IMPROVEMENT OF POND ASH WITH PREFABRICATED VERTICAL DRAIN

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ABSTRACT: Thermal power plants using pulverized coal produce large quantities of ash as a by-product. The ash ponds occupy about 30,000 hectares presently and are expected to be doubled by year 2012. This can be restricted by raising the ash pond dykes by upstream method of construction. In the upstream method of raising of ash pond dykes, strengthening or consolidation of the ash pond fill nearer to the starter dyke is required. This paper presents the application of prefabricated vertical drains to accelerate the consolidation process of pond ash deposits. Model tests under simulated conditions have been carried out on two samples of pond ash collected from an ash pond. The changes in the total settlement and moisture contents at different depths of the tank have been studied, with and without the installation of prefabricated vertical drain.

1. INTRODUCTION

Thermal power plants using pulverized coal produce large quantities of ash as a by-product. A total of about 85 thermal power plants in India with an installed power capacity of around 84,000 MW generate about 120 Million tonnes of ash per year. Consequently the ash generation per year is expected to touch around 170 Million tonnes by the year 2012 and around 225 Million tonnes by 2017. This results in the ash generated by the thermal power plants being disposed off in the vicinity of the plant as a waste material covering several hectares of valuable land. The ash ponds occupy about 24,000 hectares presently. The area is expected to increase up to 60,000 hectares by year 2012. This can be restricted by raising the ash pond dykes by upstream method of construction.

Primarily, there are two types of ash disposal being practiced by the thermal power plants in India—the wet disposal system (more commonly adopted) and the dry disposal system. In the wet disposal system, the ash is mixed with water to make a slurry which is then pumped to the ash disposal lagoons known as ash ponds through pipelines. At the disposal area, the dry ash is dumped to form mounds of ash, using elaborate earth moving machinery. The ash deposit placed in slurry form has a very low density and leads to problems such as liquefaction during earthquake, poor bearing capacity, large settlement, etc.

In this paper, a laboratory study using PVD for the consolidation of pond ash deposit under simulated conditions is presented. The effective use of PVDs in pond ash deposits has been studied by model tank studies with two types of pond ash samples collected from an ash pond. The paper depicts the significant improvements in terms of total settlements and moisture content by the use of prefabricated vertical drains.

2. BACKGROUND

2.1 Spatial Variation of Ash in Ash Ponds

As the slurry is deposited through a pipe near the dyke, at the discharge point, ash is predominantly sand sized possibly with a few lenses of fine material, whereas far away from the slurry disposal point, the ash is more likely to contain predominantly silt sized with few lenses of coarse material. The zone in between these two zones is characterized by extensive horizontal layering of fine and coarse ash. A comprehensive view of the vertical and lateral variation of ash in a typical ash pond is shown in Figure 1.

Fig. 1: Sorting and Layering in an Ash Pond  
(Modified after Datta et al. 1996)

2.2 Methods for Raising Ash Dykes

There are three different methods for raising of ash ponds. They are:
- Upstream method of construction
- Downstream method of construction
- Centre-line method of construction.
2.2.1 Upstream Method of Construction

In the upstream method of construction, the starter dyke is constructed at the downstream toe and the ash is discharged to form a beach. The beach adjacent to the starter dyke then becomes the foundation for a first or the second embankments. A typical embankment configuration by the upstream method of construction is depicted in Figure 2. The main advantages of the upstream method are cost and simplicity. Only minimal volumes of mechanically placed fills are necessary for construction of the peripheral embankment and large embankment heights can be attained at very low cost.

Use of upstream raising method, however, is limited to very specific conditions and incorporates a number of inherent disadvantages. Factors that constrain the application of the upstream method include phreatic surface control, water storage capacity and seismic liquefaction susceptibility. The dyke can be raised up to a limited height as all stages are built on top of the hydraulically filled ash.

2.3 Prefabricated Vertical Drain (PVD)

A PVD in general is made of two components, namely, the sheath and the core. The sheath is a non-woven filter fabric used to prevent the entry of the soil particles and allow only the water into the drain. The core is made of different profiles and helps in transporting water vertically through the drain. Both the core and the sheath are either joined together usually at the edges by thermal bonding or the core is inserted separately by folding the sheath over it and subjecting to ultrasonic welding. The entire PVD is approximately 100 mm wide and 4 mm to 6 mm thick and comes in rolls up to 300 m in length. The modern commercial PVDs differ from each other with respect to the method of manufacture, materials used and the geometrical shapes.

Literature on the drains reveals that the core and the sheath are made of either polyester or polypropylene and in some cases polyethylene. These materials used for the manufacture of PVDs have a long life. In the last decade a large number of PVDs have appeared in the market cutting down their costs appreciably also permitting easier installation even in difficult environment, e.g. water. Presently, more than 50 types of different vertical drains, which may be installed down to depths approaching 60 m, at rates up to 1 m/s, are available in the market. At Indian Institute of Technology Delhi, a PVD, using coir and jute yarns, was developed (Venkatappa Rao et al. 2000) which was shown to be comparable with typical synthetic drains, particularly at kinked conditions.

The design procedures commonly adopted for ground improvement by PVDs are summarized by Sarkar & Venkatappa Rao (1999).

2.4 Field Studies

Gandhi (1999) showed that the low bearing capacity of the ash deposit can be improved by the technique of installation of stone columns by vibroflotation. However, it is difficult to be executed and is an expensive technique for adoption. Nevertheless, improvement of ash near the dyke is a must by the upstream method. Hence, use of PVDs offers a potential technique.

Prefabricated Vertical Drains (PVDs) have been used successfully in many soil improvement and land reclamation project in Asia and the rest of the world (Hansbo et al. 2005; Bergado et al. 2002). In India, PVDs were installed in Kakinada Port as well as Kandla Port effectively. However, their use in pond ash slurry deposits is not yet attempted. The possible of PVDs for raising of ash dykes by the upstream method of construction is presented in Figure 3.

2.5 Model Tank Studies

The performance of the drain can best be judged by its function in the field condition. However, to simulate these conditions, in the laboratory, experiments are carried out by placing the drain in the soil for a long period and observing its performance. In one such experiment Venkatappa Rao et al. (1994) placed vertically three jute fibre drains of 750 mm long in one tank filled with kaolinite clay and evaluated their performance. Sampath Kumar (2000) also carried out experiments with a braided natural fibre drain in a tank filled with kaolinite clay.

3. EXPERIMENTAL WORK

3.1 Materials

3.1.1 Pond Ash

For the current research work, the pond ash samples were collected from the ash ponds of the Captive Power Plants of
The National Aluminum Company Limited (NALCO), Angul, Orissa, India. Two types of pond ash samples were collected from two different places from the ash pond, one from near the slurry disposal point, where the particles are generally coarser in nature (designated NC) and the other, far away from the ash disposal point where the particles are finer (designated NF). The physical properties of both the pond ash are given in Table 1.

3.1.2 Model Tank

The tank used in this study and the detailed arrangement is shown in Figure 4. Such an arrangement was previously used by Sampath Kumar (2000) for evaluating braided PVD.

Table 1: Physical Properties of Pond Ash

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NF</td>
</tr>
<tr>
<td>Grain size distribution</td>
<td></td>
</tr>
<tr>
<td>Gravel size (&gt; 4.75 mm) (%)</td>
<td>0</td>
</tr>
<tr>
<td>C.Sand size (4.75–0.475 mm) (%)</td>
<td>2</td>
</tr>
<tr>
<td>F.Sand size (0.475–0.075 mm) (%)</td>
<td>40</td>
</tr>
<tr>
<td>Silt size (0.075–0.002 mm) (%)</td>
<td>56</td>
</tr>
<tr>
<td>Clay size (&lt; 0.002 mm) (%)</td>
<td>2</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>2.02</td>
</tr>
<tr>
<td>Liquid limit (%)</td>
<td>48</td>
</tr>
<tr>
<td>Plastic limit (%)</td>
<td>Non-plastic</td>
</tr>
<tr>
<td>Maximum dry density (kN/m³)</td>
<td>10.7</td>
</tr>
<tr>
<td>Optimum moisture content (%)</td>
<td>34.5</td>
</tr>
<tr>
<td>Angle of internal friction (Degrees) at MDD</td>
<td>31</td>
</tr>
</tbody>
</table>

The model tank made up of 10 mm thick plate has 450 mm internal diameter and has a height of 750 mm. A hole of 20 mm diameter is provided at the bottom of the tank in order to freely drain out the water during the consolidation process.

The loading was done with dead weights through a guided platform made of steel. Two long travel LVDTs were fixed to record the vertical displacement of pond ash under application of loads. The LVDTs were connected to a data logger with an accuracy of 0.1 mm.

3.1.3 Testing Procedure

The inner surface of the tank was cleaned and was made smooth by polishing with fine sand paper. A thin coating of grease was applied to the surface. The tanks were filled with coarse sand up to a height of 50 mm from the bottom. The sand layer was compacted to get the required density. A non-woven geotextile was placed on the sand so as to act as a separator between the sand and the pond ash. The pond ash samples were mixed with water at water content more than their respective liquid limits. The pond ash was mixed thoroughly so that there will be no air bubble present inside the slurry. The pond ash slurry was carefully poured in small quantities at depths of 100 mm at one time and is allowed to settle down. The same procedure was repeated till the pond ash slurry was filled up to the required height of 500 mm. To fill the tank with PVD; the PVDs were first placed in the tank before pouring the pond ash slurry. The PVD was placed in between two perspex sheets of 10 cm width and was kept to stand vertical in the centre if the tank penetrating into the sand layer. The bottom non-woven geotextile must have a rectangular hole to allow the PVD to pass through it. Then the procedure of filling the tanks were the same as that of without PVDs as described earlier. A circular piece of non-woven geotextile having the diameter of 450 mm was placed on the pond ash. A rectangular hole equal to the size of the
PVD was made at the centre so that the PVD can project into the sand layer. Sand was filled on the geotextile layer and was spread over the whole area of the tank. The sand was then compacted to a depth of 50 mm. After the top layer of sand was made smooth and horizontal a wooden plank of 440 mm was placed on it. The loading frame was placed on the wooden plate and was fixed to the tank by fasteners so that there will be no danger during loading. The LVDTs were fixed to the fixed arm of the loading frame and their ends were connected to a six channel data logger. The initial readings were noted and the procedure of loading was started. The total stages of the model test are shown in step by step in Figures 5 and 6.

(a) PVD Placed Vertical
(b) Pond Ash slurry Being Poured
(c) Slurry Being Filled
(d) Slurry after Settling Down
(e) Geotextile Separator Being Placed
(f) Sand Being Placed

Fig. 5: Photographs showing Detailed Procedure for Preparation of the Model

4. RESULTS

Load was applied gradually up to a pressure of 29.4 kPa as shown in Figure 7. It took 45 days for the maximum pressure to be applied and this pressure was maintained up to the 60th day.

For the first 10 days, the settlements of the two tanks were almost equal, as can be observed in Figures 8 and 9 for both the types of pond ash. At higher pressures, the difference in the two curves becomes significant, which is obviously due to the presence of drain in one of the tanks. The difference in settlement eventually reaches to the highest value and then begins to decrease gradually. After about 45 days of the test, the curve without drain eventually becomes straight and approaches towards the curve with drain. It is observed that the total settlement in 60 days was 18.52 mm without the drain whereas it was 21.93 mm with the drain for pond ash type NF and 21.41 mm and 26.17 mm respectively for pond ash type NC.

In a way the above data reflects the performance of the drain. This may also be further reinforced through the data obtained for the moisture content measured before and after consolidation for both the pond ash as presented in Figures 10 and 11. As seen from these figures, the average moisture content of the pond ash was around 52% and 39% for NF and NC type of pond ash respectively. At the end of the consolidation, the moisture content of both the tanks was observed to be the least at about 42% and 28% respectively. Also the moisture content profile obtained with the drain is nearly vertical, with the moisture content at the center at mid-height being marginally higher indicating the general efficacy of the drain. On the other hand the moisture content profile for the tank without the drain is entirely different and
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exhibits highest moisture content at mid-height, only marginally lower than the initial moisture content. This is indicative of the fact that the consolidation that is taking place is at a much slower rate than with the drain.

5. CONCLUSIONS

It is a well known fact that ash in a slurry pond remains soft i.e. unconsolidated even when the ash level reaches the dyke crest. (Only drying is found to strengthen the pond ash). In this study, it is shown that pond ash can be consolidated by using PVD under low vertical stresses. Hence the method has great potential for application.

The following conclusions have been made from the present experimental studies:

- The consolidation settlement of both the pond ash types significantly increases with application of PVD.
- The distribution of moisture content in a pond ash deposit becomes uniform with the use of PVD.
- PVDs can be suitably used for consolidation of pond ash deposits and the pond ash dykes can be raised above the prepared pond ash deposite.

REFERENCES


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