Use of Fly Ash in Mining Sector

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1 Introduction

Social and techno-economic development of any country is mainly based on the inputs of the energy in any form mainly from the source of electricity generated from the coal, gas, oil, hydro, and nuclear resources.

The resource-based power generation is given in the following table.

Fuel	MW	Percentage
Total thermal	111,324.48	65
Coal	92,418.38	54
Gas	17,706.35	10
Oil	1199.75	<1
Hydro	37,367.40	22
Nuclear	4780.00	<3
RES	18,454.52	11
Total	171,926.40	100

Source Policy perspective: India. TERI

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A major part of electricity in India is generated from coal (about 60–65%). Coal is being mined in India for the past more than two centuries. Since 1970 onwards, coal-based Thermal Power Plants are being installed at a rapid pace to meet the national energy requirements. Accordingly, the coal production has also increased by fivefold in the last two decades. The coal production which was about 114 million tonne during 1981 has since increased to around 700 million tonne.

The rapid increase in coal production for power generation is helping in meeting the national demand for energy. However, on the other hand, the ash generated from the power plants has become an environmental problem since Indian non-coking coal has 35–45% of ash. The ash generated from the power plants during 1980–81 was recorded as 46 million tonne, has been increased by more than fivefold to 250 million tonne during 2015–16.

2 Coal Mine Sector

Since the inception of coal mining in India, underground mining has been in practice. Keeping in view the demand for coal on a large scale, and in view of the safety of men and machinery, opencast mining was resorted to, wherever possible in place of underground coal mining besides, converting working underground mines into OC mines. Presently, 88% of coal production is from O/C mines and 12% is from underground mines.

Though presently production of coal from O/C mines is dominating, it would not continue for a longer time as the shallow depth coal reserves are being depleted very fast. Hence, the coal winning activities have to be shifted to beyond 300 m depth of deposits in underground mines, which demands high resistance support systems for roof control. In view of the mine safety and conservation of coal with high productivity, the only alternative method is the introduction of coal winning advanced technologies in conjunction with rapid ash stowing technologies by paste filling/hydraulic filling.

3 Safety and Conservation in Coal Mines

Further, it is projected that coal would continue to remain the major source of energy for power generation in the country. The estimates prepared by MoP as well as Planning Commission up to the 2031–32 year, indicate that the coal requirement and consequent generation of fly ash during the year 2031–32 would be around 1800 million tonnes of coal and 900 million tonnes of ash, respectively.

In spite of the efforts by MoEF, FAU (DST) through various notifications, the 100% utilization of ash could not be achieved to date. It is clear that efforts toward large-scale bulk utilization if not resorted to; the 100% achievement would not be possible. A few mining sectors like filling of underground mine voids, backfilling of opencast mines, admixing in OB dumps, use in opencast haul roads will have to be taken up. Ash stowing in underground mine voids enhances the good support to the overlying strata besides substantial conservation of coal and good support to the roof enhancing safety. Ash adding in OB dumps enhances the dump stability and faster revegetation. Backfilling of O/C mines with ash provides improved reclamation and revegetation. Use in haul roads enhances improved load bearing capacity with high compaction and low airborne dust. The details of these factors would be discussed in the subsequent paragraphs.

4 Constitution of C-FARM in Utilization of Thermal Coal Ash in India

Center for Fly Ash Research and Management (C-FARM), a company constituted under section 25 of Indian company's Act 1956, with eminent sr. scientists, technologists and managerial group have come together for facilitation of technology, dissemination of knowledge, know-how transfer, training of consultants and providing techno-managerial guidance for adopting developed technologies in various fields like agricultural, irrigation, development of building materials for all types of construction activities, land reclamation and revegetation, roads and highways, embankments and in U/G and opencast mines. Facilitating technical advice and guidance in all the fields is actively under progress by the experts of C-FARM. In mining, the introduction of ash filling technology on a large scale is being actively considered and is likely to be commenced shortly in some underground and opencast mines in different companies.

5 Areas of Use of Fly Ash in Mining Sector

5.1 Underground Mining

In India, various methods have been adopted for winning coal like bord and pillar mining, longwall mining, blasting gallery method and sub level caving with initial preparatory development followed by depillaring. The voids so formed by depillaring can be filled with ash in place of sand which is presently a scarce material.

- Wherever ash is available from the power plants present near the vicinity of the mines, ash stowing can be adopted instead of caving in depillaring districts, which enhances the conservation of coal, safety, and environment.
- Productivity can be improved in continuous minor technology and other intermediate technologies in conjunction with ash stowing.
- Mine supports.

- Consolidation of haulage track lines.
- Construction of ventilation walls, isolation walls and water dams with specially designed ash bricks.
- Civil construction in mines like electrical substations, rest station, reserve station, etc.
- Use of fly ash in firefighting.
- Use of fly ash in development of interlocking bricks for use in emergency firefighting isolation walls.

5.2 Surface Mining

- Backfilling of O/C mines.
- Consolidation of OB dumps.
- Reclamation and revegetation of abandoned OC mines.
- Reclamation and revegetation of subsidence areas caused by depillaring in underground mines.
- Construction of embankments and barriers.
- Construction of haul roads.
- Construction of drainage network.

6 Case Studies in Utilization of Ash in Mines

Considerable efforts have been made in utilizing the ash generated by coal-based thermal power plants in Andhra Pradesh, i.e., NTPC, HWP, APGENCO, Navabharat Ferro Alloy which are situated in close proximity of SCCL coal mines.

6.1 Experimentation with NTPC Bottom Ash for Stowing at SCCL Ramagundam Mines [1]

In the year 1993, NTPC Ramagundam (TPP) came forward with an idea of disposing of ash in underground mine voids of nearby SCCL coal mines.

Laboratory investigations were made on samples of NTPC ash by Central Institute of Mining and Fuel Research (CIMFR), Dhanbad to find its suitability for using in stowing. Based on the report, DGMS granted permission to experiment ash stowing at GDK 3 Incline mine of Ramagundam. Experiments of ash stowing were conducted in September 1994 in SS2/1 and SS4/1 depillaring panels of no. 1 seam under the technical guidance of CIMFR scientists. About 30,000 tonnes of ash was supplied to the mines by NTPC, Ramagundam.

6.1.1 Observations Made During Ash Stowing

- Some of the fines from fly ash escaped through barricades and accumulated in the sumps and low laying working places.
- Free flow of ash in the surface bunker could not be achieved due to ash moisture.
- Slow seepage of water from the barricade was observed, resulting in a delay in opening the neighboring working faces.

However, these problems were overcome in the subsequent underground stowing trials.

The following modifications were adopted.

- Vibrators were installed over the bunker for achieving free flow of ash.
- Water jets were arranged for free fall of ash from the chute.
- Opening of the chute was increased to 16″ × 16″.
- 8″ dia pipe was arranged from trough to borehole in place of … pipes.
- Flow meters were installed for controlled water supply.

6.2 Case Study of Pond Ash Stowing at SCCL Manuguru PK-1 INC., Underground Coal Mine [1]

Consequent to the MoEF Gazette Notification, in 1999, Heavy Water Board, Mumbai came forward with a proposal to dispose of the pond ash, generated by its Captive Thermal Power Station of Heavy Water Plant Manuguru, in underground mines of SCCL. Stowing with pond ash was carried out in PK 1 Incline mine under the guidance of FAU (DST), DGMS, Hyderabad and CIMFR, Dhanbad during the years 2001–2004. Before commencing experimentation, laboratory investigations were carried out by CIMFR to find suitability of pond ash for underground stowing and based on the report DGMS permission was obtained. About 10,000 cum of pond ash was stowed on a trial basis. Later regular stowing was taken up in an SQ1 panel of PK 1 Incline mine during 2005 and about 12,000 cum of pond ash was stowed (Figs 1 and 2).

6.2.1 Observations During Pond Ash Stowing

Water filtration was found to be normal as in sand stowing. As per the observations and analysis, the particle size of less than 53 μm is escaping through the barricades. This needs to be arrested by adding more additive or by improving the filter media. Persons were able to walk freely over the stowing bed after 20 min of completion of stowing. The hydrostatic pressure on the barricade is only 1 kg/sq. cm which is very low when compared to the load bearing capacity provided to the barricade. Due to ash stowing the low lying unstowed areas were also filled with fly ash, which is not

Fig. 1 Ash bunker fabricated at 60°

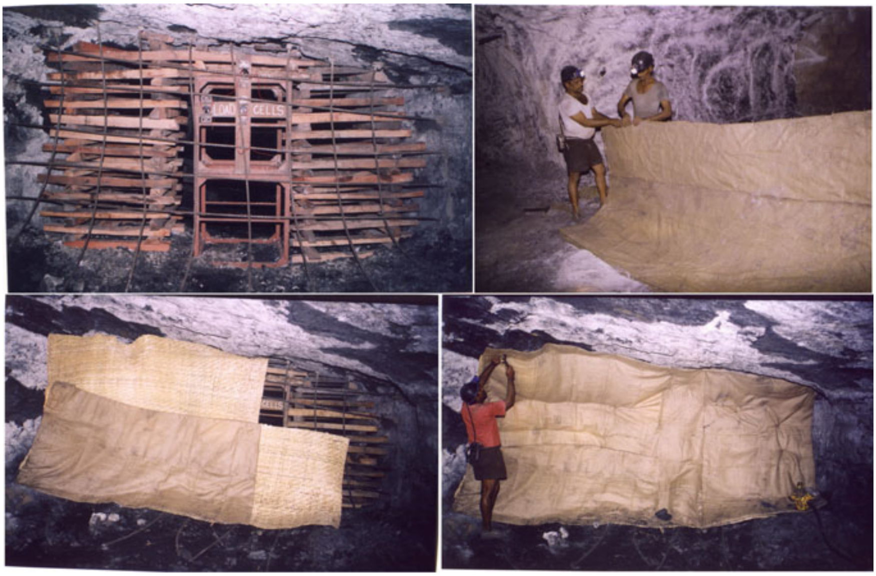

Fig. 2 Stowing barricades made of bamboo thattis and Hessian cloth

possible with sand stowing. The shrinkage factor with ash stowing was found to be only 3% when compared to the sand stowing about 10%.

Due to the high consolidation of ash and good resistance to the overlying strata, the overlying section of the same seam above the ash stowed bed could be removed safely without any roof problems.

6.3 Bottom Ash Stowing at GDK 6A Incline of SCCL [1]

Experiments were carried out with bottom ash during 2005 at GDK 6A Incline mine of Ramagundam Area, SCCL using ash from NTPC, Ramagundam.

The bottom ash collected from NTPC Ramagundam constitutes 99% of +53 μm size of ash (about 11% from +53 to 106 μm size and rest 88% of ash is +106 μm) gave very good results. About 8500 m^3 of bottom ash was stowed successfully and later discontinued due to disputes in transportation-related issues from the ash pond to the mine.

The ash water ratio was maintained at 1:0.7. The maximum rate of stowing achieved is 100 m^3/h. The shrinkage factor was observed to be less than 5%. The escapes of fines from the barricade were found to be negligible.

During the process of judicious extraction of the ribs and when the ribs were punctured to the adjacent stowed gallery, the 2.5 m high ash was self-standing like a wall and did not flow into the working area. Less shrinkage and more compaction were observed.

6.3.1 Observations During Bottom Ash Stowing

From the experiment of bottom ash stowing at GDK 6A Incline mine, it was observed that being coarser, the bottom ash stowing did not pose any technical problems. Out of the total ash generated by thermal power plants, 20% was bottom ash which can be readily used in stowing operations in underground coal mines. Thereby 20% utilization problem of total ash generated was achieved.

6.4 Ash Stowing in Jharia Division of TISCO

General Manager, Jharia Group of Mines, TISCO [2] reported that in Jharia Division about 23,000 tonnes of bed ash generated at F.B.C. Power plant has been consumed for stowing purposes. Use of ash in backfilling of abandoned open cast mines also has been carried out in TISCO besides filling in low lying areas caused by subsidence, Land Scaping, Construction of parks, etc.

6.5 Utilization of Ash for Brick Manufacturing and Filling of Low Lying Areas

Management of M/s SCCL [3] reported that SCCL has switched over to 100% use of Fly Ash bricks. SCCL received a national award for maximum utilization of fly ash products in the International Congress organized by Fly Ash Mission, DST, GOI at New Delhi during 2005. From the year 2002 to 2010, 159 million fly ash bricks were utilized in surface construction works and in underground mines. About 4 lakh cum of ash was utilized for filling the low lying areas (Figs. 3, 4 and 5).

Fig. 3 Masonry roof support with fly ash bricks

Fig. 4 Kerb walls at the man riding station

Fig. 5 Pillar sides supported with fly ash bricks

6.6 Continuous Mining with Active Fill Technology

Officers from the Directorate General of Mines Safety [4] reported that an innovative technology called "Continuous Mining with Active Fill Technology (CMAFT)" in which the voids formed after extraction of coal in the form of slice or chamber, is then immediately filled up with Fly Ash fill matrix which sets from the paste form into solid within two–three hours of filling has been developed.

6.7 Use of Ash in Opencast Mines

NTPC management in one of their presentations [5] reported that ash has been gainfully utilized in some of OC mines. Abandoned mine pits of South Balanda Colliery of Mahanadi Coalfields has been used successfully reclaimed with the ash from NTPC's Talcher Thermal Power Plant by pumping the ash in slurry form through pipes laid for about 10 km distance. The decanted water is pumped back through a Floating Pump for reclamation. Clearance was obtained from the State Pollution Control Board and DGMS. It is reported that 100% ash produced (about 1 million ton per annum) has been used on a regular basis and continuous ash filling is being done for reclamation of land in this abandoned mine.

It is also reported [6] that abandoned mines of Kajora area, ECL and Kathara area, CCL are being reclaimed with fly ash in dry form brought in dumpers from nearby Thermal Power Stations. This ash is suitably dumped and leveled for reclamation and the filled up area is then developed with suitable green cover.

Considering the limited availability of abandoned mines in the vicinity of NTPC's Coal based thermal power stations, it is proposed to use ash in operating OC mines by suitably encapsulating OB soil with ash. For a demonstration of this concept, MoC has identified Medipalli OC of SCCL and Kaniha Mine of MCL.

7 C-FARM Initiatives in Utilization of Fly Ash [7]

Appreciating the need for dissemination of knowledge, facilitation of technology/know-how transfer, training of trainers and consultants as well as providing scientific and techno-managerial guidance for adaptation of developed technologies, the C-FARM has implemented some projects, a few of them have been enumerated hereunder,

- At JSL, Jaipur, Odisha the ash generated at 250 MW TPP 100% utilization of fly ash and bottom ash was implemented.
- Reclamation of low lying areas was taken up at SP office, Jaipur, Odisha and at one of the schools in Jaipur.

- Technical advice and guidance were given to RMC plant Mumbai and for the Fly Ash concrete road at Mahindra Life Space, Mumbai.

Besides the above activities, a number of training programs and seminars were conducted for a large number of brick manufacturing units and in agriculture.

7.1 Reclamation of Laterite Mines

Centre for Fly Ash Research and Management (C-FARM) has been working for the noble cause of promoting Fly Ash Utilization in India for the last 17 years along with stakeholder agencies.

Under the guidance of C-FARM about 4.5 lakh cum voids of abandoned laterite mine at Ragadi near Jaipur have been suitably reclaimed with fly ash during 2010–11 (Figs 6 and 7).

- On the basis of expertise and work done in this area, C-FARM has prepared a Technology and Methodology Manual for Reclamation of low lying areas/abandoned quarries/laterite mines etc. which has been approved by SPCB, Odisha as well as MoEF, Govt. of India.
- The low lying areas/abandoned quarries/laterite mines reclaimed with fly ash in a manner described in above document can be safely used for habitat construction, parking lots, playgrounds and other purposes including agriculture, floriculture, horticulture, forestry etc.
- However, proper investigations and foundation design be suggested before heavy construction/usage.

Fig. 6 Abandoned laterite mine (before)

Fig. 7 Abandoned laterite mine (after)

7.2 Back Filling of O/C Pits at Talchir, Odisha of MCL and Bhupalpally Mines of SCCL

C-FARM provided technical advise and guidance for filling of 20 lac cum of fly ash generated by thermal power station located at a distance of about 30 km from O/C mine of Talcher area. The challenges of deposition of fly ash in this mine include water-filled cavity which may overflow to nearby areas/water bodies and working mines in the vicinity of the opencast pit to be reclaimed with fly ash. In addition to this, the conveying, transportation and management of fly ash at the pit including slurrification will have to be addressed.

It is proposed to use fly ash generated by KTPP, Bhupalpally, AP in underground mines and opencast mines of SCCL Bhupalpally Area (a) for stowing of underground mine voids (b) backfilling of OC mines and (c) stabilization of OB dumps.

8 Conclusions and Recommendations

From the above, it is observed that considerable efforts have been made in the utilization of fly ash generated in India. In spite of these efforts, the utilization is around 50% of the total ash generated. It is essential that in addition to the use of ash in brick, cement, roads, embankments, etc., the focus is being made on the bulk utilization in underground stowing as well as backfilling of OC mines.

Out of total ash generated by thermal power plants, 20% is bottom ash which can be readily used in stowing operations in underground coal mines along with about 65% of ash collected in the first field of ESP. The balance fly ash (about 15%) can be utilized by use of a coagulating agent for fast settling of fine particles.

Under the guidance of expert committee, C-FARM and DGMS Dhanbad, it would not be difficult to achieve 100% utilization of ash, as a large number of mines would have sufficient voids to accommodate the total ash generated in their vicinity. C-FARM would extend all its technical know-how, advise and guidance for achieving the task.

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