P. K. DEWANGAN
M. PRADHAN
and
PRINCE KUMAR

Geotechnical, environmental and other issues pertaining to fly ash disposal in opencast mine voids

The generation of huge quantity of fly ash and its utilization or safe disposal is the main concern affecting the efficient and economical working of thermal power plants (TPP) in India. Government of India is making continuous efforts and making stringent regulations to promote fly ash utilization and has given targets to all TPPs to achieve 100% utilization level. Despite various initiatives by Government, the utilization of fly ash is still around 63% and remaining 37% fly ash is poorly disposed off into ash ponds. Presently, major consumers of fly ash are for making cement, bricks, concrete and roads. The utilization of fly ash in all these activities has reached to almost saturation level. A very limited quantity of fly ash is being utilized by mines for backfilling of mine voids. One of the potential area for bulk disposal of fly ash is mine void filling which can help in achieving 100% utilization target. This paper discusses geotechnical, environmental and various operational and legal issues pertaining to fly ash disposal in opencast mine voids. Various methods of fly ash disposal in mine voids with successful implementation on a large scale in Indian opencast mines are discussed with a view to achieve 100% utilization target set by Ministry of Environment, Forest and Climate Change (MOEFCC), Government of India.

Keywords: *Backfilling, stability, leachates, overburden dumps, fly ash, mine voids*

1.0 Introduction

The ambitious programme called 'Power for all' launched by Government of India is putting a lot of pressure on TPPs to boost their generation capacity. The total installed power generation capacity of India in April 2018 stood at 343,788.40 MW. The coal based TPP account for 196957.50 MW which stands at 57.29% of total installed capacity [1]. An enhancement of approximately 50,000 MW in the installed capacity is expected to be achieved in the next five years from coal based TPP. The low calorific value and high ash content of Indian coal lead to a production of a huge quantity of fly ash for generation of same units of energy for TPP in India. Indian thermal power sector are facing various environmental issues related to safe disposal of fly ash since a very long time. Effective utilization of fly ash in various activities or its safe disposal in low lying areas and mine voids will reduce both air and water pollution in the surrounding areas of TPP. Opencast mines are responsible for almost 90% of coal production in India and large capacity TPP are located in and around these mines. Using fly ash as backfill in these mined out opencast mine is an ideal situation. This paper discusses the various methods of disposal of fly ash in opencast mine voids and related geotechnical, environmental, various operational and legal issues.

2.0 Status of fly ash utilization in India and Chhattisgarh state

Fig.1 shows the year-wise fly ash generation and utilization in India from 2000-01 to 2016-17. Despite of improvement in fly ash utilization over the years, the quantity of the unutilized fly ash is also increasing year by year because of the increase in generated quantity at the same rate. This has resulted in substantial accumulation of fly ash in the existing ash ponds and exceeding its designed capacity which has caused failure of some of the ash ponds in the past. Various modes of utilization of fly ash for the year 2016-17 in India is shown in Fig.2, which indicates maximum consumption of 40.98 Mt of

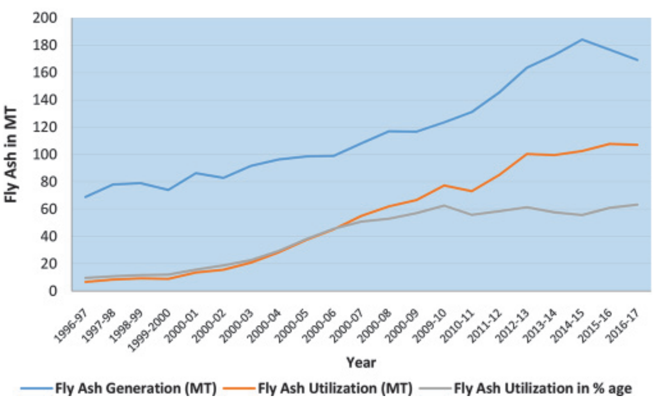

Fig.1 Yearwise fly ash generation and utilization in India (source: CEA, 2017)

Messrs. P. K. Dewangan, Associate Professor, M. Pradhan, Professor, and Kumar Prince, Student, Deptt. of Mining Engineering, NIT, Raipur, C.G., India. e-mail: pradhannitrr.ac.in and pdewangan.min@nitrr.ac.in

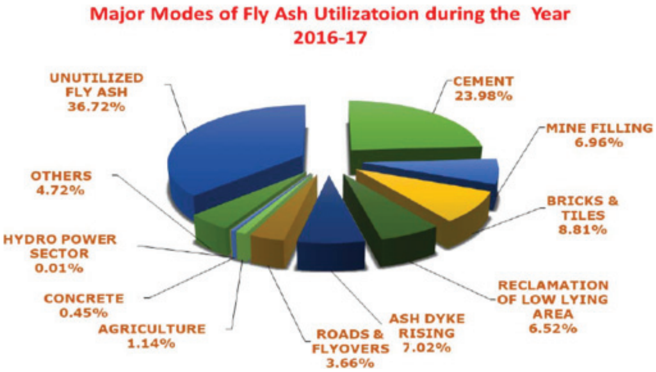

Fig.2 Modes of utilization of fly ash in various activities for the year 2016-17 in India

the ash for making cement followed by 14.91 Mt for making bricks and tiles and 11.78 Mt for mine void filling [1]. The progressive utilization of fly ash is shown in Fig.3. Chhattisgarh state is reach in coal and has 20 OC and 37 UG coal mines. A total number of 73 power plants with a total installed power generation capacity of more than 16000 MW is presently running in the state. These power plants are mainly located around two major coalfields namely Korba and Raigarh. The state generated about 25.10 Mt of ash and utilized 10.84 million tonnes, which is about 43.2% of the total ash generated in the state in the year 2016-17. Major consumption of fly ash in the state is for making of cement whereas the consumption of fly ash in mine filling is negligible in spite of large number of mines in the state [2].

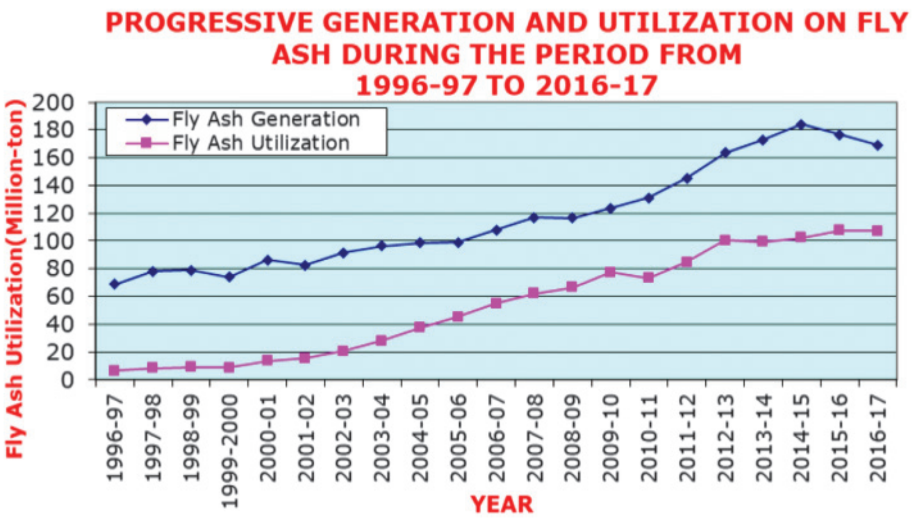

Fig.3 Progressive generation and utilization of fly ash in India

3.0 Important regulatory framework for promoting fly ash utilization in India by MoEFCC

Government of India is making continuous efforts and has taken various initiatives to achieve 100% utilization of fly ash. MoEFCC has issued number of notifications and amendments in the past. To ensure 100% utilization of fly ash from all the thermal power plants, MoEFCC, Government of India have issued a stringent notification, November 3, 2009 to promote the utilization of fly ash and to prevent its disposal on land [4]. Targets to achieve 100% utilization are given to all TPPs within a timeframe as stipulated in Table 1.

Two important provisions were made to promote disposal of fly ash in mines:

- In case of underground mine, mines located within 50 km by road from a coal based TPP have to use at least 25% of fly ash on weight to weight basis of the total stowing material used for stowing in the mine.
- In case of opencast mines, mines located within 50 km by road from a coal based TPP have to use at least 25% fly ash on volume to volume basis of the total material used of the external dump of overburden and same percentage in upper benches of internal overburden dump (backfilling).

4.0 Methods of fly ash backfilling in abandoned/active mines

The method to be adopted for ash disposal in abandoned or active mines depends on collection, handling and storage facility of ash in the nearby TPP. The fly ash is collected in dry form from the ESP or filter fabric hoppers or it is transported hydraulically in a slurry form to ash pond. Dry collected fly ash is transported further to the users in bulk tanker trucks. Most of the TPP in India uses wet collection storage facility and best suited for fly ash backfilling in mines through large diameter pipe lines. As discussed, the cost of ash backfilling is governed by the distance of mine from TPP, volume of voids available, the method of transportation and the life of TPP/ mine. The techno-economics associated with the most feasible method is required to be ascertained

Table 1: Targets given to TPP for fly ash utilization

	Percentage utilization of fly ash	Target date
1	Minimum 50% of fly ash generation	Within a year from the date of issue of this notification.
2	Minimum 65% of fly ash generation	Within two years from the date of issue of this notification
3	Minimum 85% of fly ash generation	Within three years from the date of issue of this notification.
4	100% fly ash generation	Within four years from the date of issue of this notification.

TABLE 2: A COMPARISON AMONGST VARIOUS METHODS OF FLY ASH BACK FILLING

Backfilling using fly ash slurry	Back filing using dry fly ash	Backfilling using OB and fly ash mix
• Requires high volume of void to become cost effective. • Suitable for abandoned pits/left out voids available after backfilling in active mines. • Preferred for distance up to 35 km. • Extra land to be acquired for laying pipeline. • Leakage, pipe jamming requires more care and maintenance. • Terrain from plant to disposal site must be suitable for easy transportation of slurry • High water consumption no dust issue.	• Suitable for small mine voids or quarries. • Suitable for abandoned pits. • Preferred for longer distances. • Not very capital intensive. • Road access with required carrying capacity. • Dust problem due to vehicular movement.	• Suitable in active mines during backfilling of mined out space. • May require extra land for external dumps. • Requires more supervision and careful monitoring to address any geotechnical Issue.

TABLE 3: TYPES AND PERCENTAGE WEIGHT RATIO OF SLURRY DISPOSAL SYSTEM

Low concentration slurry disposal	High concentration slurry disposal	Conditioned at disposal site
Lower concentration of 10-30% fly ash by weight.	Higher concentration of 60-70% fly ash by weight.	The ash is conditioned with water at the disposal site.
Preferred for distances up to 35 km.	Preferred for shorter distances and required high capacity slurry pumps.	Suitable for mine voids having small volume.
Mine void filling at South Balanda mine, MCL is using this system.	This mode is used for distances up to 7 to 8 km.	Mine void filling of Jagannath IV mine of MCL is using this method.

before its implementation. Hence the method to be adopted for fly ash backfilling can be classified in following three categories (Table 2):

(a) Backfilling using fly ash slurry

(b) Backfilling using dry fly ash

(c) Backfilling by mixing fly ash with OB dumps

Each of the above method is elaborated below with their applicability and by presenting case study of successful implementation in Indian opencast coal mines.

(A) BACKFILLING USING FLY ASH SLURRY

Backfilling using fly ash slurry are mainly of two types:

• Lean slurry disposal system (LSDS)

LSDS is used for disposal of ash slurry in dilute form and comprises centrifugal slurry pumps for disposal and clarifloculator/tube settler for recovery of the ash water from slurry pond.

• High concentration slurry disposal (HCSD) system

Conventional LSDS consumes a lot of water and may cause more groundwater pollution along with potential threat of ash pond collapse. HCSD system comprises controlled and monitored feeding system for fly ash and bottom ash followed by a homogenous mixing in an adequately designed Agitator Retention Tank (ART). HCSD pump transports the highly concentrated slurry from the ART to the ash disposal area through carbon steel pipelines. HCSD system has emerged as preferred option to transport coal ash in thermal power plants as it is economical and environment friendly [5].

Fig.4(a) Slurry transportation through pipes (b) Top view after ash filling

Fig.5 Snapshot of various activities of backfilling operations using conditioned fly ash at mine site

(i) Case study of South Balanda mines, MCL

- Total area of 70.75 ha with volume of 14.73 Mm^3
- The fly ash slurry is being hydraulically transported through two 300 mm pipes having length of 9.5 km from Talcher thermal power station.
- Four slurry pumps of 80 m in head are connected in series.
- Water to ash ratio in the slurry is kept 8:1.
- Ash is being transported by three pipelines (2 working + 1 standby) of about 9 km. length (Fig.4 (a) and (b)).
- The ash slurry discharged at mine void travels through gravity towards a lower level and ash particles settle down while travelling.
- The quality of the decanted water is quarterly analysed and is found within the permissible limit.

(ii) Case study of Jagannath mine void No.4, MCL by Bhushan Steel

- Total area of the mine void is 119 ha.
- Till now about 450000 T ash is disposed.
- The collection of ash is through pneumatic collection system in dry form and stored in ash silo.
- Ash is loaded into bulker pneumatically and after completion of loading, the vehicle is thoroughly washed before leaving the silo area.
- The ash is mixed with water at the disposal site.
- The water requirement for ash conditioning is met from mine void water.
- Two pumps having 125 m^3/hr. is installed on a pontoon, which is floating on water in mine void and by pipelines water is taken into water vat and conditioners.
- Total water requirement for one conditioner is 50m^3/hr.
- Moist/semi-slurry ash is disposed into mine void which is emission free.

(B) Backfilling using dry pond ash (case study of Chotia-I coal mine, Balco)

Bharat Aluminium Company Limited (BALCO) is operating Chotia coal mine in Korba district of Chhattisgarh. Chotia coal mine consists of two sub-blocks namely Chotia-I and Chotia-II, separated by a distance of 13 km. Total mining lease area is 1179.826 ha (Chotia-I -863 ha and Chotia-II -316.826 ha). Mining operation at Chotia-I has been stopped since September 2016 as opencast mineable coal reserve got exhausted. The overburden generated during mining operation till September, 2016 was simultaneously backfilled in the de-coaled area and approximately 22 hectare area is left as mine void. The company also owns a captive power plant of 1410 MW capacity located at Korba, Chhattisgarh, about 75 km from the mine. The approximate cross-sectional area of the mine void is about 780m × 280 m having an average depth

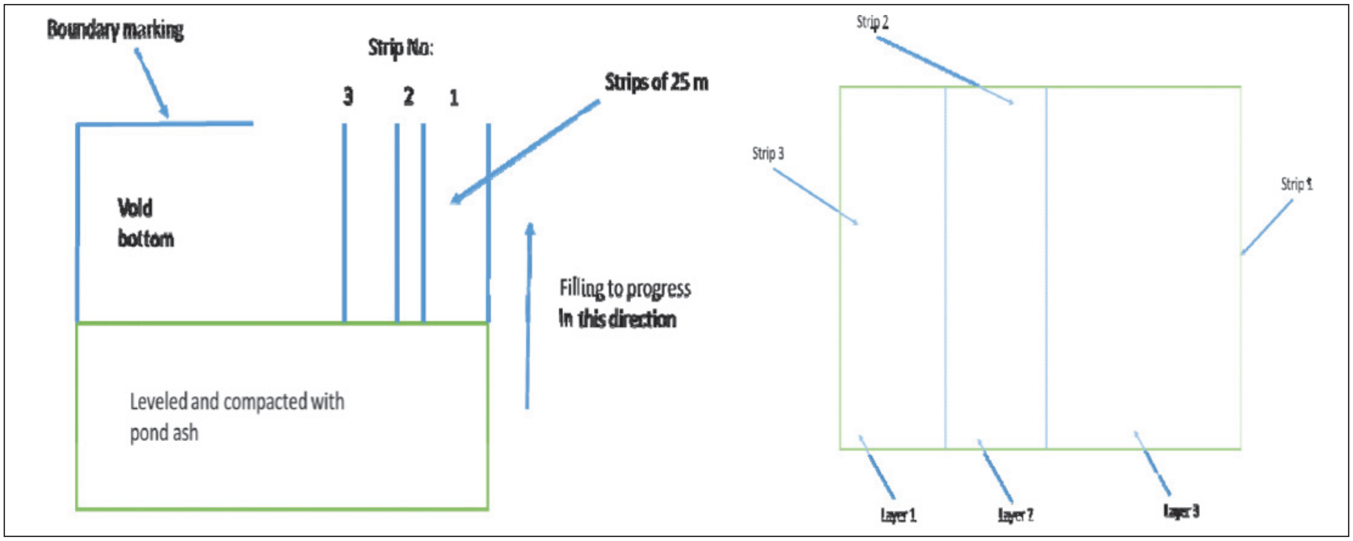

Fig.6 Method of ash filling and overlapping layers

of 25 m constituting about 5.4 Mm^3 volumes. The floor rock at the mine void is sandstone. The western wall of the void is of highwall and rest other walls are of overburden dump. The highwall mainly comprises sandstone and overburden is stabilized.

The ash utilization at mines is being recommended by MoEF and CC and SPCB from time to time. The CTO issued by CECB for Chotia mines advised to ensure ash utilization at Chotia mines generated from the power plant. Following method is being adopted for pond ash backfilling of mine void [6].

- After dewatering of the mine void area, the floor should be suitably stripped and properly levelled.
- Bentonite layering for arresting the seepage will be carried out before backfilling. For efficient drainage at the bottom of the backfill and to provide strength, coarser OB dump material/bottom ash of at least 2 m thickness will be placed.
- Ash will be spread uniformly in layers of 250-300 mm thickness in strips of minimum 25 m width and 150 m length and to move from strip (1) to (2) to (3) and so on and from levelled land to the boundary marking as indicated by the arrow in Fig.6. Two or three layers be laid on strip (1) and then one or two layers can be laid on strip (2) and progressively subsequent strips can be taken up while raising the height of preceding strips. Overlap of 5 m shall be maintained between two adjacent strips in different layers as shown in Fig.6. Similarly, 5 to 10 meter longitudinal overlap may also be maintained between two adjacent layers when the length of the area is more than 150 m.
- Proper compaction will be ensured to achieve 95% proctor with vibratory rollers.
- The backfilling activity is proposed to be staggered in such a way that backfilled area after filling up to a height of 5 m gets sufficient time for consolidation and settlement. Intermediate layers of atleast 0.6 m thick soil/OB/bottom ash shall be provided after each 5 m thick of pond ash layer to provide strength and stability to the backfilled ash structure.
- Garland drain of suitable dimension was constructed all around the void to arrest and divert surface run-off, surface water ways, swales etc.
- The area reclaimed with ash shall be finally covered with soil layer of at least 300 mm thickness.
- For reclamation of mine void area with pond ash, the following schematic arrangement is followed :

(C) Backfilling by mixing fly ash with OB dumps (Case study of Gare Palma IV/1 opencast coal mine, Tamnar, Raigarh)

- The mine is having leasehold area of 978.654 ha. with a total of five workable coal seams in the block. The ash percentage varies from 39.34 to 58.53%.The overburden consists of mainly sandstone and shale.
- The fly ash generated from the power plant was transported to the filling site in 25T dumpers and was disposed in the mine by mixing it in the overburden dumps of the mine.
- The void of the pit 1 is being backfilled by admixture of fly ash overburden dump. The method adopted for backfilling mine void using mixture of fly ash and OB was as below:

"For backfilling the mine void, initially a deck of 30 m height of overburden only was constructed along the floor of the pit. An embankment of about 15 m wide and 5 m high was then constructed all around the proposed area for fly ash overburden dump filling as is shown in Fig.7 (a), (b) and (c). A number of dumping areas were formed in such a way that each area was separated by another dump area by a 15 m wide embankment. A well-mixed admixture of fly ash-overburden, containing 25% fly ash and 75% overburden by volume was then filled in the area up to a height of 5 m. Over the layer of fly ash overburden admixture, a 5 m thick layer of overburden was laid. In the same way, alternate layers of fly ash overburden admixture and overburden only was filled in the void. Thus, each layer of admixture of fly ash overburden was followed by a layer of overburden. For ensuring the safety of the dumps, backfilling was done in 4 decks each of 30 m height. Each deck contains 3 layers of admixture and 3 layers of overburden. The sides of the dumps were kept benched with slope angle of 28°. At the top of the dumps, a layer of about 2 m thick topsoil was spread, over which thick plantation of local species of plants was done [7].

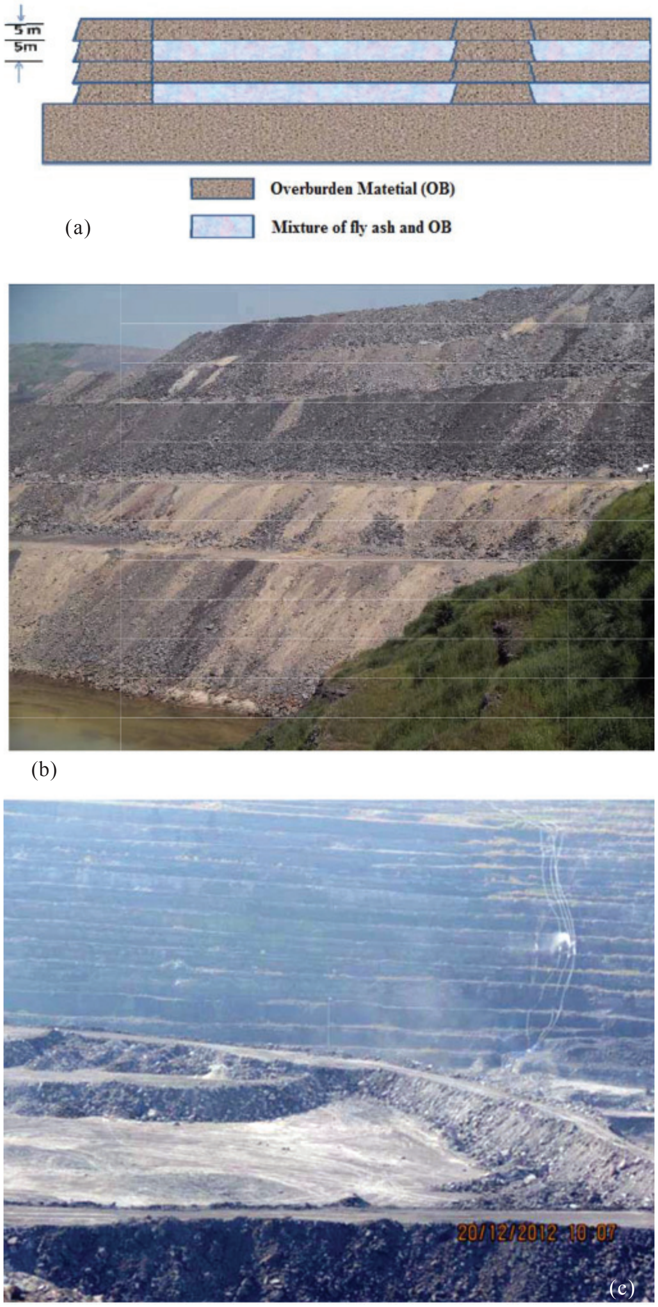

Fig.7 (a) Alternate layers of fly ash OB admixture and OB (b) Decks with fly ash as admixture in overburden material after compaction (c) Embankments constructed for backfilling the mine void

5.0 Fly ash backfilling in mines vis-a-vis geotechnical, environmental and other issues

Some of the geotechnical, environmental and other barriers in the disposal of fly ash for mine backfilling identified are:

(a) Geotechnical and environmental concern

Fly ash consists of often hollow spheres of silicon, aluminum, and iron oxides and unoxidized carbon and is pozzolanic in nature and contains some lime. Fly ash possess several physical and chemical properties/characteristics that are beneficial both from environmental and economic stand points. The low specific gravity of fly ash, good frictional properties, freely draining nature and wide range of moisture content for good compaction makes it suitable for various geotechnical applications. Abandoned opencast mine pit can be filled with fly ash. In case of active mine, fly ash can be mixed to OB dump material while forming the dumps. However there are two main concerns in the disposal of fly ash related to its mixing in the OB dumps raised by the mine operators. One being the slope stability issues arising out of mixing of fly ash in OB dumps of opencast coal mines and secondly the contamination of groundwater due to leachates. The research on slope stability issues indicates that the mixing and compaction of fly ash with the OB dump material changes the shear strength behaviour of the mixture, which is one of the most important inputs required for assessing the stability and design of fly ash mixed OB dump slopes [7-9]. Direct shear tests were conducted on OB dump material mixed with 10%, 20% and 30% fly ash by weight and it was concluded that mixing of fly ash in the range of 10% to 20% by weight improves the shear strength of the mixture [8]. It was found that OB dump of 120 m high mixed with 30% fly ash stable under both dry and wet conditions using numerical simulation [9]. The stability of dump slope of 60 m height having an overall slope angle of 32° made up of OB dump material randomly mixed with 20% fly ash by weight was also found stable [10]. Large scale direct shear tests were conducted on OB dump material mixed with 20% and 25% and found that internal and external overburden dumps having an overall slope angle ranging between 24 to 28° in two benches of 30 m height is stable [11]. Suitability of pond ash for mine void filling of Chotia I opencast coal mine was investigated and on the basis of various geotechnical investigations, methods of dry pond ash filling and safe operating procedures were recommended [6].

Some research has been carried out on the environmental characteristics of Indian fly ash leachates and it has been reported that the fly ash interaction with the ground/mine water produces toxic elements well below the permissible/ threshold [12-15]. Groundwater contaminations due to leaching of heavy and toxic metals from fly ash can also be minimized and controlled if they are separated from the groundwater aquifer by suitable liners [16]. However, some researchers have reported traces of heavy and toxic metals in surface and groundwater near ash dyke of Parichha TPP, MP and surroundings of Rajghat powerhouse and Badrapur TPS, New Delhi. Five heavy metals (Pb, Ni, Cr, Mn, and Fe) were detected in groundwater samples which are exceeding values of heavy metals prescribed by WHO for groundwater [17-18].

As the characteristic of both fly ash and OB dump material varies from site to site, it is recommended to go for site specific slope stability and environmental study before disposing fly ash in mine voids or it is mixing with the OB dumps.

(b) High transportation cost

The handling, storage and transportation cost of fly ash to the end user is one of the important barrier in its optimum utilization. The economics associated with fly ash use is governed mainly by the cost of ash disposal by the TPP. The transportation cost of fly ash backfilling in the mine void increases with the distance between the power plant and mine site. However, the disposal of fly ash in mine voids is a very cheaper alternative than the same is placed in ash ponds. Therefore, mine backfilling is preferred and is adopted only by the owner of captive TPP.

(c) No Compulsion for mine closure using fly ash

It is compulsory for all the coal mines to formulate for mine closure in the approved mine plan. There is a need for making mandatory provisions for mine closure by backfilling using fly ash.

(d) Lack of monitoring institutions or implementation agency

Government agencies or committees to act as monitoring institutions for implementation of policy on utilization of fly ash in mines are urgently needed [19]. Such committees should have representation from concerned government ministries, DGMS, mine owners, state pollution control board, academic and research institute in order to monitor implementation of policy from all perspectives and to resolve any dispute or disagreement between TPP and end users of fly ash.

6.0 Conclusions

The problem of effective management and utilization of fly ash may become a big issue, if timely action is not taken by all the stakeholders for improving its utilization in various activities. One of the most convenient and high volume disposal method for improving fly ash utilization is to dispose it in the mine voids. Most of the TPPs in the state are located near the active and abandoned opencast coal mines. The various case studies presented in this paper provides different methods of ash disposal in the voids of opencast coal mine with minimum damage to the environment. Though there is a mandatory provision of fly ash disposal in the mines either by mixing with stowing material in underground mines or by mixing with overburden dumps in opencast mines, the same has not come into practice because of the various issues as discussed above. It is the need of the hour to address and resolve all these issues on priority basis. There is a need to frame a proper roadmap for fly ash disposal in active/ abandoned mines locating the TPP and mine void available in its vicinity with the most feasible and economical method of ash disposal. A committee should be constituted with representation from all stakeholders to formulate strategy and suggest roadmap for the same. The characteristics of fly ash and OB are site specific. Geotechnical and environmental aspects must be fully addressed before its implementation in the proposed mine.

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