DESIGN AND MAINTENANCE OF ASH POND FOR FLY ASH DISPOSAL

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ABSTRACT: Thermal Power Plants using coal is chief source of energy in our country and it is likely to remain so in near future. The total production of fly ash per annum has already crossed 100 million tones and the disposal of the fly ash is causing several challenges. Utilization of fly ash has picked up but till the percentage utilization is far below satisfaction and power plants are no option but to dispose the fly ash in ash pond. No well defined design procedure or codal provision exist for the ash pond construction and maintenance. Fly ash being a waste product, power plants do not always pay much attention on maintenance of the ash pond. There are number of serious failures in ash pond which resulted in escape of ash slurry into the surrounding areas, including water bodies and created environmental hazard. This paper describes various issues related to the design and maintenance of ash pond.

1. INTRODUCTION

Out of various alternatives for disposal of fly ash, use of ash pond in which ash slurry is discharged is most widely used by thermal power plants. Fly ash and bottom ash from the power plant is mixed with water in a ratio varying from 1 part ash and 4 to 20 parts of water. The slurry is then pumped upto the ash pond which are located within few kilometers distance from the power plant. Depending on the distance and elevation difference, energy required for pumping is very high and often requires booster pumps at intermediate locations.

There is a basic difference between an ash pond and a water reservoir. The major differences are highlighted below.

- Only the ash particles settle close to the bund and the water after decantation travel away from the bund forming a sloping beech.
- The bund is not subjected to hydrostatic pressure over the full height of the bund as the water travels away from the bund. Due to provision for good drainage all along the bund, the phreatic line is maintained at very low level to ensure that the bund section and the deposited ash particles closer to the bund are in dry condition.
- The water, after decantation is not allowed to accumulate in the pond but it is removed from the pond to ensure that the phreatic line is maintained at lower level.

The ash pond can be designed economically utilizing the advantage of low phreatic line as mentioned above. This paper describes important issues related to design, operation and maintenance of ash pond. It is noticed that in many cases, some of the important requirements have not been met with which results in unsatisfactory performance of the ash pond.

2. ASH POND LAYOUT

Following points shall be noted while selecting the location and layout of the ash pond:

1. The area shall be as close as possible to the power plant to reduce the pumping cost.
2. Provisions shall be made for vertical and horizontal expansion of the ash pond depending on estimated life of the power plant.
3. To the extent possible, the area shall be away from water bodies such as river, lake, etc. to prevent pollution of the water body due to the seepage of water from ash slurry.
4. In coastal area were ground water is already saline, area with pervious soil is preferable to effectively drain the water through the bottom of the ash pond. Such ash pond can have good drainage, gets drained faster and have better stability.
5. In the interior areas, even if it is away from water bodies, it is preferable to have a fairly impervious stratum to prevent migration of ash water into the ground water. As per Pollution Control Board norms, an impervious membrane has to be provided to prevent pollution of the ground water.
6. If hilly terrain is within reasonable distance, a suitable valley can be identified for forming the ash pond. In such case, the hill slopes will serve as ash dyke and the length of the dyke to be built will get considerably reduced (eg. Vijaywada and Mettur Power Plants).

In most of the ash ponds, the total area available is divided into two or more compartments so that anyone of the compartment can be in operation while other compartments were ash has already been deposited is allowed to dry and there after the height of the pond is further increased. If the area comprises of a single pond, it is not possible to increase the height while the pond is in operation. Each compartment is required to have certain minimum area to ensure that there is adequate time available for settlement of ash particles while this slurry travels from the discharge point to the outlet point. This distance should be minimum 200m to ensure that only clear water accumulates near the outlet.

3. DESIGN OF BUND

Unlike water reservoir, the ash pond is constructed in stages. Each stage has an incremental height of 3 5m. The advantage of constructing the ash pond in stages is that their initial cost is very low. It also saves the overall cost compare to a single stage construction. Following methods are commonly adopted for stage wise construction as shown in Fig.1:

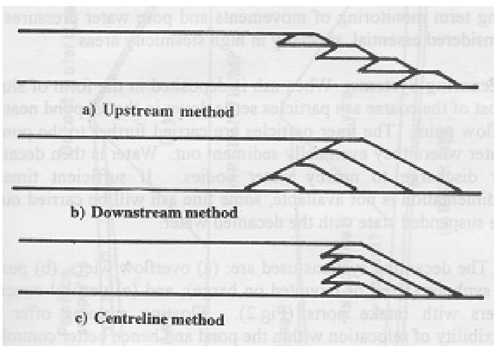

Fig.1 Methods Of Raising Dyke Height

(a) Upstream Construction Method

This is most referred design as the earthwork quantity required is minimum. However this has following disadvantages:

- The entire weight of new construction for raising the dyke is supported on deposited ash. Unless ash deposition is carefully done, there can be finer ash particles deposited along the bund and may not have adequate baring capacity to support the new dyke.
- As the height of the pond increases, the plan area of the pond goes on reducing. Beyond certain stage, it becomes uneconomical to raise the height further on this account.
- The drain provided on the upstream face needs to be suitably connected to the drain of the earlier segment. If this is not carried out properly, the drainage can be ineffective resulting in rising of phreatic line and reducing the stability of slope.
- Since the entire segment of new construction is supported on deposited ash, liquefaction analysis of the deposited ash is very important. If the deposit is not safe against liquefaction, suitable remedial measures needs to be adopted before raising dyke.
- While raising the height of the dyke, it is not possible to operate the pond as it needs to be dried, particularly along the periphery to initiate the construction.

Out of the above 3 alternative methods, the upstream method is mostly chosen due to its minimum cost. The aspects to be taken care are adequacy of the deposited particles to support the additional weight. Apart from the stability of the dyke, following features shall be included in the design:

- The entire upstream face of the dyke shall be provided with stone pitching or brick lining or precast tile lining to prevent erosion of the slope by wave action during heavy wind.
- The entire downstream slope shall be provided with grass turfing to prevent erosion of the downstream side during rains.
- A rock toe and toe drain shall be provided for safe exit of seepage water into a natural drain without any inundation of the downstream area and thereby softening of the natural strata.
- Adequate transverse and longitudinal drains shall be provided on the downstream face. Wherever the height of the dyke is exceeding 5m, berms shall be provided at ever 3m vertical intervals with a longitudinal drain to prevent erosion.
- The material for the dyke shall be adequate resistance to erosion. The erodibility of the chosen material shall be checked by a peak hole test (Sherard).
- Decanting system shall be provided to ensure that free water inside the ash pond does not pile up to a large head. After decantation, the clear water shall be drained off ensuring minimum height of water above the ash deposition at the outlet such that the suspended particles are within the permissible limit of 100ppn.
- If natural valley is utilized for ash pond, the surface runoff from natural hill slopes outside the pond area shall not be allowed to enter the ash pond area. Instead it should be suitably diverted to the surrounding area by constructing catch drains so that the load on decanting system does not increase during monsoon. Also a spillway shall be provided for the unforeseen circumstance of very heavy rain and blocking of the decanting system. If such spillway is not provided, slurry and rain water can reduce the minimum free board required and can result in serious failure of the dyke.

(b) Downstream Construction Method

After the pond gets filled upto the first stage of construction, the pond height is increased by depositing the earth / fly ash on the down stream face of the dyke ash shown in the figure. In this case it is possible to raise the height of the pond even when the pond is in operation. However there is no reduction in the quantity of construction which is same as a single stage construction.

(c) Centre Line Construction Method

In this method, after the pond gets filled upto the first stage, material is placed for raising height of the dyke on either side of centre line of the dyke such that the center line of the dyke remains at the same location. This requires part of the raw material to be placed on the deposited ash and part of the material on the down stream face of the existing dyke. The earth work required in this case is less compared to the construction while down stream method. However, as the material is required to be deposited on the settled fly ash, it is not possible to carry out the construction when the pond is in operation. This method can be adopted only if the total area of ash pond is divided into compartments.

4. GEOTECHNICAL ISSUES

Some of the ash dykes have large length (exceeding 5 8km) and large height (20 30m). Such structure can be classified as large dam as per the prevailing classification of earthen dams. It is therefore very important that all the Geotechnical aspects in the design is carefully looked into. The main issues are as follows:

Detailed Geotechnical investigation along the dyke alignment and at few locations in the ash pond area is essential. As per standard practice, the soil data shall be available for every 50m distance along the length of the dyke. The investigation shall be carried out upto a hard strata or upto a depth likely to be influenced by the construction of ash pond, whichever is earlier.

Presence of weak layer such as soft clay or loose sand which is likely to liquefy have to be established by this investigation. In addition tests are also required to be carried out on identified borrow soil to check its suitability for construction of ash dyke.

At present, most of the existing power plants utilizes fly ash itself as borrow soil to construct the ash dyke. This reduces cost of construction and increases the storage capacity of the pond depending on volume of fly ash excavated. However, fly ash can get easily eroded under flow of water. It is therefore necessary to provide an earth cover (generally thickness varies from 0.5m to 1m) to protect the compacted ash against erosion. Soil used for such earth cover shall be of CI/CL/GC type having liquid limit less than 50% and clay content not more than 30%.

Similarly the fly ash used shall be collected closer to the discharge point were the particles are of larger size and expected to give a higher angle of friction. It is possible to compact fly ash at varying degree of moisture content. The optimum moisture content generally varies from 25 35%. As such it is possible to carry out the construction even during monsoon. The fly ash is normally placed in layers not exceeding 200 300mm in loose thickness and compacted to 70% related density using a vibratory roller.

Stringent quality control is necessary to check the type of material used, construction method, degree of compaction, etc. It is also important to monitor the performance of the dyke using following instruments:

- Settlement gauges
- Inclinometers to check the horizontal movement of the slope, if any
- Peizometers to check the pore water pressures and to establish the phreatic line.

In many places the surface soil is less pervious compared to the strata at deeper level. When borrow soil is excavated from the pond area, it is likely that the impervious layer is excavated and the decanted water can seep through the pervious layers at depth across the dyke of the pond. This seepage water after crossing the dyke at deeper level will travel vertically up wherever the thickness of impervious layer is small and create piping. This phenomenal can gradually remove the soil particles along with the flowing water and weaken the natural strata.

If any piping failure is noticed on the downstream side, the same shall be plugged immediately. At such location, relief wells shall be installed. The relief well permits safe passage for the water under excess hydraulic pressure to exit vertically up to the ground level, through the less pervious strata without the risk of piping failure. The water drained out from the relief well is safely drained to a natural strip such that downstream area is not in undated. This makes the downstream area in dry condition with much better shear strength than the situation expected without the relief wells.

The upstream face needs protection against erosion from decanted water, in the event of no deposition along the dyke. This is normally achieved by stone pitching or brick lining or using precast tile. This more essential were the size of the pond is large and with long fetch available, the waves generated during the cyclonic wind can be high.

There are several instances of deep gulley formation on the downstream face of the ash dyke. To prevent such erosion, it is better to provide berms at vertical intervals of 3 5m along the downstream face. This will dampen the continuous runoff or the downstream face and thereby reduce the velocity of runoff. In addition, grass turfing is also required to protect the surface against erosion.

5. ENVIRONMENTAL ISSUES

Though fly ash is known to be an inert material, there is an appearansion about certain soluble chemicals in the decanted water which can have adverse effect if such decanted water is let into a river body or ground water. For this purpose, the norms of Pollution Control Board insist on providing a plastic liner over the entire bottom of the pond and upstream face of the ash dyke. New ash ponds being constructed have to provide the plastic liner to prevent pollution of ground water. Due to the presence of plastic liner, provision of the drainage becomes difficult and as result the deposited sediments could not get consolidated to the same extent as that anticipated in the pond without plastic liner. For this reason, whenever plastic liner is provided, it is important to check the adequacy of strength parameters for the deposited ash for supporting the next section of the dyke if upstream method of construction is adopted.

Apart from pollution to ground water, another major concern is dust pollution in the surrounding area during heavy wind. To prevent dust pollution, water sprinklers shall be arranged in the beach area which is in dry condition. The dust pollution is more from the pond which is not in operation and where construction is in progress by excavating the fly ash.

For the pond which has reached the ultimate height and no further extension of height is warranted, the surface shall be covered with a 300mm thick soil layer. Suitable vegetation shall be grown over the area which ensures no dust pollution.

6. MAINTENANCE OF ASH DYKE

These guidelines for maintenance of the pond are based on various observations made at various project sites. The guidelines cover important points to be observed during operation of the dyke.

(a). Method of Slurry Discharge

For ash ponds of this nature, it is most important that the discharge of slurry is distributed uniformly over the entire perimeter of the ash dyke, except at location close to the water exit point. It is observed that out of various sizes of ash particles, the coarse particles have tendency to settle near the discharge point and the finer particles get carried away from the discharge point. Therefore the properties of particles near the discharge point is much better with coarse size, high angle of friction, better permeability / drainage and less compressibility. On the other hand, the particles which are carried further (away from the discharge point) are of finer nature, with high compressibility, poor drainage and low angle of friction.

Therefore, the discharge points have to be uniformly distributed. This will provide adequate bearing capacity and resistance against slip circle failure for the construction of ash dyke over the deposited ash along the perimeter. It is noticed that though more number of discharge points have been provided, only few of them (2 or 3) are operated at a time. It is better that the discharge shall be simultaneously made from all the discharge points for more uniform beach formation along the perimeter. If any leakage is formed in the slurry discharge pipe, the same shall be immediately blocked as this will otherwise create erosion of the downstream face and deposition of ash on the downstream face leading to dust pollution.

If the distance between discharge points is more than 30m, it is preferable that one or two flexible hoses of 15 to 20m length are attached to the discharge point and the other end of the hose is manually shifted within a radius of 15 20m on either side of the discharge points. This will prevent local heap formation and provide uniform beach.

Apart from the above, careful watch shall be exercised to ensure that a minimum freeboard of 0.5m is available at the dyke location. Even after uniformly distributing the slurry, if the beach length is less than 30m, the discharge pipes shall be extended into the pond by supporting the pipe suitably over the deposited ash to the extent such that minimum 50m wide beach is formed. Reduction in beach length will increase the seepage on the downstream side and can create problem of instability of the downstream slope.

When the free board in the reservoir is less than 0.5m, further discharge shall be switched over to the other pond. The construction sequence shall be planned such a way that the other pond is ready in all respect to pond the discharge. Even if the other pond is not ready, alternate arrangement shall be made to divert the discharge elsewhere instead of taking a risk by continuing the discharge in the same pond and reducing the free board.

(b). Decanting System

The elevation of cascade wall or flash bar or opening in decanting shaft is very important. This shall be chosen to ensure the following:

i. Minimum beach length as mentioned above is formed. If the elevation of outlet wall is increased, the beach length will get reduced.

ii. The quality of decanted water should be satisfactory with total suspended solids less than 100ppm. If the elevation of outlet is low, the suspended solids will increase.

At any time during operation, if the out flowing water does not meet the requirement, the elevation of the exit of the pond shall be raised. Water samples shall be regularly collected at interval of 1 week and check for total suspended solids. A register shall be maintained with records of such measurements. Higher concentration of particles is likely to create more deposition in the recirculation sump raising the outlet elevation and it may require evacuation.

A delay in raising the outlet elevation will result in high concentration of ash. On the other hand, too early raising will result in increased area of decanted water pond and reduce the beach length.

(c). Raising of Ash Dyke

The pond which has already been filled-up shall be allowed to dry without any further discharge of slurry for a minimum period of 1 month before the construction for raising the height is taken up. The pond which is not being used shall be provided with water sprinklers at regular intervals to ensure that the surface of the pond is maintained moist to prevent dust pollution. Too much of water spraying shall be avoided as this is likely to make the surface slushy and movement of the vehicles for construction purpose will be difficult.

(d). Maintenance of Ash Dyke

It is very important to constantly supervise the ash dyke and carryout necessary remedial measures. Following aspects have to be considered during inspection of the dyke:

i. Wet patches on downstream slope

This is possible only if the beach length is not adequate and/or the drainage is choked. Corrective measures shall be taken immediately. If the wet patches continue to appear, the area shall be protected by placing a sand filter layer followed by a layer of stones to prevent piping failure. Wherever relief wells are provided, the outflow from the relief wells shall be monitored. A register shall be maintained recording rate of flow from each relief well. Such measurements shall be taken a frequency of 15 days. If any of the discharge pipe from the relief well is found to have been blocked, the same shall be cleared for effective relief of the seepage water.

ii. Gulley formation

The downstream face can have gulley formation due to surface water flow during rain. This can be prevented by maintaining grass turfing and by selecting non erodible earth cover during the dyke construction. If any gulley formation is noticed, the same shall be back-filled with cohesive soil (not fly ash) and covered with grass turfing.

iii. Rat holes / animal burrows

During inspection if any rat holes or animal burrows are noticed, the same shall be plugged using cohesive soil and covered with grass turfing.

iv. Softening of downstream area

Apart from the dyke slope, the are adjacent to downstream of the rock toe shall also be inspected. If any softening of the ground is noticed due to seepage of water, the area shall be provided with an inverted filter blanket. At such locations, relief well shall be installed for safe exit of the seepage water.

v. Growth of plants

No plants / trees shall be allowed to grow on the downstream face. If any such growth is noticed, the area shall be cleared by removing all the roots, plug the area with selected cohesive soil and cover with grass turfing.

vi. Choking of surface strains

Due to deposition of soil particles in the toe drain or drains provided on the downstream face, the function of the drain is affected. This results in stagnation of seepage water in the drain which is not desirable. All toe drains and surface drains shall be cleared by removing soil or vegetation for smooth flow.

vii. Along the ash dyke, if reduced free board is noticed at a local point due to settlement of the dyke of erosion of earth cover at the surface, the same shall be rectified by providing additional earth fill on the top of the dyke. If the earth cover is formed to be missing or eroded, the area shall be covered by additional earth cover of minimum 0.5m thickness.

viii. Site shall maintain a record of total inflow into the ash dyke through various discharge pipes as well as total outflow over the spillway. Suitable measuring system such as “V” notch or venturymeter shall be fitted for such measurements.

ix. The dyke shall be visited particularly after events like earthquake, cyclone, heavy rains, high flood in the river, etc. and a report prepared based on the observation. If any damage is noticed, the same shall be rectified as per the guidelines given in this note. If no suitable guidelines are found for the nature of the damage, the designer of the dyke shall be consulted immediately.

x. The beach area of the pond which is under operation shall be inspected. If any subsidence or sink holes are noticed along the beach, the downstream side at the same location shall be inspected. A site report of such observations shall be communicated to the designer.

(e). Monitoring the Dyke

In view of various uncertainties in the design of ash pond, it is preferable to monitor the performance of the bund through out its operation. The equipments for such monitoring are same as that used for monitoring of dams. These are readily available in the market and does not cost much. Instruments commonly provided for such monitoring are listed below:

(i) Settlement gauges along the top of the bund.

(ii) Piezometers, minimum 3 to 4 nos. at critical sections to check the phreatic line during various stages of operation to verify the efficiency of internal drains.

(iii) Inclinometers to check for any instability in the slope and lateral movement of the dyke.

All the instruments for monitoring purpose mentioned above shall be protected against damage by the local people and by movement of vehicles. The measuring instruments shall be kept under safe custody at site office and regularly cleared to prevent corrosion and malfunctioning. The batteries, if any shall be regularly charged or replaced.

It is recommended that on each of the ponds, two locations shall be identified on each side of the dyke and these locations shall be provided with instruments mentioned above. The measurements on these instruments shall be regularly carried out (every month) and the results shall be maintained in a register for review.

(f) Other General Recommendations

Following are desirable for effective operation and maintenance of the ash dyke:

(i) The entire area of the ash dyke shall be provided with fencing and unauthorized entry within this ash pond area shall be strictly prohibited. Security guards shall be posted for vigilance of the ash dyke area round the clock. This is very important as there are chances of sabotage.

(ii) The entire dyke perimeter shall have accessible roads with atleast WBM topping.

(iii) The entire dyke area shall be provided with street lights or flood lights for inspection purpose. These lights need to be turned on only in case of inspection during night.

(iv) A site office shall be constructed with a full time Engineer responsible for inspection and monitoring of the ash dyke.

7. SUMMARY

This paper highlights important issues related to design, construction, operation and maintenance of ash pond. Most of the observations are based on experience at various ash pond sites. Various case studies will be discussed during the lecture.

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