ISSN No. 2456-0472
The Engineering Journal of Application & Scopes, Volume 2,Issue 1, February 2017

Emerging Global Trends in the Utilization of Ash Produced in Thermal Power Stations

Anshul Tewari, Tribhuwan Singh Bora, Aditya Bhatt, G.C Misra
College Of Engineering Roorkee, Roorkee
Email: anshul.tewari.8@gmail.com

Abstract–Significant amount of flyash and bottomash is produced as a by-product of the combustion of fossil fuel in the Thermal power plants. With themanifold increase in electricity demand in the Asian continents and particularly in India, inspite of more focus on exploiting unconventional energy sources, dependency and enhanced impetus on the thermal power will continue in the future. Indian Coal available in abundance has inherent properties of higher Sulphur and ash content. So thermal power plants will continue to produce alarge amount of ash which pose big challenges in transfer, disposal & utilization in view of environmental hazards.Present paper deliberates on the key initiatives taken to maximize the Utilization of Ash to the more advantageous and fruitful applications, major issues involved, global outlook, bottlenecks and expected future scenario. Lots of concerted efforts are required at the earliest by the stakeholders viz. policy framers, power utilities, Research institutions, environmentalists, media, and Industries to formulate a time bound action plan for narrowing down the big gap between Ash Generation & Utilization.

Keywords–Fly Ash, Bottom Ash, Availability, Disposal and Utilization of Ash.

I. INTRODUCTION:

A. How Ash is produced:

Coal ash also referred to as coal combustion residuals or CCRs, is produced primarily from the burning of coal in coal-fired power plants.

B. About Fly Ash and Bottom Ash:

Two types of ash deposits — fly ash and bottom ash — were being collected from the boilers of the thermal power station; the first one mostly from the sides and upper portions of the boilers and the second from the bottom of boilers.

C. How much Ash is produced in India and its utilization:

Currently, more than 100 million tons of fly ash is being generated annually in India. 65000 acres of land is being occupied by ash ponds.

Over the years, ash consumption level has reached from meager 0.3 million ton in 1991 - 1992 to 30 million tons in 2012-13. The important areas for this utilization are cement industry, bricks industry, road embankment, mine filling, land development and ash dike raising.

D. Percentage increase in Ash Utilization:

A graph showing fly-ash generation and its utilization (in milliontons) for the period from 1996-97 to 2012-13.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. The percentage of fly ash utilization during 2014-15 is 55.69% which is behind the target set by MoEF vide its notification. Approximately 400 kg of coal is required to produce a megawatt/hr of electricity and 1 ton of coal produces 250-300 kg of fly ash and 20-30kg of bottom ash.

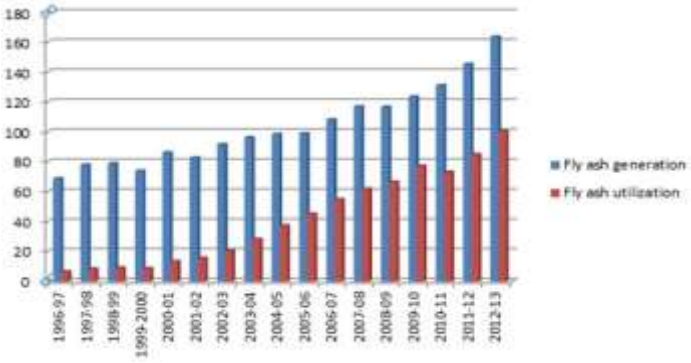

Fig. 1. Graph depicting the increase in fly ash production and utilization.

II. CHEMICAL COMPOSITION OF ASH:

The chemical properties of fly ash are influenced to a great extent by those of the coal burned and the techniques used for handling and storage.

There are basically four types, or ranks, of coal, each of which varies in terms of its heating value, its chemical composition, ash content, and geological origin. The four types, or ranks, of coal are anthracite, bituminous, sub-bituminous, and lignite. In addition to being handled in a dry, conditioned, or wet form, fly ash is also sometimes classified according to the type of coal from which the ash was derived.

Table 1 compares the normal range of the chemical constituents of bituminous coal fly ash with those of lignite coal fly ash and sub-bituminous coal fly ash. From the table, it is evident that lignite and sub-bituminous coal fly ashes have a higher calcium oxide content and alower loss on ignition than fly ashes from bituminous coals. Lignite and sub-bituminous coal fly ashes may have a higher concentration of sulfate compounds than bituminous coal fly ashes.

Table 1. THE NORMAL RANGE OF CHEMICAL COMPOSITION FOR FLY ASH PRODUCED FROM DIFFERENT COAL TYPES(EXPRESSED AS PERCENT BY WEIGHT).

Component	Bituminous	Sub-bituminous	Lignite
SiO_2	20-60	40-60	15-45
Al_2O_3	5-35	20-30	10-25
Fe_2O_3	10-40	4-10	4-15
CaO	1-12	5-30	15-40
MgO	0-5	1-6	3-10
SO_3	0-4	0-2	0-10
Na_2O	0-4	0-2	0-6
K_2O	0-3	0-4	0-4
LOI	0-15	0-3	0-5

III. ENVIRONMENTAL HAZARDS:

- Ash typically contains heavy metals including arsenic, lead, mercury, cadmium, chromium, and selenium, as well as aluminum, antimony, barium, beryllium, boron, chlorine, cobalt, manganese, molybdenum, nickel, thallium, vanadium, and zinc. if eaten, drunk or inhaled, these toxicants can cause cancer and nervous system impacts such as cognitive deficits, developmental delays, and behavioral problems. They can also cause heart damage, lung disease, respiratory distress, kidney disease, reproductive problems, gastrointestinal illness, birth defects, and impaired bone growth in children.
- The Environmental Protection Agency (EPA) has found that living next to a coal ash disposal site can increase your risk of cancer or other diseases. If you live near an unlined wet ash pond (surface impoundment) and you get your drinking water from a well, you may have as much as a 1 in 50 chance of getting cancerfrom drinking arsenic-contaminated water.

IV. VARIOUS ON-GOING PROJECTS:

- Fly ash based polymer products are also being used as wood substitutes. They have been developed by using fly ash as the matrix and jute cloth as the reinforcement. The Jute cloth is laminated by passing through a polymer fly ash matrix and then cured. The number of Laminates is increased to get the desired thickness. The product can be used in many applications like door shutters, partition panels, flooring tiles, wall paneling, and ceiling. The developed material is stronger more durable, resistant to corrosion and cost effective as compared to wood. This technology has been developed by the Regional Research Laboratory, Bhopal in collaboration with Building Materials and Technology Promotion Council (B.M.T.P.C) and TIFAC. One commercial plant has been set up based on this technology near Chennai, India.
- The Neyveli Lignite Corporation(NLC) has demonstrated the suitability of bottom ash as a construction material that has the potential to replace sand to compensate the scarcity of riverbed sand and also its fast rising prices.

Fig. 2.Neyveli Lignite Corporation

V. POLICY FRAMEWORKS:

A. *USA*

The Federal Government through the US Environmental Protection Agency(EPA) is currently developing regulations regarding the disposal of solid wastes under the Resource Conservation and Recovery Act of 1976. Part of the program involves classifying types of waste as to whether or not they are hazardous.Another part of the program involves developing regulations for the disposal of hazardous wastes. EPA is trying to develop standard criteria for classifying wastes.

B. *India*

The Ministry of Environment & Forests (MoEF), Govt. of India vide its notification (amendment) dated 3rd Nov 2009 has made it mandatory:

Major Projects where fly ash has been utilized:

1) *Within 100 Km radius of a Thermal Power Plant:*
   a) To use fly ash based building products such as cement or concrete, fly ash bricks, blocks, tiles etc. in all construction projects.
   b) To use fly ash in road or flyover embankment construction.
   c) To use fly ash in thereclamation of low lying areas.

2) *Within 50 Km radius of a Thermal Power Plant (By Road):*
   a) To use fly ash in backfilling of underground and open cast mines.
   b) Financial institutions to include a clause in their loan documents for compliance of this notification.

VI. CONVENTIONAL APPLICATIONS:

Many of the following uses are discussed further below. Coal ash uses include (approximately in order of decreasing importance):

- Concrete production, as a substitute material for Portland cement and sand.
- Embankments and other structural fills (usually for road construction).
- Agricultural uses soil amendment, fertilizer, cattle feeders, soil stabilization in stock feed yards, and agricultural stakes.
- Loose application on rivers to melt ice.
- Loose application on roads and parking lots for ice control.

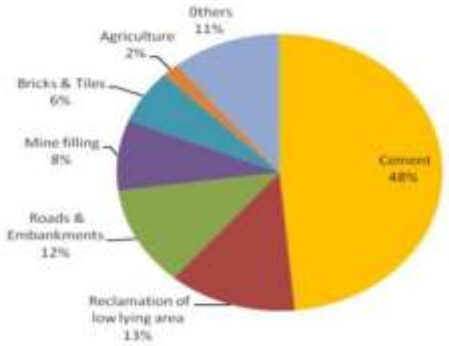

Fig.3.Fly Ash utilization scenario in India

A. FILLING IN THE MINES, LAND:

1. South Balanda Mine being filled with ash from NTPC Talcher-Thermal Station
2. A feasibility study is being conducted at Talcher-Kaniha by M/s Design for finalizing the techno-economically optimum mode of transporting ash from thepower plant to mines on long term basis. Infrastructure shall be created accordingly for filling of mines with fly ash from NTPC Talcher- Kaniha.
3. The research study is being done by the Central Institute of Mining & Fuel Research (CIMFR), Dhanbad for taking up technology demonstration project for random filling of ash from NTPC Ramagundam with Mine over Burden (MOB) at Medapalli Mines.

B. CEMENT:

Research has shown that the quality of fly ash produced at NTPC's power stations is extremely good with respect to fineness, low unburnt carbon and has high pozzolanic activity and conforms to the requirements of IS 3812 - 2003-Pulverized Fuel Ash for use as Pozzolana in cement, cement mortar, and concrete. The fly ash generated at NTPC stations is ideal for use in the manufacture of cement, concrete, concrete products, cellular concrete products, bricks/blocks/ tiles etc.

C. BRICK:

India is estimated to consume about 200 billion bricks annually. This roughly translates into 800 million tons of clay, which, in turn, erodes about 66000 acres of topsoil, making the land infertile. This industry creates environmentally disastrous amounts of pollution. Not only do the brick kilns themselves pollute, but they consume staggering amounts of fuel as well. Rough estimates indicate that the brick industry in India consumes over 40 million tons of coal annually, producing over 58 million tons of CO_2.The changed perception about fly ash has meant that the demand for fly ash bricks and blocks is already booming. An estimated 27 million tons of fly ash is being put to use in thebrick segment and over 37 million tons for the production of Portland PozzolanaCement(PPC) in India. The manufacturing method saves energy, reduces mercury pollution, and costs 20% less than traditional clay brick manufacturing.

Fig.4. Bricks made using fly ash.

D. USE OF FLY ASH IN CONCRETE:

- Fly ash from NTPC Dadri Station is being utilized in all underground concrete works by DMRC for its metro projects in Delhi.
- Fly ash is being utilized by all Ready Mix Concrete (RMC) Plants.
- Fly ash used by ACC Ltd. in theconcrete road at its RMC Plant in Greater Noida.
- Fly ash used in concrete road construction from Dehra Jhal to NTPC Dadri.

Fig.5. Use of fly ash bricks and concrete in making pathways.

E. BUILDING:

- Administrative Building of Greater Noida Industrial Development Authority (GNIDA) constructed with fly ash bricks.
- *NTPC's own Buildings* constructed with fly ash bricks.
- NETRA office at Greater Noida.
- 'D' Type residential quarters at Noida Township.
- Northern Region Headquarter building at Lucknow.
- All Projects and Township construction.
- *Private real estate developers* in various metro cities viz. Pune, Visakhapatnam & NCR areas use fly ash bricks for theconstruction of residential complexes.

VII. UNCONVENTIONAL APPLICATIONS:

A. ROAD CONSTRUCTION

Ash based Bituminous Road:Demonstration project for construction of fly ash based bituminous roads have been taken up in association with CRRI at NTPC Badarpur and Dadri.

1) ROAD EMBANKMENT CONSTRUCTIONS AND FILLING WORKS:

Fig.6. Road Embankment made using fly ash.

- 67 lakh Cubic Meters (Cu.M) of pond ash from NTPC Unchahar Station has been utilized in Allahabad Bypass Road executed by NHAI.
- 20 lakh Cu.M of pond ash from NTPC Badarpur Station has been used in Noida - Greater Noida Expressway
- About 1.5 lakh Cu.M of pond ash from Indraprastha thermal power station has been utilized in 2nd Nizammudin approach road embankment
- About 5.0 lakh Cu.M of pond ash from NTPC Badarpur Station has been utilized in Yamuna Expressway &Badarpur Flyover
- More than 15 lakh Cu.M of pond ash has been used by Delhi Metro Rail Corporation (DMRC) in their ShastriPark railcar depot from NTPC Badarpur Station.

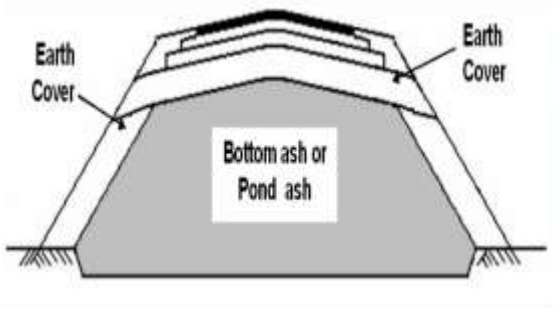

Fig.7. Road Embankment construction using fly ash.

B. AGRICULTURE:

- Use of fly ash in agriculture, as a soil modifier and source of micro and macro nutrients, has been successfully demonstrated through "Showcase projects" in collaboration with the local farmers under the direct guidance of reputed agriculture institutions/universities.
- Various crops have been grown and harvested in varying agro-climatic conditions and different soil-crop combinations and following increase in crops yield has been successfully demonstrated:

TABLE 2. INCREASE IN YIELDS OF CROPS USING FLY ASH.

S.No.	Name Of Crop	Increase In Yields
1.	Wheat	16-22%
2.	Paddy	10-15%
3.	Sugarcane	20-25%
4.	Banana	25-30%
5.	Maize	More than 30%
6.	Vegetables	10-15%

- Fly ash contain many minerals such as *Zn, K, Ca, Fe, and Na* which increases the productivity of Crops. Fly ash also improve soil properties such as texture, pH, and WHC. But fly ash effects on Crop yield may be beneficial or toxic depending upon its contents.

C. RAILWAY EMBANKMENT:

To demonstrate theuse of ash in theconstruction of railway embankment, aresearch study was carried out in association with the Central Road Research Institute (CRRI), New Delhi. The design of railway embankment developed by CRRI was validated by conducting Centrifuge Model Tests at IIT Bombay. Construction of railway embankment for NTPC's Merry-Go-Round (MGR) rail track for coal transportation is planned at NTPC Kahalgaon and NTPC Talcher-Kaniha.

VIII. FUTURISTIC INITIATIVES:

- *Flux bonded Bricks/Tiles:*

Research study for use of fly ash in flux bonded bricks/tiles has been conducted at NTPC Ramagundam, in association with NIIST Trivandrum.

This is where the flux-bonded fly ash technology developed by the CSIR's (Council for Scientific and Industrial Research) National Institute for Interdisciplinary Science and Technology (CSIR-NIIST)-Thiruvananthapuram makes a big difference.

The new technology uses fly ash to the extent of 80 per cent in typical building material, scientists claim. In turn, this has the potential to reduce the clay demand to less than 15 percent.

- *HDPE Products:*

Use of fly ash in themanufacturing of HDPE products taken up by Vindhyachal through IIT Delhi.High-density polyethylene (HDPE) is a polyethylene thermoplastic made from petroleum. It is sometimes called "alkathene" or "polyethene" when used for pipes. HDPE is known for its large strength-to-density ratio. The density of HDPE can range from 0.93 to 0.97 g/cm^3 or 970 kg/m^3.Although the density of HDPE is only marginally higher than that of low-density polyethylene, HDPE has little branching, giving it stronger intermolecular forces and tensile strength than LDPE.The difference in strength exceeds the difference in density, giving HDPE a higher specific strength.It is also harder and more opaque and can withstand somewhat higher temperatures (120 °C/ 248 °F for short periods). High-density polyethylene, unlike polypropylene, cannot withstand normally required autoclaving conditions. The lack of branching is ensured by an appropriate choice of catalyst (e.g., Ziegler-Natta Catalysts) and reactionconditions.

- *Cellular Light Weight Concrete*

Cellular Light Weight Concrete (CLC) can be manufactured by a process involving the mixing of fly ash, cement, coarse sand, fine sand and a forming agent in a mixer to form athin slurry. The slurry is then poured intomolds and allowed to set. These blocks are especially useful in high-rise construction reducing the dead weight of the structure.

- *Fly ash-Lime-Gypsum Product named 'Fal-G'*

A process of blending fly ash, lime and calcined gypsum for making a useful product, named Fal-G has been developed by Bhanu International, Visakhapatnam. Phosphogypsum, a waste product from fertilizer plants is washed and refined followed by calcination. Fly ash lime mix is mixed in predetermined proportions with calcined gypsum which produces Fal-G having strong binding proportions and can be used as a cement.

- *Ameren's Taum Sauk Hydroelectric plant*

The upper reservoir of Ameren'sTaum Sauk hydroelectric plant was constructed of roller-compacted concrete that included fly ash from one of Ameren's coal plants.

Fig.8. Ameren's Taum Sauk hydroelectric plant.

IX. CONCLUSIONS:

A number of environmental problems have been brought to light. Ways to control these problems have been critically analyzed and it was deduced that huge amount of Fly Ash is available as a by-product of coal-based thermal power plants. It's safe disposal is a great problem. At present Fly Ash is dumped in ponds. Use of Fly Ash in civil engineering construction and others have been taken up.

Fly Ash has become an important material for various industrial and construction applications. It is widely used in themanufacturing of bricks, cement, asbestos-cement products and road/embankments. The studies are carried out for improvement in yield of agricultural crops, wastelands, etc. It can also be used in reinforced concrete construction since the alkaline nature will not corrode steel. This not only solves its disposal problems but also helps in conserving the precious topsoil required for growing food crops. On the basis of the studies carried out on Fly Ash utilization, it is sighted that use of Fly Ash in building construction poses great gains. If we make proper arrangement of safe disposal and optimum use in civil engineering construction, agriculture, etc. Utilization of Fly Ash also creates significant benefits in terms of energy saving as well as environment.

REFERENCES

[1] DISPOSAL AND UTILIZATION OF FLY ASH TO PROTECT THE ENVIRONMENT- I. NAWAZ
[2] ASH UTILIZATION- NTPC
www.ntpc.co.in/en/environment/**ash**-utilisation
[3] Journal of Environmental Science and Sustainability- Dr. S.K. CHAUDHARY
[4] FLY ASH- WIKIPEDIAhttps://en.wikipedia.org/wiki/Fly_ash
[5] FLY ASH BRICK- WIKIPEDIAhttps://en.wikipedia.org/wiki/Fly_ash_brick
[6] CENTRAL ELECTRICITY AUTHORITY, ANNUAL REPORT ON FLY ASH GENERATION AND UTILIZATION 2011-12 and 2012-13.