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Raising of ash pond for augmented storage

Sushma B.V
Tata Consulting Engineers Ltd., Bangalore, Karnataka, India

ABSTRACT
In thermal power plants, huge amount of ash will be generated as a result of combustion of coal in large quantities. The generated ash will generally be transported and stored in designated areas called 'ash pond,' before finding use in cement plants or any other engineering purposes. Ash pond is generally formed by creating an earthen embankment all along the identified periphery. In primary phase, the earthen embankment is constructed to contain the ash slurry up to maximum ash fill level, which is termed as 'starter bund'. In the secondary phase for augmenting the ash storage volume, the ash bund height will be increased by formation of bund of equal heights in stages over and above the starter bund, which is termed as 'raisings'. This paper covers the raising of bund, construction material, design and construction aspects.

1 INTRODUCTION

Coal based thermal power plants generate fly-ash during steam generation by burning of coal. Fly ash generated is collected in Electro Static Precipitator (ESP). Fly ash from ESP is transported in dry or wet form and disposed in a pond formed by constructing earthen embankment around an identified place within the plant site. After commissioning of power plant, ash will be deposited in the pond till it gets filled up to the design fill level termed as maximum ash fill level. Once the pond is filled, second stage of pond formation will be started using the settled ash. The raising of ash pond is generally carried out by 3 methods:

a) Upstream construction method
b) Downstream construction method
c) Centre line construction method.

In upstream construction method the deposition of ash for raising is carried out on upstream face of the ash pond. In downstream construction method deposition of ash for raising is carried out on downstream face of the ash pond. In centre line construction method the deposition of ash for raisings is carried out from the centre of the ash pond. Out of the elaborated three methods, upstream method is commonly adopted and regarded as the most viable technique (Gandhi S R 2005). The ash from the plant will be transported to ash pond by:

i) Dry method and
ii) Wet method

In dry method the ash in dry form is transported by trucks whereas in wet method the ash is mixed with water and conveyed to ash pond through pipes in slurry form. The ash slurry is pumped to the ash pond through various discharge points. The ash slurry can be in lean slurry form or High Concentrated Slurry Disposal (HCSD) form depending on the concentration of ash in the slurry. (A Biswas et al., 2000). The transportation of ash in slurry form to the ash pond is considered to be the most economical, environmental friendly and hence generally adopted. The lean slurry ratio is generally maintained 1 (ash): 4 (water) by weight.

When ash slurry is disposed to the ash pond, ash gets accumulated at the discharge point end where the ash laid water flows towards the other end. Ash particles take sufficiently long time to settle and further the water need to be steady condition without any turbulence for ash particles to get settled. The turbulence of water can be cut down by discharging ash slurry in multiple points in phased manner and recovering the water at the end, opposite to that of the discharge end. Alternatively the ash water flow can be channelized in the pond by creating baffles and recovering the clear water at the end opposite to the discharge end. The process of sedimentation of ash particles and collecting the relatively clear water for reuse is termed as decantation system. The clear water thus recovered is again used for mixing with ash to obtain lean slurry.

The project under consideration is raising of ash pond for a thermal power project in coal belt region near Odisha. Ash pond is around 170 acres and created by constructing starter bund of height around 7m all along the identified periphery. The ash was filled up to the max ash fill level in around 4 years.

Figure 1. Existing ash pond with ash slurry filled up to the maximum ash fill level.

Fig 1 shows the site photo of the max ash fill level of the earlier constructed starter bund. Further raising of bund was initiated from this level in multiple of 4m using upstream method of construction. Ash disposal by lean slurry discharged at multiple points.

2 DESIGN PHILOSOPHY

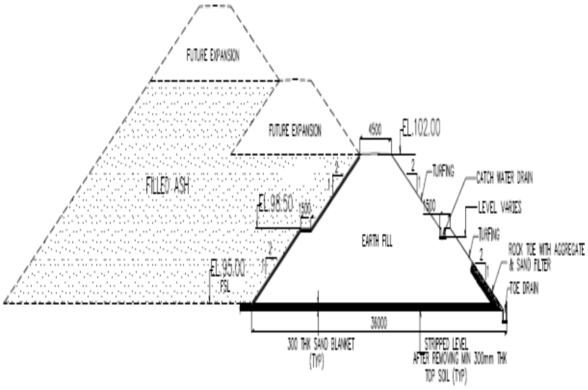

Figure 2. Section of Starter bund

The starter bund is an existing earthen embankment of 7m height. The slopes of the bund were 1 in 2 with provision of berm of 1.5m at 3.5m height. The section of starter bund is shown in Fig. 2.

The requirement of project was to create divider bund for each stage of bund raising so as to facilitate parallel operation of ash slurry filling and bund construction. If fully earthen bund is planned as divider bund, it will reduce the capacity of ash pond, hence the partition wall was planned by constructing bund using majorly ash material. Earth cover of around 0.5m was provided for each raising of ash bund to provide more stability. Thus the partition bund will be a notional bund which will exist till the completion of each raising of the considered stage.

The partition bund was formed as illustrated in Fig. 3 creating Area1 and Area 2 for raisings of ash pond. This bund was formed little earlier than filling of ash slurry into the pond. This will facilitate ash filling in Area 1 while raising the peripheral bund of area 2. The ash filling to be carried out in the Area-1 and raising of the ash bund on periphery was carried out in the Area-2. After filling is reached up to maximum ash fill level in the Area-1, the ash slurry pipe lines were shifted to the Area-2 and ash filling was carried out till desired ash fill level in area 2 was attained. Parallely further raising of the ash pond was taken up in the Area-1.

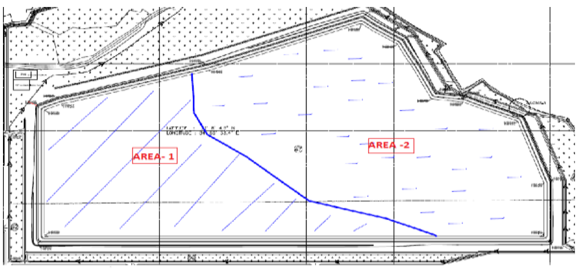

Figure 3. Plan showing demarcation of Area1 and Area 2 for raisings of ash pond

The construction and raising of ash bund sequence repeated as required up to the final designed raising of the bund.

HDPE liner is provided in the upstream slope and certain portion of bottom of the raising bund to prevent the seepage from the bund raising. HDPE liner is protected by sand and fly ash bricklayer which are provided over the HDPE liner.

3 SLOPE STABILITY ANALYSIS OF THE RAISING OF ASH POND

The slope stability analyses were carried out using Geostudio 2007 Slope/w software. The slopes were checked for various loading conditions against minimum factor of safeties for respective conditions, as per clause 5.1.1 of IS 7894. The applicable stability conditions for ash bund raising are end of construction and steady seepage condition.

The end of construction condition will be applicable for the empty condition of the ash pond, soon after construction. This condition is checked for both upstream and downstream slopes. In the steady seepage condition, the seepage is considered from upstream slope to downstream slope and hence this condition was checked only for downstream slopes. The above conditions were analyzed for both normal and seismic cases.

3.1 Material properties

For the economic considerations, suitable soil, available from nearby borrow pits was considered for the bund raisings. Soil available nearby borrow pit was of 'SC' type of soil classification as per IS 1498 which was selected for ash bund extensions. The soil properties were considered based on the "ash test report & soil test report" shared by the customer. The subsoil properties are inferred from the available Geotechnical investigation report. The properties used for stability analysis are tabulated in Table 1.

Table 1. Soil Strength parameters

Sl. No	Soil Type	Cohesion (kpa)	Angle of Internal friction (deg)	Bulk unit weight (kN/m^3)	Permeability (m/sec)
1	Fly ash	0	30	13.5	1 e-008
2	Embankment material	10	28	18	1 e-006
3	Soil cover	10	28	18	1 e-006
4	Foundation soil	10	30	18	1 e-006

The site is located in Seismic zone III as per IS 1893. The below seismic coefficients were calculated from IS 1893 and used in seismic co-efficient method for slope stability analysis.

(a) Horizontal seismic co-efficient =0.136

(b) Vertical seismic co-efficient =0.091

The above coefficients were adopted for seismic case in slope stability analysis. The slopes were analyzed in the software for both seismic normal cases.

As the HDPE liner is provided on the upstream slope, practically seepage will not be expected in the bund raising. However to consider the critical case of HDPE lining getting ruptured and resulting in seepage inside the bund raising, the bund is checked for steady seepage condition. Hence the slopes were analyzed for end of construction and steady seepage conditions under normal and seismic cases.

The maximum ash fill level in the ash pond was designed upto 1 m from the top of the bund. For steady seepage conditions, this level was considered for start of the phreatic line which travels into the section of the bund raising.

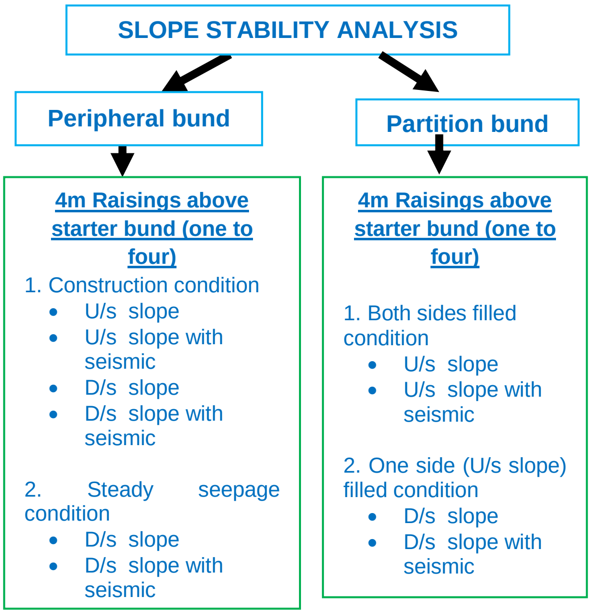

Figure 4. Flow chart of iterations of Slope stability analyses

Fig. 4 shows the flow chart of the slope stability analyses iterations carried out for Peripheral and partition bund. U/s represents upstream face of the slope whereas D/s represents downstream face of the slope.

3.2 Peripheral bund

The peripheral bund need to be critically designed as this will be permanent bund storing the entire ash fill. For the enhanced stability of the peripheral bund, it is considered to be constructed with ash as core material and earth as shell material. The width of the earth shell material is kept minimum to the extent corresponding to the roller width of the compacting equipment. As the width of vibratory roller proposed to be deployed would be around 1.5m. The earth shell material thickness is generally considered to be 1.5m.

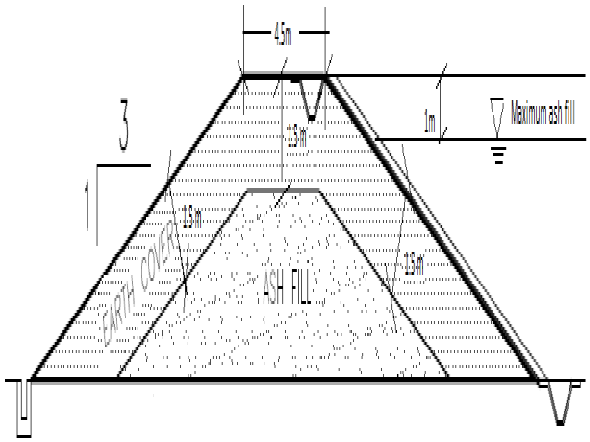

Figure 5. Peripheral raising bund

The top width of the raising bund was considered as 4.5m, which is same as that of the starter bund. The upstream & downstream slopes of both soil (shell) & ash (core) are considered as 1 in 3. The same is depicted in Fig 5.

In the Geostudio analysis software, the starter bund and each raising was modeled as in fig. 6. The ash fill and soil properties were considered as in table 1. The model was analyzed for end of construction and steady seepage condition as mentioned in the flow chart (fig. 4). The analysis is repeated for each raising of the bund.

The steady seepage condition was modeled by defining the below inputs: zero pressure head as downstream toe, potential seepage face as the total upstream face with 4 raisings stage and the water head as max ash fill level at 4^{th} stage that is 22m. The phreatic line thus obtained as output from the steady seepage condition is shown in fig 7.

The factor of safeties obtained for downstream slope for steady slope seepage with seismic condition is shown in fig. 8.

The ash bund upto 4 raisings for both construction and steady seepage conditions were found safe. The further extensions of the bund were attempted, but the slope stability was failing beyond 4 extensions of the bund. Hence the final height of the ash bund was concluded as 7 (starter bund height) + (4 x 4) (4 raisings of 4m height each) = 23m from the lowest RL in the area. Considering 1m free board, the total ash fill possible is 22m.

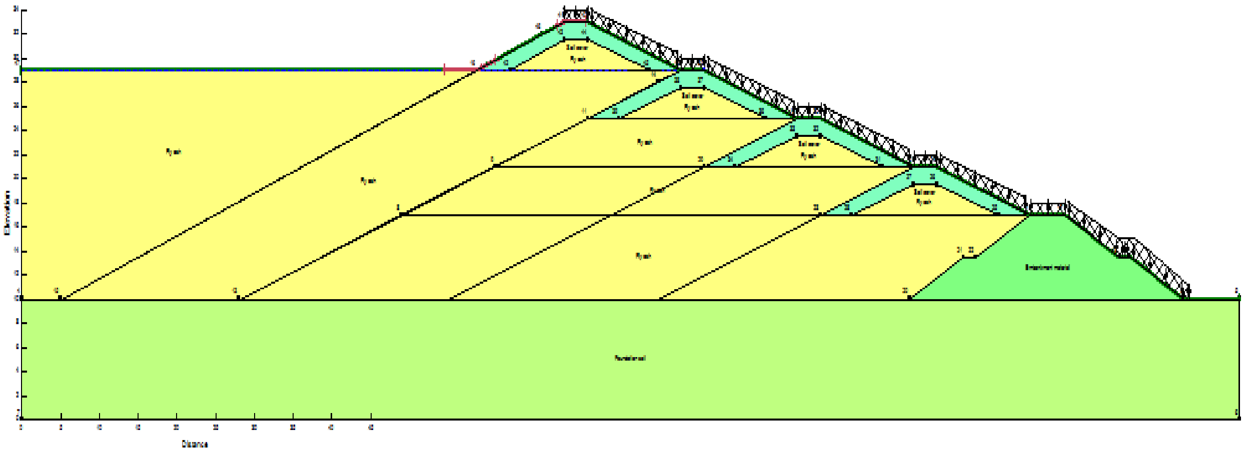

Figure 6: Input model showing 4th stage raising of ash pond

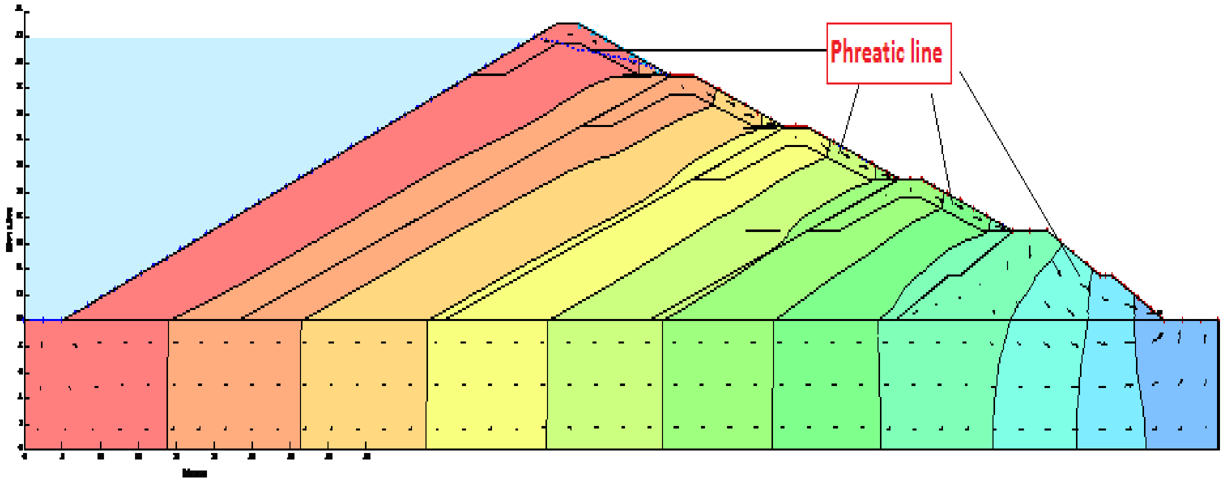

Figure 7: Output model showing Phreatic line from steady seepage condition

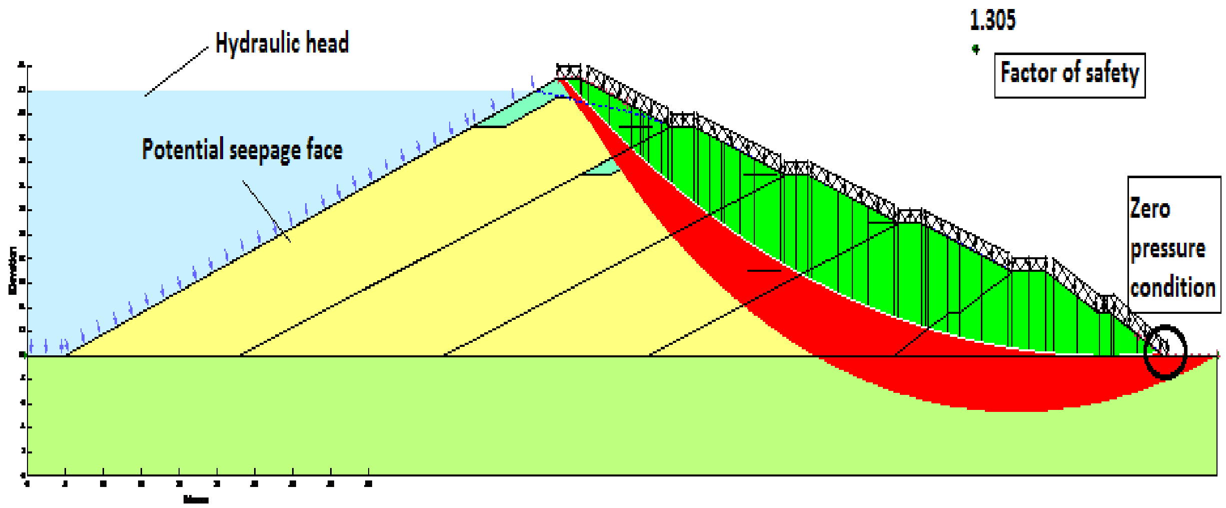

Figure 8: Output model showing steady seepage condition- With Earthquake forces

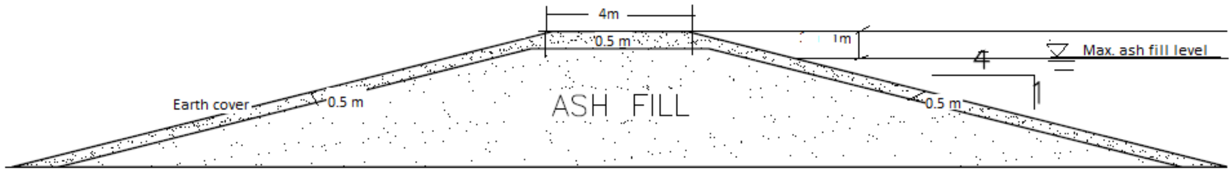

Figure 9. Partition raising bund

3.3 Partition bund

The partition bund is a temporary bund which will exist at each bund raising. As explained earlier the partition bund is constructed with maximum ash fill and with minimum earth cover just to prevent erosion of ash during construction. The top width of the partition bund was considered as 4.0 m and earth cover was considered of minimum 0.5 m thickness. The upstream & downstream slopes of both soil (shell) & ash (core) are considered as 1 in 4. The above cross-section was analysed for stability and found satisfactory for each stage of ash bund raising . The same is depicted in Fig 9.

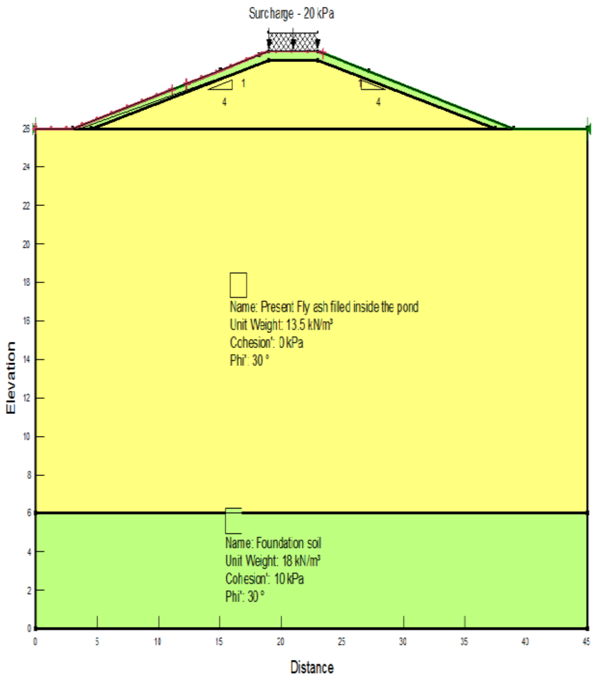

Figure 10: Input model showing partition bund at 4th stage

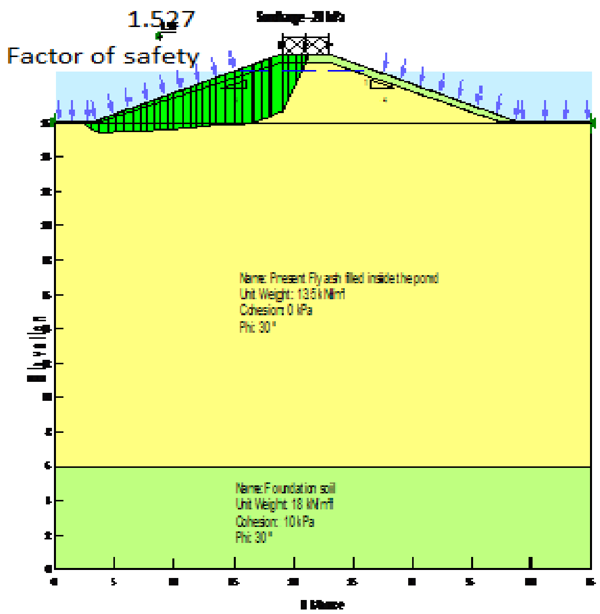

Figure 11: Output model showing partition bund- Stability of Upstream slope- Both side filled condition

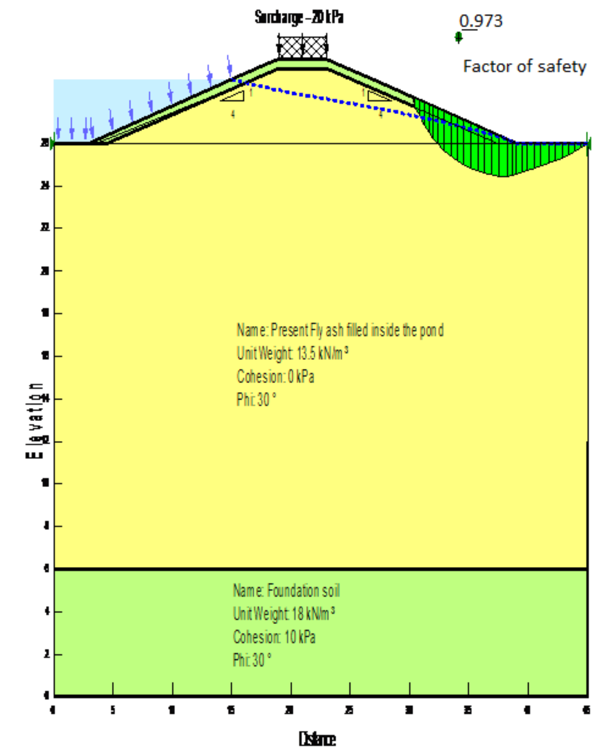

Figure 12: Output model showing Divider bund- Stability of Downstream slope- One side filled steady seepage condition

Partition bund is a notional bund that exists only for one stage of bund raising. After ash filling, the partition bund will be fully submerged with ash and for the next stage again, it will be created. The partition bund of 4th stage is found to be critical as it rests on the total ash fill of 19 m (7 (starter bund height) + (4 x 3) (3 raisings of 4m height each) = 19m). Hence 4th stage raising bund was modeled for partition bund in Geostudio analysis software as in fig. 10.

It is noted that partition bund will be having ash slurry on one side and empty on the other side during construction phase. During operation phase, both sides of the partition bund will be filled with ash slurry. As the raisings are provided on upstream face, upstream slopes will be more critical, for 'one side filled' condition, hence only upstream slope was checked. For 'Both sides filled' seepage condition was analyzed considering seepage indicated by phreatic line from the upstream slope and moving towards downward slope as illustrated in fig 11 and fig. 12. Hence 'both sides filled' condition was checked for downstream slopes only. The above conditions were analyzed for both normal and seismic cases. The factor of safeties obtained for raising is shown in fig. 12, the slopes were found to safe for both 'one side filled' and 'both sides' filled conditions.

The factor of safety obtained for 4th stage bund raising under steady seepage condition and seismic case was lower compared to all other cases and hence this was considered the governing case in the slope stability analysis.

4 SPECIFICATION AND CONSTRUCTION SEQUENCE OF THE RAISING OF ASH POND

Raising of ash bund will be done in four stages by construction of peripheral bunds along the inner side of ash pond. One partition bund at each stage is proposed inside the ash pond area to facilitate the parallel operation of ash bund raising and ash filling. The total height of proposed ash bund raising is considered to be 16 m.

4.2 Material

The materials used for the construction of raisings are hereby elaborated.

4.2.1 Ash available at ash pond

The available ash from the ash pond having properties mentioned in table 1 was used for the construction.

4.2.2 Earth material

The earth from one of the identified borrow pit having properties given in Table -1, have been considered for the construction. Earth material used for earth cover shall be free from clods, salts, sulphates, non-expansive, neutral in pH and organic or other foreign material. All clods of earth have been broken or removed. It was to conform to SC/GC/CL/ CI as per IS 1498 soil classification system. The soil from the borrow pits were tested for plasticity, compaction and gradation characteristics for checking conformity with requisite characteristics. This was carried out for every 3000 cubic meter of earth from borrow pits.

4.2.3 HDPE Liner

The HDPE liner provided was 1mm smooth UV resistant type and the properties conforming to GM 13 GRI standards.

4.2.4 Fine sand cover

The fine sand cover used as a protective layer above HDPE was of non expansive clayey / silty sand or a mixture of these. The sand cover was fine and free from kankar/ gravel and other sharp edged material. The sand material having particles passing through 2.36mm IS sieve was used.

4.2.5 Fly ash bricks

Fly ash bricks was hand/machine moulded and have been made from the admixture of suitable soils and fly ash in optimum proportioned as per IS 2117 and are used for protection of u/s and d/s slopes of the bund.

4.3 Methodology of raising of ash bund

A layer of soil of around 1m was spread above the maximum ash fill level of the starter bund before starting of each raising of the ash pond. This layer acts as a drainage layer for draining out, seepage water if any.Peripheral and Partition ash bund raising at each stage was constructed using ash and earth. The ash was used as the core layer and the selected earth from the identified borrow pits was used as the covering for the bund raising.

4.3.1 Peripheral bund

The raising of each peripheral ash bund was started by spreading the ash in the centre and soil covering at the edges. Sufficient quantity of earth and ash was delivered to the proposed embankment location at a uniform rate to permit bund construction process.

The bund formation was done in layers of thickness not less than 225 mm. The compaction was carried for each layer upto to 95 % modified proctor density using rollers and by sprinkling required quantity of water. The achievement of the desired compaction was tested for optimum moisture content and field density for every 1000m^2 of the compacted area. After completion of filling by compaction upto the top bund level, both upstream and downstream slopes the slopes were trimmed to the required 1V: 3H slopes. The typical section of the peripheral bund is shown in fig. 12.

On the prepared even surface HDPE geomembrane was laid. The geomembrane was securely anchored at both ends of the slope by provision of anchor trench. A protective layer in the form of 50mm thick sand was laid on HDPE liner on part of the pond bed and u/s slope. A 75mm thick ash brick lining was laid over the sand layer along the slope and top of the bund in correct line set in 25 thick cement mortar.

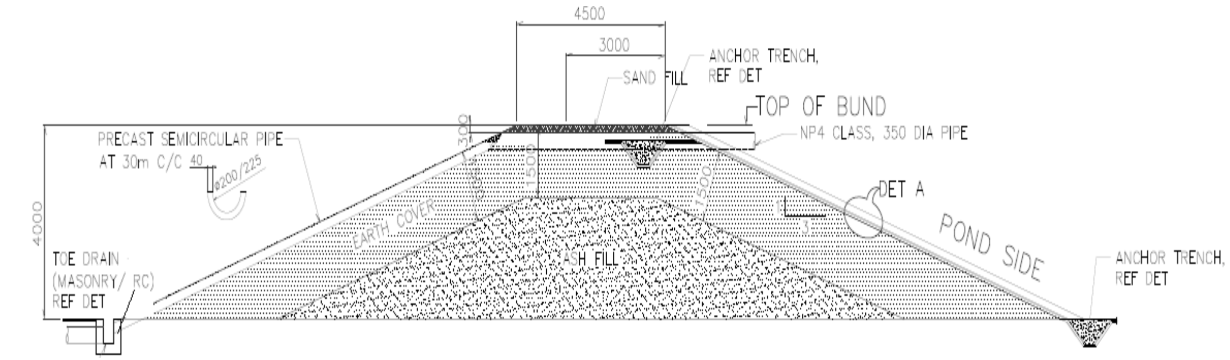

Figure 13. Typical cross-section of Peripheral bund

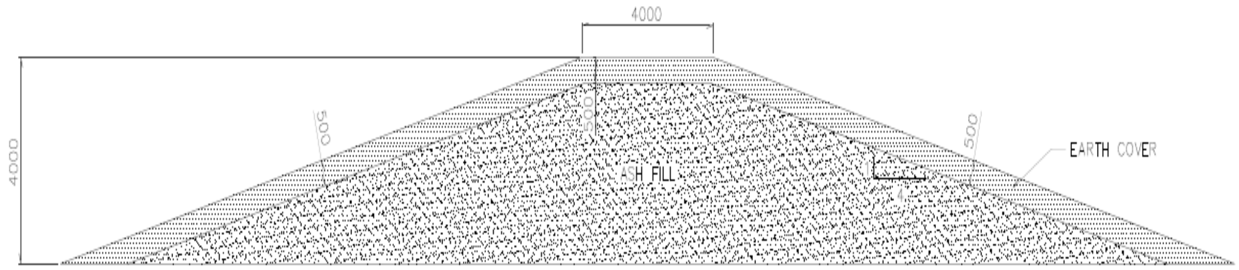

Figure 14. Typical cross-section of partition bund

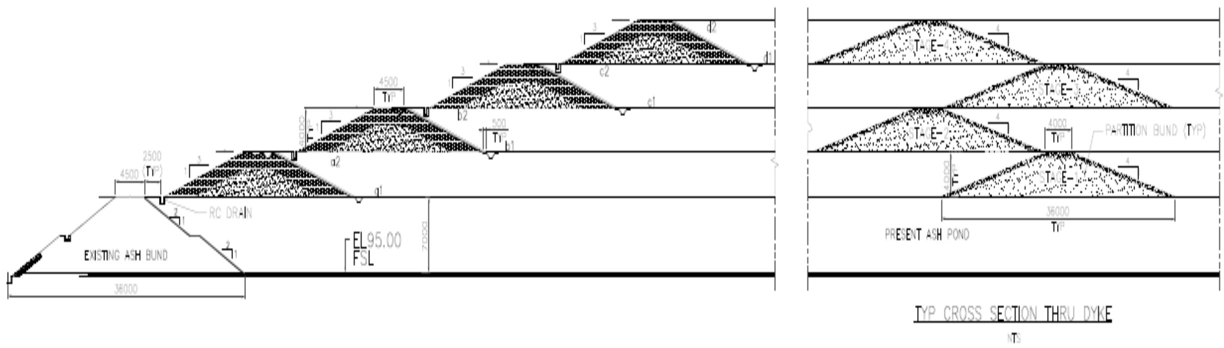

Figure 15. Typical cross-sectional arrangement of peripheral and partition bund raising

4.3.2 Partition bund

The raising of partition bund at each stage was constructed by dumping the ash to minimum 1 m height and compacting it by moving the roller over the dumped ash. The 3.5 m high ash core was constructed in this manner, subsequently 0.5 m wide earth cover was provided all around the ash core. The typical section of the partition bund is shown in Fig. 14.

The typical section of raising of partition bund and peripheral bund is shown in Fig. 15.

5 DECANTATION SYSTEM

After construction of raising of peripheral and partition bund the ash slurry is disposed to the ash pond at the discharge points. The ash gets accumulated at the discharge point end where the ash laid water flows towards the other end, which is shown in site photo in Fig. 16.

The ash laid water is made stagnant, so that fine particles of ash get deposited by sedimentation, this process is known as decantation system. After sedimentation, sufficient clear water exists as water head which can be collected for reuse.

Dewatering pumps were deployed to collect clear water for reuse purpose. The pipe end of dewatering was covered with fine mesh so that fine particles of ash will not escape. The process of ash deposition on discharge end and recovery on opposite end was continued till the ash gets deposited upto the maximum ash fill level of the raising. Subsequent to that, the discharge point was shifted and the above process was repeated till the maximum ash fill level is reached.

Figure 16: Construction of first stage raising of ash bund

6 CONCLUSIONS

- Raising of ash bund is secondary phase considered for augmenting the ash storage. However the design and feasibility of raisings of the ash bund, needs to be finalized during the initial design of starter bund.
- Partition bund made of ash could be considered while raising of ash bund to facilitate parallel operation of ash slurry filling and construction of bund raising.
- The factor of safety obtained for 4th stage bund raising under steady seepage condition and seismic case was lower compared to all other cases and hence was considered the governing case in the slope stability analysis.
- Maximum 4 raisings of ash bund over and above starter bund was proved to be safe for considered ash and soil properties.

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