DENSIFICATION OF DEPOSITED ASH SLURRY

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ABSTRACT

In India, ash content in coal is usually high and percentage utilization for construction is limited. As a result, about 90 to 95 percentage of the ash generated has to be deposited in ash pond. The present ash generation is about 75 million tonnes and it is likely to exceed 100 million tonnes by the end of this century. During the last decade, several laboratory studies have been made on densification of deposited ash slurry by vibration, application of vacuum, electro osmosis, etc. In last few years, with assistance from Department of Science and Technology, field experiments have been carried out to densify the deposit by vibro flotation technique and also by explosives. This paper describes brief literature review on the subject and summary of compaction achieved in field by vibroflotation as well as explosives. Based on the study carried out so far, it appears that densification in ash pond is very effective for rehabilitation of the area for housing or other use. It also eliminates chances of liquefaction during earthquake.

Keywords:- Fly ash, Compaction, Ash pond, Bearing Capacity, Shear Strength

INTRODUCTION

Coal is chief source of energy in India and it will continue to be so in the near future. The present generation of fly ash of all the Thermal Power Plants in the country is about 70 million tonnes and it is likely to cross 100 million tonnes by the end of this century. The percentage utilization of fly ash in various construction is rather limited in India compared to other countries.

The coal is obtained in India is normally from shallow mines which has large impurities and in absence of washeries at the coal mines, resulting ash content is very high (40% to 50%). In view of the high ash content and low percentage utilization of fly ash, most of the fly ash has to be disposed off suitably into the ash ponds. This demands ash pond of very large area. Typically, ash pond measuring 3 to 10 km^2 for a 500 MW power plant gets filled with ash to 10m height in a period of 5 years. Therefore the cost of ash dyke and land is a major burden for the power plants. In addition, large agriculture area is converted into ash ponds.

To minimize the above mentioned problem, the technology mission on fly ash, set up by Department of Science and Technology has identified various areas of research under the Task Force on ash ponds and dams. One of such area aims at densification of the deposited ash. In the present paper, a detailed review has been made on different techniques available for densification of deposited ash slurry in the ash pond for the following benefits.

- The densified deposit has lesser moisture content, higher shear strength and it is capable of supporting higher surface loading for rehabilitation.
- The pressure exerted by such densified deposit on the ash dyke is much less and therefore the cost of the dyke can be significantly reduced. This will also reduce the chances of failure of the dyke which can be a serious hazard.

The height of the ash pond can be increased significantly (upto 40 to 50 m against 10 to 15 m being adopted at present).

In view of the above, following promising technique of densification were experimented in laboratory at IIT Madras.

- Electro Osmosis
- Vacuum Dewatering
- Stabilization with Lime Column
- Densification by Vibration

Apart from a brief review of results obtained from the above techniques, the paper also presents, field experiments carried out in the ash pond at two sites for densification by vibrofloation and by explosion.

LITERATURE REVIEW

Large number of technical papers are available on various work carried out for densification of loose cohesionless deposits. However, limited information is available on densification of fly ash deposits, particularly of deposited ash slurry in the ash pond. Basically, fly ash is an inert material with particle size similar to silt/fine sand and hence, the success of different compaction techniques is expected to be similar to that in the case of cohesionless soils.

Brown (1977) described in detail the vibroflotation compaction technique for cohesionless soils. The paper suggests range of particle sizes suitable for vibroflotation compaction, and accordingly, fly ash can be compacted with the technique.

Kirsch (1986) described compaction of loose sandy sea bed with vibro compaction operated from a floating barge. The SPT 'N' values before and after compaction clearly shows significant compaction of the treated sea bed. This paper amply proves that, compaction of loose sediment even under saturated condition, can be achieved by vibro compaction.

Solymar (1984) describes such ground improvement for 42m high dam in Nigeria. The procedure is basically driving a casing pipe into the ground through which an explosive (gelatin supplied in 25mm diameter sticks) is lowered to the required depth with suitable detonator. The relative density of the sandy strata was found to increase appreciably after the blast.

Dowding and Hryciw (1986) have presented laboratory tests to investigate the potential of blast densification on saturated cohesionless soil. After the blast, a gradual increase in cone resistance is observed with time due to the gradual improvement of inter granular bonds and dissipation of explosion generated gases.

LABORATORY STUDY

(a) Compaction by Vacuum

For studying the behaviour of settled ash under vacuum, a mild steel tank open at top having size 600 x 600 x 300 mm was used. A central vertical drain pipe of 20 mm dia was provided at the center of the bottom plate. This tank was supported on a high pedestal and arrangements were made to collect the drained water from outlet pipe continuously. Totally eight experiments were carried out, four each on two different ash sample under different drainage conditions. The fly ash slurry in the ratio 1 : 3 was poured and the discharge from the outlet pipe was measured with respect of time till the gravity drainage ceased. The water content in the fly ash deposit was measured. Vane shear tests and self weight cone penetration tests were conducted. The results of the above mentioned tests are furnished in Table 1. Thereafter, the top surface of the ash was covered with a plastic sheet and the gap between the edges of plastic sheet and side of the tank was sealed with bentonite to maintain air tightness.

Table 1. SUMMARY OF RESULTS OF VACUUM DEWATERING

Property	Test A	Test B	Test C	Test D
Water content after gravitydrainage (%)	73.6	79	75	72
Water content after vacuum drainage (%)	30.0	39	38	30
Cohesion after gravity drainage (kPa)	7.46	6.85	7.8	9.63
Cohesion after vacuum drainage (kPa)	62.6	45	49.1	65.5
Settlement (mm)	1.8	2.6	2.8	1.9
Direct shear test results after vacuum drainage				
Angle of Friction (°)	41	30	38	40
Apparent Cohesion (kPa)	7	10	6.5	9
U.C. Strength (kPa)	7.6	6.4	8.4	8.8

A - vertical drain (radial flow)
B - horizontal filter (vertical flow)
C - horizontal filter + Geotextile (vertical flow)
D - vertical drain + filter (combined flow)

A vacuum pump of 0.25 mHP was used for laboratory study. It was observed that, in all the tests, a maximum vacuum of 500 mm. of Hg (approximately equal to 700 kPa) was developed within 2 minutes after the starting of the pump. After sealing the top surface of the deposited ash with a plastic sheet and bentonite, vacuum was applied to the vertical drain/filter bed. The cumulative discharge of the water collected and the corresponding time were noted. Application of vacuum was continued till there was no further flow from ash deposits. Top plastic sheet was removed and water content remaining in the ash deposit was determined. Vane shear tests were conducted on the vacuum stabilized ash deposits and the results are furnished in Table 1.

(b) Compaction by Vibration

The same tank discussed above was filled as earlier to 20 cm thickness of fly ash slurry. Vibration with concrete needle vibrator of frequency 300 rpm and 27 mm dia was imparted for five minutes and the needle was moved throughout to ensure uniform compaction. After vibration was stopped, initially drainage of water was at quite faster rate but it reduced slowly after 35 minutes and became almost negligible. During vibration it was observed that, moving of needle became gradually difficult with time as slurry becomes thicker. The main principle behind stabilization is the development of pore pressure which liquefy the deposit and subsequent rearrangement of particles reduces voids.

The results are given in Table 3. Reduction of moisture content was observed from 60% to 26%. Apparent cohesion and ϕ after this treatment were found 36 kPa and 40° respectively. After compaction, the tank was flooded again with 2 cm deep water and outlet was closed for 48 hours. There was no change in moisture content even after flooding.

TABLE 2 - RESULTS OF COMPACTION BY VIBRATION

Soil Deposit	Moisture (%)	Cone Penetration	c kPa	ϕ	γ (kN/m3)
Untreated	60	Full	8	27°	7.56
Treated with needle vibration	26	Nil	36	40°	12.80

FIELD DENSIFICATION BY VIBROFLOTATION

Based on the review of various compaction techniques and laboratory test results, it was decided to carry out compaction of deposited fly ash over a trial area in one of the ash ponds. For this purpose, a site chosen was at Vijayawada Thermal Power Station, where Stage I of the ash pond was filled to a depth varying from 15 to 20 m. After reaching maximum height of storage, the surface of this ash pond was provided with an earth cover of 300 mm thickness.

The main purpose of this field compaction is to demonstrate the use of vibroflotation technique for densification of deposited fly ash slurry and rehabilitating the area for any useful construction. The technique consists of penetration of a vibrofloat of about 400 mm diameter into the deposited ash slurry upto a depth of 10 to 12 m. The penetration is achieved by combined action of vibrations and water jetting. After achieving the maximum penetration, the vibrofloat is gradually extracted and the opening created is back filled with clean coarse gravel. The repeated lowering of vibrofloat also compacts the gravels placed in the hole. Completed stone column has an average diameter of 900 - 1000 mm. As a result of this, the general stiffness of the strata improves significantly.

Test Programme

The layout of vibroflotation column for densification is shown in Fig.1. Three different spacings namely 2m, 2.5m and 3m center to center in a triangular pattern have been used. For each spacing, following measurements have been carried out both prior and after compaction.

1. Static Cone Penetration.
2. Standard Penetration Test at every 1.5 m depth intervals.
3. Light Cone Penetration test
4. Footing load test.

The locations for various tests are also shown in Fig.1. After densification, large scale footing load tests were carried out in the area of each spacing to determine the safe loading intensity that can be supported after treatment.

TEST RESULTS AND DISCUSSIONS

(a) Standard Penetration Test

The Standard Penetration test values before and after compaction in three different spacing is shown in Fig.2. The tests were carried out at the center of 3 columns. As can be seen, upto depth of 4m from the ground level there is not much improvement in the compaction. However, beyond 4m depth, SPT tests have marked increase compared to precompaction value. The poor compaction in top 4 m could be due to the disturbance created by vibration for lack of over burden pressure.

(b) Footing Load Test

The results of footing load tests are summarised in Table 3. As can be seen from Table 3, for the area treated with columns at 2m spacings, the bearing capacity has increased almost twice compared to the untreated deposit. The ultimate load carried by untreated ground is only 150 kN/m^2 compared to 295 kN/m^2 in case of area with column at 2 m spacings. Based on this results, it is concluded that loading intensity of 80 to 150 kN/m^2 can be safely supported by providing columns at spacing 2m center to center to 3m center to center respectively.

TABLE 3 : SUMMARY OF FOOTING TEST RESULTS

Test No.	Type of Deposit	Ultimate Load Intensity (kN/m^2)	Settlement under Ultimate Load (mm)
1	Untreated	160	102
2	Compacted with column at 3m spacing	180	70
3	Compacted with column at 2.5m spacing	245	80
4	Compacted with column at 2m spacing	295	36

Based on the above results, it is concluded that building/industrial structures with a maximum loading intensity upto 180 kN/m^2 can be safely supported on deposited ash. Further analysis to evaluate liquefaction characteristics of such compacted deposit is in progress. However, in presence of stone columns, the chances of liquefaction is significantly reduced.

COMPACTION BY BLASTING

Two trial blastings have been conducted at fully saturated ash pond area of Mettur Thermal Power Station. Ground level readings were taken before and after balsting. SPT and LCPT had been conducted before and after blasting in the third trial blast.

Boring and Installation of Charges

A PVC pipes fitted with metallic shoe as a casing was used to place the charge inside the deposit. The pipe was then pushed into ash deposit using a wagon drill and an air compressor. The quantity of charges (Blastogel) used in first two trials were 6.95 kg and 3.67 kg at 8.0 m depth and 4.3 m depth respectively. In the third trial, 8.25 kg explosive was placed at a depth of 9.5 m. The pipes were then filled with wet sand and compacted.

Observations Made

Immediately after blasting it was seen that water had been coming out like a fountain from the blast holes located in the wet area and it remained for half an hour. A saucer shape crater had been formed around the blast hole in all the cases. Settlement readings were taken before and after blasting using dumpy level. Typical contour of the ground after blasting is shown in Fig.4. The radius of crater formed was approximately 10 m. The volume of crater formed varies from 40 to 65 m^3.

Test Results

Pre and Post Standard Penetration Test (SPT) and Light Cone Penetration Test (LCPT) were carried out before and after blasting in the third trial blasting area. Post SPT was conducted at 2m distance from blast point after 10 days of blasting. The result of both Pre and Post SPT is shown in Fig. 5. There is a remarkable increase in SPT 'N' value after blasting.

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SUMMARY AND CONCLUSIONS

Based on the available literature review, small scale laboratory experiments and preliminary field tests in ash ponds it is noted that deposited fly-ash slurry can be effectively compacted with some of the techniques used for densification of loose saturated cohesionless soil. The densification achieved is adequate to support residential/Industrial Buildings at reasonable cost. The analysis also indicates that, treated deposit can prevent liquefaction during an earthquake.

The field tests reported here are of preliminary nature and therefore detailed cost analysis is difficult. Further field tests on densification by explosion is in progress and results are expected by March 1998.

Electricity boards/Power plants have already shown keen interest in experimenting the compaction technique by explosion in their ash pond as it is found to be simple and economical. The results available sofar indicate 5 to 10% reduction in the volume of deposited ash.

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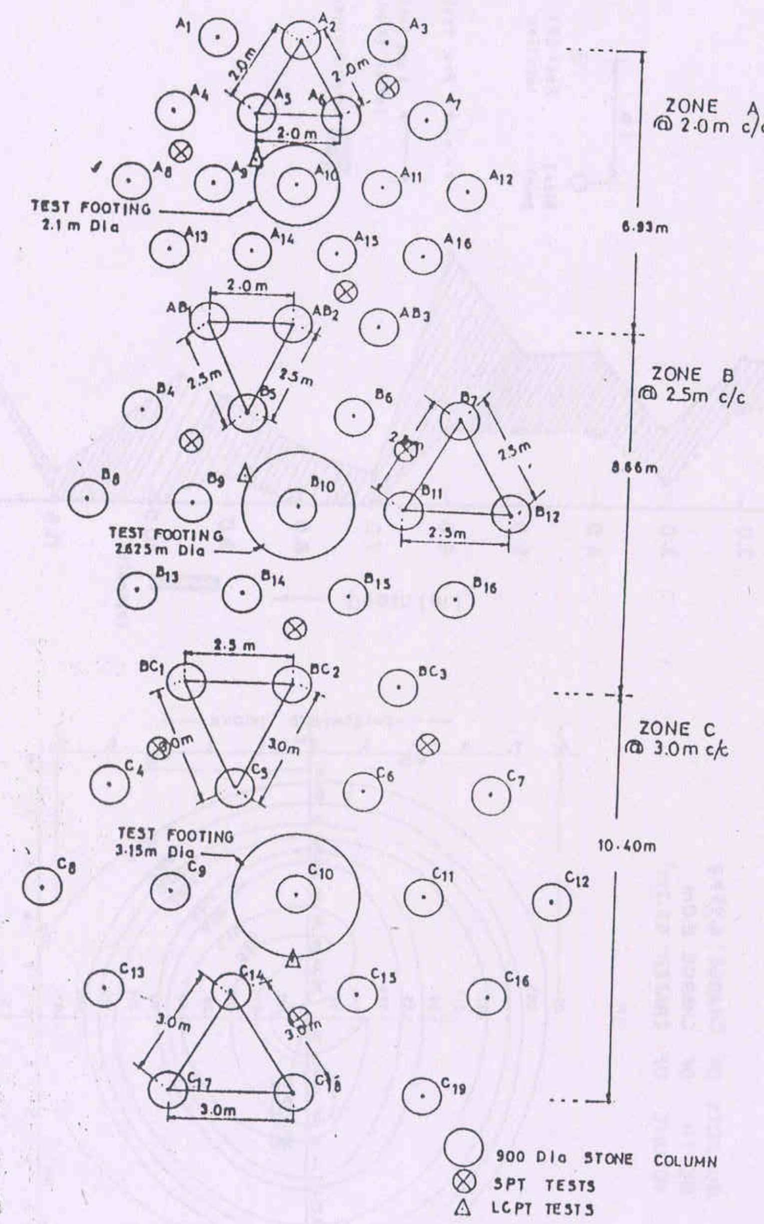

Fig.1. LAYOUT OF STONE COLUMNS

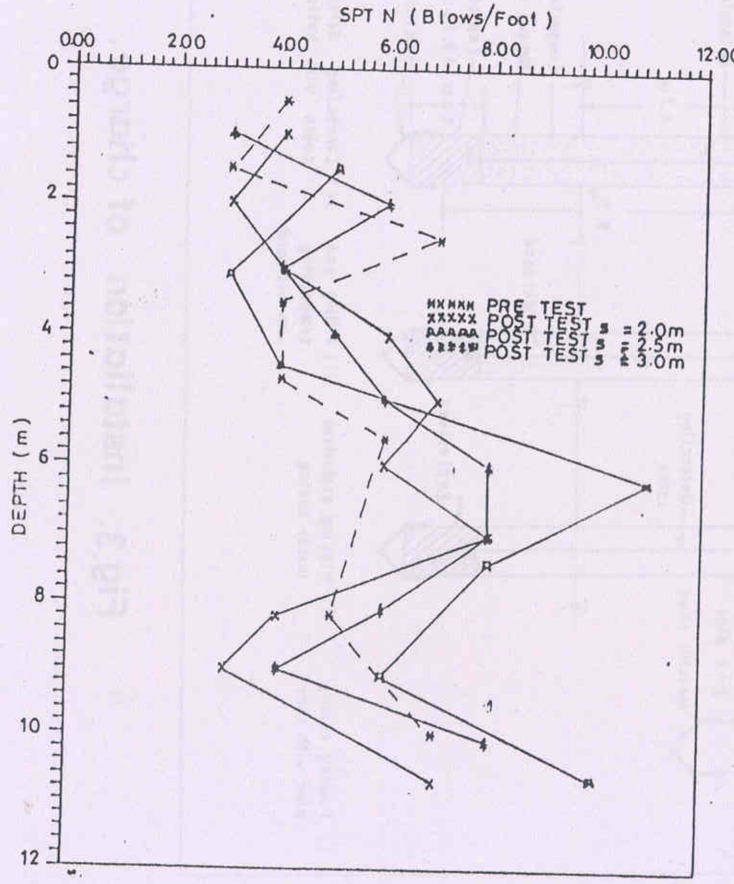

Fig.2. RESULTS OF STANDARD PENETRATION TEST

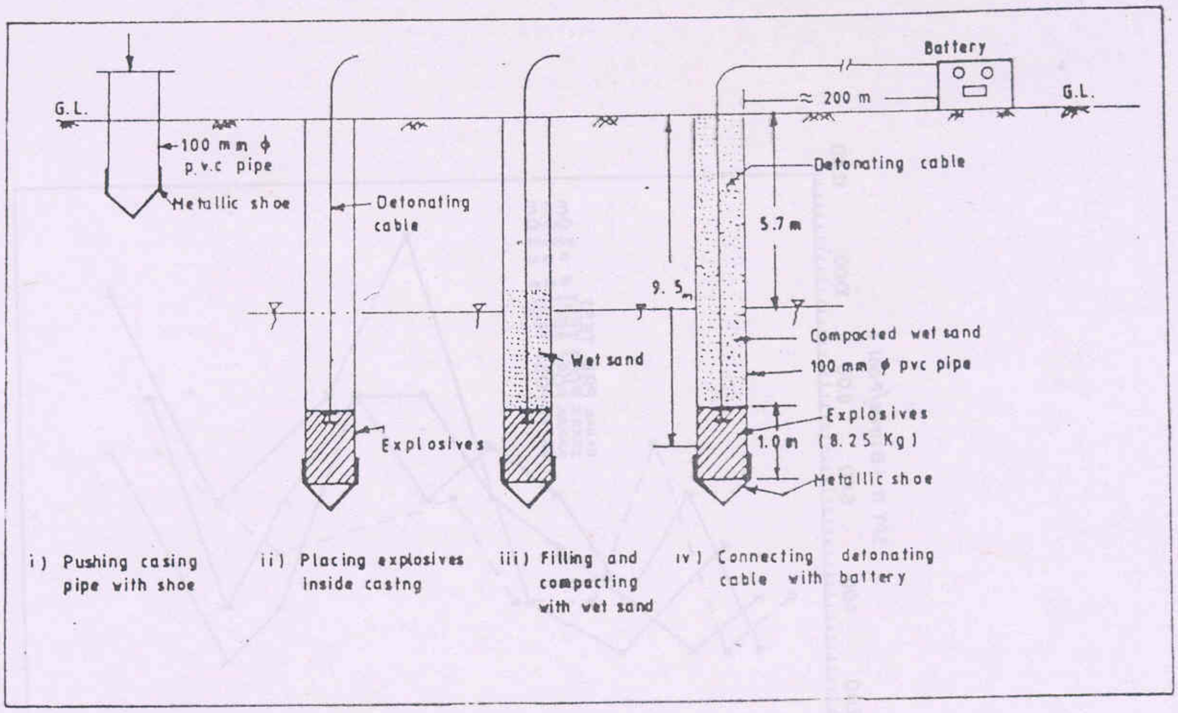

Fig.3. Installation of charge.

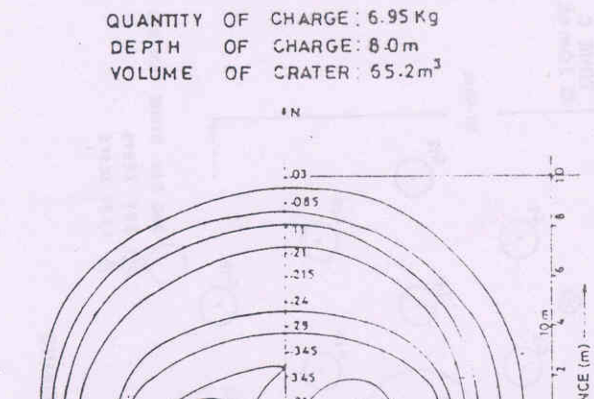

Fig.4 . Contour of depression at trial blast

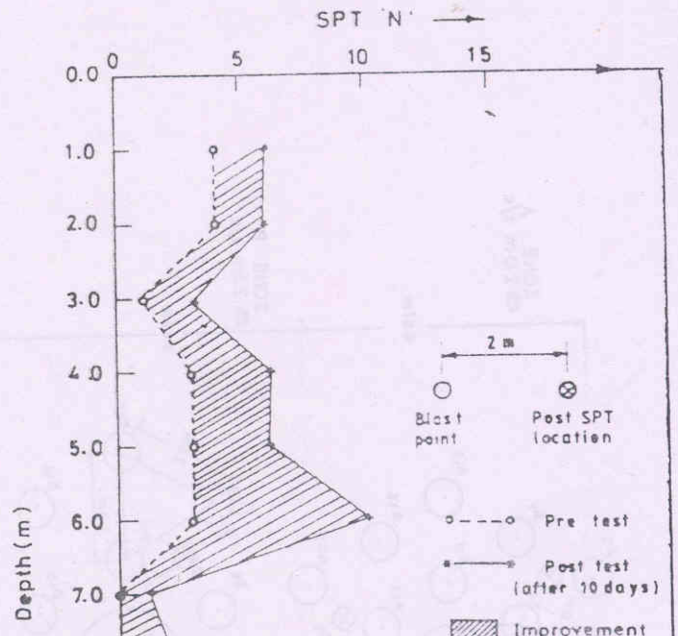

Fig.5 . Results of pre and post SPT