observed that both the initial and final setting times got retardedand accelerated by replacement of silica fume in the ordinary Portland cement.

Table 13 : Initial and Final setting time values cement with replacement of 5% Aluminium slag and10%, 20%of silica fume

S.NO	Details of Material	Initial Setting Time (minutes)	Final Setting Time (minutes)
1	100% OPC +0%AS+ 0% SF	40	380
2	85% OPC +05%AS+ 10% SF	45	300
3	75% OPC +05%AS+20% SF	45	320

5.4 GRAIN SIZE DISTRIBUTION

5.4.1 Grain size distribution of fine aggregates

Table: 14 Grain size distribution of fine aggregates

S.No	Sieve size	Weight retained (gm)	Percentage of weight retained (%)	Cumulative percentage of weight retained (F)	Percentage of passing (100−F)
1	4.75mm	46	4.6	4.6	95.4
2	2.36mm	128.5	12.85	17.45	82.55
3	1.18mm	326	32.6	50.05	49.95
4	600μm	237.5	23.75	73.8	26.2
5	300μm	201	20.1	93.9	6.1
6	150μm	40.5	4.05	97.95	2.05
7	Pan	20.5	2.05	100	0
		∑WT=1000			

The grain size distribution of fine aggregates is found taking 1kg of fine aggregates and is passed through the sieves (4.75m,2.36mm, 1.18mm, 600μm, 300μm, 150μm, pan lid). Weights of aggregates retained in sieves are noted in above table.

5.4.2 Grain size distribution of coarse aggregates

The grain size distribution of coarse aggregates is found by taking 5kg of coarse aggregates and is passed through the sieves (20mm,16mm,12.5mm,10mm,6.3mm). Weights of aggregates retained in sieves are noted.

Table: 15 Grain size distribution of coarse aggregates

S.No	Sieve size (mm)	Weight retained (gm)	Percentage of weight retained (%)	Cumulative percentage of weight retained(F)	Percentage of passing (100−F)
1	20	2520.5	50.41	50.41	49.59
2	16	1389	27.78	78.19	21.81
3	12.5	975.5	19.51	97.7	2.3
4	10	103	2.06	99.76	0.24
5	6.3	12.5	0.25	100	0
		∑WT=5000			

5.5 INITIAL SETTING TIME & FINAL SETTING TIME

5.5.1Initial setting time of 100% cement

Weight of cement used = 400 gm

Amount of water used = 0.85×p×400

=0.85×0.34×400

=115.6ml.

Table: 16 Initial setting time of 100% OPC

S.No	Time (min)	Depth not penetrated (mm)
1	30	2
2	35	3
3	40	5

Initial setting time = 40 min

Final setting time =380 min.

5.5.2 Initial setting time of 95% cement +5% Aluminium slag

Weight of cement used = 400gm

Amount of water used =0.85×0.34×400

=115.6ml

Table:17 Initial setting time of 95% OPC + 5% AS

S.No	Time (min)	Depth not penetrated (mm)
1	30	3
2	35	3
3	40	4
4	45	5

Initial setting time = 45 min

Final setting time = 270 min.

5.6 SOUNDNESS

Table below shows the values for soundness of 100% OPC

Table: 18 Soundness of 100% OPC

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Trails	Initial reading(mm)	Final reading(mm)	Soundness (mm)
1	9	11	2
2	7	9	2

Soundness of cement =2mm.

Table below shows the results for 5%,10%,15%,20%, replacements of cement with Aluminium slag.

Table: 19. Soundness of OPC with different replacements of AS

S.No	Replacement percentages (%)	Initial reading(mm)	Final reading(mm)	Soundness (mm)
1	5	7	9	2
2	10	9	12	3
3	15	11	15	4
4	20	8	12	4
5	30	15	20	5

Table: 20 Soundness of OPC with 5% of AS and different replacements of SILICA FUME

S.No	Replacement percentages (%)	Initial reading(mm)	Final reading(mm)	Soundness (mm)
1	85%OPC+5%AS+10%SF	8	9	1
2	75%OPC+5%AS+20%SF	8	9.3	1.3

5.7 VARIATION OF COMPRESSIVE STRENGTH OF DIFFERENT REPLACEMENT OF CEMENT WITH AS

5.7.1Variation of Compressive strength (3 days) of different replacements of AS

Table:21 Variation of Compressive strength (3 days) of different replacementsof AS

S.No	Details (3 Days)	Compressive strength (N/mm^2)
1	100% OPC + 0% AS	17.1
2	95% OPC + 5% AS	20.44
3	90% OPC + 10% AS	18.44
4	80% OPC +20%AS	15.9

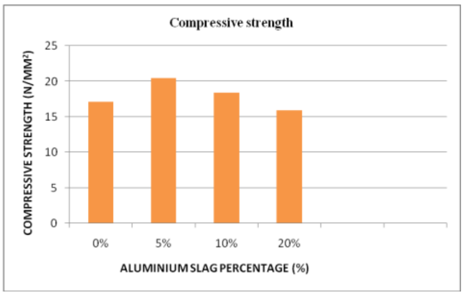

Fig.13. Variation of Compressive strength (3 days) for different replacement of AS

5.7.2 Variation of Compressive strength (14 days) of different replacements of AS

Table:22 Variation of Compressive strength (14 days) of different replacements of AS

S.No	Details (14 days)	Compressive strength (N/mm^2)
1	100% OPC + 0% AS	21.78
2	95% OPC + 5% AS	26.5
3	90% OPC + 10% AS	20.20
4	80% OPC +20% AS	16.76

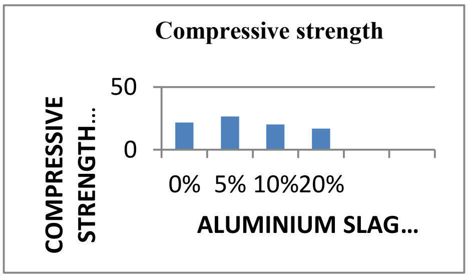

Fig.14. Variation of Compressive strength (14 days) of different replacement of AS

5.7.3Variation of Compressive strength (28 days) of different replacements of AS

Table:23 Variation of compressive strength (28 days) of different replacements of AS

S.No	Details (28 days)	Compressive strength (N/mm^2)
1	100% OPC + 0% AS	30.6
2	95% OPC + 5% AS	32.44
3	90% OPC + 10% AS	20.22
4	80% OPC +20% AS	15.12

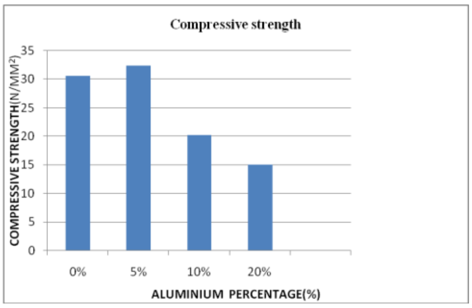

Fig.15. Variation of Compressive strength (28 days) of different replacements

VI. CONCLUSION

The normal consistency tests were performed on concrete.

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1. The normal consistency for replacement of 20% aluminium slag in cement has considerable increase in consistency
2. The normal consistency test shows a very slight decrease in consistency the partial replacement of cement with 10%,20% silica fume and keeping the aluminium slag at constant dosage of 5%
3. The normal consistency for the combination of 20% silica fume and 10% aluminium slag has slight increase in consistency
4. The normal consistency of test shows a very slight increase with partial replacement of cement by 20% fly ash and 5%aluminium slag
5. The normal consistency for combination of 10% aluminium slag and 20% fly ash has slight decrease in consistency

Initial and final setting time test were performed on concrete

1. Initial and final setting time for the combination of aluminium slag and silicafume has retarded and accelerated
2. Initial and final setting time for the combination of aluminium slag and fly ash has also retarded and accelerated
3. The replacement of aluminium slag in cement,it is clearly obsorved that when the percentage of aluminium slag is increase in concrete,the initial serring time increased considerably and the final setting time decrease considerably by increasing the persantage of aluminium slag

Soundness test were performed on concrete

1. The replacement of aluminium slag in cement is increased then the soundness increased considerably
2. The replacement of silica fume in cement increases by keeping the aluminium slag at constant dosage of 5% and 10%respectively then the soundness also increases considerably
3. The replacement of fly ash in cement increases by keeping the aluminium slag at constant dosage of 5% and 10% then the soundness also increases considerably

Compressive Strength and Acid attack tests were performed on concrete

1. Specimens prepared with Aluminium slag 5%,10%,20%and varying Fly Ash and Silica Fume with 10% and 20% . Using the test results , it can be concluded that for Aluminium Slag 5% the strength increased and further there is a rapid decrease with additional increase in Aluminium Slag (i.e. 10%,20%)
2. The compressive strength for combination of 5%AS and 20%FAhas shown considerable increase in strength. All other combinations with Fly Ash has no increase.
3. It is observed that combination of AS 5% and 10%SF the compressive strength increased but further increase in aluminium slag and Silica Fume content compressive strength reduced when compared to control concrete.
4. The compressive strength of cubes after Acid attack for controlled concrete is observed to loose 7.78% of strength and with replacement of AS with 5%,10%,20% , the percentage of strength loss further increase to 17.82,24.73and 25.07 respectively.
5. The combination of 10% AS and 10% FA is observed to have better resistance against Acid attack and the combination of 10% AS and 10% SF is also observed to have better resistance against Acid attack.All other Combinations of FA and SF had relatively lesscompressive strength after Acid attack.

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6. Hence it is recommended to replace AS to improve the Compressive Strength properties and combination of AS with FA and SF can also be employed to achieve more compressive strength.

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2) IS 12269-1987-Specification for OPC 53 grade.
3) IS 10262-1982-Recommended guide line for concrete mix design.
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