CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

India is a vast country and it holds 7th position in the area among other counties and holds second position in terms of most populated countries in the world. India is also the world's largest democracy but is still in counting of developing countries. There are many factors that determine the parameter to get upgraded to developed countries. One of the most important aspects to come in the list of developed countries is the fulfilment of its energy demand. In terms of energy, India is not in a very good position when compared to other developed countries that are using all possible ways to meet their energy demands. India is somewhere lagging. India is not only poor in terms of technology but also in the utilisation of resources available.[1]

To meet the power requirements of today's India, we need to install power plants. The instalment of power plants need resources and technologies. At present, the 78% of the total energy produced in India is heat based, it means that with the application of heat leads to the rotation of the turbines which further gives energy. Out of this amount 68% is coal based power plants and it works on the burning of coal.

In order to meet the today's energy crisis[2] we need to find out ways by which efficient and proper utilization of each component to be done without affecting our environment as the percentage of coal based power plants are so high and nearly all the thermal power plants in India are coal based and also India has great coal reserves in various states such as Chhattisgarh and Jharkhand. But the real problem to deal with these power plants is that they are not much eco friendly and generates waste which is harmful for our environment and surroundings. The waste product which is generated in the coal based power plants are the ashes which is left after the burning process and stays as residue in the plant. If these residues can be utilized in an effective manner, this will help the environment.

This ash which is produced in these thermal power plants is totally a waste and it is disposed in the environment and hence gets completely wasted.[3] We can use this ash in a much more affecting manner than disposing it. Various use of this ash can be developed like in recent studies it has efficiently been used as a substitute of clay in brick formation and other building applications. We can experiment with it by mixing polymer in it at various concentration and then check various properties like compressive strength, tensile strength and see how we can utilize these in various applications of daily use instead of getting it wasted in environment. The work in this project report is a step towards this.

1.2 PROPERTIES OF WASTE COAL ASH

The ash generated in the thermal power plants is termed as "coal ash". It is formed by the combustion of coal inside the thermal power plant. Coal ash, 80% of which is very fine in nature and is thus known as fly ash is collected by electrostatic precipitators in stacks. The coal that is burned inside the boiler produces this residue of ash which has unique structure and functions. It contains basically the oxides of aluminium and silicon in it. It can be used in various applications of civil and mechanical engineering because silica provides strength and durability to the structure and hence can be used for a purpose.[4-13] Also, it is different from other types of ashes that is available like the normal ash produced after the burning of wood and the ash which is generated after the volcanic eruption. In some properties, they are alike but structure wise they are apart. The method of generation and sources are different and hence their structure and method of applications are also different.

The ash which is generated in the thermal power plant is spherical in shape. The reason behind this spherical shape is the formation of various bonds when it is subjected to such high temperature among the impurities that was present in this coal ash. The coal ash is glassy in appearance and possesses lightness in weight. Due to this particular property we can use it in various practical applications as the aluminium is used in cars because of its light weight property and like titanium used in aeroplanes which is also used owing to its property of light weight. The coal ash that is generated can be used in certain machineries or applications depending upon its feasibility with the application.[4-13]

Another property which is very unique about the coal ash is its pozzolanic property. Pozzolan is considered as a material which is rich in silicon and aluminium and forms cement like structure when it is exposed in moisture. This property helps the coal ash to be used in various civil engineering applications such as substitute of cement material which may be costly as compared to this coal ash which is just an industrial waste of thermal power plant. The coal ash when mixed with various materials behaves in a different manner depending upon the amount of coal ash used.

Various other advantages of the coal ash over conventional materials are:

1. It is cheaper and readily available.
2. The material need to form the used part of an application is either free of cost or has very low cost as it is an industrial waste.
3. The availability in the cities is easy as all the thermal plants are located in cities
4. No higher cost of installation is required for the formation of these bricks.

Coal ash can be classified in various ways and one of the ways of classifying coal ash is the way the coal ash was produced and the quality of coal that was being used in the thermal power plant. There are certain qualities of coal in which it can be used like the bituminous which is of higher quality and peat and lignite which is basically of lower quality when compared to bituminous and anthracite. India is a country where large coal reserve of lower quality of coal has been found hence the coal ash generated are not of that much of higher quality.

Now there is also another way by which coal ash can be classified like the presence of constituents in it. The coal ash contains lime and hence based on the presence of lime coal ash is classified into various categories:

1. Class F coal ash
2. Class C coal ash

Class F coal ash

This is the type of coal ash which is produced when the presence of lime is less than 7%.

Class C coal ash

This type of coal ash has the presence of lime more than 20%.

Based on these two classes of coal ash the better one is class F which can be used in research applications.

The various physical and chemical properties of coal ash are given below:[14-16]

Particle size variation

The particle size of coal ash varies from 1 micrometer to 100 micrometer

Surface Area Coal ash of Coal Ash

The surface area[5] of Coal ash typically varies between 300 to 400/meter^2.

Density of coal ash

The density of coal ash varies from 540 to 860 kg/meter^3.

Specific gravity of coal ash

The specific gravity of coal ash varies from 2.85 to 2.95.

Uses of Coal ash

Coal ash[17] has various applications in different sectors:

- Large quantity of coal ash can be used in various areas which have very low cost value. Out of many application, the main use is in brick industry apart from that mine filling, making of ridges, surface filling with the recovery of land etc are also the applications where coal ash can be used efficiently. Several efforts were made for the manufacturing of bricks by various methods not only in the presence of lime, but also with different types of resins, gypsum and clay. These products are mixed with coal ash in various proportions and several types of products having different configuration and application is made available in the market. The bricks which are made of coal ash are highlighted because it really saves the topmost layer of the soil.
- Coal Ash is also used as cement stabilizer, with some applications in the light weight filler material for pressurised structures and also in the use of wall slates and roofing tiles, for insulating blocks, in paints and enamels and as herbicide in agricultural science to destroy unwanted vegetation. These all comes under the category of medium cost values.
- Coal ash can be used in the recovery of several types of Magnetic oxides, Aluminum oxides (Al_2O_3), and other trace elements. It can also be used for the synthesis of Zeolites and for the making of inorganic wools. Bleach removal and removal of organic compounds from waste water, adsorbents for cleaning of flue gases (SOx and NOx emissions). It can be grouped as high cost value.

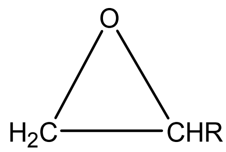
Coal ash utilization in an efficient manner

- It was observed that large quantity of coal ash has been generated in India whose electricity generation is primarily based on thermal power plants.[18] So the coal which gets burned can be utilized for the production of electricity but apart from that there is also waste coal which doesn't take any role in the generation of electricity and forms just shear waste which needs to be disposed properly otherwise it can cause damage to the environment. This waste if used properly can find applications in various industrial sectors. The disposal of this coal ash has been a great issue in a developing country like India
- These coal ash particles which are produced can be found in both dry and wet state depending upon the conditions of handling etc. This coal ash disposal really takes a lot of land for the disposal and also it destroys the fertility of soil. Thereby affecting the productivity of our country.
- In dry condition it is really difficult to handle the coal ash particles since they are very dispersive in nature and destroys the internal structure of the soil.
- It is not eco friendly and creates pollution by various means. i.e air, soil, water etc.

1.3 EPOXY RESIN

An epoxy resin is a thermosetting resin which is made by copolymerization of an epoxide with another compound possessing two hydroxyl groups. Epoxy resins have been used as a binder to provide inner bond between the coal ash particles and to increase the strength of the complex that forms.

The epoxy resins were discovered by Prileschajew in 1909 and are defined as low-molecular-weight pre-polymers possessing more than one epoxide group (**1**).[19,20]



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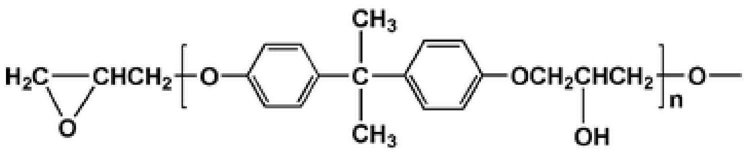
These resins for their better applications are cured using curing reactions with the utilization of a wide variety of curing agents. Their properties depend on the specific combination of the type of epoxy resins and curing agent's used.[21-24] The epoxy resins are being used across a wide range of fields due to their excellent mechanical properties and high adhesiveness to many substrates. They also possess good heat and chemical resistances.[25-27] The epoxy resin has been utilized with coal ash in this report.



Epoxy resin

CHAPTER 2

EXPERIMENTAL SECTION

2.1 MATERIALS USED

Coal ash

The Coal ash that was used in the experimental work that is being done in this project was taken from the electrostatic precipitators of the thermal power plant in dry condition. The fine powdered particles that were used were oven dried at $115^{O}C$-$165^{O}C$ and they were kept in an air tight bottle for further use.

Epoxy Resin and Binder

The epoxy resin, diglycidyl ether of bisphenol A (DGEBA, trade name: CYD-128) used as core materials, was purchased from reputed vendor.

2.2 EXPERIMENTAL METHODS

Preparation of Samples

The samples were prepared with the technique of powder metallurgy.

Intermixing

Three different samples were prepared with the concentrations of coal ash (75%, 80% and 85%) and epoxy resin (25%, 20% and 15%) weight by weight (w/w). These various compositions were then mixed by a suitable vibrator, to get a homogenous mixture of coal ash and epoxy resin. Various concentrations of coal ash along with epoxy resin were kept in different small size bottles.

Water treatment of samples

Different samples from different compositions were cured in water at 115 - 185 ^{o}C for 48 hours.

2.3 DETERMINATION OF VARIOUS MECHANICAL PROPERTIES

Hardness Measurement

Hardness testing machine as shown in figure 1 has been used to find the hardness values of all the samples using 30 gf Load for a dwell time for 20 seconds. Minimal eight measurements were taken at various positions for each sample in order to get desired results.

Figure 1: Hardness Tester machine

Compressive Strength

Compressive strength is defined as the stress that a sample can take before its fracture. To find the compressive strength of all the samples, the machine INSTRON 1196 was used. Before conducting the test, all the readings were taken individually such as gauge length and gauge diameter with the help of vernier calliper. The temperature maintained was 300K i.e the room temperature with a crosshead speed of 2 mm/min and the load of 60 kN. This machine provides the load and displacement curve on the screen which can further be recorded and produced.

Determination of Thermal conductivity

Thermal conductivity is defined as the ability of a material to conduct heat from it. It is also defined as the level of resistance that a particular material offers when heat flows through it. The machine on which it was tested comprises of single handhold controller and variety of sensors that can be used with any material. A probe of 5 cm long and 0.130 mm diameter was inserted in a small plastic bottle filled with coal ash & epoxy resin to determine the value of conductivity. At most 10 values of each composition were taken. These values which are recorded were analyzed further to know its use in various applications in practical working conditions.

The machine working mechanism is a bit different from other machines and also the values recorded are also of very high accuracy and preciseness. The machine simply uses the transient line heat source mechanism to find the thermal conductivity as well as diffusivity of the sample which were put in the testing slot.

Water Absorption

All the samples were tested for water absorption with the test code ASTM C642. First, the weight of all the samples were taken whether they were dry or water treated. The samples were made dry in oven at 110 - 125 ^{O}C. It ensures the removal of moisture from the sample completely and hence further it is allowed to cool at the room temperature. The samples of various compositions were immersed in beakers which are filled with water and were kept in an oven at 120 – 190 ^{O}C for 48 hours. Samples were dried after the removal and then final weight of the samples were measured.

After the calculation of the water absorption test, the density of dry and wet samples were calculated and measured.

Microstructural characterization of the samples

SEM Study

A Scanning Electron Microscope (Figure 2) was used to characterize the changes at micro structural level, calculation of the size of the particle and morphology of coal ash samples. To have resolution of a better image, another imaging of electron with an accelerating voltage of 16 KV was used.

Figure 2: SEM machine

FTIR Study

FTIR is a spectroscopic technique and it is used for the understanding of the chemistry of the surface of the coal ash. Coal ash in a more thermally active state altogether constitutes different phases of minerals, for the investigation of various groups on silica and alumina material. FTIR is classified as Fourier transforms infrared radiation (FITR) spectrometer and it basically is used for the calculation of the transmission percentage of infrared rays.

CHAPTER 3

RESULTS AND DISCUSSION

Compositional analysis of Coal ash

Coal Ash contains SiO_2, Al_2O_3, CaO and oxides of iron (Fe_2O_3)

Compounds	SiO_2	Al_2O_3	CaO	MgO	P_2O_5
Composition (%)	50.495	30.529	4.1287	1.5769	0.6698

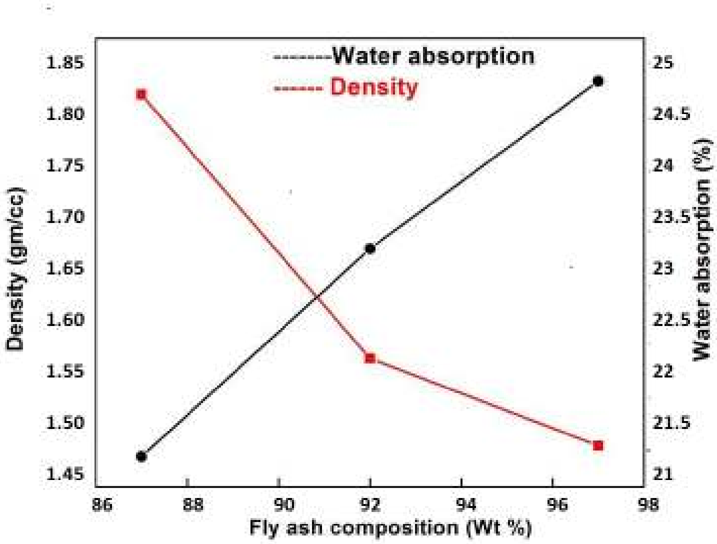
Water absorption Test

Given table shows the quantity of water that was absorbed by the samples that corresponds to various coal ash compositions. The given data of various coal ash composites lies within the range of 15.70 % to 19.23% and hence that can be seen all the composition meets the criteria of absorption having standard values determined by various countries.

Table 1. Percentage (%) of water absorbed by samples

Mix Composition (Wt. %)	Weight (gm)		Water Absorption (%)	Average Water Absorption Value (%)
	Dry sample	Wet sample		
(coal ash) 60%+ (ER) 40%	5.579	6.302	15.78	15.80
	5.630	6.340	15.33	
(coal ash) 65%+ (ER) 35%	5.452	6.151	15.70	17.61
	5.642	6.456	17.53	
(coal ash)70%+ (ER) 30%	5.502	6.356	18.96	18.09
	5.329	6.162	19.23	

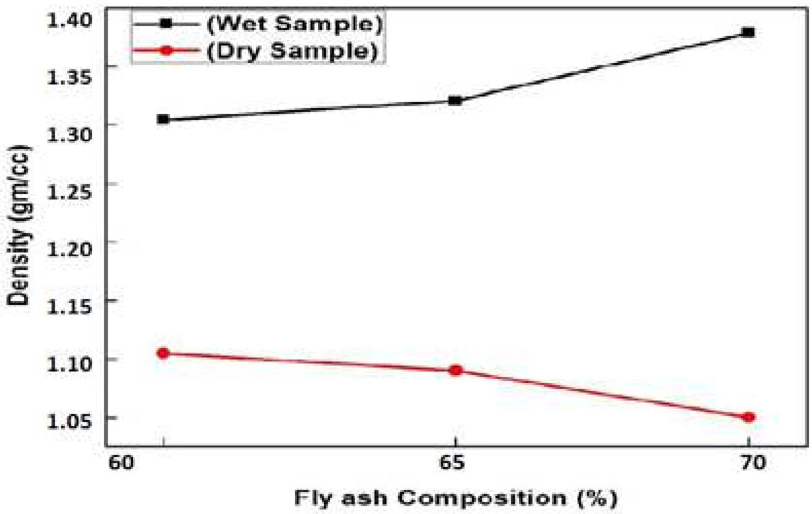
The given graph shows the variation of water absorption capacity of different samples as we can see from the graph the water absorption capability of the samples increased with the increase in the composition of the coal ash content it means it can be used in place of bricks and can absorb water with not much difficulty and we further examine if the water absorption content put any role in the strengthening effect of the sample.



Water absorption and density as a function of coal ash Composition

Density Measurement

Density of a material is defined as the space a material occupies for a given mass in this case of observations the density of all the samples were taken thoroughly after the water absorption test and before the water absorption test and it was concluded from the given graph that has been shown further that with the increase of the fly ash composition the density of dry samples are decreasing but with the increase in the coal ash content the density of the wet samples are increasing this is because of may be the amount of water that resides in the dry sample and occupies some space and hence increasing its density.



Variation in dry and wet density wrt coal ash composition

Table 2. Density values of dry and wet coal ash polymer samples

Mix Composition (Wt. %)	Density (g/cm^3)	
	Dry	Wet
(coal ash)75%+ (ER)25%	1.30	1.05
(coal ash)80%+ (ER)20%	1.33	1.09
(coal ash)85%+ (ER)15%	1.39	1.03

Hardness Measurement

Hardness is defined as the resistant of a material when subjected to an indentation with an object to produce a projection in it. In the present study we have noted down all the values of hardness of the samples that were prepared whether they were dry in condition or water treated.

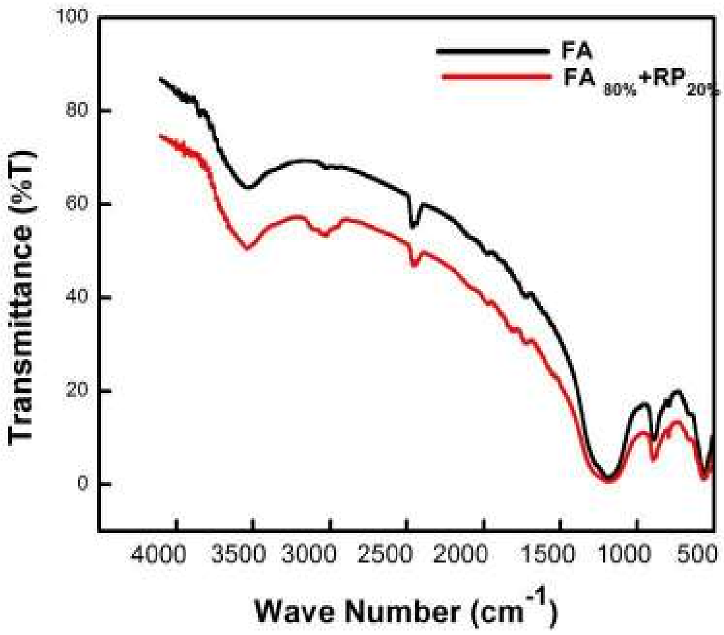
Table 3. Hardness values of different Coal Ash resin samples

S.No.	Mix Composition (Wt. %)	Micro hardness value (HV)	
		Dry	Wet
1	$(COAL\ ASH)_{75\%}+(ER)_{25\%}$	33.93	40.78
2	$(COAL\ ASH)_{80\%}+(ER)_{20\%}$	39.26	44.04
3	$(COAL\ ASH)_{85\%}+(ER)_{15\%}$	45.08	48.37

The conclusion derived after analysing all the values of the samples taken is that as we keep on increasing the weight percentage of the content of coal ash, i.e., by decreasing the resin content the hardness values of all the samples increases to a substantial amount.

FTIR Analysis

The spectra show the FTIR of the coal ash and coal ash – resin (4:1, w/w).



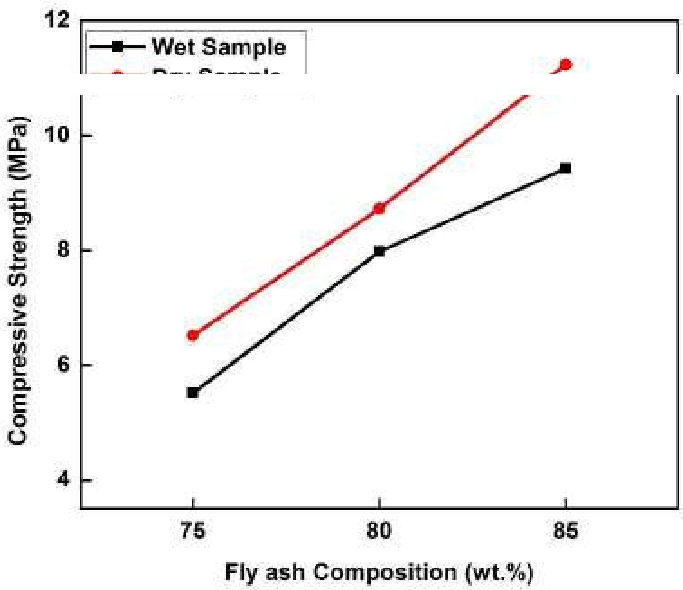
Infrared spectra of the coal ash and coal ash resin Powder mix

Determination of Compressive Strength

Compressive strength is defined as the resistance a material can give while a compressive load is applied upon it

Table 4. Compressive strength values of different coal ash resin mix compacts

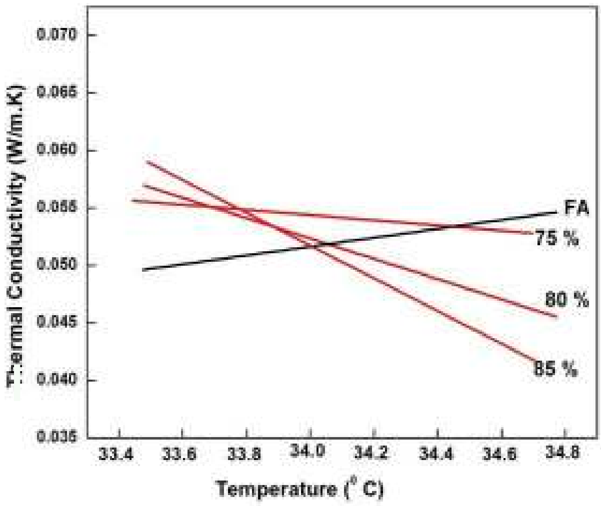
S.No.	Mix Composition (Wt. %)	Compressive Strength (MPa)	
		Dry sample	Wet sample
1	(COAL ASH)75%+ (ER)25%	7.565	6.5258
2	(COAL ASH)80%+ (ER)20%	9.7398	8.9847
3	(COAL ASH)85%+ (ER)15%	12.2845	10.4332



Compressive Strength of samples at different Coal Ash

Thermal Conductivity

Thermal conductivity is defined as the property with reference to which the material shows the resistance to flow of heat through it

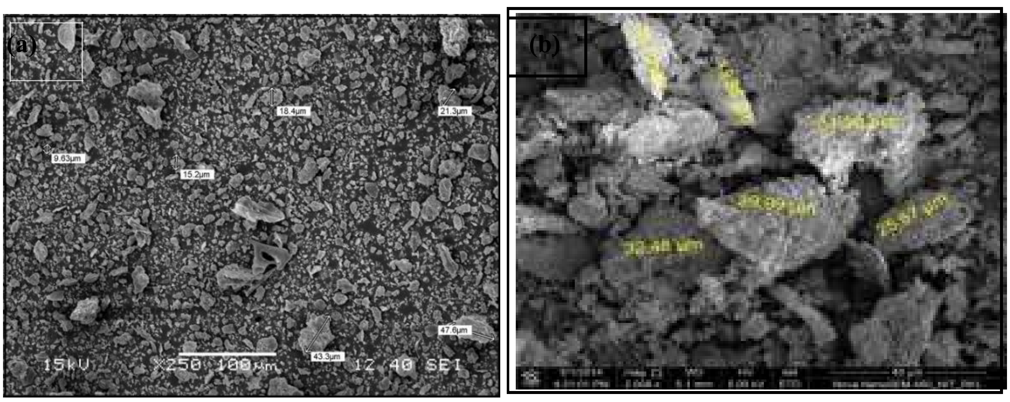


Graph of thermal conductivity at various temperatures

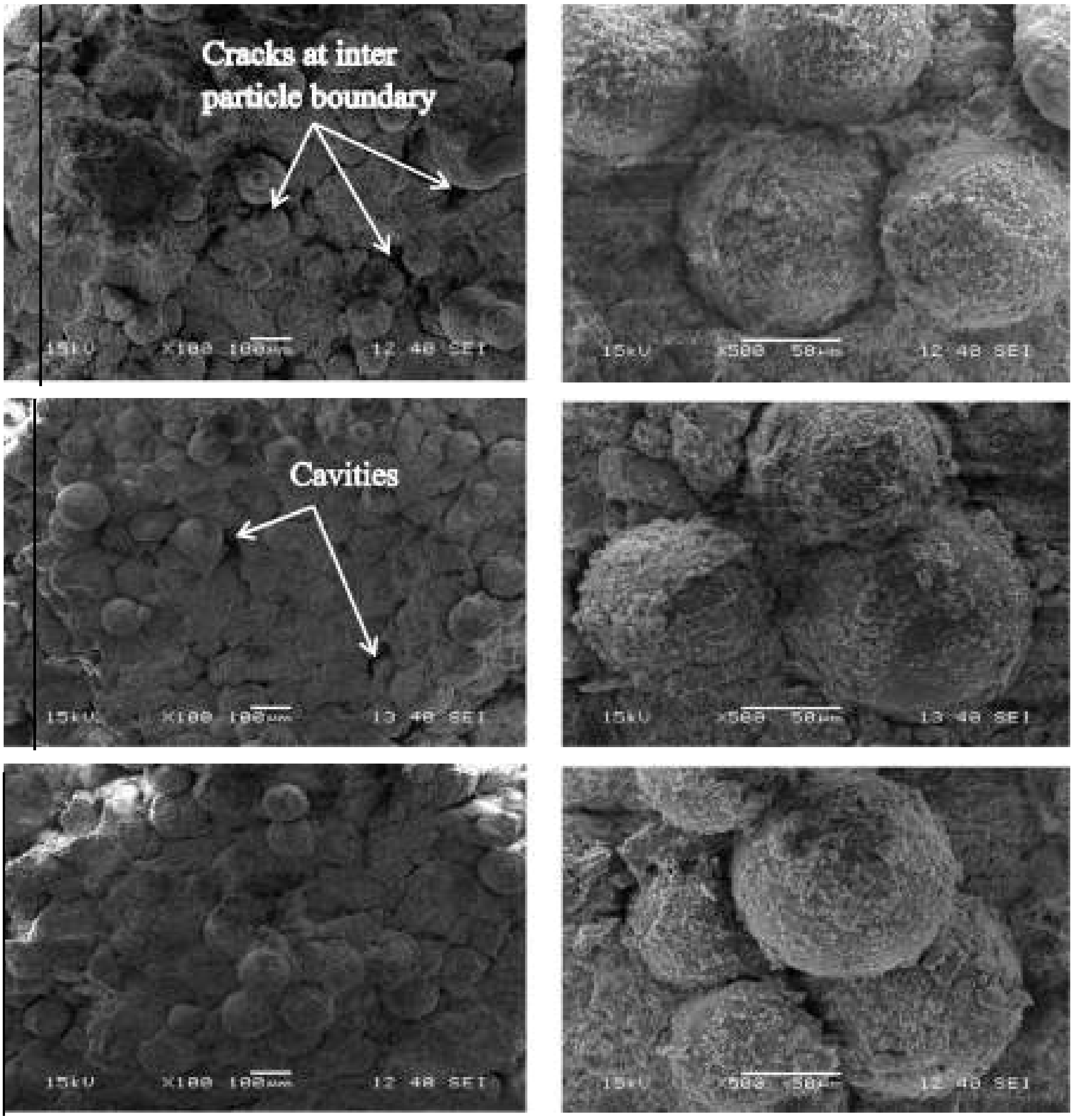
Originally the thermal conductivity of clay is much higher than coal ash. This Coal ash itself contributes that in order to save the energy loss. We can use the coal ash as a substitute of clay. This low value of the thermal conductivity of coal ash is very useful in the formation of various electrical devices. Various tests have been carried out to utilize the insulation capacity of the epoxy resin which is used in coal ash,

Structural analysis of Coal ash polymer Composite

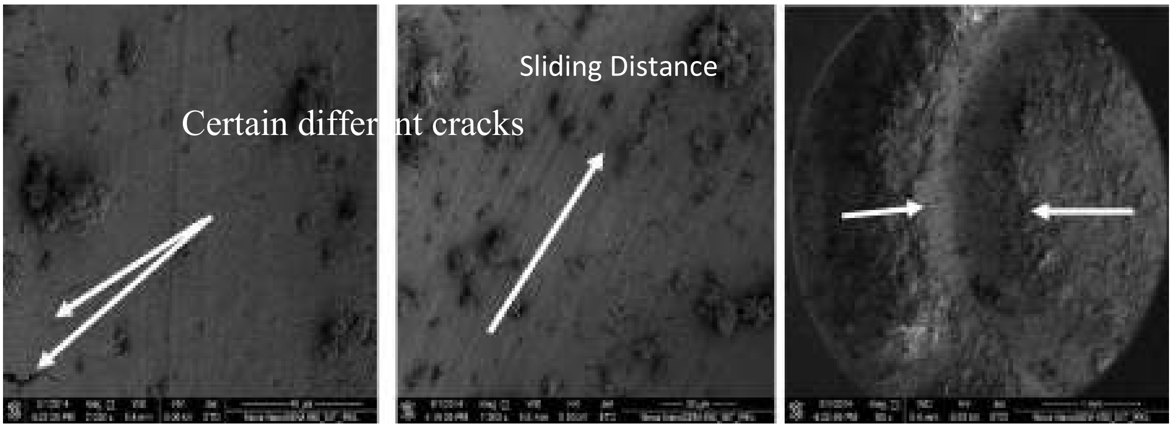
SEM Analysis



Particle size distribution of Coal Ash powder at different Magnifications



SEM images for structure analysis of Coal ash samples at different compositions and at different magnifications



SEM images of samples at different magnification

CHAPTER 4

CONCLUSIONS

Following conclusions can be withdrawn owing to the present research of coal ash polymer composite:

a) The water treated samples showed worthwhile effects on the values of hardness. Out of all dry samples, coal ash with 85 wt % has higher hardness value of 45.08 HV. Great improvement can be seen in the hardness values of the samples when it is water treated at 120 – 190 ^{o}C and the value go up to 48.37 HV.

b) With the increase in polymeric addition (epoxy resin), the compressive strength of the dry samples decreased to a value of 7.5 MPa. At composition of 75 wt % coal ash showed a lower value.

c) Thermal conductivity of coal ash shows increment with the increase in temperature, whereas in case of epoxy resin coal ash mixes, the thermal conductivity of the composite decreases with the increase in the value of coal ash.

d) Water absorption shows an increment with increase in coal ash. Maximum of 20% water can be absorbed in case of 85 wt % coal ash.

e) With the increase in coal ash content the density decreases.

f) SEM analysis showed the structure of coal ash particle that were mostly spherical in shape. With the decrease in polymeric addition i.e. with the increase in coal ash content the inter bonding becomes good and less amount of cracks were found at the surface of coal ash.

g) The coal ash – epoxy resin composite generated in present study seems to be appropriate for use as construction material. The production of this type of composite will certainly contribute to the use of coal ash for value added products.

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