3.1 Introduction

In India, coal/lignite based thermal power plants produced around 65% of electricity [115]. Indian coal (ash content of 30-45 percent) is the lower grade in contradiction of imported coal (ash content of 10-15 percent). Therefore, the 1st half-year of 2019-20 Central Electricity Authority (CEA) reports that around 129 million tons of fly ash have been generated by the thermal power stations. India still depends on coal for its significant energy needs; thus, coal fly ash management and utilization will remain a substantial challenge for Indian thermal power plants [9]. India is in electricity generation and consumption, the sixth-largest country, and fly ash, assumes the world's fifth largest raw material resource [116]. Some applications of fly ash in India are manufacturing of brick, roads construction, and production of cement [117]. A significant quantity of Coal Combustion Byproducts is fly ash, implying substantial stress on the waste management and atmosphere. However, the pressure could be reduced by using fly ash as the raw materials for a variety of innovative products. Fly ash particles are detrimental to the environment due to toxic trace elements. Because of the fly ash ecological issues, an impressive investigation has been attempted on the point around the world [13]. However, various researchers have utilized coal fly ash in lightweight aggregate, landfill liners, road construction, plastic composite materials, and sewage sludge treatment [22,118–121]. Notwithstanding, innovative applications and opportunities for coal fly ash usage are essential. It required an innovative and economically viable solution to utilize the waste materials for new goods rather than land dumping. In this study, the fly ash was characterized which is not reported yet.

Refractories are extensively used in various industries such as petrochemical, iron & steel making, boiler, power plant, ceramic, and glass industries due to their high mechanical strength, high PCE, good corrosion resistance, and good TSR [102]. Mullite has high strength, good creep resistance, and low thermal coefficient of expansion; thus, it has extreme demand in the fields of refractory and ceramics [122]. Currently, in industry-main focuses are given to save energy. Only insulation refractory can provide this solution. They can be used in the ceramic industry, power plant, incinerator, boiler, petrochemical, and kiln due to their high-temperature stability.

The utilization of fly ash to fabricate insulation refractory bricks meets this need. This technique is advantageous since it employs waste as a raw material to produce a commercial product that would otherwise have proved hazardous for the environment. This study characterizes fly ash collected from a power plant NLC India Limited, located at Barsingsar in Bikaner district, Rajasthan, India. Our next work will be the possible application of insulation refractory bricks from this fly ash solid waste.

3.2 Results and discussion

The chemical compositions of fly ash solid waste materials determined using the XRF technique are displayed in **Table 3.1**. The essential fly ash constituents are alumina, silica and ferrous oxide. In broad-spectrum, it can be observed from the Table.1 that fly ash contain various type of metal oxides in the sequence of $SiO_2 > Al_2O_3 > Fe_2O_3$

> CaO > TiO_2 > Na_2O > MgO > K_2O. The coal fly ash contains significant components of 67.20 wt.% silica, 23.89 wt.% of alumina. Fly ash chemistry depends on the type of coal used to generate it. The American Society for Testing and Materials (ASTM) categorized the fly ash is into two types: C and F. **Table 3.1** displays that Class F fly ash possess greater than 70% combined SiO_2, Al_2O_3 and Fe_2O_3 content. Class C fly ash is generated from lignite and sub-bituminous coals and class F fly ash are a by-product of bituminous and anthracite coals [21].

Table 3.1 Chemical composition of fly ash solid waste collected from NLC India Limited, Bikaner, Rajasthan, India

Chemical Formula	wt. %	SiO_2+ Al_2O_3+ Fe_2O_3
SiO_2	67.20%	96.62%>70% Class F Fly Ash
Al_2O_3	23.89%	
Fe_2O_3	5.53%	
CaO	0.99%	
TiO_2	0.93%	
Na_2O	0.60%	
MgO	0.28%	
K_2O	0.17%	

The XRD pattern indicates that the fly ash's mineral phases consist mainly of quartz and mullite. **Fig. 3.1** shows the XRD outline of fly ash solid waste. The results show that the significant crystalline peaks were quartz and mullite. Mullite and quartz are suitable refractory materials due to their superior properties [122].

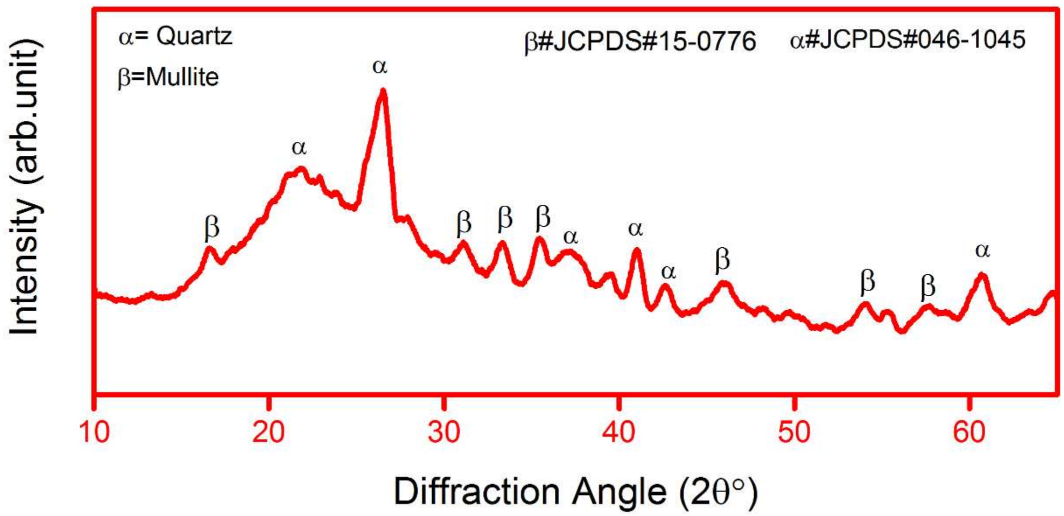

Fig. 3.1: XRD pattern of fly ash solid waste collected from NLC India Limited, Bikaner, Rajasthan, India.

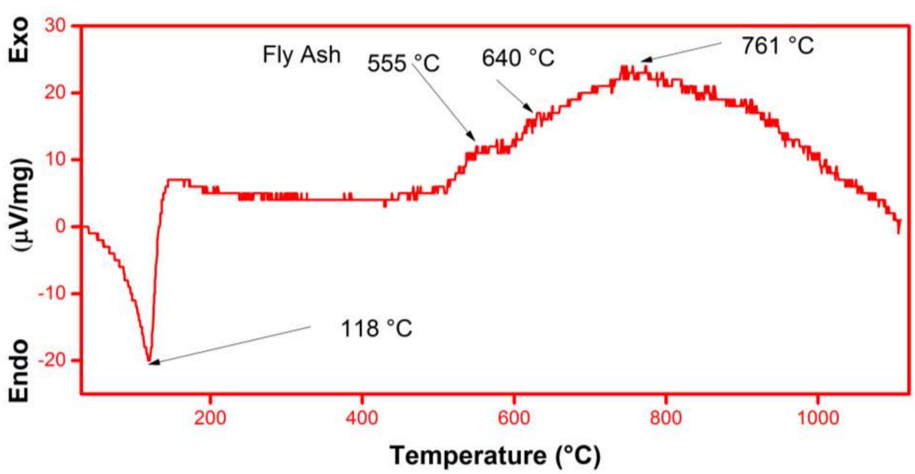

Fig. 3. 2: DTA graph of fly ash solid waste collected from NLC India Limited,

Bikaner, Rajasthan, India.

The DTA curve in **Fig. 3.2** exhibits strong and broad exothermic peak at 555 °C, 640 °C, and 761 °C, respectively. These exothermic peaks are due to unburned carbon combustion. The peak at 555 °C represents amorphous carbon, and the peak at 640 °C is due to the crystalline variety of carbon in treated fly ash. The combustion of the organic matter in the biomass materials occurs in the range 300–761 °C.

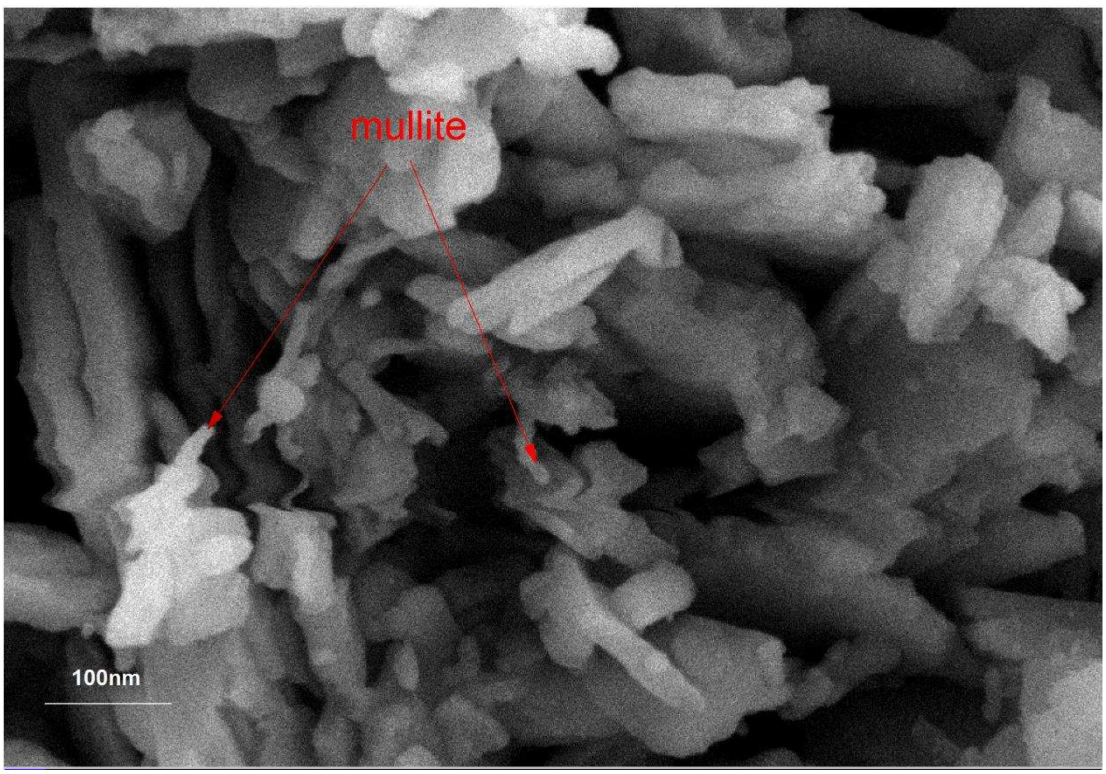

Fig. 3.3: SEM of fly ash solid waste from collected NLC India Limited, Bikaner, Rajasthan, India.

Fig. 3.3 shows SEM graph of fly ash. Scanning Electron Microscope (SEM) was conducted to investigate fly ash solid waste's morphology. Moreover, fly ash particles' morphology predicts the materials' mechanical and physical properties. The microstructure of fly ash particles is restricted mainly by the burning temperature and later cooling rate.

It was experiential that the fly ash particles were irregular in the direction in lengthwise needle shape. The needle shape structure shows the presence of mullite in the fly ash. Some reactive mullite started changing into stable mullite and has high-temperature resistance, a base material for refractory [40]. It may happen due to a series of complex coal transformations at higher temperatures [21].

3.3 Summary of results

From the analysis of fly ash solid-waste the alumina and silica concentration are 23.89 wt. % and 67.20 wt. % respectively. The XRD graph also shows the fly ash comprises mullite, which are good refractory materials. It will provide strength to the insulation refractory bricks. The DTA graph shows that relatively low temperature the insulation refractory can be made. The SEM graph also exhibits the needle shape microstructure, which supports the XRD results. Therefore, it concluded that the fly ash is a suitable candidate for insulation refractory bricks.