Fly Ash Utilization: A Brief Review in Indian Context

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Abstract: Power Industry has been, and continues to be, a key factor in the economic growth of most of the developed and developing countries. In general, the power sector represents the industries with highest environmental impact and has constantly been subject of increasing pressure from new economic, energy saving and environmental issues. Coal based Power Generation has been the backbone of the any developing country. Indian coal is of low grade, having ash content as high as 45% in comparison to imported coals which have low ash content of the order of 10-15% (CEA, 2014-15). Thus, a large amount of ash is being generated by the coal based thermal power plants in India, which not only requires huge areas of precious land for its disposal and management, but, is also one of the major sources of pollution of air, water and soil. This article attempts to underline the uses of this industrial solid waste to make an efficient tool for management of fly ash. To save our environment more research and development needed to discuss the above stated issues.

Keywords: Fly ash, Generation**,** XRD, Thermal Power Plants, Heavy Metals, Environmental Management.

Introduction: Coal based thermal power plants, contributing to the 61.5 percent of total installed power capacity, are the major source of electricity generation in India (CEA, 2015). Most of industries are using pulverized coal as the fuel, producing enormous quantities of coal fly ash every year. India has 211 billion tonnes of coal reserves. Indian coal used in thermal power plants is of low grade quality and has an ash content of 40 to 50% (Theis et al., 1978). The power generation in India was about 200,000 MW in 2012 and it is expected to increase up to 300,000 MW by 2017. The present fly ash generation rate is about 131.09 million tonnes per year and the utilization rate of coal is 73.13 million tonnes per year (Singh and Gupta, 2014). The coal reserve of India is about 200 billion tones (bt) and its annual production reaches 250 million tonnes (MT) approximately. About 70% of this is used in the power sector. In India, unlike in most of the developed countries, ash content in the coal used for power generation is 30–40%. High ash coal means more wear and tear of the plant and machinery, low thermal efficiency of the boiler, slogging, choking and scaling of the furnace and most serious of them all, generation of a large amount of fly ash. India ranks fourth in the world in the production of coal ash as by-product waste after USSR, USA and China, in that order. Fly ash is defined in Cement and Concrete Terminology (ACI Committee 116) as the 'finely divided residue resulting from the combustion of ground or powdered coal, which is transported from the fire-box through the boiler by flue gases'. Fly ash is fine glass powder, the particles of which are generally spherical in shape and range in size from 0.5 to 100 µm. Fly ash is classified into two types according to the type of coal used. Anthracite and bituminous coal produces fly ash classified as class F. Class C fly ash is produced by burning lignite or sub-bituminous coal. Class C fly ash has self-cementing properties. Fly ash generation & utilization data for the Years 2011-12 and 2012-13 has been received from 124 (One hundred twenty four) and 138 (One hundred thirty eight) coal/lignite based thermal power stations of various power utilities in the country. statistics received has been analyzed to derive conclusions on present status of fly ash generation and its utilization in the country as a whole. A brief summary of status is given in Table-I below:

TABLE-I

SUMMARY OF FLY ASH GENERATION AND UTILIZATION DURING THE YEAR 2011-12 AND 2012-13				
Description	**2011- 12**	**2012-13**	**2013-14**	**2014-15**
Nos. of Thermal Power Stations from which data was received	124	138	143	145
Installed capacity (MW)	1,05,925.3	1,20312.30	1,33,381.30	1,38,915.80
Coal consumed (Million tons)	437.41	482.97	523.52	549.72
Average Ash Content (%)	33.24	33.87	172.87	184.14
Fly Ash Generation(Million tons)	145.42	163.56	99.62	102.54
Fly Ash Utilization (Million tons)	85.05	163.56	57.63	55.69
Percentage Utilization	58.48	61.37	33.02	33.50

Source: CEA (CENTRAL ELECTRICITY AUTHORITY)

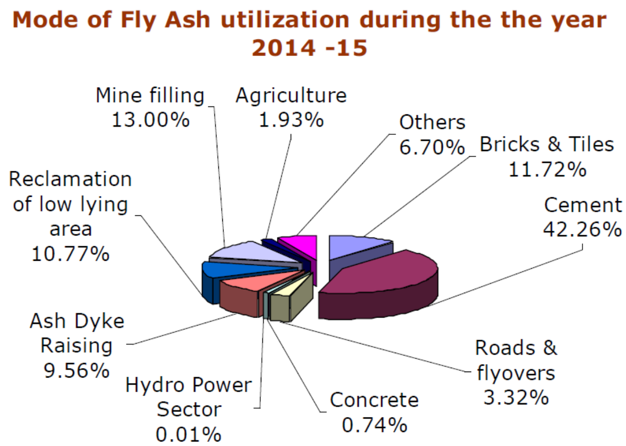

Figure 1: The pie diagram showing the modes of utilization of fly ash during the Year 2014-15

Source: CEA (CENTRAL ELECTRICITY AUTHORITY)

The maximum utilization of fly ash, during the Year 2014-15, to the amount of 42.26 % of total fly ash utilized was in the Cement sector, followed by 13.00 % in mine filling, 11.72 % in making bricks & tiles, 10.77 % in reclamation of low lying area, 9.56 % in ash dyke raising, 3.32 % in roads & embankments, 1.93 % in Agriculture, 0.74 % in Concrete, 0.01 % in Hydro Power Sector & 6.70 % in Others etc (CEA, 2014-15).

Effluent and disposal: Scientific disposal and management of fly ash is still a most important problem by coal based thermal power plants. Fly ash emissions from a variety of coal combustion in thermal power generation units prove a broad range of composition. All elements below atomic number 92 are present in coal ash. The fine particles of fly ash reach the pulmonary region of the lungs and remain there for long periods of time; they behave like cumulative poisons. The residual particles being silica (40–73%) cause silicosis. All the heavy metals (Ni, Cd, Sb, As, Cr, Pb, etc.) generally found in fly ash are toxic in nature. Fly ash can be disposed-off in a dry or wet state. Studies show that wet disposal of this waste does not protect the environment from migration of metal into the soil (Senapati et. al, 1999). Heavy metals cannot be degraded biologically into harmless like other organic waste. Studies also show that coal ash satisfies the criteria for landfill disposal, according to the Environmental Agency of Japan (JEAN, 1973). According the hazardous waste management and handling rule of 1989, fly ash is considered as non-hazardous. With the present practice of fly-ash disposal in ash ponds (generally in the form of slurry), the total land required for ash disposal would be about 82,200 ha by the year 2020 at an estimated 0.6 ha per MW. Fly ash can be treated as a by-product rather than waste (Matani, 1982).

ENVIRONMENTAL PROBLEMS: Environmental pollution by the coal based thermal power plants all over the world is cited to be one of the major sources of pollution affecting the general aesthetics of environment in terms of land use, health hazards and air, soil and water in particular and thus leads to environmental dangers (Ashoka et al., 2005). The greatest part of the radioactivity in coal remains with the ash but some of the fly ash from coal-fired power plants escapes into the atmosphere (Pvrecek, Lbendik, 2003). Air pollution in the vicinity of a coal fired thermal power station affects soil, water, vegetation, the whole ecosystem and human health (F˙IL˙IZ G ¨ UR and G ¨ UNSEL˙I YAPRAK, 2010).

FLYASH UTILIZATION : A large number of technologies have been developed for productive utilization and safe and sound management of fly ash under the concerted efforts made by Fly Ash Mission/Fly Ash Unit under Ministry of Science & Technology, Government of India since 1994 and the utilization of fly ash has increased from 6.64 million ton in 1996-97 to a level of 102.54 million-ton in 2014-15. (CEA, 2014-15). Fly ash management has taken considerable strides over the past few years. Researchers have been attempting to convert this by product of coal into wealth by means of exploring viable avenues for fly ash management. Fly ash is oxide-rich and can be used as the raw material for different industries and construction. Few common modes of fly ash utilization that are presently followed in India are as follows:

Cement Industry- Fly ash is being currently used by Cement Industries as a pozzolanic material for manufacturing of Portland Pozzolana Cement (PPC). It saves both precious lime stone and coal. The utilization of fly ash in manufacturing of cement is highly value added use. It may be seen from Figure-2 below that 2.45 million-ton of fly ash was used by Cement Industry in 1998-99 which increased to 43.33 million-ton during 2014-15 and constituted 42.26 % of total fly ash utilization in the aforesaid year. (CEA).

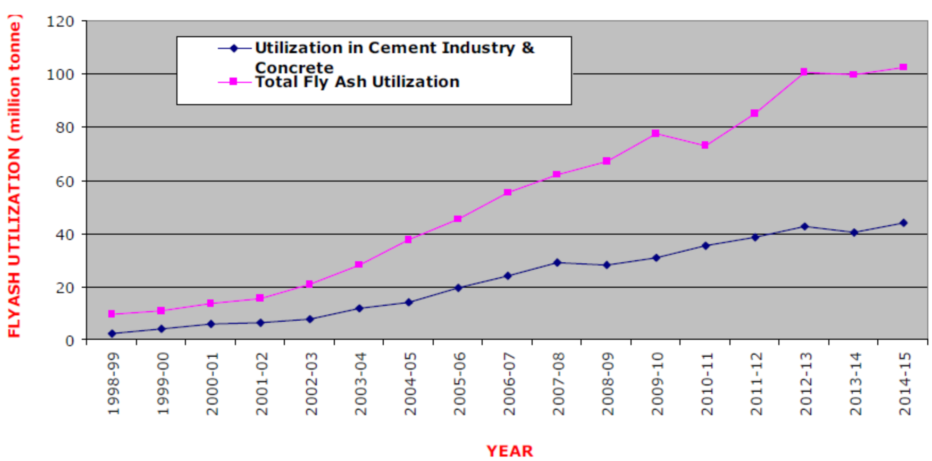

Figure 2: progressive utilization of fly ash by Cement Industry for the period from 1998-99 to 2014-15
(Source: Central Electricity Authority, annual report, 2014-15)

Reclamation of Low Lying Areas- Fly ash is also being used for reclamation of low lying areas which results in saving of fertile top soil. It may be seen that 4.17 million-ton of fly ash was used for reclamation of low lying area in 1998-99 which has increased to 11.04 million ton in 2014-15 constituting 10.77 % of total fly ash utilization during the aforesaid year. However, utilization under this mode has become stable availability wise (CEA, 2014-15).

Construction of Roads/Embankments/Flyovers and raising of Ash Dykes- Fly ash is being used in construction of roads/embankments/flyovers and the raising of ash dykes which results in saving of top fertile soil and it has a large potential for fly ash utilization. In the application of flyash as highway construction material (as soil stabilizer) for road bases, the importance is given to the self hardening properties of flyash (Mohapatra, el, 2001). It may be seen that 1.055 million-ton of fly ash was used in the construction of roads/embankments/flyovers and raising of ash dykes etc during 1998-99 which increased to 13.21 million-ton in 2014-15 and constituted 12.88 % of total fly ash utilization in the aforesaid year. However, falling trend in recent past is seen (CEA, 2014-15).

Back Filling/Stowing of Mines- Fly ash is being used for backfilling of open cast mines and stowing of underground mines which results in saving of top fertile soil and precious river sand. It may be seen that 0.65 million-ton of fly ash was used for backfilling/stowing of open cast and underground mines during 1998-99 which increased to 13.33 million-ton in 2014-15 constituting 13.00 % of total fly ash utilization in the aforesaid year and the trend is on increasing side(CEA, 2014-15).

Building Materials like Bricks, Blocks and Tiles etc. - Fly ash is being used in manufacturing of fly ash based building products like bricks, blocks, tiles etc which results in saving of fertile top soil. Fly ash based bricks/blocks/tiles are as good as clay based conventional building products. It has substantial potential of fly ash utilization especially for thermal power stations located near load centers(CEA, 2014-15).

Agriculture- Fly ash is being used as manure in agricultural sector as it has many micronutrients. Fly ash provides the uptake of vital nutrients/minerals (Ca, Mg, Fe, Zn, Mo, S and Se) by crops and vegetation, and can be considered as a potential growth improver. It serves as a good fertilizer. It may be seen that 0.70 million-ton of fly ash was used for making of fly ash based bricks/blocks/tiles etc during 1998-99 which increased to 12.02 million-ton in 2014-15 and constituted 11.72 % of total fly ash utilization in the aforesaid year(CEA, 2014-15).

Fly ash in distemper- Distemper manufactured with fly ash as a replacement for white cement has been used in several buildings in Neyveli, Tamil Nadu, in the interior surfaces and the performance is satisfactory. The cost of production will only be 50% that of commercial distemper(CEA, 2014-15).

Fly ash-based ceramics- The National Metallurgical Laboratory, Jamshedpur has developed a process to produce ceramics from fly ash having superior resistance to abrasion(CEA, 2014-15).

XRD ANALYSIS OF FLY ASH

The structural analyses of four random samples were carried out by using the X-ray diffraction pattern (XRD) obtained as shown in Figure 3. From figures it reveals that, the materials are composed of polycrystalline particles with good crystallinity. The XRD pattern on comparing with the standard JCPDS card 86-1563 for SiO_2 show characteristic peak at 2 theta values of approximately 22, 27, 38, 40 and 52 degree corresponding to (100)h, (011)h, (110)h,(102)h, and (112)h orientations. It results; there is a major portion of SiO_2 in the material. However, some other small peaks are also observed, which indicates the presence of other constituents of Fly Ash. By comparison with the data, all diffraction peaks can be indexed as hexagonal structure of SiO_2. The narrow peaks show that the material has good crystallinity preferentially oriented along the (011) direction which is the maximum intensity. On increasing pH level in the samples, there is no significant change in the position of peaks and no other peaks are observed. But intensity level of the peaks has been changed.

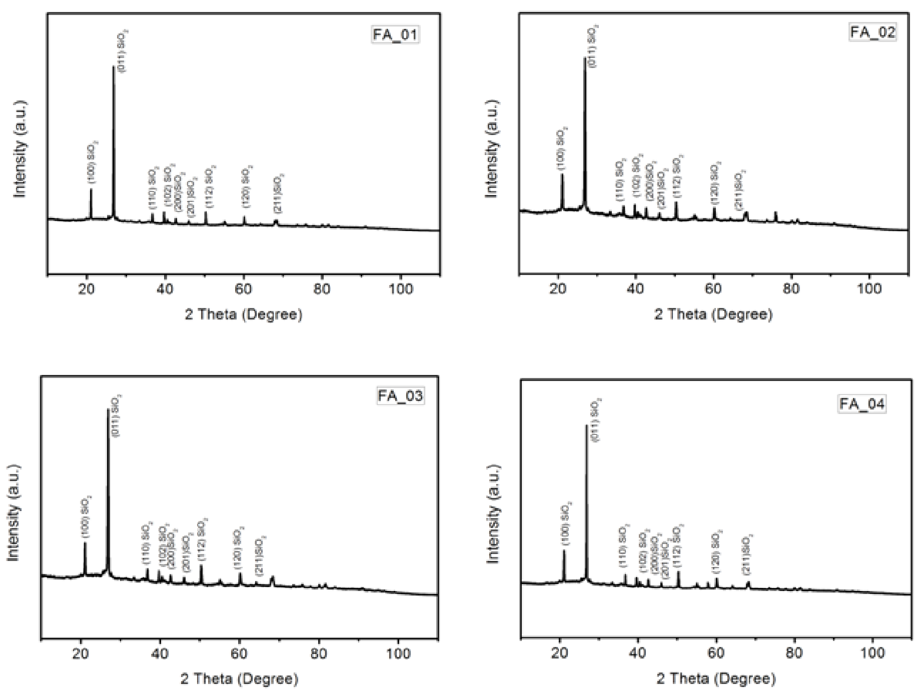

Figure 3: X-ray diffraction pattern (XRD) of Fly ash

CONCLUSIONS & RECOMMENDATIONS

Fly ash is a potential source of pollution and can have negative influences on water and soil because of their granulometric and mineral composition as well morphology and filtration properties. Fly ash is now recognized as valuable substances which confers certain advantageous characteristics in its many applications. Utilization of fly ash is already well established in a variety of construction works and waste solidification and stabilization process. There is urgent need to undertake research and development for studying the metal speciation and the change associated with fly ash reuse to utilize 100%. The chemical composition, morphology as well as the categorization of fly ash depends on coal quality and size distribution of particles despite the fact that reactivity of the ash seems to increase with surface area. Higher particle sizes low is the reactivity, so we have to take care of the fly ash to increase its grain size for different pH. Fly ash contains macro-nutrients such as N, P, and K and micro-nutrients such as Cu, Zn, Fe, and Mn in sufficient quantity for consideration for agricultural applications. Apart from these it also contains heavy metals like Pb, Hg, As, Cd, Se, Mo, Sc, Ni, V, and Zn in trace quantity. Trace metal concentration in the leachate depends on fly ash weight/solution, pH and concentration of the elements. Some of the problems associated with fly ash are land required for disposal and toxicity associated with heavy metals leached to ground water, so we have to treat it for higher grain size. The highest level of fly ash utilization of about 62.6% was achieved in the year 2009-10 and it is, however, 55.69 % in the year 2014-15 (CEA, 2014-15). Listed below are few of the many recommendations that can further enhance the utilization level of fly ash:

1. Modernization of coal/lignite based Thermal Power Stations.
2. Use of fly ash in the construction of embankments to lay railway lines and roads has too significant potential for large scale utilization of fly ash.
3. Thermal Power Stations have to ensure the utilization of fly ash itself.
4. The use of fly ash in Agriculture and waste land improvement has large potential.
5. Thermal Power Stations have to explore and promote all possible modes of fly ash utilization by establishing in-house research cell.

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