Fly Ash Utilisation for Value Added Products
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Fly ash for high value added applications

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ABSTRACT

The applications of fly ash under the category of manufacturing value added products have been broadly classified under two groups i.e., its use for extracting various resource materials like alumina, magnetite, carbon, cenospheres, titanium, gallium and various other trace elements and (ii) its use as raw materials for various specialized applications like ceramics, high temperature and acid resistant bricks, floor and wall tiles, mineral wool, light weight refractory, fillers, synthetic wood, sintered pozzolanic aggregate, building distempers etc. Other promising areas are ash alloys, foam insulation products and decorative glasses. In this paper, various fly ash value added applications/ products have been subsequently covered.

Key words : *Fly ash utilisation, Value addition, Ash alloys, Foam insulation products, Decorative glass*

1.0 INTRODUCTION

Fly ash is a finely divided residue resulting from combustion of pulverized coal or subbituminous coal/lignite in thermal power plants. It consists of organic mineral constituents of coal and organic matter which are not fully burnt. It is generally grey in colour, abrasive, acidic, refractory in nature and has a fineness of 4,000 to 8,000 sq. cm. per gram and posses pozzolanic characteristics. Particles range in size from as much as 150 to less than 1 micron in equivalent diameter.

For long, the potential of Fly ash as raw material to value added products has been ignored. Various studies conducted on Fly ash have proved beyond doubt that Fly ash has intrinsic properties to emerge as a valuable raw material to these products. Number of technologies have been developed and demonstrated successfully intentionally & we need to intensify efforts in this direction in our country also.

Some of the high value added applications of Fly ash are as follows :

USED IN EXTRACTION/BENEFICIATION

* Magnetite
* Cenospheres
* Alumina

* Mineral Fillers/ Enhanced pozzolana
* Carbon
*Other Metal oxides and trace elements.

AS A RAW MATERIALS
* High wear resistance ceramic tiles
* Foam insulation products
* Light weight refractories
* Fly ash metal composites/ Ash alloys
* Continuous casting powders for steel plants
* Castable synthetic wood
* Light weight bodies e. g. panels, blocks. railway sleepers
* Distemper
* Domestic cleaning powder
* Ceramic fibre
* Mosaic titles/ glazed facing tiles
* Fire abatement
* Adsorbent for toxic organics
* Oil-well cement
* Mineral wool
* Decorative glass
* Fly ash fire bricks.

2.0. A GLOBAL TECHNOLOGY STATUS / TECHNOLOGY STATUS - INDIA AND EMERGING TRENDS

2.1. Mineral extraction

Literature survey over the last 50 years has revealed a number of methods and concepts to accomplish the extraction of various minerals from fly ash. The technical literature is full of different methods of recovery of the metal - values from coal ash. Of the elements present in coal ash, iron and aluminium have been examined most extensively for recovery. Of the minor and trace elements, extraction of gallium, germanium, uranium, and molybdenum have been investigated most frequently. The major recovery processes have been developed in USA, Poland, England and Hungary.

In India, the technology development for extracting minerals from fly ash is in its infancy. Very few organisations are working in this direction. Most of the work is currently at the lab scale. In India, CPRI (Central Power Research Institute) has done some work in this direction. They are planning to set up a pilot project for extracting alumina, based on lime sinter process. RRL Bhubaneswar, under Fly ash Mission acivities has developed a novel technique, called Down Drafting Sintering, by which fly ash in the presence or absence of lime soda, salt soda can be sintered using solid fuel in the charge. The sintered mass when leached with water or alkaline/acidic solution, alumina present in the flyash gets converted into soluble state and leached in solution.

Various improvements are being attempted at present to make the currently developed metal recovery processes more flexible, versatile, economical, and to commercialize them for various conditions of fly ash quality.

The recovery of the elemental constituents from coal ash have been accomplished using either physical or chemical processes.

2.2 Recovery of Alumina

Chemical processes for the recovery of the major constituents like alumina from coal ash that have been formulated or at least tested on a laboratory scale can be divided into four general categories.

* Hydrothermal leaching
* Sinter-leach
* Gas-solid reaction
* Direct reduction

The hydrothermal leaching processes involve treating the solid ore with an aqueous solution to selectively dissolve the minerals to achieve separation. After the solution is isolated from the insoluble residue, it is treated to recover the minerals in pure form by solvent extraction, ion exchange, crystallization, precipitation or similar methods.

In sinter-leach processes, a high temperature solid state reaction is used to modify the aluminosilicate matrix and make it more amenable to leaching. Various processes use either an alkaline or acidic leach to extract the aluminium from the sinter residue.

Gas solid reaction processes involve reacting coal ash with a gaseous reagent(s) to convert the metal values present into volatile compounds and permit their recovery. Typically, one reagent is needed to reduce the aluminosilicate (or serve as an oxygen sink) which another reagent is needed to form the volatile species.

Direct reduction processes produce a metallic alloy by high temperature or electric-arc reduction. High-temperature reduction of coal ash (1700-1750°C) with charcoal produces a silico-aluminium alloy. Electric-arc reduction of coal ash can produce a ferrosilicon alloy of a silico-aluminium from which aluminium can be obtained by extraction with zinc.

The coal-ash metal recovery processes that appear to hold the maximum promise at present, are the hydrothermal and the sinter leaching processes.

2.3 Magnetite Separation

Physical process for recovery of the iron rich fraction of ash from bituminous coal ash by magnetic separation has been established on commercial scale. The separation of magnetite is achieved through magnetic action on fly ash. The separators used for magnetite separation from flyash are of low intensity type and they have a working field of 500-2000 gauss at effective working distances. The magnetic separators in use are of two types :

* Dry drum magnetic
* Wet drum magnetic

The commercially available dry drum magnetic separators used for magnetite separation from flyash are of alternating polarity pole type and commonly are 36" in diameter and upto 80" in drum width. They are available in a variety of magnet assemblies having different numbers of poles from as few as 4 or 6 to 55 and more depending upon the quality of fly ash.

Most wet drum separtors employ the pick-up principle in which magnetic particles are lifted from the wet feed while the non-magentic gangue streams through. The wet drum magnetic separators are most widely used in the world, primarily in connection with the concentration of vast tonnages of low grade iron ores.

Magnetic ore concentration often takes place in three distinct processing stages. The primary stage is known as cobbing and here high recovery of the magnetite including those attached to gangue particles takes place. Since flyash is a finely ground material, this is the only stage possible in magnetic separation from fly ash using wet drum separators.

A Method is now under development, utilizing both dry and wet magnetic drums separation, with the dry separation step occurring prior to wet separation. Dry separators typically maximize the quantity of magnetic materials separated out of the raw flyash feed while the wet separators enhance the quality of the recovered magnetite apparently by aiding the elimination of clay particles from the magnetite.

2.4 Cenospheres

In USA, M/s Ceno Science Research Incorp; and in U.K., M/s Fillite Limited have developed collection, separation and classification techniques for removal of cenospheres from the fly ash residues. The conditions that are favorable to the formation of cenospheres do not appear to be clearly established. The amount of floaters differ considerably at various generating plants and is influenced by the nature of mineral mater in the coal being fired and the method of its collection and disposal.

The process of separating the cenospheres is comparatively simple. After removal of the carbon by flotation, the cenospheres are the lightest components of the fly ash and are readily separable by allowing the fly ash slurry to settle for a few minutes and scalping of cenospheres that have floated to the surface. The yield of the cenospheres is increased by brief agitation of the slurry followed by a second setting. Cenospheres continue to rise to the surface during several stirring- setting-scalping cycles.

2.5 Carbon Concentrates

The attempts to remove carbon from fly ash by flotation were moderately successful initially. Through experimentation, it has now been found that kerosene is a relatively cheap and effective conditioning agent and that a variety of frothing agents are suitable, including pine oil and dow froth which work very well. Conditioning at high solids for half and hour or more is found to improve separation; it breaks up particle agglomerates, scrubs the particles and thoroughly mixes the conditioner.

2.6 Mineral Fillers and Enhanced Pozzolana

The spent ash material produced from alumina extraction processes is low in carbon and iron; it can be dried and size classified, so that different size fractions could be supplied to different markets. The finer size fractions size for pigments, cement and aggregates.

Various companies in India are utilizing flyash for the manufacture of Flyash based portland pozzolana cement. Proportion of flyash in the cement will be regulated depending on the quality of flyash and clinker. Generally, the content of flyash in the cement should be less than 50% .The strength of the cement depends on the quality of clinker and quality of flyash.

2.7 Titanium and Manganese Dioxide

These oxide have now been extracted on pilot scale level as by-products of Cal-sinter and salt soda processes of alumina extraction.

2.8 Benefication of Gallium

The method for the benefication of gallium from fly ash involves subjecting the ash to particle size classification while avoiding substantial rupturing of cenospheres in the ash and isolating thereby upto 30 percent of the finest ash particles in the flyash. The fines can then be subjected to a variety of treatments to extract the beneficiated valuable trace elements. In the case of gallium, extraction techniques could include an alkaline halide melt and acid dissolution and extraction. The technologies for extracting gallium or for that matter any other minor and trace items have not been commercialized due to unfavourable economics.

2.9 Ferrosilicon

A promising method developed in Canada is the direct reduction of metals from fly ash through development of plasma furnace technology - the use of a long, stable plasma flame in a more or less conventional arc furnace. The program is under development in Canada and the extended arc smelting process has been successfully tested in small capacity furnace for recovering ferro-silicon.

3.0 FLY ASH AS A RAW MATERIAL FOR HIGH-VALUE PRODUCTS

Various developments have taken place internationally to explore the possibility of utilizing fly ash as raw materials for various high value added applications and products. Most of the work is at lab scale or pilot scale. However, some work developed are described below.

3.1 Insulation Products-

GEC of USA has devised a technology on lab scale in which precipitated silica is mixed with a fly ash material and is employed as an insulating material having a low thermal conductivity. The mixture of precipittated silica and fly ash material is dried, compressed, placed in an evacuable pouch, and evacuated. The resulting board-like insulation configuration is used directly as insulation. The board-like material which is produced may be used as insulation in household refrigerators and freezers by placing it in an insulation space between the inner liner and the outer case and encapsulating the board-like material with a foamed insulating material.

M/s Dual Fabs, Chennai (INDIA), under Fly Ash Mission activities have developed Fly ash based light weight concrete, Cellular blocks of variable density & other precast building components which have very low thermal conductivity. Biltec & Seporex, Pune are manufacturing commercially Autoclaved Aerated Concrete having very low thermal conductivity.

3.2 Ash Alloys

Extensive work is being carried out at the University of Wisconsin, USA, to develop ash alloy through studying the solidification processing of metal-matrix-fly ash particle composites. In the research sponsored by EPRI, (Electric Power Research Institute) USA, cast aluminium fly ash composites have been synthesized by using an inexpensive casting technique. Using this technique, it has been possible to incorporate upto 25 volume percent of fly ash particles in many aluminium alloys as well as in many aluminium-silicon casting alloys. Solidification characteristics of aluminium-fly ash composites have been studied and their casting fluidity has been found to be adequate for casting a variety of shapes including thin section engineering components. The pilot project is in implementation to manufacture products for automobiles industry.

3.3 Application Fly Ash as Fillers

Researches are in progress on the technical and economic feasibility of spent ash as a filler for various industrial applications. The fly ash has been tried before as a filler with poor results. Cenospheres are now successfully used as the filler. But his material makes up only about 1 percent of the ash produced. The spent ash materials produced from alumina-extraction processes, are similar to cenospheres and are now being established as ideal fillers in many industrial applications especially as replacement for calcium carbonate and other fillers. Studies are also in progress to investigate the use of cenospheres as plastic filler material.Its use has been commercially established by EPRI for nylon and polypropylene applications. Smither Scientists Services, USA, is investigating the possibility of using unburnt carbon recovered from flyash as a substitute filler for carbon black in tyre manufacturing.

3.4 Floater Based Light Weight Refractory Products and Pouring Basins

Research with cenopspheres has led to the development of light weight refractory products where floaters are sintered in the presence of certain proprietary agglutinating agents and form light weight refractories.

3.5 Heat Insulation Fire Bricks

Technologies have been developed on pilot scale for manufacture of fire bricks using floaters in fly ash with key controlling technologies of raw material preparation, type of adhesion agent, mixing, modelling and sintering processes.

3.6 Decorative Glasses

The black decorative glasses have been made on lab scale with flyash as main raw material with industrial slags and a small quantity of chemical agents being the remaining materials. Results indicate that the transition temperature of the glass is higher than that of the most silicate glasses and there is no crystalline phase in the glass, which can be used as a novel material because of its good physical and chemical properties.

3.7 Mineral Wool

The technologies for manufacturing mineral wool from coal ash are now commercially possible and plants are in operation. The process/technologies have been developed to manufacture products with quality even better than the conventional wool product consumes 7000 ton of coal ash roughly.

3.8 Waste Water Treatment Using Flyash

Field demonstrations/ studies (at the University of Notre Dame) have revealed that flyash is very effective in the improvement of water quality in polluted lakes and results in excellent reduction of inorganic phosphorous, suspended matter, watercolor and organic concentrations. The flyash readily settles on to the take lake muds and develops a physical barrier at the mud water interface which impairs the release of bottom pollutants into the overline water. Certain characteristics of flyash like adsorptive properties provide effective removal of soluble organic matter from polluted water. The particulate characteristic allows this material to be used as a conditioner of waste water sludge for excellent dewatering by vacuum filtration. The most desirable flyash for dewatering of biological sludge would be one with a high carbon content. The addition of flyash to biological sludge to enhance dewatering leaves a residual filter cake with a now moisture content and contributes to the potential value of the cake (the extent of which depends on the carbon content of flyash). These studies have indicated that flyash has the capability to neutralizing synthetic and actual acid mine drainage in much the same manner as lime is used a neutralizing agent. The degree of acid neutralization with fly ash is time dependent because longer contact times result in more lime release from the fly ash particles and thus a higher degree of acid treatment.

Fly Ash Mission is supporting one M. Tech Project at IIT, Bombay to develop methodology to synthesize Zeolite using Fly ash for its various agricultural and environmental applications in general and molecular sieve for liquid wastes and contaminants in particular.

3.9 Use of Flyash in Fire Abatement Applications

Method of fire abatement have been developed to extinguish underground burning in the coal mines. In this, fly ash slurry is pumped into the voids and crevices to extinguish the fire. Flyash is dumped into high volume mixers with about 100-200 gallons of water per ton of ash. The resultant slurry in pumped from the batch plant, through a high pressure hose and down the grout pipes driven into the ground. Refuse fire abatement using flyash injection has proven to be a safe and effective technique. Considerable work has been done in this area by engineering construction International Incorp., Pittsburg, USA.

4.10 High Wear Resistant Ceramic Tiles/pipe Lining

National Metallurgical Laboratory, has carried out extensive R& D work aimed at developing high value added ceramic products using fly ash. High wear resistant ceramic lining material has been produced Conventional steels and basalt lining can be replaced with NML developed flyash based ceramic products. This product has application in the area of high corrosion and abrasion in material handling equipments of thermal power, steel, cement and coal washeries etc. Some of the specific areas of applications are pulverized fuel (coal) band pipes, hoppers, chutes, ash slurry pipe lines and other form of equipments. Similarly, an attempt has been made to replace costly alumina by preparing fly ash based high wear resistant ceramic tiles. The product has equivalent properties with respect to high alumina based material used for similar applications. A project for manufacturing these tiles is under implementation.

Under Fly Ash Mission activities, centre for Glass and Ceramic Research Institute, Ahmedabad is working on the project of gainful utilization of fly ash in the production of high value added ceramic products for the use of common people as house hold articles as well as construction material.

4.11 Synthetic Wood

RRL, Bhopal, has developed technology for manufacturing synthetic wood, using fly ash as replacement of conventional wood both in terms of physical properties and cost.

4.12 Ceramic Fibers

Technologies have been developed at lab scale at PDIL, Sindri, to produce mullite which is used for manufacture of ceramic fibers. The ceramic fibers have high refractoriness - 1100°C. The product reduces the thickness of thermally insulating layer by a factor of 2-3 and has vast scope in energy saving applications in industry.

4.13 Flyash Building Distempers

Neyveli Lignite Corporation has prepared distempers of various types using flyash. These distempers have been used in several buildings at Neyveli exhibiting satisfactory performance.

4.14 Domestic Cleaning Powder

Neyveli Lignite Corporation has also demonstrated the use of domestic cleaning powder manufactured from flyash. The performance of the powder is found comparable with that of the commercially available cleansing powders.

4.15 Glazed Floor and Wall Tiles, Mosaic Tiles, etc.

CPRI claims to have developed on Lab. scale technologically feasible and economically viable high value added products based on flyash including glazed floor and wall tiles, mosaic tiles and high strength insulating bricks.

5.0 CONCLUSION

Flyash with pozzolanic characteristics, fineness and various other useful properties has many applications in different value added products. Rapidly depleting natural resources and safe disposal of industrial wastes make it imperative to tap the potential of this accumulated resource material (Flyash), which undoubtedly is going to be extremely useful.

Though Fly Ash Mission is primarily for bulk utilisation of Flyash and does not support basic research and development activity but it does support incremental research and development projects which are technically and commercially viable.

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