Assessment of Flyash Polymer Composite Material

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Abstract - The utilization of industrial waste in the development of sustainable construction and engineering materials has gained significant traction over the past decade. Among such materials, fly ash—a byproduct of coal combustion in thermal power plants—has emerged as a promising candidate for use in polymer composite systems. This study investigates the structural, mechanical, and thermal properties of fly ash reinforced polymer composites, focusing on their potential applications in construction, automotive, and aerospace industries.

Fly ash, primarily composed of silica, alumina, and unburnt carbon, is incorporated into thermoplastic and thermosetting polymer matrices in varying proportions (typically ranging from 5% to 40% by weight). The selection of polymer matrix (e.g., epoxy, polyester, polypropylene) significantly influences the composite behavior. This assessment analyzes the fabrication methods—such as compression molding, injection molding, and hand lay-up—and their influence on composite quality, interfacial bonding, and dispersion uniformity.

Experimental results demonstrate that the addition of fly ash improves the composite's compressive strength, stiffness, and dimensional stability while reducing overall material cost and environmental impact. The improvement in mechanical properties is attributed to the fine particle size and pozzolanic nature of fly ash, which promotes better matrix-filler interaction. However, beyond a certain filler threshold, agglomeration and porosity can negatively affect toughness and impact strength.

Thermal analysis reveals enhanced thermal resistance and stability, with increased glass transition temperature and delayed degradation onset. Morphological studies using scanning electron microscopy (SEM) confirm homogeneous dispersion at optimal filler loadings and highlight challenges related to interfacial voids and particle pull-out at higher concentrations.

The study concludes that fly ash polymer composites are a viable, eco-friendly alternative to conventional synthetic composites. Their performance can be further optimized through surface treatment of fly ash, compatibilizers, or hybridization with natural fibers. As a low-cost, sustainable solution, these materials hold promise for structural and semi-structural applications where moderate strength, durability, and thermal performance are required.

Keywords: Fly ash; Polymer composites; Waste utilization; Mechanical properties; Thermal stability; Sustainability; SEM analysis; Epoxy resin; Composite materials; Environmental impact.

1. INTRODUCTION:

1.1 Introduction

With the growing emphasis on sustainability and waste management, industrial by-products like flyash are being increasingly explored as reinforcement materials in composites. Flyash polymer composites merge the structural and thermal advantages of flyash with the versatility and durability of polymers. This integration not only reduces environmental impact but also results in materials suitable for diverse applications in construction, automotive, and

consumer industries. This report explores the development and performance of flyash-based composites using cold setting resins as a binder.

Composite materials are engineered materials made from two or more constituent materials with significantly different physical or chemical properties. When combined, they produce a material with characteristics different from the individual components. Typically, one is a matrix (such as a polymer, metal, or ceramic) and the other is a reinforcing agent (like fibers, particles, or flakes). This combination allows the resulting composite to achieve enhanced mechanical, thermal, or chemical performance not obtainable by the constituents alone.

Over the past few decades, polymer matrix composites (PMCs) have gained prominence due to their light weight, corrosion resistance, and ease of fabrication. However, traditional reinforcing materials like glass fibers, carbon fibers, and synthetic fillers are often expensive and energy-intensive to produce. As industries seek sustainable and cost-effective alternatives, interest has grown in utilizing industrial by-products and natural fillers for reinforcement. One such material is fly ash, a waste product from coal combustion.

Fly ash is a fine particulate residue resulting from the combustion of pulverized coal in thermal power plants. It is primarily composed of aluminosilicate spheres, including oxides of silicon (SiO_2), aluminum (Al_2O_3), iron (Fe_2O_3), and calcium (CaO). Annually, millions of tons of fly ash are generated worldwide, and only a fraction is reused—mainly in cement and concrete industries. The remainder is often disposed of in landfills or ash ponds, creating serious environmental challenges such as groundwater contamination and land degradation.

Fly ash's microspherical shape, pozzolanic activity, and thermal stability make it a promising candidate as a filler in polymer composites. By incorporating fly ash into polymers, not only can the mechanical properties of the material be enhanced, but a value-added utilization of an industrial waste product can also be achieved. This makes fly ash polymer composites a sustainable option in materials engineering.

The motivation behind developing fly ash polymer composites lies in addressing two primary concerns: the rising cost of composite materials and the need for sustainable waste management. Fly ash is an abundant, low-cost material with beneficial properties such as hardness, thermal stability, and good compatibility with many types of polymers. Its utilization in polymer matrices serves multiple advantages:

- **Economic Benefits**: Fly ash is significantly less expensive than traditional fillers like glass fibers or carbon black. Using it can reduce the overall cost of composite production.
- **Environmental Sustainability**: Reusing fly ash helps reduce landfill burden, curbs air and soil pollution, and supports the circular economy model.
- **Performance Enhancement**: Properly processed fly ash can improve stiffness, dimensional stability, thermal resistance, and durability of the composite.

1.2 Flyash: An Overview

Fly ash is typically classified into two main categories based on the type of coal burned:

- **Class F Fly Ash**: Produced from the combustion of bituminous or anthracite coal. It contains lower calcium content and is rich in siliceous and aluminous materials. It is primarily pozzolanic in nature.
- **Class C Fly Ash**: Derived from sub-bituminous or lignite coal, it has higher calcium content and exhibits both pozzolanic and cementitious properties.

The choice of fly ash type influences its interaction with different polymer matrices. Thermoplastics such as polypropylene (PP), polyethylene (PE), and polyvinyl chloride (PVC), as well as thermosets like epoxy and unsaturated

polyester resins, have been successfully reinforced with fly ash in various studies. Surface treatments of fly ash (e.g., silane coupling agents) are often used to improve interfacial bonding with the polymer matrix and enhance dispersion.

1.3 Flyash Bricks

Flyash bricks are a widely recognized application of flyash in the construction industry. Made by mixing flyash with lime, gypsum, and sand, these bricks are cured under pressure and at room temperature. Their benefits include:

- High strength and uniformity.
- Reduced water absorption and improved durability.
- Environmentally friendly production process.

While flyash bricks represent a mechanical blend and compaction of materials, the flyash polymer composite explored in this work represents a more chemically and thermally bonded system, expanding the utility of flyash in novel material domains.

1.4 Cold Setting Resin: An Overview

Cold setting resins are polymeric materials that cure or harden at ambient temperatures without the need for external heating. Common types include epoxy, polyester, and phenolic resins. They are particularly useful in field applications, repairs, and low-energy processing environments.

Key features:

- Cure at room temperature.
- Provide excellent adhesion, chemical resistance, and mechanical strength.
- Suitable for embedding or bonding with inorganic fillers like flyash.

In the present work, cold setting resin serves as the binding matrix for the composite, allowing room-temperature fabrication and setting, which simplifies processing and reduces energy consumption.

1.5 Objective of Present Work

The primary objectives of this study are:

- To develop a composite material using flyash as the filler and a cold setting resin as the matrix.
- To evaluate the physical, mechanical, and thermal properties of the flyash polymer composite.
- To investigate the effect of varying flyash content on the performance of the composite.
- To explore the potential of this material as a sustainable alternative for construction and industrial applications.

The assessment of fly ash polymer composite materials involves evaluating the physical, mechanical, thermal, and chemical properties of the composite under various conditions. Key parameters of interest include:

- Mechanical strength: Tensile, flexural, and impact strength to evaluate load-bearing capacity.
- Thermal behavior: Thermal stability, conductivity, and degradation temperature.
- Morphological structure: Microstructure analysis through SEM (Scanning Electron Microscopy) and XRD (X-ray Diffraction) to understand dispersion and bonding.

- Water and chemical resistance: To assess durability in hostile environments.

2. Literature Reviews:

a. **Sridharan etal.,** studies the micrographs of FA particles through SEM. These particles are mostly solid spheres with glassy appearance, hollow spheres with smooth-edged porous grains, asymmetrical agglomerates and irregular absorbent scraps of unburnt carbon. Presence of iron particles which are dark grey in color can be identified as pointed grains.

a. According to **Mohini Saxena and P.A sokan** a lot of multi disciplinary tests on coal ash have been conducted at various lab centers. Regional Research laboratory, Bhopal has worked a lot on FA and enhanced the various methodologies for pilot scalede monstration. They cultivated Crops, vegetables and cereals and reported that the yield increases greater than before by FA utilization with no toxicity. They also developed paints using FA and epoxy systems for safety and embellishment. These FA paints has improved resistance to rust, abrasion and wear.

b. **Mitchell and Brown** said that the soil, FA and lime displays unique behavior and are much more dependent on the physico chemical properties of the flyash and soil like porosity, segregation, lime content , time and pressure applied during compaction.

c. **Sevelius et al.,** studied the utilization of Fly ash and Bottom ash in bricks manufacture and in refractoryproducts. He also studied that there is a remarkable increase in the consumption of FA as a basic raw material.

d. **Mathur and cow orkers** focused on the influence of heavy weight metal present in FA on various species of plant like Ipomeas carnea, Typha Angustata and calotropis procera.

e. **Martin etal.** Stated that FA in wet but unsaturated state displays cohesive properties which are due to the tensile stress developed by the capillary action of water. Since this property limits the long term solidity of the compacts. He concluded that for improving the mechanical strength angle of shearing is more important.

f. **Indraratna et al.** showed a comparison between the intercept of cohesion and angle of shearing resistance of dry and wetfly ash specimens .He reported that there is 100% loss of cohesion mainlyto dry specimen with no change in resistant shearing angle.

g. **Gray and Lin** studied the difference in specific gravities of the Fly ash and displayed that the differences are due to the particle shape (sphere, plerospheres, etc.), and chemical configuration.

h. **Rajasekhar** specified that fly ash particles are mostly amorphous (glassy) with spherical shape. The low specific gravity is due to the existence of large number of small hollow spheres enclosed in big spheres (plerospheres). Reason behind that the trapped air can not be detached from hollow spheres or due to the difference in configuration of these particles.

3. METHODOLOGY:

Experimental work and methodology

3.1 Introduction

Fly ash has been used in various architectural and industrial applications on large scale. Hence Consumption of this huge amount of fly ash greatly reduces the difficulties met by coal based TPPs for its dumping. Analysis on the performance of FA at various statesis essentially required before its usage. So to understand the characteristics features of FA, experiments cannot be performed on field domain. There is no any alternate option except research laboratory test to assess its importance. The research conducted in laboratory provides a calculative approach to govern several parameters that come across during practice.

Brief description of the types of material used, sample preparation and its characterization through SEM, XRD, and FTIR, Mechanical and surface properties like Compressive strength, Hardness and wear resistance, Thermal conductivity measurement and others are outlined in this section.

3.2 MATERIALS USED

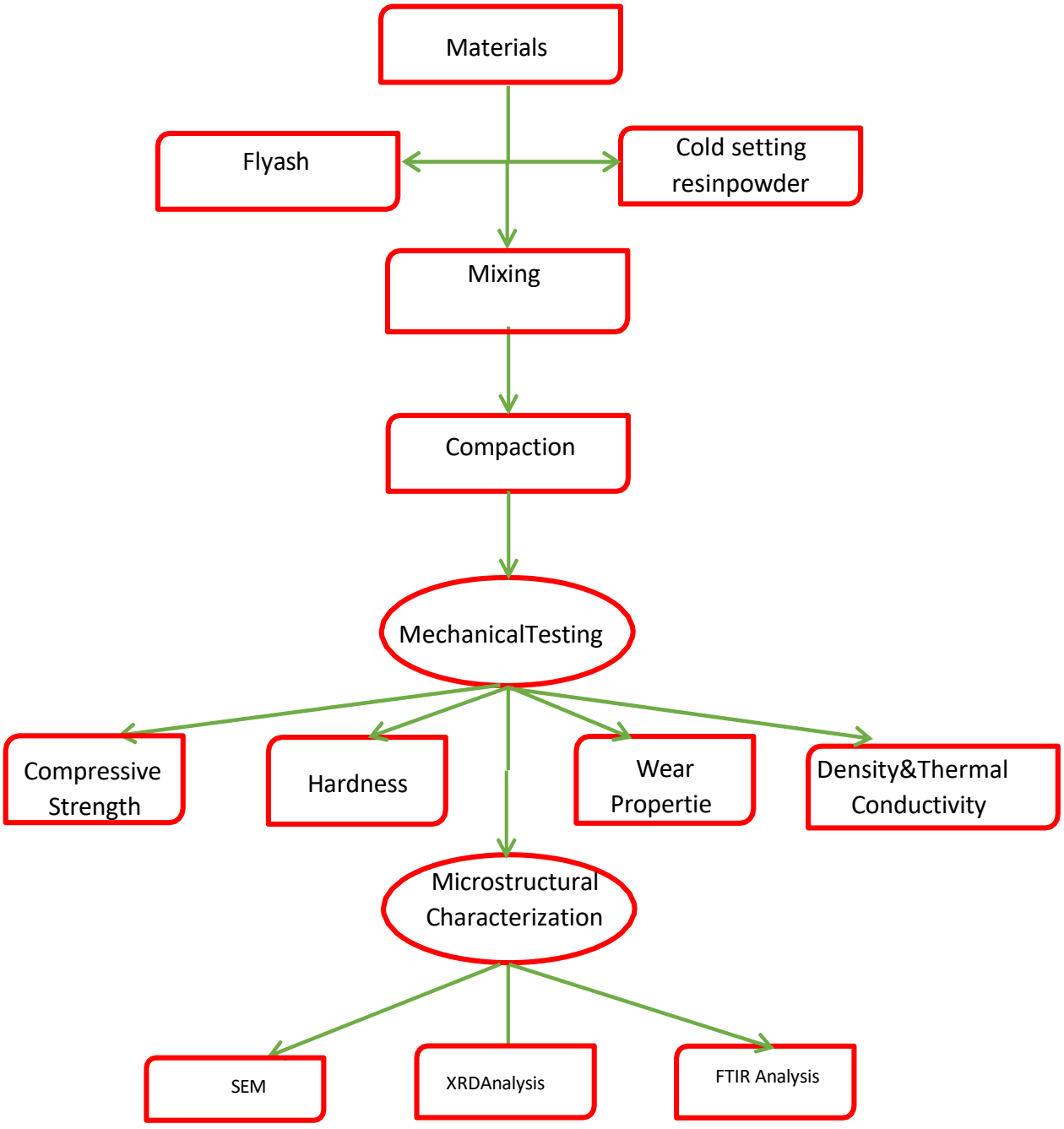
3.2.1 Fly ash

The Flyash used in this project was collected from electrostatic precipitators of the captive power plant (CPP-II) in dry condition. The fine powders were oven dried at 110ºC-160ºC and kept in air tight bottle for later use.

3.2.2 Cold setting Resin and Binder

The resin powder and hardener used in the present study was supplied by Geosyn private Ltd. Kolkata.

Flow chart of experimental procedure



3.3 Experimental Methods

3.3.1 Preparation of Samples: The samples were prepared by Powder metallurgy route.

3.3.1.1 Mixing

Three different weight percentages of Fly ash and resin powder with (75%, 80% and 85%) and (25%, 20% and 15%) were taken respectively. These compositions were mixed thoroughly by a mechanical vibrator (Abrasion Tester Model PEI-300), to get a homogenous mixture. Different compositions of Fly ash along with resin powder were kept in three different small size bottles. Around 6-10 small steels balls are kept inside for proper mixing. Mixing was done till the vibrator shows 1000 revolutions which almost took five hours.

3.3.1.2 Compaction

The compaction experiments were executed to make cylindrical FA compacts. Cylindrical die and punch having 15 mm diameter made of stainless steel was used to make cylindrical Fly ash compacts. Mixture of approximately 5 gm. Was taken for each composition. Then the punch & die was cleaned with cotton followed by acetone so that all the dustis removed from the inside surface of the die and outside surface of the punch. Then greasing was done to avoid sticking. The mixture prepared earlier was poured inside carefully. During the packing slight shaking was done to accommodate the maximum possible amount of material. Finally the whole system was subjected to hydraulic seal valve made tight, mounting was done co axially. Maximum of 6 tons of load was applied on it very slowly. Once the maximum load was achieved, the apparatus was powered off. The whole system was relaxed for 5 minutes which then followed by unloading. Compact was ejected from the Die in the same direction as the compression and was kept in normal atmosphere for 1 day. The cold setting liquid (hardener) was applied on the surface of the compacted samples with the help of a dropper, so as to harden the newly made compacts. The amount of Hardener used was $1/6^{th}$ or $1/4^{th}$ of the mixture. Hence in this way twelve samples for each composition were made. All the samples were dried in open atmosphere for 2 days.

3.3.2 Water treatment

Three samples from each composition were cured in water at 110^{o}C -180^{o}C for 48 hours.

3.4 Determination of Mechanical properties

3.4.1 Hardness

Vickers hardness tester (LECO,LM248AT)as shown in Figure 3.1, was used to find the hardness values of all the dry and wet samples using 20 gf Load for a dwell time of 15 seconds. At least eight measurements were taken at different position for each sample in order to get constant results.

Fig.3.1- Leco, LM248 AT Micro indentation Hardness Tester

3.4 .2 Compressive Strength

In order to measure the compressive strength of dry and wet samples INSTRON 1196. Prior to test, gauge length and gauge diameter of the dry and wet specimens were measured individually by the aid of Vernier caliper . The tests were carried out at room temperature (300 K) with a constant cross head speed of 1mm/min and the full scale range load of 50kN. This computer integrated machine gives the Load vs displacement signals directly when the specimens were subjected to tests.

3.4.3 Wear resistance and Friction

In this study computerized Ball on Plate Wear Tester (TR-208-M1) as shown in Figure -3.2 was used to evaluate the wear performance and sliding contact resistance of the Fly ash compacts. The experiment was carried out with the help of 4mm diamond indenter keeping the different track radius of 4 and 8 mm respectively. Prior to wear, constant normal load of 10 and 20N was applied. The indenter rotates on flyash compact with a constant speed of 20 rpm for different time period of 600s. At the end of each test, loss in weight of the samples was noted. Results obtained have been expressed in terms of wear depth, and friction co-efficient.

Fig. 3.2- Ball-On-Plate Wear Tester (TR- 208M1)

3.4.4 Thermal conductivity

To measure the thermal conductivity of Fly ash and resin powder mixture, KD2 Pro analyzer as shown in figure 3.3 was used and it follows ASTM Standard D5334-08 [28]. It comprises of a hand held controller and a various sensors that operator can embed into very nearly any material. Single probe of 6cm long and 0.127mm diameter was inserted in a small plastic bottle filled with FA & resin powder to find the conductivity value. Atleast ten values of each composition was recorded to get the appropriate result. KD2 Pro uses the transient line heat source mechanism to evaluate the conductivity and diffusivity of the given mixture. A restrictive calculation fits time and temperature information with exponential functions via nonlinear least squares technique.

Fig. 3.3 KD2 Pro analyzer

3.4.5 Water Absorption

The cylindrical compacts were tested for water absorption according to ASTM C642. The weights of all the samples were taken. The compacts were first dried in an oven at 100^0C-120^0C ensuring removal of moisture and hence allowed it to cool at room temperature. The weights were taken after drying and the variation in weight was less than 5%, considered it as dry. Now the compacts of different composition was immersed in a beaker filled with water and was kept in an oven at 110^0C-180^0C for 48 hours. Compacts were surface dried after removal and final weight was measured. The amount of water absorbed (%) was calculated using equation-1.

M_1 and M2 are the mass of dry and wet sample respectively.

$$\frac{M2-M1}{M1} * 100 \text{ ---------- } (1)$$

Where;

M_1 and M2 are the mass of dry and wet sample respectively.

3.4.6 Density

On the basis of Water absorption test, the density of dry and wet compacts was calculated.

3.5 Micro structural Characterization

3.5.1 SEM Study In present study, A JEOL 6480 LV Scanning Electron Microscope (Fig. 3.4) was used for the characterization of micro structural changes (pits, cavities, and porosity), determination of particle size and morphology of FA compacts. To get the better image resolution, secondary electron imaging with accelerating voltage of 15 KV was used.

Fig. 3.4 Scanning Electron Microscopy (JEOLJSM- 6480LV)

3.5.2 XRD Study

The mineralogical composition of Flyash and the different phases present was determined by XRD analysis in a Philips X-pert multipurpose x-ray diffractometer (shown in figure.3.5) using CuK α (λ =1.5418A^{o}) radiation. The patterns were examined by comparing the positions of peak and intensities of the samples with those in the (JCPDS) data files. The diffraction patterns were recorded in the scanning range of 20^{0}-80^{o} with a step size of 2^{0}C per minute.

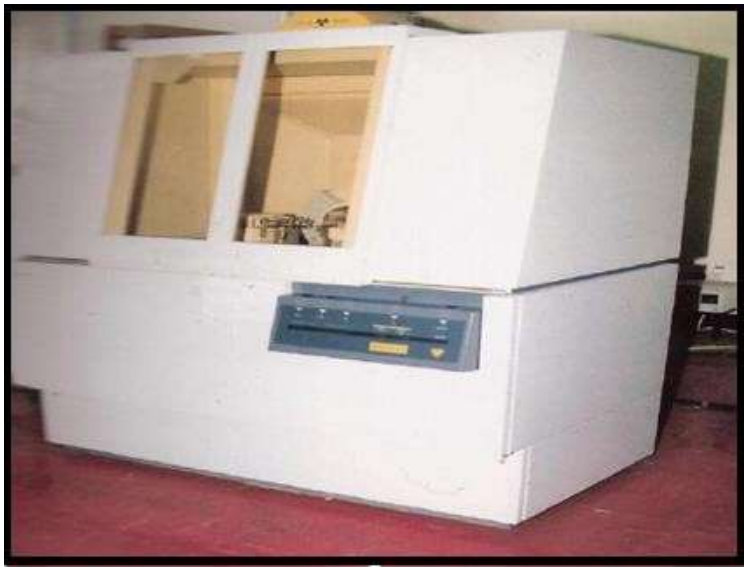


Fig. 3.5 Philips X-pert multipurpose x-ray diffractometer

3.5. 3 FTIR Study

FTIR spectroscopic technique is used to understand the chemistry of surface for fly ash in thermally active state along with different state of mineral phases, H_2O and –OH group on silica and alumina. Fourier transforms infrared radiation (FITR) spectrometer (shown in figure.3.8) is used to calculate the transmission percentage of infrared. In order to prepare pellet little quantity of potassium bromide (KBr) was segregated with powder sample and after that pressing of mixture was done. Analysis of that pellet was done using FITR by keeping the pellet in sample holder.

Fig. 3.6 Perkin-Elmer Spectrum RXI, (FTIR) Spectrometer

4. Results

4.1 Composition of Flyash

FA mainly consists Silica (Sio2), Alumina (Al2o3), Calcium Oxide (CaO), and Iron Oxide (Fe2O3). The chemical composition of Fly ash is tabulated in table 4.1.

Table 4.1Compositional analysis of Fly ash

Compounds	SiO_2	Al_2O_3	CaO	Mgo	P_2O_5	Fe2o3	SO_3	K_2O	LOI
Composition (%)	54.5	26.5	2.1	0.57	0.6	-	-	-	14.18

4.2 Water Absorption Test

Table 4.2 shows the amount of water absorbed corresponding to different FA composition. The water absorption values of FA composites lies in the range of 15.55 % to 19.09%. It can be seen that all the composition met the absorption criteria set by several developing countries. India permits the maximum of 20 % water absorption when compacts are immersed for 24 hours.

Table 4.2 Percentage (%) water absorbed by various FA polymer compacts

Mix Composition (Wt. %)	Weight (gm)		Water Absorption (%)	Average Water AbsorptionValue (%)
	Dry	Wet		
(FA)75%+(RP)25%	4.579	5.302	15.78	15.55
	4.630	5.340	15.33	
(FA)80%+(RP)20%	4.452	5.151	15.70	16.61
	4.642	5.456	17.53	
(FA)85%+(RP)15%	4.502	5.356	18.96	19.09
	4.329	5.162	19.23	

Fig. 4.1 shows a relation between the amount of water absorbed and density of dry composite with respect to FA composition. It is evident from the graph that the water absorption increases with increase in FA content. 85 wt. % FA absorbs water to a maximum of 19.09%. This indicates that that most of the openings of the compacts are open to outside.

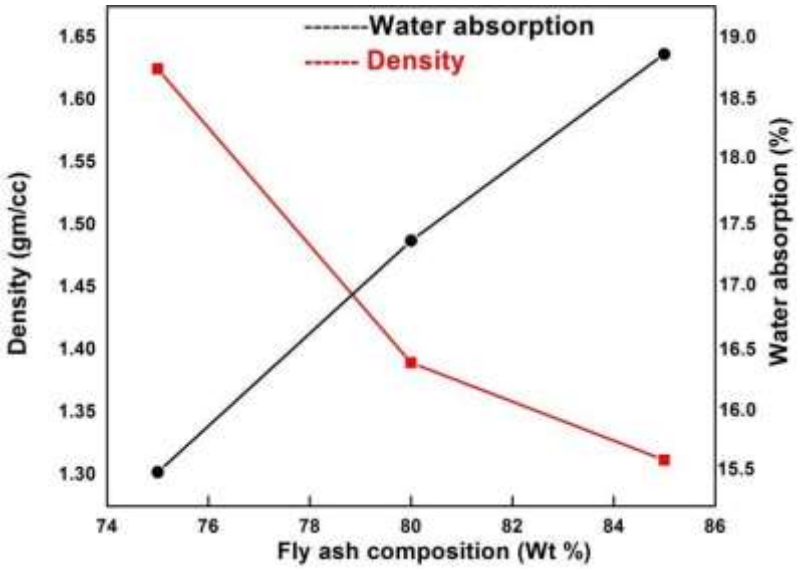


Figure. 4.1 Water absorption and density as a function of FA Composition

4.3 Density Measurement

Density of the samples was calculated before and after treatment. From Fig. 4.2 we can say that density of dry compacts decreases with increase in weight percentage of FA. As the dry compacts are immersed in water at 110^0C -180^0C, then through capillary action voids are filled and it becomes hard and the porosity is eliminated. As a result of which the compacts become dense and finally the density increases with increase in FA content.

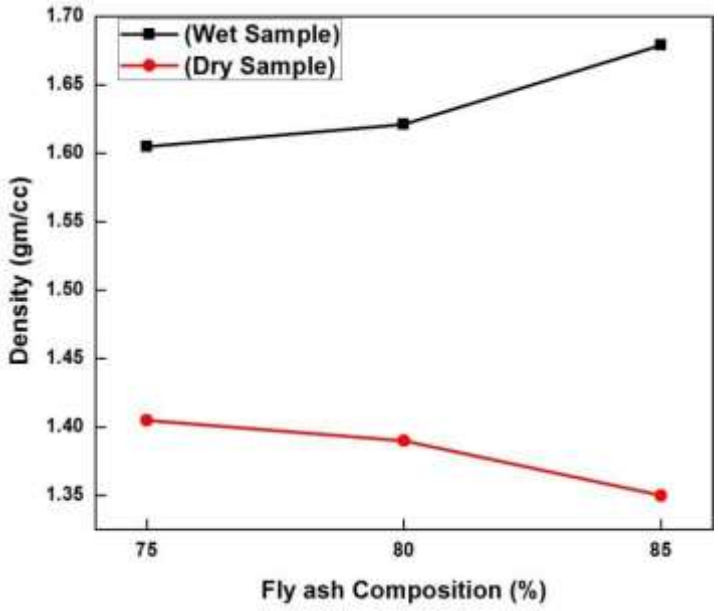


Fig. 4.2 Variation in dry and wet density w.r.t FA composition

Table 4.3 Density value of dry and wet FA polymer compacts

Mix Composition (Wt. %)	Density (g/cm^3)	
	Dry	Wet
(FA)75%+ (RP)25%	1.40	1.60
(FA)80%+ (RP)20%	1.38	1.62
(FA)85%+ (RP)15%	1.35	1.67

4.4 Hardness Measurement

Hardness values of all the Fly ash polymer composite of different compositions, both in dry and wet state, were measured bythe help of LECO, LM 248AT Vickers hardness tester. The Hardness values as obtained are shown in Table 4.4. The values of hardness are in the range of 32.93 HV – 44.08 HV for dry composites and 39.78 HV – 47.37 HV for wet FA composites respectively.

Table 4.4 Hardness values of various FA resin mix compacts

S.NO	Mix Composition (Wt. %)	Micro hardness value (HV)	
		Dry	Wet
1	(FA)75%+(RP)25%	32.93	39.78
2	(FA)80%+(RP)20%	38.26	43.04
3	(FA)85%+(RP)15%	44.08	47.37

Fig. 4.3 shows a comparison between the hardness values of dry and wet flyash composites. It is evident from figure that as we go on increasing the wt. % of FA, i.e., resin content decreases the hardness values of both the wet and dry compacts increases. Maximum hardness values in case of 85 wt. % FA is achieved.

It is evident from the XRD analysis as shown in fig. 4.4(b) of water treated 85 wt. % FA compact that a Calcium Silicate Hydrate (C-S-H) and Calcium Aluminate Silicate Hydrate (C-A-S-H) phase appears which are responsible for the hardness improvement. Both these phases are formed by the reaction of $Ca(OH)_2$, Sio_2 and H_2O when treated in water at 110^0 C-180^0 C.

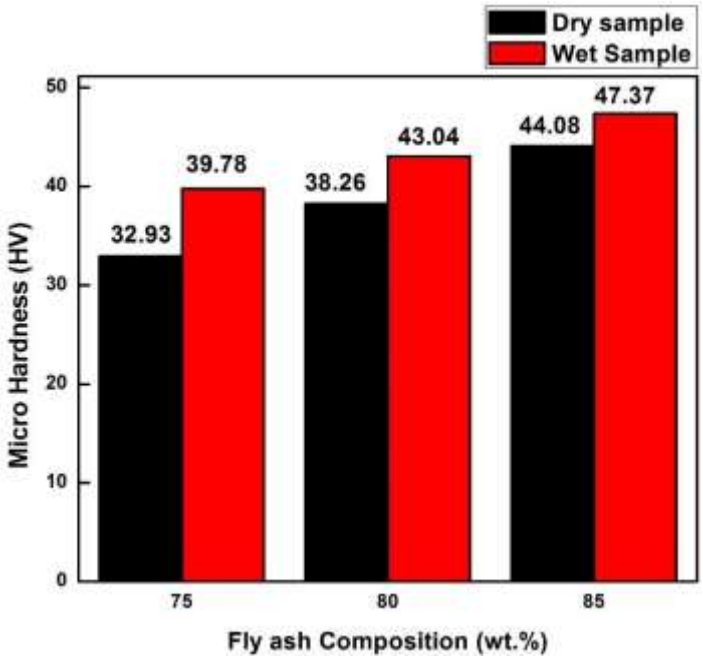
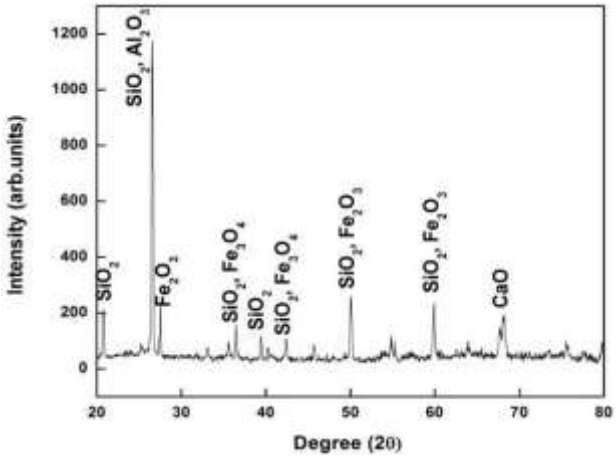


Fig. 4.3 Variation in hardness values with wt. % of FA

4.5 XRD Analysis



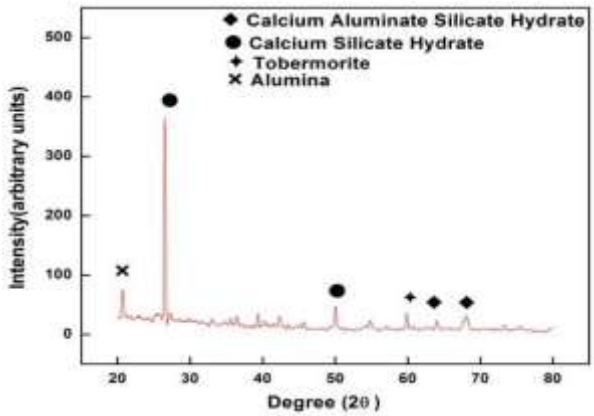


Fig. 4.4(a) XRD analysis of Flyash and Fig. 4.4(b) XRD analysis of water cured compact

Fig. 4.4(a) shows that Flyash particles primarily consists of Silica and Alumina. Fig 4.4(b) Shows the XRD analysis of water treated compacts. It has been found that in the presence of moisture, pozzolanic reaction occurs that leads to the formation of new phase i.e. calcium silicate hydrate (CSH) and calcium aluminate silicate hydrate (CASH) . These phases are responsible for solidification of unfired compacts and hence creating strong structures, excellent inter particle bonding with improved mechanical properties like hardness etc. CSH and CASH are considered to be an initial reaction product which changes in to a semi crystalline solid phase called Tobermorite ($C_5S_6H_5$).

4.6 FTIR Analysis

Fig: 4.5 shows the Fourier transforms infrared radiation (FTIR) spectrometer plot of 100 % FA along with 80% FA + 20 % RP mix . It can be seen that for 80 % FA mix the (%) transmittance is getting decreased with respect to 100% FA . With comparison of FTIR spectrum phase transformation of FA and FA mix can be recognized. The most characteristic difference between theFTIR spectrums ofthesetwo is the shifting ofband attributed to the asymmetric vibrations of Si-O-Si and Al-O-Si. The broad ness in band appeared to be around 1250 cm-1 in the FTIR spectrum, which became sharper as compared to FA mix. . Then after these bands starts shifting towards low frequencies at around (950 cm-1) indicating the formation of a gel like phase named alumino silicate which is connected with the suspension of flyash in the strong alkaline activating solutions. Stretching vibration of Si-O-Al appeared at around 600 cm-1. The wide band groups showed up in both IR spectra in the area of 3500 cm-1 are assigned to stretching (-OH) and bending (H-O-H) vibrations of bound water atoms, which are surface consumed or entangled in the huge depressions of the polymeric skeleton [30, 31]. This broadness indicates the presence of strong hydrogen bonding [32].

As a conclusion, water content is a crucial synthesis parameter that affects their mechanical strength. Peaks appeared around 2400 cm-1 attributed to O-H stretching. The gradual decrement in the intensity and broadness in the band confirms the loss of water. Peak at 3000 cm^{-1} – 2000 cm^{-1} could be assigned to C-H stretching vibration of organic contaminants which may be introduced during sample handling or some hydro carbon present in fly ash [33].

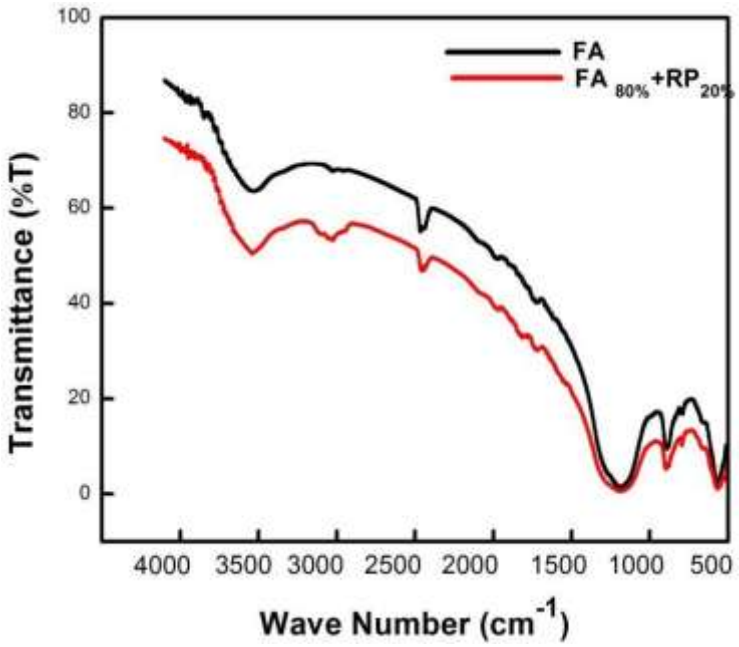


Fig .4.5 IR spectra of the FA and FA resin Powder mix

5. CONCLUSIONS:

On the basis of present study following conclusion can be drawn:

1) Water treated compacts shows positive effects on the hardness values. Out of all dry compacts, FA with 85 wt. % possesses a higher hardness value of 44.08 HV. Much improvement in the hardness value is achieved when the composites are treated in water at 110^0- 180^0C and this value rose to 47.37 HV. This increment in hardness value is due to the presence of CSH and CASH in the presence of moisture as obtained from XRD analysis.

2) With an increase in polymer addition (resin powder), the compressive strength of dry compacts decreases to a lower value of 6.5MPa. Composition of 75 wt.% FA shows lower value. No significant reduction in Compressive strength is achieved in the case of wet compact.

3) Wear study of different composites can easily be correlated with the hardness value. In both the dry and wet state, FA with 85 wt. % composition shows better resistance to wear than other two compositions. Wear resistance increases with increase in FA content. The co-efficient of friction decreases with increase in FA percentage and follows a linear trend throughout the time of testing.

4) Thermal conductivity of FA increases with increase in temperature, whereas in case of resin powder FA mixes, the conductivity of composite decreases with increase in temperature. A much lower conductivity value is obtained and hence can be used as a substitute material with respect to clay.

5) Water absorption increases with increase in FA content. Maximum of 19% water is absorbed in case of 85 wt. % FA.

6) Density of dry compacts decreases with increase in FA content. While in case of wet compacts, it increases with increase in FA content.

7) SEM analysis revealed the morphology of FA particles that are mostly spherical in shape. With decrease in polymer addition i.e. increase in FA content the interface bonding becomes better and less amount of cracks were found at the interfaces.

8) XRD analysis revealed that FA particles mostly consist of Silica and alumina with less percentage of Fe2O3, Cao and others.

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