Management of Ash Disposal

Naresh, D.N.
Additional General Manager, NTPC Ltd., Noida (UP), India

ABSTRACT

Management of Ash Disposal of coal based Thermal Power plant has to comply with the stipulations of the MoEF. The environmental aspects are to be considered during planning and design stage of ash dyke itself. The main environmental aspect which requires attention for ash dyke are mainly air pollution, surface contamination & ground water contamination. To minimize the impact of ash disposal on the environment it is essential to manage safe environment of ash dyke during construction, while disposing, while raising the dyke and also on abandoned dyke. For this purpose the dyke needs to be continuously monitored, inspected and maintained. This paper presents some of the key issues associated with planning safe dyke, management of ash disposal for coal based thermal power project.

1. INTRODUCTION

One of the major and important part of any coal based Thermal Power plant is combustion of coal. The by product of combustion i.e. ash mainly consists of two types of ash viz Furnace bottom ash which is collected at the bottom of the boiler units and pulverized fuel ash which is collected in electrostatic precipitators and economizer hoppers. In NTPC plants it is found that about 20% of the total ash is bottom ash and the balance 80% is fly ash. Generally Indian coal contains about 30 to 45% ash. In typical thermal project of 2000MW capacity, the daily ash production will be about 2200 tonnes of bottom ash and about 11000 tonnes of fly ash. The MoEF (Ministry of Environment & Forest, Govt of India) stipulates various conditions to be implemented while issuing environmental clearance to the power utility. Some of the main stipulations related to ash disposal are

(a) 100% fly ash utilization to be achieved in 4 years for new projects. (MoEF 2009)
(b) Effluents to meet the prescribed standards
(c) Safe ash dyke design
(d) Prevent ground water contamination
(e) Control of fugitive dust.
(f) Area limitation for Ash disposal.

For utilizing and disposing the ash, the facilities to be provided for ash utilization and disposal management is planned at the conceptual stage. The design, planning of disposal system and ash utilization shall fulfill the requirement of plant and comply with the MoEF norms. The factors affecting the environment are land for ash disposal, pollution on Ground water and surface water bodies, fugitive dust emission and failure/breach of ash dyke.

One of the major challenges in management in ash disposal is to protect the environment with safe disposal. For this purpose it is necessary to have a well planned design, construction, continuous monitoring and safe ash disposal management in place. Some of the aspects related to ash disposal and management like design, construction, monitoring, inspection, training, factors to be considered, emergency preparedness are briefly presented in this paper. A suggested check list which may help the operating stations are mentioned in the paper.

2. PLANNING, DESIGN & CONSTRUCTION

Planning and Design

The disposal system has to be planned in advance keeping in view the requirements of the MoEF stipulations and keeping the dyke ready for discharge as per the predetermined schedule. In exigencies/emergency, alternate arrangement is desirable to divert the discharge instead of taking the risk by continuing the discharge. The other aspects to be considered are the distance to the ash dyke, properties of coal, topographical conditions, geological locations, metrological conditions etc. The volume of ash generated during the design life of the plant is worked out based on the characteristics of coal. The volume of ash to be disposed is worked out at the conceptual stage on the basis of ash utilization stipulated by MoEF. The unutilized ash is disposed to an identified area contained within dyke
generally referred as tailings. To protect the environment due to ash disposal various site specific studies like topographical survey, earlier land use map, drainage pattern, environmental impact assessment, archives, meteorological data, hydrological studies, and geotechnical investigations are carried out at the proposed site.

A detailed laboratory tests are conducted to establish the physical, chemical and engineering properties of soil and analysis of subsoil water. Typical properties of pond ash are presented in Table-1. Based on the properties of founding soil and fill material, the stability and seepage analysis is carried out. Dyke is designed as per best engineering practice including IS and studies by reputed institutions. The design is done for the ultimate height and the unutilized ash to be stored.

### Table 1: Typical Properties of Ash

<table>
<thead>
<tr>
<th>Engineering Properties</th>
<th>Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bottom Ash</td>
</tr>
<tr>
<td>Grain size, %</td>
<td></td>
</tr>
<tr>
<td>-Clay</td>
<td>0</td>
</tr>
<tr>
<td>-Silt</td>
<td>15-40</td>
</tr>
<tr>
<td>-Sand</td>
<td>50-80</td>
</tr>
<tr>
<td>-Gravel</td>
<td>0</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.85</td>
</tr>
<tr>
<td>Maximum Dry Density</td>
<td>1.004</td>
</tr>
<tr>
<td>Optimum Moisture</td>
<td>39.4</td>
</tr>
<tr>
<td>Content, %</td>
<td></td>
</tr>
<tr>
<td>Effective Cohesion, (kg/cm²)</td>
<td>0</td>
</tr>
<tr>
<td>Effective angle of</td>
<td>42</td>
</tr>
<tr>
<td>shearing resistance, degree</td>
<td></td>
</tr>
<tr>
<td>Coefficient of</td>
<td>10⁻² to 10⁻¹</td>
</tr>
<tr>
<td>Permeability, (cm/sec)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chemical Constituents</th>
<th>Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bottom Ash</td>
</tr>
<tr>
<td>Silica (SiO₂)</td>
<td>70.0</td>
</tr>
<tr>
<td>Alumina (Al₂O₃)</td>
<td>24.4</td>
</tr>
<tr>
<td>Iron Oxide (Fe₂O₃)</td>
<td>2.50</td>
</tr>
<tr>
<td>Calcium Oxide (CaO)</td>
<td>0.50</td>
</tr>
<tr>
<td>Magnesium Oxide (MgO)</td>
<td>1.1</td>
</tr>
<tr>
<td>Sulphur Oxide (SO₃)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Soft wares like Geo slope, Plaxis, visual FEA etc. are also used to aid in the design.

A typical case of seepage and stability analysis is presented in fig.1 and 2. Based on the seepage analysis the internal drainage and exit gradient are arrived.

**Fig. 1: Seepage Analysis**

The stability analysis for a typical case is presented in fig. 2. Based on the analysis for static and seismic cases stable slopes are arrived.

**Fig. 2: Slope Stability Analysis**

**Construction**

Construction is a critical phase in achieving a safe dyke. Modern construction equipment permits to achieve speed with quality. Generally a starter dyke is constructed and subsequent raising is done by either upstream / inward raising or downstream/ outward raising. Refer 3 and 4 respectively. In d/s method the volume of ash to be handled is more. This may add to ash utilization. Depending upon the seismic zone the method of construction may be finalized. In seismic zone V d/s method appears to be better option than u/s construction.
Ash Disposal

Ash disposal system needs to be planned at the conceptual stage of the project. The ash is disposed either in wet disposal or dry disposal system. For use in manufacture of cement, dry fly ash is preferred.

Dry Ash Disposal

In order to make available the dry ash without mixing water, dry extraction system is adopted. In dry ash extraction system, ash collected in the ESP hoppers is removed in dry form by using either a vacuum system or a pressure system and is conveyed to a buffer hopper located adjacent to ESP. From this hopper, a part of the ash can be transported in dry form by pneumatic conveying to the storage site for further use. Fig. 5

Ash is transported in a conditioned form through conveyors and placed in predetermined manner.

Fig. 5: Ash Disposed Thru Conveyor at Disposal Site

The ash is deposited and compacted in this disposal. To avoid erosion, soil cover is placed. As there is no water used in disposal, the leachate is minimal. To control fugitive dust, plantation is done Fig. 6.

Wet Disposal

In Wet Disposal, the ash is mixed with water and the ash slurry is transported to the disposal area. In wet disposal system, there are two methods, lean concentration slurry disposal (LCSD) and high concentrated slurry disposal (HCSD). Based on the technology scanning and discussion with experts and visits to some of the power plants, the recent revolution in the area in wet disposal is HCSD with reduced water content. The mixture behaves like semi-solid and a Non-Newtonian fluid. The disposal of this highly viscous and non-Newtonian fluid requires special type pumps. Following are the few merits of HCSD over LCSD which is attracting the more use of HCSD system.

1. Water consumption is reduced due to high concentration in HCSD (60-70%) in comparison with LCSD (15-25%)
2. HCSD is highly impermeable, leaching, erosion & wear tendency is very less.
3. Specific energy consumption is reduced.
4. Fugitive dust is minimal as compared to LCSD. Because of less water, there will be no breach of the dyke. This is major relief in the safe disposal of ash.

HCSD is environmentally friendly. According to Paterson, it is important to maintain the density and rheology of the thickener under flow within a narrow range. As per limited information, the limitation in the system, is capital intensive and transportation of HCSD is generally up to 10-12 Km.

For the first time in NTPC, considering the site specific aspects at one of the projects, the fly ash is planned to dispose through HCSD by placing in layers one over the other in cells. Bottom ash is disposed off in LCSD. Separate lagooning arrangement is made for HCSD and BA. Refer fig. 7.a

For disposing HCSD, literature suggests that a slope of 1 in 20 may be maintained. To maintain such a slope during monsoon and flushing of pipes, the top ash is likely to spill over including erosion which may have a negative impact on the environment. India being tropical climate, to avoid erosion in HCSD and negative impact on environment, containment dyke is required and the same is provided which is shown in fig. 7(b). It is seen from figure that due to catchment area and to exit the surface rain run off
spillways at suitable locations around the dyke is provided. Internal drainage arrangement and toe drain around the dyke is also provided.

The top sub soil comprise of sandy Silt/Clayey Silt which is semi impervious. The ground water table at the time of investigation in 2006 is about 13 – 18m below ground level. However to prevent ground water contamination if any and to conform to the stipulations, liner is provided in following manner.

(a) The OFL and lagoon 1A is provided with bentonite blended soil.

(b) Lagoon IB and III a layer of HCSD of about 300mm thick is envisaged to be spread as the mix is highly impervious and act as barrier or as liner to prevent pollution of ground water if any.

3. MANAGEMENT OF ASH DISPOAL

Management of safe ash disposal thru wet disposal involves lagooning arrangement within the allotted land, method of disposal, continuous inspection, monitoring and maintenance ,commitment for safe disposal. In order to minimize the risk of failure, preventive measures are accorded top priority. Instrumentation of dyke is necessary and shall form an integral part of monitoring mechanism.

In order to achieve

(i) more or less uniform ash filling within the lagoon
(ii) completely utilize the available storage capacity
(iii) maintain water cover throughout to avoid island formation within the lagoon leading to dust problem

Multi point discharge may be adopted.

Preventive measures, recirculation of ash water, operation and maintenance, emergency action plan and preparedness, control of fugitive dust, control of pollution of ground water etc. some of them are briefly described here in this paper.

Land Requirement

Some of the factors affecting land requirement are ash utilization, PLF (Plant load factor), height of dyke, shape and topography of land, substrata, land use pattern, seismic zone, coal parameters etc.

MoEF has given the stipulation of land requirement for emergency fly ash storage for thermal power plant an area upto 50 hectares ( equal to 125 acres) for a 500MW unit . For storing ash a dyke is to be built which occupies certain land. Land is also required for overflow lagoon, garlanding of pipes, inspection road, toe drain etc. Typically for storing ash in 125 acres the land occupied by dyke is about 33 acres ,by garland pipes, inspection road, toe drain etc. Typically for storing ash in 125 acres the land occupied by dyke is about 33 acres ,by garland pipes, inspection road, toe drain etc. Typically for storing ash in 125 acres the land occupied by dyke is about 33 acres ,by garland pipes, inspection road, toe drain etc. Typically for storing ash in 125 acres the land occupied by dyke is about 33 acres, over flow lagoon is about 25 acres. i.e about 70 acres for 500MW unit and about 100 acres for 2 X500MW units. The land for 2X500 MW shall be 2X125 + 100 = 350 acres or 0.35 acre/MW.

To maintain the effluents like TSS within permissible limits the ash slurry needs to be decanted, for this purpose settling area may also be estimated from Stoke’s Law .

Lagooning Arrangement

In case wet disposal the planning of discharge, type of dyke, method of construction and dyke construction shall be such that at no point the generation is to be affected for want of discharge area. This is one of the challenges in ash disposal management. For this purpose and for optimum use of land there is need for multi lagooning arrangement. A typical arrangement with over flow lagoon and garland pipes around the dyke is shown in fig8(a) and the land for auxilaries are shown in fig8(b). The planning of raisings
are done as per the utilization and discharge requirement. For this purpose, a continuous monitoring of the discharge becomes essential component of management.

![Diagram](image)

**Fig. 8:** (a) Typical Lagooning Arrangement

![Diagram](image)

**Fig. 8:** (b) Land Required for Auxiliaries

<table>
<thead>
<tr>
<th>Land Description</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land for dyke (500mw)</td>
<td>35</td>
</tr>
<tr>
<td>Land for garland pipe and inspection road</td>
<td>10</td>
</tr>
<tr>
<td>Land for overflow lagoon</td>
<td>25</td>
</tr>
</tbody>
</table>

* - As the perimeter increases, dyke encroachment also increases.

To avoid ground water pollution, MoEF stipulates liner for the ash disposal area. The liner may be natural or synthetic depending upon the substrata encountered and the permeability of soil. To avoid the contamination of nearby fields, toe drain is provided all around the periphery of outer dyke which will collect the seepage water from storage lagoon which is either lead to the nearest natural drain or channel or pumped back to the OFL for recirculation. Water escape structure for decantation, method of discharge and recirculation of decanted water are provided as per requirement.

**Table 2:** Suggestive Checklist

<table>
<thead>
<tr>
<th>Checkpoint</th>
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<tbody>
<tr>
<td>1. Whether there is any signs of sinking/caving-in/boiling on the</td>
</tr>
<tr>
<td>(a) Upstream</td>
</tr>
<tr>
<td>(b) Downstream</td>
</tr>
<tr>
<td>(c) Foundation very near to the d/s toe.</td>
</tr>
<tr>
<td>2. Whether any wet spots/areas are observed on</td>
</tr>
<tr>
<td>(a) D/s slope</td>
</tr>
<tr>
<td>(b) Foundation very near to the d/s toe.</td>
</tr>
<tr>
<td>3. Whether any seepage is observed on</td>
</tr>
<tr>
<td>(a) u/s and d/s slopes</td>
</tr>
<tr>
<td>(b) Foundation very near to the d/s toe.</td>
</tr>
<tr>
<td>4. Whether any longitudinal and transverse cracks are observed</td>
</tr>
<tr>
<td>(a) On the top of dyke</td>
</tr>
<tr>
<td>(b) u/s slope and d/s toe.</td>
</tr>
<tr>
<td>5. Whether there is any damage to the turfing protection</td>
</tr>
<tr>
<td>6. Whether any stone pitching/brick lining is dislodged or caved in</td>
</tr>
<tr>
<td>7. Whether any rat holes are present on the top of dyke. u/s &amp; d/s slope.</td>
</tr>
<tr>
<td>8. Whether the rock toe is maintaining its design shape.</td>
</tr>
<tr>
<td>9. Whether the toe is in good condition.</td>
</tr>
<tr>
<td>10. Whether the toe drain is shifted/slided from its original position and clean with no obstruction for flow of water.</td>
</tr>
<tr>
<td>11. Whether there is any erosion on the u/s slope due to wave action or draw down in the lagoon.</td>
</tr>
<tr>
<td>12. Whether the filters placed to guide seepage water is not shifting from its original location.</td>
</tr>
</tbody>
</table>

This is only suggestive and may be modified as per actual requirements.

**Preventive Measures for Safety of Dyke**

Adequate free board shall be maintained to prevent overtopping. Overtopping leads to breach.

The slopes shall be maintained as per the drawings. Upstream slopes shall be protected to prevent erosion due to wave action.

Periodical inspection of ash dykes shall be done to detect weakness signs, if any.

Piping and seepage is one of the main cause for excessive settlement or instability of the dyke. There may be several reasons and the measures to prevent shall be arrived at. Cracks, rain cuts, rat holes, sink holes, water boils, settlement etc. shall be attended immediately.

Prompt remedial measures to correct the weakness.

Shallow rooted vegetation cover like grass shall be grown on the dyke top and slopes. Big shrubs and trees will affect dyke stability and also prevent visibility during inspection.

Protect downstream slopes to prevent erosion due to rain cuts and also from wave action if tail water is likely to build up.

Provide slope drains to guide the rain water falling on dyke top to the toe drains.

Provide internal drainage system to control the phreatic
line to prevent slip and piping failures.

Regular maintenance of the dyke with turfing will prevent the possibility of rain cuts. Gullies if any shall be back filled with earth and covered with grass turfing.

Stagnation of seepage water in the drains is not desirable. All toe drains and surface drains shall be cleaned periodically to remove silt or vegetation for smooth flow.

Water logging at the d/s side shall be avoided to prevent subsidence/instability of the dyke. In case of water boils placing of reverse filter is found to be effective in arresting sand boils.

In case of water stagnation on the downstream side the provision of relief wells is found to be effective.

Other suitable methods like artificial drainage through reverse filter/sand wicks/relief wells/sand blanket/surface loading etc may be undertaken. Intermittent pumping can also be considered on case to case basis.

**Operation and Maintenance of Ash Pond**

Local management instruction shall be prepared by the generating station for operation and maintenance of ash disposal. The instructions cover the function and procedures to follow to ensure safety of the dyke. Periodic inspection by cross functional team will enable the management to monitor and plan safe disposal. Awareness of the safety of dyke shall be part of monitoring system. It is experienced that preventive measures and timely repair of dykes thus prevent avoidable damage to dyke and environment.

**Monitoring**

Monitoring dykes and reacting quickly to inadequate performance or to danger signals is a continuing critical aspect for dyke safety. Awful monitoring and quick response can prevent failure to a large extent. It is very important to constantly inspect the dyke and carry out necessary remedial measures. Instrumentation data will foretell of any abnormal behavior and quick response to any abnormal behavior can prevent failures in many cases.

**Inspection**

The purpose of inspection is to verify throughout operating life of the project with structural integrity of the dyke and appurtenant structures, assure protection to human life and property around the area. Periodic inspection will disclose conditions which may disrupt operation or threaten safety. Inspection frequency shall be outlined by the local unit.

**Training**

The personnel connected with operation, inspection, maintenance of the dyke, management may be provided adequate training on regular basis which will increase the awareness and commitment to the safety. Rotation of training programmes at different sites will enable to share the experience of different site specific problems.

4. **EMERGENCY ACTION PLAN AND RESPONSE PREPAREDNESS**

In order to mitigate the risk of failure, preventive measures shall be accorded top priority. Preplanning is required to identify condition which could lead to failure. A suggestive emergency plan and response preparedness is included in this paper which shall be reworked as per local management instructions to minimize the effects of failures if any.

**Emergency Preparedness & Response Procedure**

- **Source of hazard:**
- **Area & location:**
- **Cause of emergency:** Breach of Ash Dyke
- **Emergency Response:**
- **Procedure to tackle:** Inform to the Shift-in-Charge Engineer & Fire Station and higher authority about the incident. - Ask for help Personal Safety -First-Aid Kit available

**Ambulance & Hospital:** Round the clock medical aid available in township

**Mitigation:** plug the breach portion by dumping sand/ash filled bags and restore the section. -Shift the discharge to other lagoon. Attend to the distressed area immediately - plug the breach.

**Requirement:** Round the clock inspection. Actual occurrence report to be available with respective deptt. And the cause may be looked into and arrive at long term remedial measures.

5. **CONTROL OF POLLUTION OF WATER BODIES (SURFACE & GROUND WATER)**

The disposal of ash whether a landfill or in a pond, can have significant effects on nearby surface waters if sufficient precautions are not taken. One of the control measures of pond effluent is to monitor effluent during discharge to maintain the prescribed TSS. This is maintained by providing adequate length of escape weir and recirculation of the effluent into OFL. Leachates may be prevented to contaminate ground water supplies by providing liner. To control pollution of water bodies MoEF stipulates the need for liner.

6. **CONTROL OF FUGITIVE DUST EMISSION**

Dry fly ash is readily lifted up by wind due to less cohesive
force in the fine solid particles. One of the conditions stipulated by MoEF is to control fugitive dust emission. The fugitive dust emission could be either from ash pond from a) operating lagoon, b) non operating lagoon and c) abandoned ash pond. Some of the measures on abandoned pond only are briefly described in this paper.

Fig. 9: (a) Safe Disposal for Control of Fugitive Dust. With Uniform Discharge and Free Board

Fig. 9: (b) Safe Disposal for Control of Fugitive Dust. With Sheet of Water

Fig. 9: (c) Safe Disposal for Control of Fugitive Dust. With Sprinkler

By maintaining the designed free board, uniform ash filling, judicious use of sprinklers and compaction of the exposed ash surface wherever feasible, vegetation growth etc. the fugitive dust emission from the operative and non operative lagoon, can be controlled. Refer fig 10 a to c

Abandoned Ash Pond
At one of the station the ash pond has been raised upto the ultimate height. Once the ash is filled upto the final height, to control the dust emission the final ash surface has been covered with 300mm thick soil. This cover also assisted in the growth of vegetation over the abandoned ash pond which also controlled fugitive dust emission.

Fig. 10: (a) Abandoned Dyke - Reclaimed

Fig. 10: (b) Abandoned Dyke–Vegetation

7. CONCLUDING REMARKS
One of the major challenges in ash disposal is to protect the environment. To manage safe disposal and conform to the stipulations of MoEF it is necessary to have proper
planning, studies/investigations, method of disposal at design stage, implementation stage, and management of safe disposal during operating and non-operating stage. MoEF (2009) has stipulated the land for emergency storage of ash.

Based on the technology scan and visits/discussions with experts/utilities/manufacturers it is gathered that HCSD has several advantages compared to other disposal methods.

To contain the material within the boundary there is need for containment dyke. The design shall ensure necessary drainage arrangements and free board to account surface and rain run off. HCSD helps to mitigate the pollution of water bodies. Risk of breach will be minimum. The cake like formation on drying fugitive dust emission is minimal compared to other disposal methods.

The system despite being capital intensive is environmental friendly. The present limitation is in the pumping distance and size of the particles.

Monitoring and Periodic inspection and preventive measures enable a safe ash disposal. Tendency to overfill will avoid overtopping and this will minimize the risk of breach. Preventive measures shall be accorded top priority. Instrumentation of the dyke is a useful tool in maintaining the dyke.

Training to increase the awareness for reducing water and natural resource consumption, responsibility towards pollution prevention measures shall form a part of management in ash disposal which will help in a long way in protecting the environment.

Thus the challenge arising out of ash disposal in pond can be mitigated through response management and adequate resources.

ACKNOWLEDGEMENT

I take this opportunity to express my profound gratitude and sincere thanks to management of NTPC, for allowing me to publish this paper I acknowledge with thanks to my colleagues for their generous help in the form of discussions.

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