Utilization potential of coal combustion residue in Indian mines

The demand for power in the country has increased tremendously in recent time. This means more power grade coal will be utilised in the thermal power generation to meet the increasing demand. Indian coal being high in ash content, it will lead to more and more coal combustion residue (CCR) generation resulting in more disposal and environmental related problems. As per the available estimates the coal combustion residue production has crossed the 100 Mt mark and with the present rate of power generation coal combustion residue generation is likely to touch 150 Mt level in a decade or so. Though the utilization of coal combustion residue from 1994 onwards has shown a progressive increase, the rate is still low when compared to some other countries where it is 70 to 100% and in some case it is almost 100%.

The present paper highlights several uses that the coal combustion residue can be put to in the mining areas and the several environmental benefits of its use. Several case studies prove beyond doubt the utilization potential of coal combustion residues. Judicious handling of the coal combustion residue, especially with respect to those power stations that are situated in and around mining areas and those coming up in the mining areas in the near future, will not only solve the disposal problem but, at the same time, it would solve several other existing problems of the mining areas.

Introduction

India generates more than 100 Mt of coal combustion residue (CCR) from its existing 82 or more thermal power stations. This figure is likely to reach to 175 Mt by 2012 with the present rate of power generation using coals having an average ash content of about 40% [1, 2, 3, 4]. The coal used in India generally low-grade high ash content coal. Higher-grade coal is preserved for metallurgical purposes, railways, etc. The power grade coal in our country is mostly mined by opencast method. Opencast mining accounts for more than 75% coal mined in India and this trend is expected to continue as such in future too [5, 6, 7].

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At present more than 50% of the energy requirement in our country is met by coal-based thermal power stations [6, 8, 9]. The use of coal for the power generation results in huge amount of coal combustion residues (fly ash and bottom) production. These residues are generally disposed off in slurry form to nearby ash ponds especially made for this purpose. As reported in United State Geological Survey (USGS), 2002, the utilization of coal combustion residue was 13% in 2000 and the remainder simply finds its way in the ash ponds [10]. Vimal Kumar et. al., 2003 in their study reported utilization of coal combustion residue at 41% [11]. The storage of ash in the ponds has various environmental implications and needs urgent attention. Various environmental implications associated with the ponding of ash in ash ponds are outlined below:

- Requirement of agricultural land/watershed for storage of ash which otherwise could have been put to some other use.
- The ash in the ash pond need to be kept wet all the time in order to prevents ash particles from getting airborne especially, during dry summer season.
- There are chances of water pollution due to discharges of effluents from ash ponds to surface water bodies as well as leachates from ash ponds reaching groundwater bodies. The effluents and the leachates may contain heavy metals and trace elements, which may cause water pollution to alarming limits.

The country is already hard pressed due to increased population and tremendous pressure on land. Under such circumstances one cannot think of losing land for storage of coal combustion residue. It is high time now that there is switchover to the concept of bulk utilization and thus minimize land requirement for the storage of coal combustion residue. In the recent years ash utilization has increased considerably. It was around 3-5% in the early nineties and presently it is more than 41% [11]. The utilization would further improve with the Ministry of Environment & Forests (MOEF) notification in 1999 and its amendment in the year 2002 [12]. The notification also outlines the potential usage on commercial basis in cement industry, construction materials, roads, dams, etc.

Avenues of coal combustion residue utilization

Coal combustion residue has the potential of being put to varied uses. Coal combustion residue has unique physical, chemical, mineralogical and engineering properties. Various areas of coal combustion residue utilization can be broadly classified into three groups namely: (1) low value added possible utilization, (2) medium value added possible utilization and (3) high value added possible utilization. Table 1 outlines the possible utilization in the three categories.

The present paper has attempted to look for the avenues of bulk utilization of coal combustion residue in mines.

Mine reclamation

Most of the thermal power stations in our country are situated in and around coal mining areas. The reason being that power grade coal is easily available in these areas. The requirement of power grade coal in the thermal power stations is mostly fulfilled by coal being mined by opencast method. In future a large number of thermal power stations are expected to come up in the vicinity of the coal mining areas besides other regions. These mining areas offer tremendous opportunity to power stations to solve their coal combustion residue disposal and handling problems. Close examination of the conditions prevailing in the Indian coalfields reveals that coal combustion residue can be used for the following purposes:

- Arresting advances of mine fires and combating the fires
- Backfilling of disused, abandoned and old workings
- Stabilization of caved out areas
- Stowing in underground workings
- Reclamation of subsided areas and their re-shaping
- Reclamation of mined out areas in opencast mines

In the opinion of the author the most important bulk scale use of the coal combustion residue should be in the reclamation of the mines whether it is opencast or underground workings [13, 14, 15]. Till the end of the last century, reclamation planning was not mandatory but now it is legal along with mine closure planning. This calls for backfilling the voids created by opencast mining and redeveloping the surface in such a manner that it can be brought back to economic uses equal to if not better thôn the pre-mining status to support the population living in the areas during post mining period.

The present opencast coal mining scenario in the country calls for redesigning the surface topography with due regard to surface drainage system and anticipated end use. In majority of the situations the end use should be agriculture as after coal mining has been completed there is nothing else to support the people. A study by Saxena (2001)[16] indicated that unless the overburden-coal ratio by volume in the opencast mines is 6.66 or more the surface topography cannot be restored and most of the present mines have this ratio on the lesser side. Even the addition of the ashes to the overburden would not be sufficient for backfilling to restore the original topography. Since, a major portion of the coal combustion residue is generated in the plants situated close to the opencast mining areas the ash can be easily planned for backfilling in the mine voids along with the overburden rock mass.

In addition to this, stowing using coal combustion residue with suitable additives can be carried out to fill the voids created by underground mining. This will help prevent subsidence in such highly subsidence sensitive zone. Also coal combustion residue can reclaim the already subsided surface in the underground mining areas.

The most important characteristics of the coal combustion residue which may raise objections is leaching of heavy metals which may contaminate the surface and underground water bodies and hence may also have some influence on the post mining use of the reclaimed areas.

TABLE 1: SEVERAL AREAS OF COAL COMBUSTION RESIDUE UTILIZATION

Low value added possible utilization	Medium value added possible utilization	High value added possible utilization
1. Structural fill	1. Light weight aggregate	1. Metal recovery such as Fe, Al, Ge, etc.
2. Road construction	2. Cement manufacture	2. Extraction of alumina, magnetite
3. Underground stowing	3. Bricks	3. Manufacture of floor and wall tiles
4. Lime fly ash stabilized soil	4. Slabs and wall panels	4. Manufacture of acid resistant and insulating bricks
5. Lime fly ash concrete	5. Land reclamation and soil conditioning material	5. Manufacture of building distemper and domestic cleaning powder
6. Cement fly ash concrete	6. Filler for asphalt/bitumen	6. Mineral wool
7. Water dam concrete	7. Filler for low grade refractory bricks	7. Plastic fillers
8. Control of mine fires	8. Prefabricated building blocks	8. Ceramics
9. Backfill material	9. Cellular concrete	9. Exotic high temperature resistant tiles
10. Damming material for blasting	10. Manufacture of granulated fertilizer	
11. Insulating material		
12. Embankment		
13. Grouting		

Mining areas offer immense opportunity of bulk utilisation of coal combustion residue. Thermal power stations in the country are mostly established near the coal mining areas as the power grade coal is available in these areas, e.g., Korba, Talchir, Ib Valley, Singrauli, Ramagundam coalfields, etc. In future many thermal power stations are to be established in the vicinity of the coal mining areas. On a close examination of the conditions prevailing in the Indian coalfields it reveals that fly ash can be used for the purposes outlined later. In-depth analyses of the characteristics of coal combustion residue indicates that backfilling in the underground and opencast mines and for reshaping of subsided lands in the mining areas, and development of surface topography afford bulk use.

The possible ways in which coal combustion residue can be used in the mining areas are discussed hereunder.

Arresting advances of mine fires and combating the fires

There are more than 120 mine fires in the Indian coalfields and many of which are raging for decades. Combating mine fires is one of the most important necessity for the coalfield areas as these are not only consuming coal reserve but are also blocking huge quantities of coal underneath and in their vicinity. At the same time it is also not permitting effective exploitation of coal seams in their vicinity.

Attempts have been made to arrest advance of mine fires by erecting stoppings in the underground workings in advance galleries from the surface so as contain and then combat the fires. For combating mine fires various methods have been used which include trench cutting in advance, blanketing, digging out, extraction of coal seams areas on fires by opencast method, etc. Among the Indian coalfields Jharia coalfield has the highest number of mine fires and the Coal India Limited conducted a diagnostic study of the fires for this coalfield so as to design and implement the mitigative measures. So far wherever digging either for mining or otherwise is not feasible, blanketing has been found to be the most effective method for combating the fires. The uses of coal combustion residue especially fly ash in the fire areas can be envisaged in the following ways:

1 Fly ash being a product of combustion of coal is an inert material if it does not contain a sizable percentage of free carbon. Hence, it can be used in the erection of the stoppings in the underground openings as well as in the blanketing of the fire areas in combination with some other material, e.g., soils and clays. The area after blanketing can be planted with suitable varieties of plants.

2 Fly ash thick slurry can also be injected in the areas having active fires and being an inert material having very fine particles this will tend to choke the fire.

3 Fly ash injection in combination with some suitable additives in the areas in advance of the fires may tend to retard the progress of fire front.

Backfilling of disused, abandoned and old workings

The Indian coalfields have in many places disused, abandoned and old mine workings that are not likely to be opened or exploited due to various reasons. In many of the situations these workings are threatening the surface properties. If water logged, these workings are not permitting effective exploitation of underlying seams. It may also not be economical to opencast these workings due to various constrains. Hence, it is advisable that these workings be stabilized. This will also tend to avoid the possibilities of illegal mining in such places. These workings can be backfilled with thick fly ash slurry or even with fly ash mixes with other suitable solids. Fly ash aggregates can also be used for the backfilling of the workings. It would be appropriate to identify the locations where such backfilling can be taken up.

In many a situation such workings may not be approachable. These can be backfilled through boreholes from the surface. In Ranigunj coalfield some such workings have been backfilled by sand using hydro-pneumatic system of backfilling, which while being very slow, consumes sand affecting the ecology of nearby river systems.

Stabilization of caved out areas

In the areas having one or even two coal seams in the coalfields and extraction of coal is done with caving it becomes necessary to stabilize the caved out areas so as to bring the surface to economic uses. Fly ash in the form of slurry with suitable additives can be used for injection in the broken rock mass for the purpose of stabilization of the rock mass for ultimately developing the surface land use.

Stowing in underground workings

In many a situation in underground mining of coal seams and minerals it becomes necessary to backfill/stow the mined out areas either for the protection of surface properties or for any other reason. The most commonly used stowing solids are the river sand, bottom ash, crushed stones, etc. Due to its properties of high compressibility and flow in water coal combustion residue has not found much use in underground stowing.

However, underground stowing with thick fly-ash slurry, fly ash aggregates, and suitably conditioned fly ash mixes with other suitable solids can be experimented. Recent experiments in this direction have shown some promise. Central Institute of Mining and Fuel Research (CIMFR), Dhanbad is constantly striving to come up with the technology that can help in easy stowing of coal combustion residue.

Reclamation of subsided areas and their re-shaping

Surface subsidence due to underground mining of coal seams and minerals not only alter the surface topography but also alter the surface drainage pattern. In addition when cracks develop due to subsidence water from the surface find way to the underground workings and thus the make of water in the underground workings increases. The development of the cracks also tends to enhance the chances of occurrence of the mine fires due to the leakage of air through the cracks.

By re-shaping the surface topography with the use of fly ash not only the cracks can be closed but also the surface drainage pattern can be suitably developed and the subsided land can be brought back to the economic uses. Such experiments have been done in the mines of TISCO in Jharia coalfield by backfilling the subsided low-lying areas.

Reclamation of mined out areas in opencast mines

Reclamation of the mined out areas in opencast mines can be divided into the following two categories:

1 Reclamation of old abandoned mined out areas

2 Reclamation in currently operating opencast mines and new projects

Fly ash can be used in both the situations. However, the question of backfilling and reclamation of the abandoned mines involves many other considerations including the economic aspects. But, from the point of view of technical feasibility the matter is same in both the situations. The objectives of reclamation planning include

1 Minimization of solid waste generation in the total process of mining to thermal power generation and converting the wastes into resources.

2 Restoring, if not improving, the land use in the mining areas by suitably implementing the reclamation and rehabilitation of the areas.

The fly ash from the nearby power stations can be used as a backfilling material in the following ways:

1 Reclamation of the mined out areas.

2 Reshaping the topography for improving surface drainage.

3 Amending the top soils, if the characteristics of the ash are suitable.

Such efforts of reclamation will help in improving the aesthetics of the area, surface drainage pattern and also open some post mining land-use opportunity in the area.

The results of the studies of the physical, chemical and leaching characteristics of the coal combustion residue samples from thermal power stations around mining areas of West Bengal and Jharkhand conducted by the author [17] and several other researchers [18, 19, 20, 21, 22, 23, 24] indicate that in general the characteristics of the leachates from all the coal combustion residue samples were confirming to the provisions in IS 2490 [25]. Hence, the use of coal combustion residue of such characteristics is not likely to pose practically any problem in the use in reclamation and other uses in the mines outlined above. The other properties of the coal combustion residue, i.e., particle size, moisture retaining characteristics, etc. can be used in developing suitable mixes of coal combustion residue and overburden rock mass for backfilling. In the areas deficient in topsoils fly ash can be used for augmenting the crop supporting characteristics of the soils as in case of their use in agriculture.

The study by the author has shown that coal combustion residue are a source of macro nutrients, i.e., nitrogen, phosphorus, and potassium, and micronutrients, such as, copper, iron, manganese, zinc etc. Therefore, the coal combustion residue can be used as a source of nutrient in the soil having such deficiencies. The study further shows that coal combustion residue behaves in many respects as soil and that food and forestry species can be successfully grown on it. Hence, coal combustion residue can be used for land amendment to solve specific problems related to physico-chemical characteristics of soil. It may also be feasible to mix various types of coal combustion residue, modify them by adding the materials or use them to modify existing materials at a site in order to achieve successful results in almost any application in agriculture. These findings are supported by the results of the various experiments conducted in the country.

The studies reported by various researchers [26, 27, 28] and others on vegetation growth and plantation on fly ash pond samples from various thermal power stations have shown the potential of food crops growing or greenery development on such fly ash samples. In the study it had been suggested that fly ash and soil in the ratio 50:50 or 75:25 could be used to grow food crops, pulses and vegetables without any risk of trace element pollution. Better production could be achieved if this fly ash and soil was supplemented with a thin layer of chopped green mulch or cow dung compost. Some forestry species like shishum (Dalbergia sissoo), jungle jalebi (Inga dulicis) and utility plants like lemon grass can develop even on the unamended fly ash ponds into lush green field.

Presence of heavy/toxic elements in coal combustion residue has been a cause of concern to many. Use of coal combustion residue in agriculture has to take note of the possible negative impacts, if any, due to the presence of these trace elements. Two situations exists, firstly, heavy metals/toxic trace elements from coal combustion residue may leach underground and may contaminate groundwater and secondly, toxic trace elements may transfer to the agriculture produce and finally to food chain, which may lead to health hazard. The results of the leaching experiments as per author's study have shown that coal combustion residue when in contact with water do release certain metals, such as, copper, manganese, zinc, iron, lead, magnesium, sodium, potassium, etc. but these are in traces and hence do not pose threat to groundwater contamination and may not be a threat to the people eating the agriculture products. It was also observed that the concentration of these elements decreased after about three to four months. Therefore, the apprehension regarding heavy metals/toxic trace elements leaching underground and thereby contaminating groundwater is completely ruled out in this context. Leaching study conducted in the laboratory simulating the field condition has established that the concentration of elements in the leachates were within the permissible limits as per IS 2490. The study on the impact of heavy metals/toxic trace elements uptake by the agriculture produce in various parts of the country has not shown any alarming condition.

Given below are some case studies of coal combustion residues utilisation in mines and their surrounding areas that proves beyond doubt the steps taken in order to solve this increasing issue of safe disposal and proper management of coal combustion residues.

Some case studies of coal combustion residue utilisation

CASE STUDY 1

The work of stowing is in progress in many parts of the country with the help of Central Institute of Mining and Fuel Research (CIMFR) expertise [29, 30, 31, 32, 33, 34, 35, 36, 37, 38]. CIMFR is handling many projects related to the use of coal combustion residues as mine fill and as a stowing material. The work of hydraulic stowing has been carried out in many parts of the country, such as, Durgapur Rayatwari Colliery (WCL), Swang Colliery (CCL), GDK-3 Mine (SCCL), 1-2 Incline of Jamadoba Colliery (TISCO) and PK-1 Incline of SCCL, Manuguru area.

· In Durgapur Rayatwari colliery, pond ash from Chandrapur thermal power plant of MSED was used for stowing. About 10,000 m^3 of pond ash has so far been stowed.

In PK-1 Incline of SCCL, Manuguru area about 3000 m^3 of pond ash from captive power plant of HWP (Manuguru) was used for stowing.

In GDK mine, SCCL, bottom ash of RSTPS, NTPC in dense slurry form was used for stowing.

In Swang colliery, CCL pond ash from Bokaro thermal power station of DVC was used for stowing.

In 1-2 Incline of Jamadoba Colliery, TISCO fly ash from fluidised bed combustion plant either alone or mixed with sand was used for stowing.

CIMFR, therefore, is constantly making effort to develop technology for easy stowing of coal combustion residues in underground mines. The work done so far in this direction has given some hope and it looks that CIMFR would emerge successful in the near future in solving this burning disposal problem of coal combustion residues. With the success in stowing the utilisation scenario of coal combustion residues are likely to shoot up and this would definitely be at par with the developed countries of the world.

CASE STUDY 2

Recently CIMFR has developed fly ash based mine support for underground coal mines [39, 40]. This fly ash prop can prove to a good substitute for timber prop. Due to its scarcity this timber prop is getting costlier day by day. Also this timber prop is putting pressure on the forest. Besides this, disadvantages such as high moisture, irregular shape, etc. can be got away by using fly ash prop. This fly ash prop if exploited commercially can open a new way for waste utilisation and this way several environmental problems related to fly ash disposal and handling can be solved. Besides this, the area of the land blocked due to dumping of fly ash will also reduce considerably.

CASE STUDY 3

Tata Iron and Steel Company Limited (Tata Steel) management at Jamadoba has been using coal combustion residues generated at their fluidised bed combustion plant (FBCP) in various ways, such as, reclamation of land, landscaping, and underground stowing and in agricultural applications. As per one of the report about 38000 tonnes of bed ash was consumed for stowing in Tata Steel Collieries Division, Jharia in 1998. Again in 1999 about 8000 tonnes of fly ash was used for the stowing purpose. Besides this, the fly ash generated at the FBCP has been regularly used for backfilling of abandoned opencast mines and other low-lying areas. Report says that approximately 140 acre of land has already been reclaimed with fly ash. Successful plantation has also been done on such reclaimed land. Eco-friendly park on such fly ash reclaimed land is another success story of fly ash utilisation. Agriculture is another area where fly ash has been successfully used by the Tata Steel management. The study [41, 42, 43, 4, 45, 46] have shown that fly ash can be very effective in reclamation of degraded/waste land and such land can be successfully used for agriculture produce. Presently the management is facing problem with the disposal of ash as all the depression available with Tata Steel have already been used up. Now the management is concentrating on using the fly ash for brick manufacturing and stowing.

CASE STUDY 4

Pond ash at Bokaro thermal power station (BTPS) is mainly being used as mine backfill material and for filling low-lying areas. At Bokaro thermal power station the mine backfilling is being done from BTPS to S&T patch quarry No. 5 of Kargoli seam at Bokaro colliery of CCL. Besides this, hydraulic stowing of pond ash from BTPS was also carried out at Swang colliery of CCL [47].

CASE STUDY 5

Abandoned Jamunia opencast mine at Barora area has been backfilled with pond ash from Chandrapura thermal power station (CTPS). Around 28-lakh cubic meter of ash from the pond area has been used in the process. The area has then been covered with thin layer of mud. It is being planned to develop a park there to improve the aesthetic look of the area. This way the disposal problem of the power station has been solved to some extent [47].

Case study 6

NTPC, Korba has set up a fly ash brick plant and is encouraging people of the area for using such bricks, which not only has strength more than the conventional bricks but also has regular shape. Government has also given a notification, which states that any construction industry engaged in the construction work within 100 km radius of the power plant have to make use of such fly ash bricks in the construction work. If this gets commercialized then definitely this will reduce pressure on the soil that is being used for the manufacture of the bricks [48, 49].

Such fly ash brick plants are also set up near Kolaghat thermal power station. Tata Steel management at Jamadoba, Dhanbad is also planning for setting up such brick plant to solve the disposal problem of their fluidised bed combustion plant.

Case study 7

Coal combustion residue generated at DTPS is being used for mine filling. Coal combustion residue from DTPS is transported in a protective manner and dumped in two abandoned opencast mines of ECL namely, Ghanshyam and Dhandadih colliery. After filling with ash, area is dozed and then covered with thick layer of earth to facilitate plantation in future [47].

Besides this there are other success stories of using fly ash as backfill material and for stowing in the foreign countries too [50]. Countries like Poland, Hungary, Germany, Canada and South Africa have been using fly ash for stowing and as backfill material.

Environmental benefits of utilisation of coal combustion residue in mines

As discussed earlier, coal combustion residues possess unique physical, chemical, mineralogical and engineering properties. It can be put to varied uses. The following are the advantages of CCR use in mines.

(a) It will result in the reduction in the requirements of land for coal combustion residues disposal as same disposal area can be used again,

(b) When used in part/full replacement for sand for stowing purpose, the requirement of sand would be reduced and this will further reduce sand mining,

(c) By filling the subsided land and low-lying areas and levelling, the land can be brought to some use which otherwise previously was of no use,

(d) Stowing will help reduce subsidence and occurrence of similar events,

(e) It will help in reducing acid mine drainage,

(f) It will also help in the conservation of natural resources,

(g) It will help in eliminating ash discharge to the rivers and reservoirs,

(h) It will help in restoring soil fertility and

(i) It will help in reclamation of mined out lands.

Conclusions

It has been rightly pointed out in the above discussions that the CCR can be used advantageously in the mining areas. Whatever be the choice one cannot rule out the possibility of trace element and heavy metal contamination of surface and groundwater bodies from the leachate generated from the coal combustion residues where it has been used for various purposes. We are at a stage that we need to win the confidence of the people and remove their apprehensions that they have been carrying over the years about the possibility of ground and/or surface water contamination due to bulk use of coal combustion residues.

Long-term leaching study is one way to assess its feasibility as a fill material whether stowing or filling up abandoned opencast mines. Some recent studies conducted in most part of the country have shown that all coal combustion residues do not have the potential of heavy metal contamination and hence this study on leaching characteristics of coal combustion residues from different thermal power stations can be used in the mining areas for several uses outlined earlier. Transportation of coal combustion residues to the site of fill is yet another area that requires utmost care. Fly ash especially due to its fine nature has the tendency to get airborne and this may lead to air pollution problem in the area. Transportation of coal combustion residues especially fly ash therefore, can be done in a closed wagon, using pipeline transport via hydraulic pumping or pneumatic pumping or by forming fly ash aggregates.

In the end we realize that the increasing problems associated with the surface disposal and utilisation of coal combustion residues can be solved. The only requirement is to go for area specific solution. In case of mining areas lots of options are there for achieving successful utilisation and disposal of coal combustion residues. The case studies of coal combustion residues as cited earlier in the paper have shown some promise in realizing the goal of bulk utilisation. All these demand for proper handling of coal combustion residues in order to suit the specific needs. At the same time it is high time now to look for some newer technology, which should not only be economically feasible but also environmentally friendly.

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