5.0 AREAS OF ASH UTILIZATION
5.0 AREAS OF ASH UTILIZATION:

Coal ash is a versatile material which can be used in a variety of applications. Its Geotechnical Properties permit it to be used in areas like construction of roads and embankments, structural fills, reinforced fills etc. It also has excellent Pozzolanic Properties which enables its use in areas such as manufacture of Cement, Concrete & its products, building materials, etc. Its Physico - Chemical Properties being similar to soil and presence of essential plant nutrients in it enables it to be used in Agriculture/ Soil Amendment.

During the past two to three decades, lot of R&D work has been carried out all over the world, by scientists and engineers, to seek and establish usage of ash in variety of areas. The efforts made by Several Institutions and thermal power plants in India have also resulted in development of various technologies and establishing use of ash in diversified areas. Areas of Ash Utilization are listed below:-

THE MAJOR USAGES OF ASH

- Fly Ash Bricks / Blocks
- Cellular Concrete products
- Light Weight Aggregates
- Concrete and Mortar
- Cement manufacturing
- Asbestos Products manufacturing
- Road construction.
- Embankment/ Back fills/ Land Development.
- Controlled Low Strength fill Material (CLSM)
- Use in Agriculture
- Mine Filling
- Manufacture of Fertilizer

OTHER USAGES

- Manufacture of Distemper
5.1 FLY ASH UTILISATION IN BRICK MANUFACTURE

5.1.1 CLAY-FLY ASH BRICKS

Major considerations for flyash utilisation in the production of burnt clay flyash building products are:

(a) compatible physico-chemical and mineralogical properties
(b) close resemblance of micro-crystalline phases of heat indurated clay mass with flyash constituents
(c) saving in thermal energy
(d) capacity to modify the drying behaviour of sensitive plastic clays
(e) need for conservation of natural resources

Manufacturing process of clay fly ash bricks by manual or extrusion process involves mixing of flyash (60%) with clays of moderate plasticity. The green bricks are dried under ambient atmospheric conditions or in shed to equilibrium moisture level of below 3 percent. Dried bricks are fired in traditional brick kilns at 1000° ± 30° C with a soaking period of 5-7 hours at maturing temperature. This technology has great potential to reduce not only precious top soil and consumption of coal in making conventional clay bricks, but also requires minimum changes in existing set up at kiln sites and is not very much susceptible to quality of ash.
Properties of clay flyash bricks (commercial product) made optimal mix composition from clay mass of different geological origin and fly ash are as under (source: CBRI, Roorkee):

<table>
<thead>
<tr>
<th>Type of Clay</th>
<th>Method of Production</th>
<th>Comp. Strength kg/cm²</th>
<th>Water Absorption %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial</td>
<td>Manual</td>
<td>60-120</td>
<td>12-18</td>
</tr>
<tr>
<td></td>
<td>Extrusion</td>
<td>75-300</td>
<td>8-15</td>
</tr>
<tr>
<td>Residual</td>
<td>Manual</td>
<td>35-100</td>
<td>15-20</td>
</tr>
<tr>
<td></td>
<td>Extrusion</td>
<td>50-150</td>
<td>12-16</td>
</tr>
<tr>
<td>IS : 13757:1993</td>
<td>-</td>
<td>&gt;35</td>
<td>&lt;20</td>
</tr>
</tbody>
</table>

To encourage and promote use of ash in burnt clay brick making, NTPC has taken an important policy decision that use of ash based products shall be encouraged by NTPC and wherever there are existing burnt clay brick making units near/around power stations, necessary techno-managerial assistance shall be extended by NTPC personnel.

5.1.2 FLY ASH - SAND - LIME BRICKS

In presence of moisture, fly ash reacts with lime at ordinary temperature and forms a compound possessing cementitious properties. After reactions between lime and

*A view of Hydraulic press manufacturing Fly Ash bricks*
fly ash, calcium silicate hydrates are produced which are responsible for the high strength of the compound. Bricks made by mixing lime and fly ash are, therefore, chemically bonded bricks. These bricks are suitable for use in masonry just like common burnt clay bricks. These bricks have the following advantages over the clay bricks:

1. Possess adequate crushing strength as a load bearing member.
2. Have cement colour in appearance, are uniform in shape and smooth in finish and require no plastering for building work.
3. Are lighter in weight than ordinary clay bricks.

Generally, dry fly ash available from power plants meets the properties specified in IS: 3812 and is suitable for manufacture of Fly Ash-lime bricks in accordance with the requirements of IS:12894.

**Technologies for Manufacture of Fly Ash - Sand - Lime Bricks**

Several research organizations in India have developed technologies for manufacture of fly ash sand lime bricks. Some of them are as follows:

1. M/s Central Fuel Research Institute (CFRI), Dhanbad.
5. M/s INSWAREB, Visakhapatnam Fal-G Technology. (Fly ash lime-gypsum)

All these processes involve homogeneous mixing of raw materials (generally fly ash, sand, and lime), moulding of bricks and then curing of the green bricks. Some technologies call for usage of chemical accelerator like gypsum. These processes are almost similar and vary slightly from each other. The requirement of curing is different for different technologies varying from water curing to steam curing at low pressure or autoclaving at 10-14 kg/cm². Comparison of process and properties of such bricks is presented in Table-4 & Table-5.

**TABLE -4**

**COMPARISON OF MAJOR TECHNOLOGIES FOR MANUFACTURE OF FLY ASH-SAND-LIME BRICKS**

<table>
<thead>
<tr>
<th>S.N.</th>
<th>PARTICULARS</th>
<th>TECHNOLOGIES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw Material Requirement*</td>
<td></td>
</tr>
<tr>
<td>a)</td>
<td>Fly Ash</td>
<td>80%</td>
</tr>
<tr>
<td>b)</td>
<td>Sand</td>
<td>9.8%</td>
</tr>
<tr>
<td>c)</td>
<td>Lime</td>
<td>10%</td>
</tr>
<tr>
<td>d)</td>
<td>Ordinary Portland Cement</td>
<td>-</td>
</tr>
<tr>
<td>e)</td>
<td>Gypsum</td>
<td>NIL</td>
</tr>
<tr>
<td>f)</td>
<td>Accelerator</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>CFRI</th>
<th>CBRI-I</th>
<th>CBRI-II</th>
<th>NCBM</th>
<th>AEC</th>
<th>FAL-G</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a)</td>
<td>50-80%</td>
<td>70-80%</td>
<td>50-60%</td>
<td>70-80%</td>
<td>75-76%</td>
<td>50-80%</td>
</tr>
<tr>
<td>b)</td>
<td>10-20%</td>
<td>10-20%</td>
<td>30-40%</td>
<td>0-10%</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>c)</td>
<td>8-10%</td>
<td>8-10%</td>
<td>8-10%</td>
<td>8-15%</td>
<td>8%</td>
<td>10-30%</td>
</tr>
<tr>
<td>d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.N.</td>
<td>PARTICULARS</td>
<td>CFRI</td>
<td>CBRI-I</td>
<td>CBRI-II</td>
<td>NCBM</td>
<td>AEC</td>
</tr>
<tr>
<td>------</td>
<td>--------------------------------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>----------------------</td>
</tr>
<tr>
<td>2.</td>
<td>Hydraulic Press</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pressure requirement</td>
<td>200-240</td>
<td>Kg/cm²</td>
<td>200</td>
<td>Kg/cm²</td>
<td>Vibro-Compaction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kg/cm²</td>
<td>Kg/cm²</td>
<td></td>
<td></td>
<td>upto 80 Kg/cm²</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Depending upon the requirement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not</td>
<td>Req'd.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Autoclaving/ Steam Curing/ Water Curing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a)</td>
<td>Pressure</td>
<td>2-2.5 Kg/Cm²</td>
<td>10-14 Kg/Cm²</td>
<td>Steam Curing (1Kg/cm² water curing)</td>
<td>Steam Curing (No pressure involved)</td>
<td>Water Curing</td>
</tr>
<tr>
<td>b)</td>
<td>Temperature</td>
<td>120°C</td>
<td>180°C</td>
<td>100°C</td>
<td>100°C</td>
<td>Normal</td>
</tr>
<tr>
<td>c)</td>
<td>Time</td>
<td>3-4 hrs.</td>
<td>4-6 hrs.</td>
<td>6 hrs/ 10-15 hrs.</td>
<td>21 days</td>
<td>20 days</td>
</tr>
</tbody>
</table>

*The requirement of raw materials would vary depending upon the quality of various materials.

** Manual moulding or hand presses/hydraulic presses/vibro tables (pressure is not mandatory from the process point of view except to give shape and early handling).

*** 3-6 days of humid curing at elevated temperature, preferably based on solar energy, wherever rapid strengths / high early strengths are required for quick turnover.
## Table -5
**COMPARISON OF PROPERTIES OF FLY ASH - SAND - LIME BRICK AS PER VARIOUS TECHNOLOGIES**

<table>
<thead>
<tr>
<th>S.N.</th>
<th>PARTICULARS</th>
<th>TECHNOLOGIES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CFRI</td>
<td>CBRI-I</td>
</tr>
<tr>
<td>1.</td>
<td>Compressive Strength</td>
<td>100-150 kg/cm²</td>
</tr>
<tr>
<td></td>
<td>(Wet Comp. Strength)</td>
<td>100-150 kg/cm²</td>
</tr>
<tr>
<td>2.</td>
<td>Water absorption</td>
<td>20%</td>
</tr>
<tr>
<td>3.</td>
<td>Durability</td>
<td>Good</td>
</tr>
<tr>
<td>4.</td>
<td>Efflorescence</td>
<td>Free</td>
</tr>
<tr>
<td></td>
<td>from</td>
<td>from</td>
</tr>
<tr>
<td></td>
<td>Efflorescence</td>
<td>Eflore-</td>
</tr>
<tr>
<td></td>
<td>scence</td>
<td>scence</td>
</tr>
<tr>
<td>5.</td>
<td>Bulk Density</td>
<td>1570 kg/m³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150 kg/m³</td>
</tr>
<tr>
<td>6.</td>
<td>Shape</td>
<td>Uniform</td>
</tr>
<tr>
<td>7.</td>
<td>Finish</td>
<td>Smooth</td>
</tr>
</tbody>
</table>

NTPC has installed thirteen pilot plants for manufacture of ash based bricks at its various power stations. More than 1500 lakhs ash bricks have been produced so far and utilized in various construction activities in power plants.

There are other technologies also which are promoted by foreign agencies. Notable ones among them who are keen to transfer their technologies for setting up of units in India are:

### 5.1.4. FLUX BONDED FLY ASH BRICKS, BLOCKS AND TILES

The Regional Research Laboratory, Thiruvananthapuram (RRL-T), a CSIR laboratory, and TNO TPD in The Netherlands, have together developed a process for the manufacture of bricks, tiles and blocks with a high fly ash content. The material has been called “CFBA-BUILDING PRODUCTS” (patented).
A view of office building in Greater-Noida constructed with Fly Ash bricks

The process is similar to the one in the conventional tile industry: fly ash is mixed with less than 10% plastic clay and a few additives and titles, bricks or blocks are pressed. These shapes are fired in the range of 900°C to 1000°C to make the final product. More than 85% of fly ash is used in the process. The process is based on the formation of low melting fluxes at the firing temperature, which partly react with the fly ash and form a high temperature reactive glass binder phase. The bricks, tiles and blocks are brick red in colour, but a variety of colours can be made by changing the initial composition. The process has been tested at pilot plant scale under factory conditions. The technology is promoted by the Regional Research Laboratory in Thiruvananthapuram.

5.1.5 COLD BONDED LIGHTWEIGHT FLY ASH BRICKS, BLOCKS AND TILES

TNO TPD has developed a new lightweight building material. The material has been called “KERATON” on the basis of its properties (“ceramic concrete”).

The material can be produced in a variety of building blocks, bricks and tiles, depending on local markets and regulations. Keraton consists of cheap and ubiquitous raw materials such as fly-ash and/or other waste materials.
These materials are mixed and a cold bonding agent is added. The mixed raw material is cast in moulds, after which the moulds are processed in a microwave oven for about 4 minutes. After cooling and de-moulding the building blocks are ready for transportation to the building site. The products can be applied as a light-weight material in the house-building industry and utility building, such as stables, barns, garages, etc.

A view of industrial building in NOIDA constructed with Fly Ash bricks

A surface treatment or coating for colouring is possible. Strong points are the ability to use fly ash, the insulation properties and the production flexibility. Initial experiments have shown that also other waste materials can be used to produce Keraton, although properties will change. The full potential of Keraton has not yet been exploited. The technology is promoted by the Regional Research Laboratory, Thiruvananthapuram.

5.2 MANUFACTURE OF CELLULAR CONCRETE PRODUCTS

There are two types of processes in vogue for manufacturing Cellular Concrete Product viz.
A view of residential building in NOIDA constructed with Fly Ash bricks

i) Process-I : This process necessarily employs autoclaving of the product.

ii) Process-II : This process avoids autoclaving and the product can be cast at sites and normal curing methods are employed.

5.2.1 PROCESS-I

Autoclaved Aerated Concrete (AAC) Blocks and other building elements are manufactured by the process of mixing Fly Ash, Quick Lime, Cement and Gypsum along with water in a high speed mixer to form a slurry. A small amount of foaming agent (Aluminium Powder) is added and mixed into this slurry which is then poured into large steel moulds to fill the mould partially. The mix begins to rise (because of reaction between Aluminium powder and hydrated lime—from quick lime and cement) until the mould is completely filled with a porous mass which is still soft. After around 3 hours, as a result of hydration of unslaked lime and the cement, the mixture sets sufficiently to be cut into required sizes of blocks and panels.

To prepare the material for cutting to required sizes, the mould is turned through
90 degrees before cutting. Three sides of the mould then stripped off and set mass (AAC cake) inside is positioned on its narrow long side which acts as a support as well as curing plate for the mass (cake).

Rotating the mould through 90 degree makes it possible to shape all sides of the green mass (cake) i.e. cutting profiles like tongue and groove etc. This also facilitates curing of the mass, as maximum surface of the mass is exposed to steam pressure.

It is particularly important that during these shaping (or cutting) processes, the uncured mass (cake) always remains on a stable supporting-curing plate. In this way the material can be worked on while it is still comparatively soft. Because of this, it is possible to use only small amounts of binding agents by keeping the waiting period short.

For reinforced elements (slabs and wall panels etc) anti corrosive mix coated steel cages (or wire meshes) are positioned in the mould before pouring the slurry.

Subsequently uncured AAC cakes are steam cured for about 15 hr in Autoclaves at pressure+10 bar. The entire cycle from mixing operation till the curing operations takes about 20 hrs.

Afterwards products are allowed to cool and palletized and stacked for use/despatch.

These AAC Products are excellent material for walling, prefab floors and roofs being light weight and having high thermal insulating value. The dry density of these products ranges from 550 Kg/m$^3$ to 650 Kg/m$^3$ which is much lighter than regular concrete having density of 2400-2500 Kg/m$^3$. The relevant BIS specification is IS: 2185 (Part-III).

A large scale manufacturing unit BILT INFRASTRUCTURE LTD. based on above mentioned process (know-how transferred from M/s. Ytong, Germany) has been set up near Palwal (Haryana) by M/s. BALLARPUR INDSTRIES LTD. (BILT) which is the flagship company of the reputed Thapar Group. They are using Fly Ash from Badarpur Thermal Power Station of NTPC in Delhi. BILT can provide technology and support to the entrepreneur who wish to set up similar units in India.
5.2.2 PROCESS-II

In this process Cellular Lightweight Concrete (CLC) is produced by mixing sand, fly ash, cement, water and stable foam in requisite proportion in ready mix plant or ordinary concrete mixer. The mixed slurry is then poured into moulds of pre-cast blocks/structural components/assembled form-work of building elements or over flat roofs for thermal insulation as per I.S. : 6598. The foam is produced with the help of a Foam Generator by using a foaming agent. The foam contains isolated air bubbles, which create millions of unconnected tiny voids/cells in the mix resulting in lighter weight of concrete. CLC can be produced in a wide range of controlled densities from 400 kg/m\(^3\) to 1,800 kg/m\(^3\) as against conventional concrete of density 2,400 kg/m\(^3\). The use of CLC in housing construction can result in nearly 40% reduction of dead load. The use of CLC in housing was started by DLF in Gurgaon, near Delhi, but it is now being used by over ten agencies including L&T, Shapoorji Pallonji, Sintex etc. Under a technology demonstration project of Fly Ash Mission, TIFAC a pilot plant for production of CLC has been established at Chennai. The plant is running successfully for about more than four years and the product has been accepted by the market. NTPC has also set-up a pilot CLC block manufacturing plant at its Dadri thermal power station. M/s Neopor System GmbH, Germany have developed the technology and M/s System Building Technologists, New Delhi, promote the fly ash version in Indian sub-continent.

5.3.1 SINTERED LIGHT WEIGHT AGGREGATE:

Sintered Light Weight Aggregate is produced by pelletisation or nodulisation of flyash and sintering of the pellets or nodules at a temperature of 1000\(^0\)C-1300\(^0\)C. Unburnt fuel in the flyash nodules supports ignition. Sintered light weight aggregates substitute stone chips in concrete reducing dead weight. It can also be used for various purposes such as in manufacture of structural light weight concrete and precast light weight concrete building units for use as load and non-load bearing elements etc. It has got good potential in places where flyash is locally available and stone aggregates are costly.

The technology for manufacture of sintered light weight aggregate using about 75-90% fly ash has been developed by RRL-Bhubaneshwar under a technology demonstration project of Fly Ash Mission, TIFAC.
5.3.2 COLD BONDED LIGHT WEIGHT AGGREGATES

Cold bonded Light Weight Aggregate is produced without the process of sintering of flyash. Here, Lime is used as a binding agent along with more than 90% fly ash. The technology from M/s Aardelite of Netherland is available in India through M/s. Tata Electric Company, Bombay.

5.3.3 MAN MADE AGGREGATE

Man Made Aggregate (MMA)- Neopor Richter System produces lightweight aggregate from any type of fine raw material such as fly ash, kiln dust, rock dust, silt etc. Cement based slurry is mixed with pre-formed stable foam as per Neopor System to give foamed concrete in density range of 300-1,200 kg/m³. This foamed concrete is poured into 500 mm. wide and 500mm. deep open channels and allowed to have initial set. An aggregate processor with cutting edges moving over the channels gives an output of 10 m³/hr of raw Man Made Aggregate (MMA) in granular size 8 20mm size with bulk density varying from 250 to 800 kg/m³. MMA requires no primary energy and the hydration of cement is achieved with water curing. M/s System Building Technologists, New Delhi are also offering an alternative production process.
5.4 USE IN MANUFACTURE OF CEMENT CONCRETE AND MORTAR

Fly ash is extensively used in manufacturing of cement concrete in most of the developed countries such as USA, U.K. etc. Addition of fly ash in cement concrete mix improves the properties of concrete as well as reduces its cost. During the setting and hydration of concrete, lime is liberated. When fly ash is available in concrete mix, it reacts with this lime and forms additional cementitious material.

IS: 456-2000 code of practice for plain and reinforced concrete allows the use of fly ash as mineral admixture in the concrete. As per this standard, fly ash addition can be taken into account as a cementitious material with respect to cement content & water-cement ratio. IS: 2250-1981 code of practice for preparation and use of masonry mortars also specifies the use of fly ash in cement mortar / lime mortar mix. It has been established that several benefits can be gained by incorporating fly ash in cement concrete. Some of the important benefits are listed below:

1. Greater long term strength
2. Improved Workability
3. Reduced Heat of Hydration
4. Reduced Permeability
5. Resists Sulphate Attack
6. Reduced Alkali - Aggregate reactions
7. Reduction in cost of concrete
8. Increased resistance to corrosion

In mass concreting use of fly ash reduces the huge expenditure incurred on cooling to a great extent. Using roller Compacted Concrete Technology for mass concreting, 60-70% cement can be replaced with fly ash. This technology (RCC) is being used for construction of dams for the first time in India under a technology demonstration project of Fly Ash Mission at Ghatghar Pumped Storage Scheme, near Nashik, Maharashtra.

♦ Some examples of use of fly ash in cement concrete world over as well as in India are presented below:
- **WORLD OVER**
  - Fly Ash Concrete was used in Prudential Building (the first tall building in Chicago after World War II).
  - 8,000 cu. yds. of fly ash had been used in Ledrock Dam construction in U.K. in the year 1955.
  - Fly ash concrete was used for the foundation of Ferrybridge C Power station in 1964, in U.K.
  - About 7,500 tonnes of fly ash have been used in concrete for Water Tower Place, in USA.
  - Heysham B. Torness and Sizewell B Nuclear Power Stations were constructed using fly ash concrete in 1980's in U.K.
  - Fly ash concrete was used in tunnel linings and slip-formed surge shafts of the Dinorwig Pumped Storage Scheme in the year 1979 and 1980, in U.K.
  - Fly ash concrete was used in construction of channel link between England and France.
  - Fly Ash concrete was used in foundations, walls, floors and concrete fire proofing of Sears Tower, one of the world's tallest building in USA.
  - 10,000 tonnes of wet ash have been used in construction of Puylaurant Dam in France in the year 1994-95.
  - Fly ash from NTPC Dadri and NTPC Singrauli was exported for use in Dam construction in Nepal.
  - Fly ash has been used in Petronas Tower of Kuala Lumpur.
IN INDIA (RECENT APPLICATIONS)

DLF has utilized fly ash concrete in building construction at Gurgaon (Haryana) near Delhi.

Unitech Prefab has also utilized fly ash concrete in building construction at Gurgoan (Haryana) near Delhi.

- Fly ash utilized in tunnel lining unit of NJPC project.
- Fly ash from NTPC, Dadri is being utilized in cement concrete work of Delhi Metro Rail Corporation project.
- Ready Mixed Concrete Plants located in Delhi Area are also utilizing Fly Ash from NTPC Dadri in cement concrete.

5.5 MANUFACTURE OF CEMENT

The manufacture of Portland Pozzolana Cement conforming to IS 1489- Part I is a commercially viable area wherein fly ash can be utilized in considerable quantity. Fly ash can be utilized in its manufacture through either of the following three methods:

1. As a raw material, i.e. burning of fly ash with Lime Stone and Coal in Kiln.
2. Grinding of cement clinker and fly ash together in the Mill.

In India, it is noted that cement companies, in general prefer to adopt second method i.e. intergrinding of clinker and fly ash in Mill.

Portland Pozzolana Cement (PPC) produced using fly ash has many important characteristics. It produces lesser heat of hydration and offers greater resistance to attack of aggressive water and sulphates as compared to Ordinary Portland Cement. It also reacts with free lime liberated during hydration of the cement and forms calcium - silicate - Hydrated bond which gives more strength to the concrete/mortar. As per IS 1489- Part I (1991) it is equivalent to Portland Cement of 33 grade on the basis of 3, 7 and 28 days Compressive Strength. In July 2000, BIS has enhanced the
minimum & maximum permissible limits of fly ash in PPC from 10% to 15% and from 25% to 35% respectively.

For manufacture of fly ash based Portland pozzolana cement, the physical and chemical properties of fly ash should be in line with IS:3812-1981. Several cement manufacturers are taking fly ash from NTPC's power stations to produce Portland Pozzolana Cement. **List of some of the Cement Manufacturers is given below:**

1. Associated Cement Co. Ltd.,
2. Maihar Cement Works,
3. Jaypee Cement,
4. Lafarge,
5. Century Cement,
6. Satna Cement,
7. Grasim Cement,
8. Birla Corporation Ltd.,
9. Prism cement,

5.6 **ASBESTOS CEMENT PRODUCTS**

Asbestos cement industries utilize fly ash as a pozzolanic material as a replacement of cement. This industry, however, requires very fine ash having high lime reactivity i.e. ash collected from normally 3rd field of Electrostatic Precipitators. NTPC has been supplying fly ash from its various power stations to several Asbestos Cement Product Manufacturers. List of such Asbestos Cement Product Manufacturers is given below:

1. Eternit Everest Ltd. Kymore,(M.P)
2. U.P. Asbestos Ltd. Lucknow (U.P)
3. Ramco Asbestos, Maksi (M.P)
4. Utkal Asbestos, Denkanal (Orissa)
5. Hyderabad Asbestos Industries, Faridabad, (Haryana)
6. Assam Asbestos Ltd. Guwahati.
5.7 USE OF FLY ASH IN ROAD CONSTRUCTION:

It has been established by extensive research work conducted in different parts of the world as well as in India, that fly ash can be utilized successfully and economically in the pavement layers of road construction. There are many techniques available which utilize fly ash in road construction. These techniques have been highlighted below:

1. Use as Granular Sub-base Material.
2. Use as Soil Stabilizer.
4. Stabilized Fly Ash in Sub-base and Base Course.
5. Utilization of Fly Ash in Semi-rigid and Rigid Pavement as:
   - Lean Cement Fly Ash Concrete.
   - Lime Fly Ash Concrete.
   - Fly Ash in Rigid Pavement Construction.
   - Fly Ash as filler in Bituminous/Asphalt concrete.
   - Roller Compacted Concrete.

IRC has published “Rural Roads Manual” vide its special publications 20-2002 where in above techniques of utilization of ash in road construction are covered.
5.8 EMBANKMENT / BACK FILLS / LAND DEVELOPMENT

Fly ash is a relatively light weight material as compared to earth. The well compacted fly ash exhibit good shear strength comparable to soils normally used in earth fill operations. Its light unit weight property is particularly advantageous in situations where filling is necessary on relatively weak subsoil. Coal ash in loose state has good permeability. This characteristics is conducive to achieve better rate of construction during rainy season. In addition to this, it is easier to compact coal ash as compared to earth as its moisture - density curve is more even. All these properties of coal ash make it a desirable material for use in embankment construction, backfilling and land development works.

In this regard, NTPC has taken an important Policy decision to utilise pond ash for construction of core embankment for all its Ash dyke raising activities and low lying area development within plant boundary.

*Indian Road Congress (IRC) has approved use of ash for road embankments and has issued its special publication IRC : SP - 58 “Guidelines for Use of Fly Ash in Road embankments”.*
The typical cross sections for Ash based embankment recommended by IRC in SP-58 are:

- **Typical Cross-Section of Embankment (Height < 3m) with Core of Ash**

- **Typical Cross-Section of Embankment (Height < 3m) with Alternate Layer of Ash and Soil**

- Some of the recent examples for use of coal ash in embankment construction are presented below:
  - Nearly 20 lac tonnes of pond ash form NTPC, Badarpur Thermal Power Station has been utilized in road embankment of NOIDA-Greater NOIDA Express Highway.
  - Large quantity of ash has been utilized in railway embankment work in Tamluk-Digha section of Kharagpur Division near Kolkata.
  - More than 15 lakh tonnes of pond ash has been utilized by Delhi Metro Rail Corporation in rail embankment.
  - About 1.5 lakh tonnes of pond ash had been utilized is second Nizamuddin bridge embankment construction by Delhi PWD at New Delhi.
NTPC has so far utilized more than 124 lakh tonnes of ash in low lying area development and in embankment for raising height of ash dykes.

2.75 lakh tonnes and 2.50 lakh tonnes of coal ash has been utilized in area development of stock yards and construction of railway embankment of Steel Authority of India Ltd., at Dankuni and Haldia in West Bengal respectively.
- 2.85 lakh M$^3$ of Pond ash has been utilized from NTPC Badarpur TPS for area development of LPG plant of Indian Oil Corporation near Badarpur.

5.9 USE OF ASH FOR REINFORCED EMBANKMENT CONSTRUCTIONS.

Embankments can be constructed using reinforced earth technique adopting ash as fill material. Reinforced embankment constructions technique has advantages like avoiding necessity of providing retaining walls, faster constructions and saving in constructions cost. Provision of reinforcements such as Geogrids or Geotextiles for ash embankment reduces the shear stress and minimises lateral deformations. Many such structures constructed in Delhi have been showing very good performance. Ash embankments constructed using geotextile reinforcement can have steeper side slopes. Such structures can be used as noise barriers along highway.

![Reinforced ash fill being laid for Sarita Vihar Flyover in Delhi](image)

Some of the recent examples for use of coal ash in Reinforced Embankment are presented below.

- About 10,000 tonnes of pond ash from Badarpur Thermal Power Stations has been utilized in Sarita-Vihar Fly over in Delhi.
• About 4000 M$^3$ of pond ash and 800 M$^3$ of Bottom ash has been utilized by CPWD in construction of Okhla fly over bridge constructed at National highway No 2. Subsequently fly ash was also utilized in construction of "Hanuman Setu" in New Delhi.

5.10 CONTROLLED LOW STRENGTH MATERIAL (CLSM)

Fly ash can be utilized in manufacture of Controlled Low Strength Material (CLSM). CLSM is a fluid mixture made of small quantity (4-6%) of Portland Cement, sufficient quantity of water and large quantity of fly ash or fine aggregate or both. The CLSM

*CLSM is being laid in road cut portion at Dadri*

is neither a concrete nor a soil cement but it has property similar to both. CLSM or fly ash slurry fill material provides many advantages, which are as follows:

• Excellent flowability; can be filled with minimal efforts; fills all the voids, spaces.
• No compaction and curing required.
• Easy to produce and apply.
• No settlement after final set.
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- Low unit weight.
- Can be dug back later, when required.
- Different strengths can be designed as per requirement.
- Reduced labour cost.
- Cost effective.
- Uses large quantum of ash.

The CLSM or fly ash slurry fill material, get their strength from cement and pozzolanic reaction of fly ash. Dry fly ash or pond ash can be used in this. The properties of CLSM make it useful in many places. It can replace compacted soil as structural fill. It is ideal for use in restricted access areas where placing and compaction is difficult such as back filling in narrow trenches, filling of trenches of utilities, sanitary and storm sewers, pipes, abandoned under ground structures, such as mines, tunnels, tanks, conduits, wells etc.

NTPC has innovated use of CLSM in new area to control elephant grass growth. CLSM is being utilized in the entire switchyard area of NTPC Kahalgaon station.

*A view of switch yard area at Kahalgaon where CLSM has been laid*
5.11 USE OF FLY ASH IN AGRICULTURE / SOIL AMENDMENT

Fly ash has a good potential for utilisation in agriculture fields in the following manner:

(a) As a soil amendment to modify the pH of the soil.
(b) As a soil conditioner to improve the physical and chemical properties of soil.
(c) As a source of essential plant nutrients like P, K, Ca, Mg, Cu, Zn, Fe, Mn etc.

The physical, chemical and mineralogical properties of most of the common soil types and Fly ash are more or less similar in many respects. The Fly ash in fact is superior in some respects in regard to its high Water Holding Capacity (WHC) and low Bulk Density. NTPC has conducted studies at Rihand and Farakka power stations through Regional Research Laboratory (RRL), Bhopal and Central Fuel Research Institute (CFRI), Dhanbad respectively in the area of Fly ash use in agriculture. Various cereal crops like paddy, wheat, maize; pulses like tur, chana etc; vegetables like tomato, potato, brinjal, pea and commercial grasses like berseem, medicinal and aromatic plants were tested. Depending upon the soil type and its characteristics, Fly ash up to 560 tonnes/hecate can be used in agriculture/soil amendment. The above crops have been grown in ash admixed soils at various proportions and the yields of various crops have shown a considerable increase.

Similar studies have also been conducted by CFRI, Dhanbad at NTPC Ramagundam (A.P) and by RRL Bhopal at Madhya Pradesh Electricity Board (MPEB), Sarni (M.P) and Captive Power Plant, National Aluminium Company (NALCO), Angul (Orissa). Since this involves use of Fly ash in a sensitive area involving food chain, follow up studies at the above sites are conducted under the supervision and control of Indian Council of Agricultural Research (ICAR) under the aegis of Fly Ash Mission (FAM) of Government of India. Fly ash mission has taken up a comprehensive study/demonstration programme covering about 55 sites spread all over country in different agro climatic conditions under 15 technology demonstration projects. The data are being generated, collected and monitored regularly by the experts teams drawing members from various institutes viz ICAR, ICMR, CSIR, Dept. of Atomic Energy, Agricultural Universities etc. Various extension activities like Kisan Melas, farmers get-together meets, awareness campaigns etc have motivated the farming community
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for the use of Fly ash in the agricultural fields. The positive outcome of these results is expected to encourage large-scale use of Fly ash in agriculture.

5.12 USE OF FLY ASH IN MINE FILLING

OPEN CAST MINES
Use of ash in back filling of open-cast mines and stowing of underground mines, can be a major area of utilization of ash. In open cast mine after extraction of coal and completion of mining operation, mines are back-filled with over burden materials and remaining area can be backfilled with ash. In India most of the open cast mines are quite young and back filling operation is yet to start.

In Singrauli region, M/s Northern Coal Field Ltd. (NCL) has abandoned Gorbi mines for back filling operation using ash. In Talcher regions, Mahanadi Coal fields Ltd. (MCL) had abandoned South Balanda mine for back filling operations using ash. For these mines Environment Impact Assessment including hydro-geological studies are being carried out in associations with Central Mine Planing & Design Institute (CMPDI) by NTPC.

UNDER GROUND MINES
In case of under ground mines the conventional material for back filling is river sand.

Front view of ash stowing hopper for stowing ash at mine end
NTPC has got studies conducted (including field trials) through Central Mining Research Institute, Dhanbad for use of bottom ash from our station at Ramagundam for stowing operation in the under ground mines of Singreni. The study indicates that it is technically feasible to utilize bottom ash in stowing operations. More than 1,00,000 tonnes of bottom ash has already been stowed in these underground mines. Fly Ash Mission along with CMRI-Dhanbad has taken up two projects at the underground mines of Western Coalfields Ltd., Chandrapur and at Singreni Colliery Companies Ltd., Manuguru utilising pond ashes from nearby power stations.

5.12 OTHER USES:

5.12.1 FLOOR TILES AND WALL TILES

Fly ash can be utilized in manufacture of floor tiles and wall tiles with fly ash content up to 50%. These tiles are stronger than conventional masonry tiles. Tiles also have been developed to use in exterior part of building to give much longer life, even in coastal area. The technology has been developed by Central Power Research Institute, Bangalore.

Ash based floor tiles being manufactured at NTPC, Dadri
5.12.2 MANUFACTURE OF DISTEMPER

Fineness and pozzolanic nature of fly ash can be advantageously utilized in replacing the commonly used white cement as a base material for the preparation of distemper. Distemper manufactured using fly ash has been utilized in many buildings at Neyveli in the interior surfaces and the performance is satisfactory.

5.12.3 USE OF FLY ASH IN REFRACTORY BRICKS

At Neyveli Central laboratory, the process for manufacture of fly ash based thermal insulation bricks has been developed. In this process the bricks are manufactured using finer grade of fly ash, good quality of lime and foaming compund (aluminium powder). These bricks are considerably cheaper and their performance, in comparison with other commercially available bricks is also good. Fly ash can also be utilized in manufacture of acid resistant bricks. The process has been developed by Central Power Research Institute, Bangalore.

5.12.4 FLY ASH BASED CERAMICS

Fly Ash can be used to produce wear resistant Ceramics of various shapes. The extremely dense, hard, and impenetrable ceramics have superior resistance to abrasion and can be extensively used as lining in material handling equipment. Use of such ceramics substantially decreases maintenance cost and increases the life of components to almost 8-10 times that of a metal. The National Metallurgical Laboratory, Jamshedpur has developed process to produce various fly ash based ceramic products which are ready for commercialization. These products are:

i) Mullite Aggregates for Refractory castables.
ii) Ceramic floor and wall tiles.
iii) Heat and Sound Insulation sandwich panels.
iv) Polished resistant type tiles.
v) Wear resistant ceramic products.

CGCRI-Ahmedabad has developed a technology under one of technology demonstration projects of FAM for use of fly ash in ceramic products namely.
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i) Unglazed semi-vitreous ceramic tiles for flooring, facing & paving.

ii) Glazed wall tiles

iii) Crockery & noveltyware

iv) Ceramic water filter candle.

The technology uses about 20-40% fly ash in the raw mix, which replaces scarce conventional materials like china clay, ball clay etc.

5.12.5 USE WITH FERRO-CEMENT:

Ferro-cement is used for manufacture of fishing fleets, coastal streamers, pleasure boats, floating marine units and barges, modular housing units and all kinds of prefabricated self contained units. When fly ash is added with ferro-cement it improves its workability, increases the strength, increases corrosion resistance and sulphate resistance, besides reducing the cost.

5.12.6 RECOVERY OF METALS FROM FLY ASH

Fly ash contains large quantity of silica (SiO₂), Alumina (Al₂O₃) and Ferric Oxide (Fe₂O₃), with small quantities of various other oxides and alkalis. Alumina can be extracted by direct acid leach process. By using magnetic separators during process of alumina extraction, Magnetite can be separated. The Magnetite recovered from fly ash is better than commercially available Magnetite. Germanium, Gallium and Vanadium can also be extracted from fly ash.

5.12.7 USE OF FLY ASH IN GROUTING

Fly ash can be utilised in grouting. The main properties of fly ash which make it usable in grouting are its high fineness, spherical particle shape, low unit weight and pozzolanic activity. There are several types of grouts where in fly ash can be utilized.

1) Grouts containing only fly ash.

2) Lime fly ash grout.

3) Portland cement-fly ash grouts.
(4) Portland cement-fly ash-clay grouts
(5) Portland cement fly ash, sand grouts.

There is no special technique or equipment required for fly ash grouting. The grouting procedure for non-fly ash grouts are applicable to grouts containing fly ash as well.

5.12.8 MANUFACTURE OF ALUM:

Fly ash contains about 25-30% of $\text{Al}_2\text{O}_3$. This helps to manufacture Alum (Aluminium Sulphate) from fly ash. The process for the same has been developed at NTPC’s Farakka Unit. This process has several advantages:

(a) Fly ash obtained from power station is of the size 75 micron or less which is required for extraction of $\text{Al}_2\text{O}_3$ from any mineral. Extra energy cost for pulverization is saved.
(b) Easy availability of raw material.
(c) Simple process as compared to other conventional processes.

5.12.9 EXTRACTION OF CENOSPHERES

A small proportion of fly ash, normally between 1 to 2% by weight, consists of hollow spherical particles with a specific gravity less than unity. These particles are known as cenospheres. Cenospheres float on water and can be collected from surface of lagoons. The cenospheres have variety of applications in super insulating material, fire proofing fabrics, fire retardants, noise pollution control, light weight floating concrete etc.

5.12.10 DOMESTIC CLEANING POWDER

The fine particles of fly ash composed of silica and alumina are sufficiently abrasive in nature and also possess a large surface area. These properties can be effectively used in developing domestic cleaning powder. The performance of this powder is found equal to that of commercially available cleaning powders. Metalware, porcelain, and tiled glass are cleaned well with this powder. Use of fly ash in this field is advantageous as it is available in large quantities and in a form that needs minimum processing. The technology is available with Neyveli Lignite Corporation, Neyveli.
5.12.11 MANUFACTURE OF ARTIFICIAL / SYNTHETIC WOOD

Regional Research Laboratory, Bhopal has developed a 100% wood substitute product named R-Wood and transferred the technology to M/s. Duval & Visual Group Company, Madras. R-Wood is based on the use of industrial wastes such as red mud from aluminium industries and fly ash from thermal power plants. Central Public Works Department (CPWD), Government of India has banned the use of wood in its works from April 1993 and subsequently approved R-Wood products as a substitute for timber. The Building Materials Technology Promotion Council of the Ministry of Urban Development, Government of India, has supported the project. M/s. Roy Research and Technology, Calcutta have also carried out work in this area.

5.12.12 MANUFACTURE OF FERTILIZER

Fly Ash mixed with dewatered sewage sludge can be utilized in manufacture of fertilizer. M/s. N-VIRO of USA have developed a process for production of N-VIRO Soil which can be used in agricultural and horticultural projects.

In N-VIRO process raw material required are dewatered sewage sludge with 14-40% solids and contaminants, alkaline reagents i.e. dry fly ash and CaO with minimum 80% purity. In this process when sewage sludge and alkaline reagents are mixed, chemical reaction takes place between sludge and alkaline reagents raising the temperature and pH level. These reactions combined with other stresses, kill disease causing bacterial and pathogens. N-VIRO soil improves physical properties of soil, increases plant nutrients and acts as liming agent in case of acid soils and results in increased crop yield.

M/s Roy Research and Technology has also developed fly ash based Synthetic soil enriched with ligno-cellulosic nitrogen with all the bio-character. This synthetic soil will have total nitrogen including cellulosic nitrogen, water soluble nitrogen, phosphorus compound, zinc, copper, iron, boron and other stimulating agent. M/s Roy Research and Technology has a patent for this technology.