International Journal of Advance Research in Science and Engineering
Volume No 07, Issue No. 01, January 2018
www.ijarse.com
IJARSE
ISSN: 2319 - 8354

STABILITY OF ASH DYKE: A CASE STUDY

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ABSTRACT:

Energy in the form of electricity is the lifeline of one's day to day activities. Thermal power and hydro power are widely used method for generation of electricity. In India over 70 % of the electricity generated is from coal based thermal power plants. Despite the several inherent advantages/utilities, the coal based thermal power plants generate significantly large quantities of solid by-product namely fly ash. A huge amount of fly ash is generated in India. There is an unbalance between the ash generation and its utilization. Such a huge quantity poses challenging problems in the form of land usage, health hazards and environmental dangers. This paper describes some serious problems and their redress related to the stability of fly ash dyke at Panipat Thermal Power Station (PTPS).

INTRODUCTION: PTPS is coal based and as a result huge quantity of fly ash is produced. The disposal of the fly ash and bottom ash is a challenging task.

As is the case with most of the thermal power plants in India, the PTPS uses wet disposal system for the disposal, the fly ash is transported as slurry through pipes and disposed of in an impoundment called 'ash pond' resulting in formation of a large mound of ash called ash dyke.. The location and layout of the ash ponds for PTPS is suitably located near the power plant so as to reduce the pumping cost of the slurry (bottom ash mixed with water). The upstream construction method has been adopted for the ash dykes for PTPS, Panipat.

Some of the problems and the prominent areas that need attention are:

a) The side slopes of the fly ash dyke are inadequate leading to frequent slips and damage to the embankment including the anchor blocks and supports of pipes.

b) There has been no provision of an impervious membrane (plastic liner) in the interior area (the entire bottom and upstream face) of the ash pond to prevent pollution of the ground water.

c) An internal drainage system of toe drain and rock toe is absent in the case of first stage of the fly ash dyke. Even in the subsequent stages of development of the dyke, the seepage disposal system has been inadequate.

d) The nearby low lying village Khukhrana has serious problems of waste water disposal. As a temporary solution PTPS is occasionally pumping this waste water to the ash dyke, thus in process not only adding undesirable load on the dyke but also mishandling the northern part of the dyke.

e) The villagers are using the periphery on top of the dyke as a thorough fare for going to another village. For this they are frequently using motor-bikes and bicycles as well, thus damaging the side slope of the dyke.

DESCRIPTION OF ASH DYKES: There are 2 ash dykes (one for units 1 to 6 and another for units 7 & 8) located at a distance of about 2 km away from power house opposite to the thermal plant on the other side of Panipat – Assan road adjacent to existing raw water reservoirs/ pump houses for the plant.

Ash pond 1 with an area of 625 acers and bund height 12.25 m is used to manage ash slurry from Units 1 to 6. Its estimated present capacity to handle fly ash is 1.1 million tons. Ash pond 2 with an area of 200 acers and bund height 15.25 m caters to Unit 7 & 8. Its estimated capacity to handle fly ash is 1.3 million tons. Assuming 50% dry ash utilization the current capacity of Unit 7 & 8 ash pond might cater for 2.5 to 3 years, Units 1-6 ash pond 1 to 1.5 years. The future plans are:

- Unit 1to 6 ash pond – bund height increase by 4 m is planned, which could generate additional capacity of 3.5 million tons
- Unit 7 & 8 ash pond: feasibility study to increase bund height by 4m is proposed.

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a) Description of Ash Dyke No 1(For Units 1 and 6) (Earthen Embankment)

The layout of the Ash Dyke is given in figure 3.1. Presently, the fourth stage/lift of the ash dyke no 1 is in use for the disposal of bottom ash. A brief description of the various stages/lifts of the ash dyke is here under.

- **First stage/lift (i.e. mother or starter dyke):** The first stage of the dyke is 4.0 m in height. The construction material used for this stage was fly ash excavated from the lagoon (ash dyke) and a soil cover (0.5 m thick) to the embankment. No information is available on the depth of impervious stratum at the site. Further, an impervious membrane (plastic liner) in the interior area (the entire bottom and upstream face) of the ash pond had not been provided to prevent pollution of the ground water. Also the first stage has no toe drain.

- **Second stage/lift:** The second stage of the dyke is 4.0 m in height. The construction material used for this stage was fly ash excavated from the lagoon (ash dyke) and a soil cover (0.5 m thick) to the embankment. No impervious membrane (plastic liner) had been provided on the upstream face. The second stage/lift has an internal drainage system with a toe drain.

- **Third stage/lift:** The third stage of the dyke is also 4.0 m in height, taking the height of the dyke to 12 m from the ground. The construction material used for this stage was fly ash excavated from the lagoon (ash dyke) and a soil cover (0.5 m thick) to the embankment. Similar to the second lift no impervious membrane (plastic liner) on the upstream face. The third stage/lift also has an internal drainage system (with a toe drain) suitably connected to the drain of second stage.

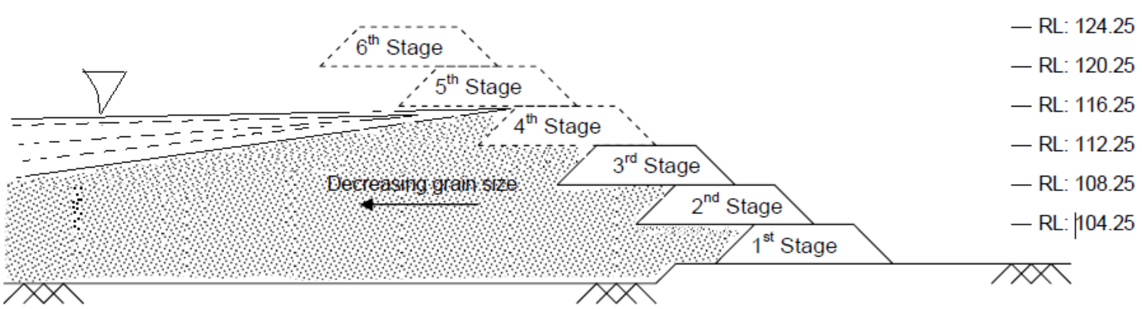

Figure 3.1 Layout of the fly ash dyke

- **Fourth stage/lift:** The fourth stage of the dyke is raising to 4.0 m in height. The construction material used for this stage is fly ash excavated from the lagoon (ash dyke) and a soil cover (0.5 m thick) to the embankment.
- **Proposed fifth and sixth stages/lifts:** The construction of the next stages/lift is expected to begin in next few months. The proposed height is 4.0 m. Two more stages/lifts of 4.0 m each (fifth and sixth stages respectively) with suitable berm widths are also proposed.

b) Description of Ash Dyke no 2 (for units 7 &8) (Earth Embankment)

Fly ash generated from Units 7 & 8 is being disposed off to a common ash disposal. Presently 2nd stage/lift of fly ash dyke is in use for disposal.

- **First stage/lift:** Initially 7.0 meter high starter dyke from elevation 100.25m to 107.25m was constructed during the year 2004-05 having storage capacity of about 26.1 Lac m^3. Later on to cater the additional requirement of ash disposal, the height of ash dyke was raised by another 8m from elevation 107.25m to 115.25m which enhanced the storage capacity to 45.6 Lac m_3 (40.7 Lac MT) and the work was completed on 30.09.2009.

- **Second stage/lift:** HPGCL propose to raise the height of the existing ash dyke of Units 7&8 from bund top EL. 115.25m, done previously in 1st raising over the starter dyke with lagoon ash at PTPS, Panipat. The 2nd raising now in ash dyke of unit 7&8 is proposed to be constructed from 115.25m to 119.25m from ash borrowed from the settled ash in the existing ash pond and from the stilling ponds. The ash from the stilling ponds is to be lifted first and then from the ash pond area. The ash bund will have earth protection layer at top. The proposed raised ash pond will also have collector wells one each for segment A and B for collecting supernatant water for recycling in the ash disposal system.

PROBLEMS, EFFECTS AND PROBABLE CAUSES/REASONS: The following problems have been identified with respect to the stability and protection of the ash dyke. The problems, along with the effects and probable causes / reasons have been stated and discussed as under:

A. **Stability of the ash dyke**: The ash dyke of PTPS, Panipat is facing some serious problems related with its stability, particularly so in the case of the northern and western portions of the embankment/bund of the mother ash dyke (first stage).

These include:

a. *Internal drainage system consisting of toe drain and rock toe:* An internal drainage system consisting of toe drain and rock toe is presently absent in the case of first stage of the ash dyke (mother dyke). Its absence has made the drainage ineffective resulting in rising of phreatic line and reducing the stability of slope. Further, due to the absence of this system for first stage of the dyke, there is no connectivity of the successive stage to the first stage.

b. *Seepage failures*: Seepage failures have been noticed at various locations, particularly on the northern bund of the ash dyke. These seepages from ash dyke towards feeder channels are causing scouring of the embankment and making slush to slip in the feeder channels. The stability of slope and quality of raw water supply to the plant via feeder channels is greatly affected by such heavy seepages from ash dyke.

These above mentioned failures can be attributed to –

(i) The phreatic line (top seepage line from the dyke) cutting the downstream face of the dyke, instead of terminating at the toe drain;

(ii) The filter comprising of aggregate at the downstream bottom portion is not in position.

c. *Failures of gasket/leakages in the joints/bursting of ash slurry disposal pipes*: Failure of gaket/leakages in the joints/bursting of ash disposal pipes is noticed, particularly on the northern bund. These are sometimes responsible for breaches in the embankment as well as pollution of the raw water feeder channels.

d. *Gully formations*: Gully formation has been noticed at various locations. Such formations greatly reduce the stability of slopes, particularly during heavy rains. The possible reasons of gully formations include surface water flow during rains and leakages from disposal pipes, lack of grass turfing, presence of animal burrows, etc.

e. *Grass turfing on downstream face*: There is no or little grass turfing on the downstream face of the embankment at various locations. This is causing erosion of the embankment during rains and leakage/bursting of slurry disposal pipes. Lack of grass turfing on downstream slopes also encourages gully formation.

f. *Ash slurry discharge points*: Ash slurry discharge points are not well and evenly distributed. While there is no more concentration of these points on the northern side of the dyke, these are visibly fewer in the additional Disposal Area adjoining the southern bund. As a result, slurry is not distributed uniformly over the entire area of the ash dyke. Also the slurry is not discharged simultaneously from all the discharge points.

g. *Beach formation*: The beach formation is not proper at many locations. The reduced beach length is a cause of increased seepage on the downstream side and can affect the stability of the downstream slope.

h. *Unauthorized entry within the ash dyke area*: The unauthorized entry of vehicles and animals within the disposal area (ash dyke area) has been damaging the embankment and, in turn, reducing its stability. The grazing of animals is affecting the stability of ash dyke in more than one way; such as-removing/decreasing the grass turfing, animals burrows leads to the formation of gullys, damaging the supports and joints of ash slurry disposal pipes, accidents, etc.

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i. *Damaged berms*: The berms are damaged at many places due to the movement of authorized and un-authorized vehicles. The damaged berms lead to the damage of slopes of embankment. The damage is severe during rainy season and / or when the berms are wet due to seepage.

j. *Delay in the maintenance works*: It has been observed that the repair of damaged portions of the embankment has not been carried out timely. The delay compounds the problems of stability of embankment.

k. *Absence of street-lights or flood-lights*: Street-lights or flood-lights have not been provided in the dyke area. These are essential for inspection purposes during night and help in early detection of the problem and, in turn, early repairs.

l. *Monitoring facilities*: Monitoring facilities necessary for the operation of the ash dyke are not adequate. As a result, certain essential measurements like checking of phreatic line, efficiency of internal drains, instability in slope and lateral movement of the ash dyke cannot be ascertained / detected at an early stage.

B. **Effect on raw water feeder channels**:

Due to the failure of gasket, leakages in the joints, bursting of old ash disposal pipes and scouring of the earthen embankment leads to the slipping of slush in the feeder channels. As a result of which the following problems have arisen:

a. *Reduced carrying capacities of the feeder channels*: The slipping and accumulation of slush has reduced the carrying capacities of the feeder channels and, in turn, the raw water supply to the Plant is greatly affected. In fact, due to the accumulation of slipped slush the Feeder Channel-2 has become non-functional in the major portion of the stretch/stage between Badshahi Drain and the existing regulator. Even the remaining portion of this stretch/stage is in very bad shape.

b. *Growth of vegetation in the feeder channels*: The slipped slush in the feeder channels also enhances the vegetation growth in the channels due to the increased soil and nutritional content in the form of phosphorous and nitrogen present in the fly ash. This,

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apart from decreasing the carrying capacity of the feeder channels, increases the pollution load as well.

c. *Pollution of raw water supply*: The slipped slush is responsible for pollution of raw water supply to the plant. The fly ash does contain some toxic heavy metals like, aluminium, chromium, manganese, iron, cobalt, nickel, copper, zinc, arsenic, lead and cadmium in varying proportions which are harmful for human beings. Since these feeder channels also supply water to the residential areas, its pollution by such toxic heavy metals is a serious health hazard.

d. *Silting of storage ponds*: The slipped slush in the feeder channels leads to the silting of storage ponds.

C. Problems faced by the residents of the village Khukhrana

Khukhrana is an environmentally challenged village located in the proximity of the Panipat Thermal Power Station on the Panipat-Jind Highway. The northern side of the ash dyke covering an area of about 800 acres is within a distance of I00-150m from the village. The contaminants containing percolating water from the dyke feeds the underground water reservoir of the area.

The probable reasons for the problems faced by the residents of the village are listed below:

- *High groundwater table*: the natural groundwater table is just at a few feet and nearly touches the surface at few locations particularly during rainy seasons. This results in water-logging of the area and causes problems like dampness in the buildings, weakening of foundation and development of cracks in the buildings/houses. Patches of weeds growth in the residential area due to formation of small pools of water. The villagers are prone to skin and waterborne diseases due to water-logging and growth of weeds. The inadequate sewage discharge and drainage facilities further compound the above mentioned problems.

- Ground water pollution due to wet disposal of fly ash: Wet disposal of fly ash causes seepage of water into the ground which causes mixing of contaminated water with ground water. The Khukhrana villagers live on the ground water which is the only source for drinking, feeding animals and irrigation. Also there is no treatment plant installed for water treatment for the villagers. There is no liner provided between the earth and the ash dyke. This causes the formation of lechate. Lechate mixes with the ground water and further pollutes the ground water.

D. **Groundwater pollution**: Groundwater pollution due to the migration of ash water into the groundwater is a major concern. Even in the areas away from water bodies (such as river, lake, etc.), as is the site in discussion, it is preferable to have a fairly impervious stratum at the bottom of the ash pond.

E. **Absence of plastic liner**: It is essential to provide plastic liner over the entire bottom of the ash pond and upstream face of the ash dyke to prevent groundwater pollution. However, plastic liner had not been provided till the present stage (i.e. the third stage) of the ash dyke.

F. **Dust pollution**: Dust pollution in the surrounding area during heavy wind is also a major concern. The dust pollution is more from the ash dyke when construction of the subsequent stage of the ash dyke is in progress.

- **Unauthorized entry within the ash dyke area**: In the absence of fencing / boundary wall, the entire area of the ash dyke is in the form of thoroughfare. The under-stated ongoing unauthorized activities are not only damaging the embankment/bund of the ash dyke and decreasing its stability, but also making the area vulnerable to sabotage.
- Free movement of unauthorized vehicles on the berms / inspection roads of ash dyke: It has been observed that people living in the nearby villages are freely using the berms/inspection roads of ash dyke. This unauthorized movement of vehicles (motorcycles, scooters, tractors, etc.) is damaging the embankment/bund of the ash dyke.
- Grazing along the slopes of ash dyke: Animals are freely grazing along the slopes (as well as on top) of the ash dyke. This uncontrolled grazing leads to serious consequence, such as-

- Removal of grass turfing that is so essential for the stability and protection of the embankment.
- Formation of animal burrows that can hold water and lead to gully formation and erosion of soil along the slope of the embankment.
- The loose soil may lead to choking of toe drain or drains provided on the downstream face of the embankment and hence affect their functioning.
- Tapping of animals in the slurry or abandoned decanting well or any other accident may lead to damage to the dyke infrastructure or un-necessary dispute with the local people
- *Usage of water*: The usage of water near the decanting system on the top of the ash dyke by humans and animals is harmful.

THEORY AND CONCEPTS INVOLVED

The engineering solutions revolve around the theoretical concepts of stability of earthen embankment with regards to its resistance against hydraulic failures. Hydraulic failure in this case implies failure due to seepage of water through the embankment leading to destabilisation of its slope.

Seepage or phreatic line:

In the earthen embankment the seepage or phreatic line is the line within embankment which separates the saturated or unsaturated zones. Below this there are positive hydrostatic pressures in the embankment. At the phreatic line the hydrostatic pressure is equal to zero or atmospheric pressure. Above this line, there is negative hydrostatic pressure and such zone is known as capillary saturation or capillary fringe. In the positive hydrostatic zone the effective weight of the soil is reduced due to flow of water through the embankment body, which reduces the shear strength of the soil due to pore pressure. The capillary fringe zone has greater shear strength; because the capillary tension in water leads to increased inter granular pressure. Thus the determination of seepage line in the earthen embankments is most essential, because it helps in:

- Determination of the line dividing the dry and wet or submerged soil in the embankment section,
- Determining and drawing flow net diagram.
- Knowing that the seepage line does not cut the d/s face of embankment, for the protection of the embankment against its softening or sloughing can be designed.

FAILURES AND PREVENTIONS

a) Prevention of hydraulic failure:

- The failure due to erosion of the downstream toe can be avoided by providing a rip rap or a d/s slope pitching.
- Failure due to erosion of d/s face by gully formation can be avoided by proper maintenance, all cuts formed should be filled as early as possible, and grass should be grown on the slope and by providing berms at suitable heights. Proper drainage arrangements should be provided.

b) Measures for seepage failures:

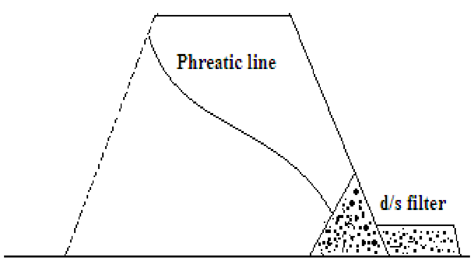

Figure 4.1 filter d/s of the toe

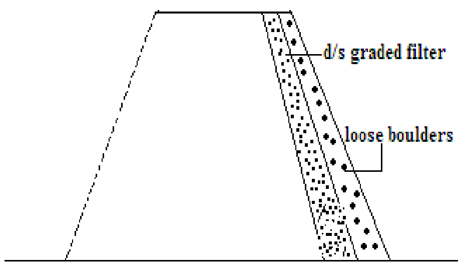

Figure 4.2 d/s coarse section

Following are the common measures adopted for prevention of seepage through dyke:

- *By providing horizontal drainage filter:* The length of the horizontal drainage filter may be 25% to 100% of the distance from d/s toe of the centre line of the centre line of the dyke. The horizontal drainage filter has the following purposes:
  - Due to shorter seepage path, it provides greater seepage.
  - It keeps the seepage line or phreatic line well within the embankment.
  - The consolidation of the embankment is accelerated.

- *By providing toe filter: P*rovision of rock toe in the dyke keeps the phreatic line within the embankment section. It also provides good facility for the drainage. The design of the toe filter should be done properly, satisfying the filter requirements

- *By providing downstream filters:* Cohesion less graded particles filters should be provided in d/s for prevention of the excessive leakage and progressive piping through the cracks of the embankment. When the water flows through these cracks of the core towards graded filters, the flowing particles are either trapped in the filter or core material swell and seal the cracks.
- *By providing d/s coarse section:* if the section of the embankment in d/s side is made with coarse material, it will intercept the seepage through the embankment and will make the d/s slope safe against piping.

c) Slope protection of earthen dyke

The protection of the upstream slope against wave action and of d/s against seepage is done by the following materials:

- Rock riprap
  - dry dumped stone boulders
  - hand packed stone boulders
- cement concrete pavement
- bituminous material pavement
- brick tile pavements
- precast cement concrete blocks

OBSERVATIONS AND RECOMMENDATIONS: The ash dyke started to accumulate fly ash more than three decades back and has reached a height of more than 15 m today. Therefore, the present situation limits the implementation of certain measures. Further the performance of the measures is curtailed because of an irreversible non provision of the impervious layer at the bottom of the mother dyke. The observations and major recommendations of the study are:

- **Observations**

a) Survey conducted at site shows that the embankment of ash dyke is in a dilapidated stage.

b) The embankment on the downstream face does not have the desired slope and hence has a tendency to occasionally slip.

c) Slippage of slope is responsible for damage to anchor blocks and supports of pipes.

d) Slipping of material from the embankment falls into the raw water feeder channels thus polluting the water.

- **Recommendations**

Following measures are recommended to be implemented as a solution:

A. Engineering solutions

a. Strengthening of the embankment/bund

b. Providing a toe drain for the present stage

c. Providing a plastic liner

d. Maintaining the beach length

e. Uniform distributed slurry discharge points

f. Deployment of flexible hose pipes for conveyance of fly ash slurry

g. Utilization of bottom ash

B. General solutions:

a. Grass turfing

b. Water sprinklers

c. Accessible roads

d. Street or flood lights

e. Boundary wall or barbed fencing around the ash dyke

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 ash pond sites at PTPS, Panipat. This paper deals with the engineering recommendations and measures for the stability problems and protection of fly ash dyke. The present work is a referred field based analytical study involving redevelopment of the earthen embankment of the ash dyke of PTPS. Though efforts have been made to utilize the fly ash being generated, yet a large quantity of fly ash remains unutilized which needs to be safely and economically disposed off.

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