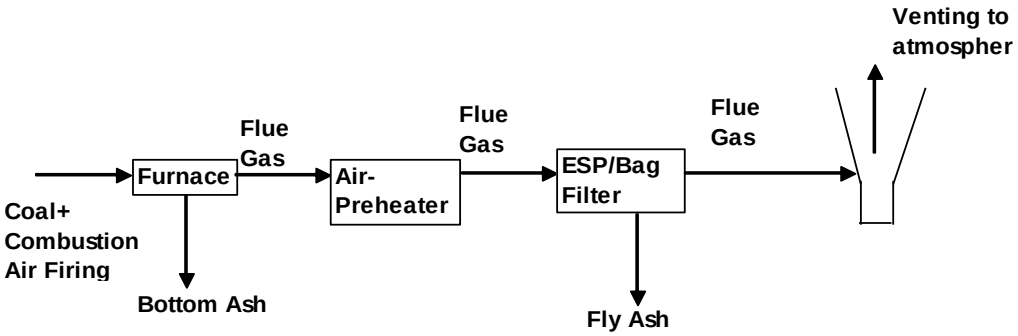
1.0 Background

Fly ash is a coal combustion by-product – a finely divided residue resulting from combustion of coal in power plants. In the thermal power stations, coal is pulverized into fine powder and pumped into the boiler along with compressed air. Coal powder is fired to generate heat, which in turn produces steam to run the turbine. After burning, the coarse ash or 'bottom ash' gets collected below the boiler. The finer particles of coal are collected in the Electro-Static Precipitators (ESP). This is Fly ash. The line diagram of how the fly ash is generated is given in Figure 1.1 below.

Figure 1.1 Fly ash and bottom ash generation



The ashes generated in the thermal power stations (TPS) are mixed with water and sent to ash pond for storage and further disposal. Storage of fly ash in ponds further requires large quantities of water (average ash: water ratio is 1:12), involving huge capital and operating costs in setting up and running the mixing, pumping and transportation facilities.

India is the 3rd largest producer of coal in the world after china and USA. However Indian coal is characterized by high ash content (35 to 48 % compared to 8 to 10 % in developed countries like USA, Japan, Germany, France etc.) and low calorific value. With more than 50% of electricity generation ion the country being coal- based and with high ash coal, it is estimated that The total ash being generated by 81 thermal power stations pertaining to various Power Utilities works out to about 117 Million Tonnes per annum. It is estimated that for the total thermal capacity of coal/lignite based TPSs by end of 11th Plan, the ash generated in the form of fly ash (80-90%) and bottom ash (10-20%) would be of the order of 173 Million Tonnes per annum considering 38% ash content in coal as an average and at 80% PLF (CEA 2009-10) It is further estimated that only about 51% of the ash generated found gainful utilization. Given the fact that economic growth of the Nation is generally linked to power availability and given the trend of high proportions of coal based thermal power stations (TPS), fly ash generation is likely to increase in future. It is estimated that about 160 Mt of ash will be generated by the end of 11th Five Year Plan which will likely to grow over 200Mt by the 12th Plan.

2.0 Characteristics of Fly ash

The chemical and physical properties of fly ash depend upon many parameters such as coal quality, type of coal pulverization and combustion process followed nature of ash collection and disposal technique adopted, etc.

2.1 Physical Properties

Flyash is generally gray in colour, abrasive, acidic (in some cases it may be alkaline depending upon the characteristics of the coal) and refractory in nature. Its specific surface area varies between 4,000 and 10,000 cm2/g, which is more than cement, which has a specific surface area of about 3,000 to 3,500 cm2/g. Morphologically, flyash consists of 3 types of particles – irregularly shaped particles, solid spheres and cenospheres. The fly ash particles range in size from about 115 microns to about 5 microns. It has unburnt carbon, cinders, minerals etc. and has pozzolanic characteristics.

2.2 Chemical Composition

Flyash is known to consist of small spheres of glass of complex chemical composition and crystalline constituents, which are mainly quartz (SiO_2), mullite ($3Al_2O_3.2SiO_2$), magnetite (Fe_3O_4) and haematite (Fe_2O_3). Except Neyveli flyash, which is high in CaO (5.0 - 16.0 %) and MgO contents (1.5 – 5.0 %) and low in SiO2 content (45.0 – 59.0 %), the range of chemical composition of Indian fly ashes is given in Table 2.2 along with corresponding data for British and American fly ashes.

Table 2.2 Typical Chemical Composition (% by w/w) of Fly ash

Composition	Indian fly ash	British fly ash	American fly ash	German fly ash
Silica as SiO_2	45 – 65.25	41.5 – 47.8	35 – 52	42.0 - 56.0
Alumina as Al_2O_3	14 – 31.10	26.4 – 29	15 - 32	24.0 - 33.0
Iron Oxide as Fe_2O_3	3 – 15.0	9.1 – 13.9	8 - 25	5.4 - 13.0
Calcium Oxide as CaO	0.1 – 6.5	4.2 – 5.3	0.7 – 8.0	0.6 - 8.3
Magnesium Oxide as MgO	0.2 – 3.9	1.5 – 1.9	0.3 – 1.5	0.6 - 4.3
Sulphur as SO_3	0.4 – 1.8	0.7 – 1.7	0.1 – 2.8	0.1 - 1.9
Loss on Ignition (LOI)	1 – 11.3	1.7 – 7.3	1.3 – 13.0	0.8 - 5.8

From the above data it can be seen that Indian fly ashes are more silicious and contain higher percentage of unburnt carbon as compared to American / German / British fly ashes.

3.0 Fly ash utilization

Ash utilization data from different TPS shows that over the years there has been a substantial increase in amount of ash dispatched. The utilization increased six fold from 9.2 Mt in 1998- 99 to 66.64 Mt in 2008 -09. The actual ash generated during 2008 -09 was 116.69 MT and ash utilized was 66.64 MT and the overall utilisation percentage was 57.11.

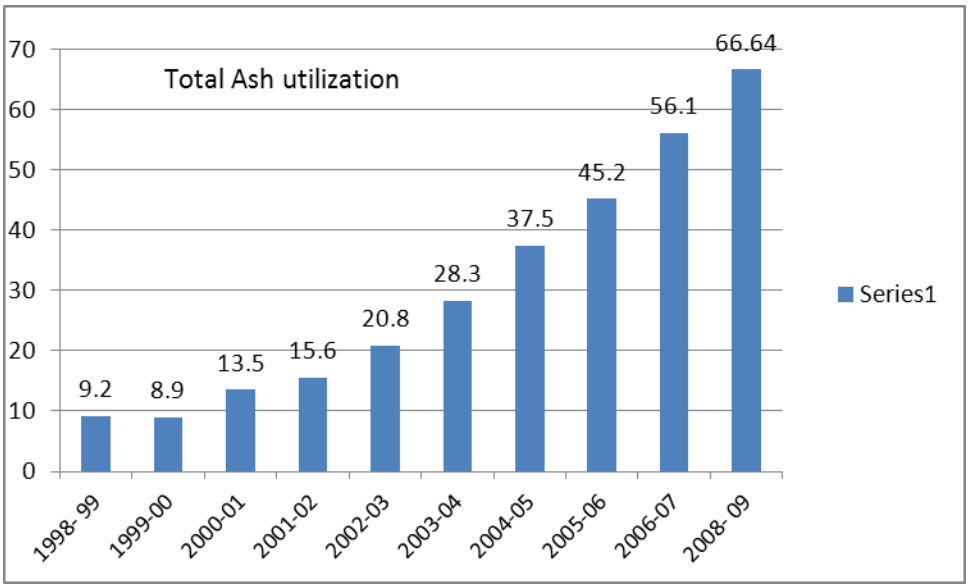


Figure 3.0 Total Ash utilization (1998-99 to 2008-09) (Mt)

Source CEA(2009-10)

Figure 3.1 shows the share of different user sectors in total ash utilisation. Cement sector utilized around 43% of total ash generated in the year 2008 -09. Construction of roads and embankments (17%) and Reclamation of land (12%) were the other large users.

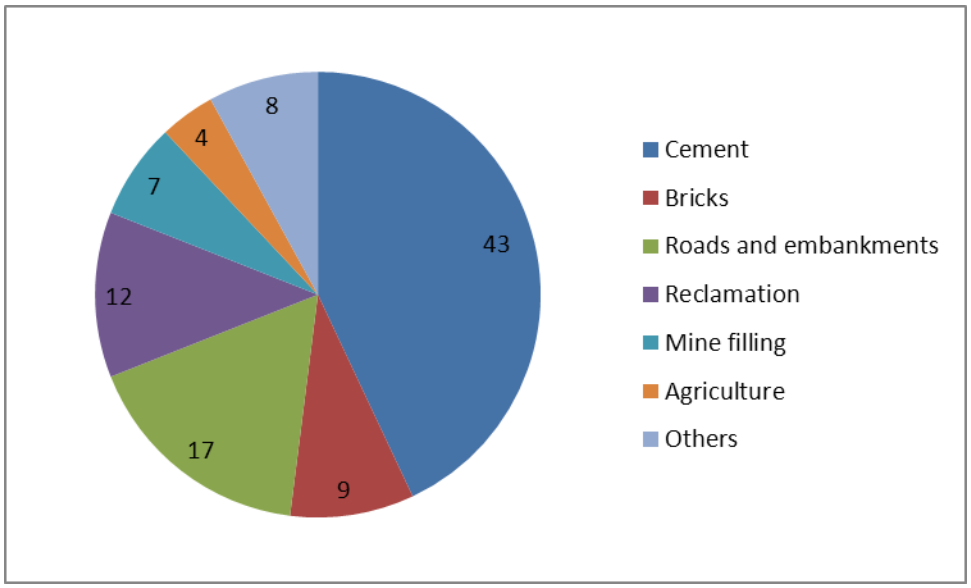


Figure 3.1 Mode of fly ash utilisation sector-wise for the year 2008 - 09

Source CEA (2009-10)

4.0 Fly ash utilization in brick manufacturing

India is second largest producer of the brick in the world after China. The brick production in India is estimated at 140 billion bricks, consuming 24 million tonnes of coal along with huge quantity of biomass fuels. The total CO_2 emissions are estimated to be 41.6 million tonnes and it accounts for about 4.5% of total GHG emissions from India. Box 1 represents the fact sheet of Indian brick industry. In the manufacture of bricks, fly ash can be an alternative material to clay. Fly ash can be used either with clay as part replacement or in combination with other materials like sand, lime, gypsum etc. to produce a substitute to conventional clay bricks.

BOX 1: Fact Sheet of the Indian brick industry

- Brick production : > 1400 billion/year
- Annual turnover: > Rs 100 billion
- No of units: > 0.1 million
- Employment: 80 to 100 million people
- Energy and Environment
  - Coal : 24 million tonnes
  - CO_2 generation – 42 million tones
  - Top Soil: 350 million tones

Source: TERI (2001)

From the soil to be used for brick manufacturing, India can be divided into three broad regions – Northern Mountanious region, Indo-Gangetic plains and peninsular region. Mountanious soil is coarse and contains parts of partially wathered rocks. The presence of brick industry in mountainous region is negligible. The Indo-Gangetic soil is 'alluvial' in nature formed by deposition of river Ganges and its tributaries. The soil is considered good for brick manufacturing and has faint yellow colour and is generally a mixture of fine sand,silt, clay and organic matter. The Peninsular soils are generally black cotton, red or lateritic in nature. They are generally considered difficult for brick making.

When fly ash is used as an admixture to plastic soil / clay for the production of fired clay bricks, fly ash reduces the plasticity of the raw-mix (thereby reducing the drying time and shrinkage cracks) and improves the texture of the product. Addition of fly ash also increases the 'internal burnability' of the green brick due to the presence of un-burnt carbon (proportionately reducing the requirement of 'external' fuel).

The technologies for the manufacture of fly ash bricks can be classified into the following main technology routes:

- Clay – fly ash bricks
- Red mud – fly ash bricks
- Sand fly ash bricks
- Fly ash – lime bricks
- Fly ash – lime / gypsum bricks

In general the soil is composed of different fractions namely, clay (particle size less than 2 microns), silt (particle size between 2 – 20 microns) and sand (particle size more than 20 microns). As per IS: 13757:1993 Burnt Clay Fly Ash Building Bricks: Specifications), clay fly ash bricks shall be hand or machine moulded and shall be made from the admixture of suitable soils and fly ash in optimum soils and fly ash in optimum proportions. As per IS 2117:1991(Guide for manufacture of hand-made common burnt clay building bricks), the clay or mixture of clay selected for brick manufacturing should preferably conform to the following mechanical composition:

Clay 20 to 30 percent by mass

Silt 20 to 35 percent by mass

Sand 35 to 50 percent by mass

The total content of clay and silt may preferably be not less than 50 percent by mass.

A number of measures are being taken to encourage various sectors to utilize fly ash. The targets of ash utilization are primarily governed by the MoE&F Notification dated 14th September, 1999 and its amendment Notification dated 27th August, 2003 & 3rd November, 2009 as well as Hon'ble High Court of Delhi directions vide its judgments dated 4th December, 2002, 10th March, 2004 as well as 5th August, 2004.

Suitability of mixing fly ash with clay for producing fired bricks

Two cases are being presented here related to production of clay-fly ash fired clay bricks:

Case 1: TIFAC in their report on Fly ash bricks has mentioned that with regard to requirements of fly ash for brick manufacture, it is desirable that the oxide composition should be similar to ordinary brick clays – the silica content should be over 40%, aluminium oxide not less than 15%, iron oxide not less than 5% and sulphide and soluble sulphite content should be insignificant. The report further mentions that the range of chemical compositions of Indian fly ashes indicates that they are suitable for brick making. However, not all the clays and fly ashes are suitable for brick making. Fly ash addition as a smaller constituent (8% - 20%) to the alluvial soil or as a larger constituent (25% - 40%) with sticky plastic alluvial red and black soils has been found advantageous to improve workability, green and fired strength and to modify drying behaviour of soils so as to check the incidence of cracking and fuel value of residual carbon. The characteristics of clay-fly ash bricks manufactured using alluvial, black and red soil region/ sites is provided in the following table:

Table Characteristics of clay fly ash bricks manufactured in alluvial, black and red soils region

Soil Type	Brick manufacturing site / soil group	Proportion of fly ash (w/w %)	Properties of bricks fired at 1000 + 200C		
			Compressive strength (kg/cm^2)	Water absorption (%)	Bulk density (g / cc)
Alluvial Soil	Haridwar	8 - 10	140 - 170	10 - 16	1.6 – 1.75
	Roorkee	8 - 10	135 - 170	10.5 - 16	1.62 – 1.75
	Faridabad	15 - 20	100 - 150	12 - 15	1.6 – 1.7
	Delhi	15 - 20	116 - 160	11 - 16	1.6 – 1.75
	Kanpur	15 - 20	170 - 200	10.5 - 12	1.68 – 1.77
Red soil	Korba	30 – 35	160 - 175	11.3 - 16	1.6 – 1.74
	Ramagundam	30 - 35	65 - 82	13.5 – 18.5	1.62 – 1.7
	Obra	20 - 25	150 - 160	16.4 – 18.3	1.65 – 1.72
	Singrauli	25 - 30	100 - 150	12 - 15	1.75 – 1.85
	Barauni	40	250 - 300	14 – 15	1.41
	Patratu	25	120 - 125	16 - 17	1.45 – 1.6
	Bokaro	40	100 - 125	20- 21	1.2
	Kargali	25 - 40	75 - 120	19 - 20	1.5 – 1.7
	Haldia	10	180 - 200	15 – 17	1.65 – 1.7
	Patherdih	25 – 40	85 - 100	16 - 20	1.5 – 1.7
	Durgapur	25 - 35	85 - 120	15 – 17	1.45 – 1.65
Black soil	Nasik	33 – 40	130 - 155	13.5 – 15.7	1.65 – 1.75
	Indore	33 - 35	65 - 80	14.5 – 18	1.58 – 1.7

Source: TIFAC report on Fly ash bricks page no. 180

Following advantages of clay fly ash bricks are mentioned in the report:

- Brick confirming to IS: 3102 – 1976 can be manufactured
- Fuel saving in the range of 15% - 35% (coal consumption) or coal saving up to 3 – 7 tonne per lakh bricks
- Drying losses are checked in the case of plastic black and red soils. Excessive linear drying shrinkage is reduced
- Brick strength in the case of black and red soils is increased by almost one and a half times (30% - 50%)

- Waste material is utilized. 30 – 40 tonne per lakh bricks in case of alluvial soils and 100 – 125 tonnes per lakh bricks in case of red and black soils
- Clay saving in brick manufacture is 10% - 40% by weight

Case 2: Aligarh Muslim university (AMU) carried out a feasibility study for mixing fly ash into the manufacture of fired clay bricks. AMU took samples of soil from the three brick kiln sites of Aligarh and Hathras districts of Uttar Pradesh. The fly ash sample was collected from the Kasimpur TPS that was within the designated distance of brick kilns as per the 1999 notification of MoEF. During the study the fluash was mixed with sol in different proportions 5%, 10% and 20% by weight and the bricks were moulded under usual working conditions (same workmen , drying and firing conditions). The following observations were made:

- Fly ash and soil mix requires more water and labour in comparison to soil without fly ash for making brick.
- Bricks moulded from soil and fly ash mix requires three times the longer duration to dry in comparison to bricks without fly ash
- Breakage in handling of green bricks was more in case of soil containing 20% fly ash
- A distinct change in colour was noticed in bricks containing 20% fly ash as compared to bricks without fly ash. The reddishness in colour was less in bricks with 20% fly ash.
- For the three soil samples collected from Uttar Pradesh, the following change in properties were found while comparing with properties of the bricks without fly ash :

	20% Fly ash	10 % Fly ash	5 % Fly ash
Reduction in compressive strength	Sample 1: 72.4 %, Sample 2: 82.5 %, Sample 3: 58.65 %	Sample 1: 42 %, Sample 2: 64.7 %, Sample 3: 1 %	39 %, 59.57 %, Sample 1: 39 %, Sample 2: 59.57 %, Sample 3: increase by 18.6 %
Increase in water absorption	Sample 1: 91.4 %, Sample 2: 119.12 %, Sample 3: 17 %	Sample 1: 66.3 %, Sample 2: 71.98 %, Sample 3: Not significant	Sample 1: 83.9 %, Sample 2: 87.52 %, Sample 3: Not significant
Efflorescence	Nil (All samples)	Nil (All samples)	Nil (All samples)

During the study, the black cotton soil using fly ash from the Virudhu Nagar district of Tamil Nadu was also included and fly ash was mixed in the proportion of 40 – 70 % by weight. It was found that up to 50 % mixing of fly

ash the compressive strength increased and water absorption decreased and with increased proportions of flay ash compressive strength decreased and water absorption increased.

The following conclusions were drawn from the study:

- The percentage of fly ash by weight that can be mixed in soil for manufacturing fired clay bricks depends upon the physical properties of soil and it should not be mixed arbitrarily
- On the basis of tests carried out in three sites in Aligarh and Hathras districts, the maximum percentage of fly ash by weight that can be mixed in soils is not more than 5 – 10 %. It may further reduce depending on the physical properties of soil.
- Determination of physical properties of soil is essential before mixing fly ash with soil for manufacture of burnt clay fly ash bricks.

The use of fly ash in brick making has many advantages and TIFAC has undertaken many initiatives to promote the use of fly ash in brick making. However, most of the brick kilns in the Indo-Gangetic belt have not used fly ash for manufacturing bricks due to following possible reasons:

- The hand-moulding process is generally used for green brick making in this region and mixing of fly ash with clay is difficult by hand moulding. Further, brick kiln owners felt that no appropriate technology is available for mixing of clay and fly ash at the scale that is presently being produced by hand moulding.
- Difficulty in logistic arrangements by individual brick kiln entrepreneur for procurement of less quantity from Thermal Power plant and transportation of fly ash to the brick making sites.
- Increase in the cost of the product due to increase in transportation and mixing cost with no additional premium being fetched by fly ash product in the market.
- Market perception of requirement of red coloured bricks also discouraged the brick kiln owners to start producing fly ash bricks that generally have grey colour of final product.
- Non-availability of reliable and low-cost technology for clay-fly ash brick making

The use of fly ash for brick making is quite popular in few States like Maharashtra where the soil quality is such that the addition of fly ash improves the properties of soil for brick making.

The benefits from the manufacture and use of fly ash bricks result in reduced energy use, conservation of top soil and qualifying under clean development mechanism etc. But in spite of these benefits, barriers on account of non-availability of reliable clay-fly ash bricks making machinery, mindset of users, lack of awareness etc. pose significant barriers in tapping the potential of brick making as a gainful use of fly ash.

Reference

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