An Assessment of Methodology for Transportation of Coal Ash from Thermal Power Station to an Abandoned Coal Mine Site

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ABSTRACT

It is imperative for any thermal power stations to run in sustainability manner. Because of limitations on the land availability for ash pond disposal, increasing the capacity of the existing generating units is being constrained, thereby necessitating the evaluation of alternative ash disposal methods. Many efforts have been made for ash utilization by using it in cement, fly ash bricks, concrete, building materials, fillers etc. but still problem is not resolved. The most effective approach for achieving sustainable operation is 100% coal ash disposal in safe and environment friendly manner is sending back coal ash to its original place from where it came and i.e. reclamation of mines with coal ash. This would drastically reduce new land requirements for ash dykes near the power plants and would simultaneously facilitate to reclaim the abandoned mine sites for afforestation & forest based cottage industries. It is interesting to see that today India has 60.81% power generation capacity based on coal, which is 1,87,802.88 MW as on November 30, 2016 against the total installed capacity 3,08,834.28 MW. As per an estimate 633 million tonne of coal was produced in 2015-16 in India which has led to the generation of coal ash to the tune of 245 million tonne of coal ash in the year 2015 and only 135 million tonne was utilized.

Singaruli region in central part of India is considered critically polluted area, where thermal power stations, coal mines, aluminum industry, cement plants, stone crushers, other industries and highway constructions works a taking place from time to time co-exist and contribute to the environmental pollution.

Falling in line with TERI’s forté the Climate Change & Sustainability; and contributing towards the efforts made for sustainable development, a study is being conducted for the possibility of Gorbi mine reclamation of Northern Coalfileds Limited with coal ash generated by thermal power stations. The Gorbi mine has already been declared abandoned and NGT has desired that reclamation of the Gorbi mine has to be done in one year’s time. It is felt that the power stations like NTPC Singrauli, NTPC Vindhyachal, UPRVUNL Anpara, Lanco, Obra etc. could be considered for such works.

This mine can accumulate about 22 million tonne of coal ash up to the ground level and 54 million tonne up to the overburden level. Singrauli thermal power station, one of the largest NTPC plants with a installed capacity of 2000 MW, is generating over 2.5 million tons of ash per year. At the current rate of ash generation at Singrauli, Gorbi mine can be backfilled for 20 years.

This paper also covers the information available with governmental and other agencies and made a study for the evaluation of different options on a qualitative basis for hauling coal ash from NTPC-Singrauli to the abandoned Gorbi mines of NCL. In the second step, evaluation of ten feasible options encompassing three different fly ash collection modes (wet, semi wet, and dry) and two methods of transportation (continuous and discrete) are carried out both with qualitative and quantitative factors. Three most attractive options are short-listed. In the final step, the selected three options are evaluated with technical factors in greater details. However, results of this analysis indicate that the dry systems have the best attributes and the semi-wet systems have fewer desirable attributes. All the three short-listed options (rail, belt and pneumatic) involve dry collection. Thus, the dry-rail system, which could be the least cost option,

may be considered for ash haulback from Singrauli. This would not be new and Dry rail mode of bulk powder materials handling is operative in Indian cement industry. Specially designed enclosed, pneumatically assisted gravity discharge wagons are being used for this purpose.

1. INTRODUCTION:

It is interesting to see that today India has 60.81% power generation capacity based on coal, which is 1,87,802.88 MW as on November 30, 2016 against the total installed capacity 3,08,834.28 MW. As per an estimate 633 million tonne of coal was produced in 2015-16 in India which has led to the generation of coal ash to the tune of 245 million tonne of coal ash in the year 2015 and only 135 million tonne was utilized ***[1]*****.**

The three highest rated coal-based power plants in India in the study by CSE are CESC, Budge Budge, in West Bengal; JSWEL, Toranagallu in Karnataka; and Tata, Trombay, in Maharashtra ***[2]***. While these plants follow certain best practices, their overall environmental performance is average when compared to the global best. Since the plants are subcritical, their efficiencies were nowhere near those of the latest ultra-supercritical plants. While their water use was comparatively good, air pollution control and ash handling needed improvements.

The scenario in Singrauli region is like this. Singrauli coalfield is a composite basin comprising of 'Moher Sub-basin' in the east and Main Basin on the west separated by a concealed Basement High. There are 10 opencast mines of NCL in Moher Sub-basin and NCL During 2015-16, produced 80.224 million tonne of coal ***[3]***. This leads to the accumulation of about at least 32 milion tonne of coal ash every year in that region, whilst the ash content in the coal is taken as 40%. As per the NTPC as on date about 60 million tonne of ash is stocked in ash dyke and is available to the consumers for their use ***[4]***.

The technology of backfilling enables a wide range of engineering solutions to particular mine sites and their unique sets of problems and opportunities, but such opportunity for large volume utilization of coal ash may provide a new dimension for attempting 100% ash utilization through ash haul back to de-coaled mines.

There is a second time God sent opportunity for NTPC and Gorbi mine of NCL is available for NTPC to put it's coal ash. NCLs Annual Report 2015-16, the Gorbi mine of NCL is a closed mine and NCL has made funds available for its closer, though it was abandoned quite some time back. In this regard it is felt that ash haul back activities be revived again to cope with acute problem of environmentally safe disposal of coal ash thus produced by NTPC from power stations such as Singrauli, Vindhyachal and Rihand.

The above requirement has become more emergent in view of the Order of the National Green Tribunal regarding pollution caused by coal mining, thermal plants, cement plants, aluminum or explosive plants and stone crushers located in the bordering Districts of Singrauli, Madhya Pradesh and Sonbhadra, dated 24/04/2014 ***[5]*** and the Affidavit on behalf of the respondent no. 02**,** the Central Pollution Control Board, New Delhi in compliance of the order of Hon'ble National Green Tribunal (NGT) dated 21.07.2015. This affidavit also includes at Clause C, 4. Page No. 94 - Coal Mines projects of Northern Coal field Ltd, Singrauli, NGT has desired that Reclamation of old Gorbi mine is to be done within 01 year as per condition of EC. In response to this NCL has commented that Quote "Gorbi mine of NCL is a closed mine. Closure Plan approved by NCL Board is submitted includes reclamation of mine. Work is not started". Un-Quote***. [6]***

As per an estimate Gorbi mine can accommodate at least about 25 million tonne of coal ash up to ground level and 54 million tonne up to dump level. This is sufficient to accommodate the 20 years of ash generation with the present capacity of 2000 MW of NTPC Singrauli.

It is felt that there is a need to take up first the work of "Engineering for Transportation" and "Process & Technology for Ash placement in Gorbi mines". The role of environmental agency would start later, when just before the actual process of ash placement starts. It is also true that due to the change in the weather conditions the pH, acidity and other components are likely to be varied, by the time "Engineering for Transportation" and "Process & Technology for Ash placement in Gorbi mines" are finalized. It appears that the major work on Hydrogeology and, EIA leaching has already been done in the past.

As per CEA ***[7]***, NTPC Singrauli generated about 44.6 million of ash and could utilize only 1.6 million tonne of ash amounting to 4.26% only and Stock of ash at NTPC Singrauli stations as on 31.12.2016 in only 600 tonne. Moreover still 95 percent of the coal ash currently produced is disposed of as a slurry into ash ponds near the power stations. Disposal in slurry ponds has it's associated environmental and social issues. NTPC has undertaken number of pioneer demonstration project in their various power plants to increase ash utilisation. NTPC has adopted number of indigenous technologies and solutions for enhancing the utilisation of fly ash. Option of large scale utilisation of fly ash for open cast mine fill can provide a quantum jump for enhancing ash utilisation. In addition, it can provide long term solution for ash disposal from thermal power stations. Singrauli being regarded as the "energy capital of India" the problem of disposal of the vast quantity of ash currently being produced becomes particularly acute NTPC is very interested in demonstrating the feasibility of ash haulback to mines as an alternative to ash pond disposal. As a matter of fact, most ash studies to date have clearly stated that for pit-head power stations high priority should be given to backfilling underground or open-cast coal mines with disposal ash.

Currently, coal for the SSTPS is being supplied from the Jayant mine in the Singrauli coalfield. NCL has offered the abandoned mine areas at Gorbi Mine (Pit No 1 & 4) as a possible location for the disposal of ash for reclamation. This mine site is also situated in the Singrauli coalfield. The Northern Coalfields Limited (NCL), a Subsidiary of Coal India Limited, is Coal Company associated with supply of coal for NTPC-Singrauli (SSTPS). This paper also covers the information available with governmental and other agencies and made a study for the evaluation of different options on a qualitative basis for hauling coal ash from NTPC-Singrauli to the abandoned Gorbi mines of NCL.

2. CONCEPT: The amount of coal ash generated by the Indian thermal power stations is in very huge quantities and yet market has not developed in India for its complete consumption and utilization and consumption, although the fact that coal ash is a very useful and excellent material for certain applications. Its utilization has started to increase little by little. Hence, as a natural corollary, the remaining unused coal ash produced by the thermal power stations can be best disposed to the places where it came form -- the coal mine-- the mother earth. Similar work elsewhere has also been reported earlier. [8-10]

3. POSSIBILITIES: The coal ash generated at the NTPC-Singrauli station can be safely disposed in the Gorbi mine, which is an abandoned open cast coal mine of NCL. It is learned that NGT has expressed its desire to NCL that fly ash/ Coal ash has to be used for the reclamation and reforestation of the abandoned Gorbi mine.

- A well developed and executed ash haulback project will accomplish several goals. One is that the large pits produced by open cast mining methods would be filled thus minimizing the safety and environmental problems they cause. Another goal is that the land would be reclaimed to a suitable level of productivity. This would have both positive. economic (employment and marketable products) and positive environmental (ecobalance and greenhouse gas sink) impacts.

4. STUDY OBJECTIVE AND METHODOLOGY:

- There is a need to conduct a feasibility study of how ash haulback can be incorporated into a NTPC’s coal ash management plan that would utilize an active or an abandoned open-cast mine site for disposal of coal ash from the Singrauli Super Thermal Power Station (SSTPS).
- Keeping in view pioneer nature of project and focused objectives of incorporating ash haulback options in NTPC's ash management plan, various aspects were studied by specialist agencies for (a) system design covering operations & transportation aspects of fly ash handling, (b) transportation of fly ash, cost and other inputs such as Indian statutory/ regulatory requirements, (c) environmental, geological, and hydrogeological evaluation of the two mine sites and (e) project design basis and inputs on the plant data.

5. GEOTECHNICAL AND ENVIRONMENTAL CONSIDERATIONS:

- Coal ash can be disposed of in a beneficial and an environmentally acceptable manner both in the abandoned mines (Gorbi) and/or in an active open cast mine (Jayant).
- The local soil and mine spoil are coarse textured and thus their ability to retain water is low. This implies its suitability for plant growth as less. Coal ash, on other hand, is fine textured. Therefore coal ash when mixed with local soil/mine spoil would enhance the ability to retain soil water and thus allowing more intensive level of vegetation.
- Fly ash in conjunction with local soil /mine spoil and other materials provide an excellent solution for reclamation of abandoned mines. The increased productivity of soil would provide

conditions for afforestation in the area. The restored land would thus enable realise twin benefits of

a. Serve as a greenhouse gas sink, and
b. Provide opportunity for sustainable economic activity for local people.

- Based on model studies on measurements of CO_2 flux over undisturbed tropical rain forest estimated carbon absorption by the ecosystems has been found at the rate of 8.5 (plus or minus 2) moles carbon (i.e 12 gram) per square meter per year. Thus for 48 hectares of reclaimed and afforested land at Gorbi (20 hectares in pit 1 and 28 hectares in pit 2) sink for absorbing about 5.4 tons of carbon per year can be created (considering one tenth forest productivity and more temperate climate).
- Both pits at Gorbi have accumulated water of about 6.0 million cubic meters. This water is acidic (pH 2.7) and has high iron and sulfate concentrations (exceeding limits set in IS: 10500 i.e. tolerance limits for drinking water). This is affecting ground water and has been observed in the analysis of sump waters in Gorbi area. The effect has however not been observed in deep tube wells water samples from Gorbi area.
- The ash from SSTPS could potentially release heavy metals if dumped with the pit water. Ash leaching studies have shown that fresh ash has the potential to leach Hg (The column experiment done in the past showed that leaching of various metals is maximised in acidic to near neutral conditions. Mercury (Hg) analyses showed that more than 7% percent of Hg was leached in the column tests). This observation therefore makes it necessary to dewater the pits prior to their availability for ash haulback. In addition to this, the pit water has to be neutralised with alkaline chemicals such as lime/hydrated lime or more reactive sodium and potassium hydroxide.

6. FLY ASH COLLECTION, TRANSPORTATION AND DISPOSAL CONSIDERATIONS:

The various options for ash collection, movement and transportation are considered as mentioned below.

Legend:** 4 **means technically feasible &** 6 **means not feasible

S. No	Methods	Modes		
		Wet	Semi-Wet	Dry
1	Continuous System			
a.	Mechanical			
b.	Ropeway	6	4	4
c.	Belt Conveyor	6	4	4
d.	Pipeline	4	6	6
e.	Pipe Conveyor	6	4	4
f.	Pneumatic			
g.	Vacuum	6	6	4

h.	Pressurized	6	6	4
i.	Dense Phase	6	6	4
2	Discrete System			
a.	Road Transport			
b.	Special Bulk Tanker	6	6	4
c.	Standard Truck (Bags: 50 Kg/5T)	6	4	6
d.	Rail Transport			
e.	Special Bulk Wagons	6	6	4
f.	Standard Wagons (Box 'N' type)	6	4	6

- The attributes affecting the selection of optimal solution have two dimensions *viz.* qualitative (covering land availability, environmental considerations, interface with other agencies, statutory regulations, operating ease/flexibility and proven technology) and quantitative factors (which would cover investment costs and O&M costs).
- Dry system for fly ash collection, transport and disposal have best attributes while semi wet has least.
- Dry_Rail, Dry_Belt and Dry_Pneumatic options have best attributes and lower operating costs.
- Dry_Rail system is the best option for the proposed ash haul back project. This appears to be highest rating on qualitative factors and expected to have has least investment and operating costs.

7. ROLE OF FINANCE:

A detailed study has to be made for the financial aspects.

The investment cost of various options would have to be evaluated for the proposed project is as follows:

Sl. No.	Option	Sl. No.	Option
1.0	Wet_Pipe	6.0	Dry_ Rope
2.0	Semi Wet_Rope	7.0	Dry_Belt
3.0	Semi Wet_Belt	8.0	Dry_ Pneumatic
4.0	Semi Wet_Road	9.0	Dry_Road

5.0	Semi Wet_ Rail	10.0	Dry_Rail

The operating and maintenance costs for various options evaluated for the project are:

Sl. No.	Option	Sl. No.	Option
1.0	Wet_Pipe	6.0	Dry_ Rope
2.0	Semi Wet_Rope	7.0	Dry_Belt
3.0	Semi Wet_Belt	8.0	Dry_Pneumatic
4.0	Semi Wet_Road	9.0	Dry_Road
5.0	Semi Wet_ Rail	10.0	Dry_Rail

8. SELECTED OPTION:

8.1 TECHNICAL CONCEPT:

(A) At Singrauli Power Station:

- Initially dry fly ash shall be collected from ESP hoppers field 1, 2 and 3 only. Present system of wet fly ash collection of bottom ash and ash from air-preheater, economizer, ESP hoppers of field 4 to 7 and stack hoppers would continue.
- For bottom ash and fly ash from air-preheater/ economizer/ESP fields 4-7/stack hoppers the collection shall be done in wet mode as present. The ash slurry would be received in present ash sumps. At ash sumps new jet pumps shall be installed to transport this ash slurry to hydrobins (dewatering bins). Hydrobins shall be located near unit 5. In Hydrobins excess water shall overflow to the settling tanks and then as a cleaner to the surge tanks. Each surge tank shall have a cooling tower. A floating decanter and eight stationary decanters will remove water. This ash collected in the bins shall be transported to load out silos with the help of belt conveyor and mixed with dry fly ash from ESP's hoppers for transport to Gorbi Mines in the load out silos.
- Hoppers of ESP's (for unit 3 to 7 and fields 1 to 3) shall be modified with side extraction (keeping intact main discharge system from hopper as wet for standby duty). The modifications shall be same as being currently carried out for unit No 1 & 2 i.e. installation of pressure tanks underneath each hopper. Collected fly ash in each pressure tank shall be conveyed to buffer/storage silo pneumatically in dense phase.
- In order to take care of differential ash collection in the various fields of ESP control/adjustments shall be made in cycle time settings. Solenoid operated gates for each discharge point at various field(s) has been envisaged. The differential time settings shall ensure constant flow through the fly ash headers.

Further details are not considered for the present paper.

(B) Transport:

As assessment has also been made to examine how the turnaround cycle time analysis for the bulk wagons (50 t) appear. The turnaround time of 9 hours is considered in this case. The requirement of 80 wagon and two rakes has emerged . This has been based on the following assumptions:

- Utilization of RDSO approved similar wagon (Volumetric Capacity of 70 m^3)
- Payload per wagon therefore has been considered as 50 t.

Rake comprises of 30 wagons. Operating norms considered for above computation are: (a) Days/annum= 330, (b) Hrs./day = 24, (c) Turnaround time/rake = 9 hrs., (d) Fly Ash quantity/day = 8,000 t, (e) Estimated Ash generation = 330 days/annum

Key issues in transportation are associated with logistics of rake movement. Major aspects of rake movement from SSTPS to Gorbi are:

- Single track between SSTPS and Gorbi.
- Branch (loop) line is available at Kerala road station (approx 35 km from SSTPS and 16 km from Gorbi siding). Cross over of loaded rake and empty rake is therefore envisaged at Kerala Road. Alternatively only one rake either loaded or empty can be committed to line at any given time.
- Movement of loaded rake from SSTPS and Empty rake from Gorbi has thus to be syncronised in order to reach Kerala road station.
- In addition, co-ordination for commercial traffic (at the moment very less) has also to be done at all the three station of Indian Railways namely Shaktinagar, Kerala Road and Singrauli (Gorbi siding is from Singrauli station).

(C) At Gorbi (Unloading Terminal):

- Fly ash shall be unloaded from the wagons into an unloading pit constructed underneath the track. For this purpose the existing siding to Gorbi shall be dismantled locally (at the position were unloading pits are to be installed) for construction of wagon unloading facility and then reassembled. Two number's unloading pit(s) are foreseen for simultaneous unloading of two wagons. Capacity of each unloading pit shall be 150 m^3 (= 2 wagonload).
- Fly ash from the pit is evacuated either mechanically (with the help of enclosed belt conveyor) or pneumatically (with screw pump) to 1,500 t silo. One number 1,500 t silo (steel construction) shall be installed. This silo has been considered to provide buffer for unloading of rake without any constraint as well as take benefit of larger time available for transporting fly ash to point of use (Rake has to be unloaded fast in about 2-3 hrs. i.e. at about 650 tph whereas to point of use fly ash can be transported at lower rates i.e. at about 175 tph). This would help in optimizing equipment costs for secondary handling i.e. between silo and to point of use.
  - Fly ash shall be extracted from the silo on to an enclosed belt conveyor and transported to pit no.1 and no 4. Fly ash shall be transported from the fixed belt conveyor discharge point to required area of back-filling application in tripper trucks. Fly ash shall be spread over with the help of mobile equipment e.g. dozer, compactors, pay loader and mobile conveyors etc.
  - The sequence of operations at Gorbi mines shall be as follows:
    - Placement of first two “loaded wagon” on unloading pit 1 and 2 by engine. At this time beetle will be in ambush position.

- After manual operations of connecting compressed air connections and vent ducts, unloading of wagons shall be started through master controller.
- First unloading bellows shall be moved to "discharge position". This shall be followed with starting of air compressors (for fluidisation of fly ash in wagons). Thereafter-downstream equipment, uphill silo, shall be started. Once all equipment are started unloading of wagons would commence.
- On completion of unloading of two wagons, beetle shall come out of it's ambush position and would engage wheels of empty wagon.
- Unloading of entire rake shall be done by precise movement of the wagons (i.e. movement to the required distance so as to ensure placement of wagon discharge openings directly onto bellow position). Beetle chain will be for movement of six wagons. Beetle movement shall be controlled by limit switches from the master controller.
- After every six wagons beetle will disengage and travel to wagon under unloading. This cycle shall be repeated till entire rake is filled.
- The entire operation of beetle shall be controlled from a local control panel and would be fully automatic. In addition processing of data for MIS purposes is also foreseen from this master controller.
- Dedicated compressor house for unloading pit and fly ash silo shall be installed. Compressor house shall be constructed either underneath storage silo.
- Common control room shall be installed near unloading pit(s). All operations shall be synchronized through master computer, located in this control room. Control room in addition would have MCC's and power distribution system for entire system.
- The details of power distribution system are also considered for Gorbi.

9. **Investment Cost and Operating & Maintenance Cost:** The nearest figures for the Following head are to be obtained after due survey and the investment costs are to be understood with accuracy range of ~ 20%. The basis considered for computing O&M costs are also to be decided.

The freight as per IRCA tariff is however applicable when goods are picked up from Consignor door and delivered to consignee. Thus all the facilities i.e. wagons, engine, track etc are of Indian railways. In present case all the facilities starting from specially designed wagons, loading and unloading of wagons, engine and operators are of SSTPS and only "Rail track between Shaktinagar and Singrauli" of Indian railways appears to be reasonable. In addition during operations track and facilities of Indian railways at Karela road and en-route are contemplated to be used. Under the scenario of operations it is therefore necessary that suitable lease charges for utilisation of Indian railway facilities should be negotiated with Indian railways at highest level as against freight charges. For 120 acres i.e equivalent area available at Gorbi. Equivalent wet ash system considered is: transportation in slurry pipe lines (high-density slurry with solid ratio of 70% and disposal in ash dykes. Equivalent dry system considered is dry collection and pneumatic transport to in-plant silo(s), whereafter transport to 50 km away with the help of belt conveyors (reference ash disposal system at NTPC, Dadri) and final disposal in the form of ash mounds. For similar concept i.e ash disposition at 50 km from the plant and at volumes of 8000 tpd. The scope of plant and machinery is same as that considered for dry rail including complete power distribution at plant, at booster stations and at unloading. O&M cost has to be estimated to be incurred for ash disposition in wet slurry form considering construction of new ash dykes at a location of about 50 km from the plant and with equivalent area of 120 acres.

2. CONCLUSION AND RECOMMENDATIONS:

It is felt that the Ash haul back implementation:

- is a feasible using available and proven technology and environmental practices.
- Would result in economical means of utilizing ash, when a long-term commitment exists.
- Would reduce the environmental impact on the property, waterways, and the population of India.
- Would comply with the mandate for 100% alternative utilization of ash.
- With the Dry-Rail method appears to be the most attractive.
- data mentioned here are estimated and actual data would be arrived at the time of start of final implementation

Further to above

- The impact on the power generation cost is very likely to be minimal.
- As per an estimate in US, on an average a $ 9 per ton of ash is allocated towards the electricity tariff.
- Ash haulback allows reclamation of land for rehabilitation of people at the Gorbi mine and provides improved soil conditions for high value agricultural products.
- An action plan is to be was developed for the implementation of the project.
- Phase I covering tests required and basic engineering has to be completed.
- Phase 2 including detailed engineering, procurement; construction and commissioning are scheduled after the Phase I and approval to proceed with the detailed designs.

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