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A Study on Behaviour of Stone Columns on Compacted Pond ash Bed

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Abstract— *Energy consumption is increasing day by day due to rapid industrialization and modernization and thermal power plants are one of major sources of electric energy. These plants use coal energy thus leaving pond ash and other bi products as residue. Pond ash possess high compressibility, low bearing capacity so several km^2 of land remains unutilized. The performance of such materials can be improved by applying various ground improvement techniques. Our study focused on improving the strength of pond ash thus attempts were made to improve the strength of pond ash by the use -of stone columns. The illustrative researches were carried out on load carrying capacity of stone column installed in compacted pond ash bed. In present study stone columns of diameter 32, 40&50 mm with constant l/d ratio of 4.5 were used. The tests was conducted in two series. In first series of tests both index as well as geotechnical properties of virgin pond ash were deemed. In second series load settlement behaviour of compacted pond ash bed and pond ash with stone columns was studied. Later diameter of stone column was varied and the effect of diameter of stone column on load bearing capacity of pond ash were studies. Further role of encasement was also studies as study is based on both ordinary as well as encased stone columns. In addition construction and demolition waste aggregates were used as granular material for stone columns. Load vs. settlement curve was plotted for different column diameters and results were compared. It was found that in case of ordinary stone columns with increase in diameter of stone columns load bearing capacity was increased however in case of encased stone columns smaller diameter showed larger effectiveness. Thus this report is focused on stabilizing pond ash bed with stone columns so as to make it suitable for various geotechnical as well as structural facilities.*

1. INTRODUCTION

The pond ash is residue delivered from burning of coal. The coal is burnt for the generation of electricity in coal based thermal power plants. Pond ash, produced during the kindling of coal for energy output, is an industrial by product that is categorized under environmental pollutant. According to the data available 64.6% of the electricity generated in India derives from thermal power plants. It is estimated that annually 112 million metric tons of fly ash are produced in India and out of it just 42 million tons are utilized, remaining unutilized ash is subjected to disposal on to ash ponds. These ash pond cover almost 65000 acres of land revealing that more than 80 million metric tons is either stored in ash ponds or subjected to landfills. An estimate shows that by year 2032, over and above 1.8 million acres of land will be covered by quantity of 225 million metric tons of fly ash. Simultaneous generation of ash in large amount is a subject of grave concern not just due of issues related with its use and disposal but also owing risk to public health and ecology.

Pond ash deposits are highly compressible, and possess low bearing capacity because of which several acres of area remains unutilized. The behaviour of such materials can be enhanced by application of numerous ground improvement methods and facilities. The techniques like stone columns and sand columns have been broadly adopted from past many years to counter act the complications associated with poor soils. These techniques have not only increased the load carrying capacity of weak soil but also. The embedding of ordinary and encased stone columns in soft cohesive soils have enhanced both the load settlement behaviour of the foundation soil, and the consolidation of the surrounding saturated soft soil. Literature review reveals that compacted stone column has been effectively used as a ground improvement technique for silty to fines and pond ash in study is categorized in same category. So, in present study an endeavor has been made to inspect the effectiveness of ordinary stone column and encased stone column in improving the load bearing capacity of abandoned ash ponds. Thus in ordered to achieve enhanced strength of compacted pond ash, a series of experiments and tests were conducted.

Ground improvement by emebeding stone columns in weak soil is one of oldest and broadly used techniques.This ground improvement technique has been successful in enhancing the load bearing capacity and in bringing down ther settlement for foundation of various structures resting over it.

Stone Coloumns have past history of several years and different studies being pursued in this subject are

Hughes and Withers (1974) conducted numerous model tests in normally consolidated clay, the results revealed that ultimate load bearing capacity of stone coloumns depends upon lateral resistance provided by surrounding soil against bulging. Murugesan and raj gopoal (2008) studies the effect of different diameters on load bearing capacity of stone colums Sadrita et.al (2010) conducted experimental studies to examine the impact of stone coloumn and pond ash on clayey silt and from the test outcomes it was concluded that load carrying capacity was increased by 2-3 times and 9-21 % in with stone columns and pond ash respectively. S.N. Malarvizhi and K. Ilamparuthi (2010) studied load settlement behavior of ordinary and encased stone columns varying sylenderness ratio and encasing material and reached to goal that load carrying capacity depends on stiffness of encasing material. Tandel (2012) proved ordinary stone columns of larger diameter prove more effective while as encased stone column of lesser diameter prove more effective Amination Marto et al (2013) used finite element method to study settlement and ultimate load carrying capacity of ordinary and encased stone columns and concluded load carrying capacity of stone column can be increased by increasing the diameter of stone column. Demir (2016) conducted model testing on use of recycled concrete aggregates as granular material in stone columns and concluded that re use of recycled concrete aggregates can be made in stone columns. Amith ks (2016) in his experimental studies regarding stone columns concluded that load carrying capacity of stone columns rose up by increasing un drained strength of clay provision of geo textile encasement and bulging was minimized by lime stabilization.

In past few years employing of stone columns for enhancing load settlement behavior of soft soil had increased vastly. The present experimental study analyses the impact of column diameter on load carrying capacity. The impact of PVC mesh as an encasing material has also been studied. Thus current paper ambitions on how to make ash ponds load bearing so that they can withstand against loads rom various geotechnical and structural facilities.

2. EXPERIMENTAL PROGRAMME:

This section endows a frame of work overtaken during the experimental exploration that includes materials used, testing methods and models and all other processes and procedures that paved path for current research studies.

The present Experimental work was carried out on stone columns embedded in compacted pond ash tank of 400 mm height and 300 mm diameter. All the experiments were conducted on end bearing stone columns. The diameter of columns was varied as 32, 40 and 50 mm diameter columns were used in study keeping constant l/d ratio of 4.5. Both ordinary as well as encased columns were used in study. Constructions and demolition waste aggregates were used as the granular materials for stone columns.

2.1 Materials used: Pond Ash is residue that gets produced on burning of coal. When pulverized coal is kinked for energy generation in coal based power plant about 80 percent of the unburnt matter is collected as fly ash and the left out 20 percent of un burnt material is collected in a water-laden repository at the base of the incinerator. The lagoon bottom ash is usually combined with fly ash. This blended fly ash and bottom ash are referred to as pond ash. All coal ash is swung wet and disposed of as pond ash. This wet practice of chucking requires thousands of acres of land incorporating agricultural and forest land. Thus making it un suitable for construction purposes . The pond ash used in study was collected from Guru Gobind Singh super Thermal Power Plant, Ropar Punjab. Pond ash was sun dried to driest state. The numerous properties of pond ash were determined and tabulated in Table 1 and .2.

Construction and Demolition Waste (CDW) aggregates are obtained by crushing and processing demolished concrete debris. The principle initiator of these cdw aggregates are demolished buildings debris, roads, bridges debris, and sometimes even from catastrophes, such as wars and earthquakes. In present study the cdw aggregates were obtained from crushing and breaking of m20 grade concrete cubes. All these aggregates were thoroughly washed so as to remove impurities and then dried in oven at 110 c for 24 hours. In present study 2- 6mm size aggregates were used. The properties of these aggregates were determined and are tabulated in Table 3.

Encasing Material (PVC Mesh) with 1mm aperture was used as an encasing material for encased Stone Column. As the aggregate size was varied from 4-6mm therefore there was need of mesh having opening less than 2 mm. The numerous properties of this material are listed in table 4.

Table 1 Physical Properties of Pond Ash

S. No	Physical Parameters	Pond Ash
1	Colour	Grey
2	Shape	Round
3	Uniformity Coefficient	3.52
4	Coefficient of Curvature	2.16
5	Specific Gravity	1.97

Table 2 Chemical Properties of Pond ash

S.NO	CONSTITUENTS PRESENT	POND ASH
1	LOSS OF IGNITION	4.52%
2	SILICA (SiO2)	56.32%
3	ALUMINA(AL2O3)	30.87%
4	IRON OXIDE (FeO2)	4.94%
5	MAGNESIUM OXIDE (MgO)	1.58%
6	CALCIUM OXIDE (CaO)	0.70%

Table 3 Physical Properties of Construction and Demolition Waste Aggregates

S. No	Physical Parameters	CDW Aggregates
1	Colour	Light Grey
2	Shape	Round/Oval
3	Size	2-6 mm
4	Specific Gravity	2.44
5	ρd,max & ρd, min	13kn/m^3 & 11kn/m^3

Table 4 Physical Properties of Encasing Material (PVC Mesh)

S. No	Properties Of Pvc Mesh	Value
1	Mass per unit area	8gram/cm^2
2	Thickness	1.5mm
3	Apparent opening size	1mm
4	Diameters used	32,40 and 50mm

2.2 Preparation of Pond Ash Bed: The air-dried sample of pond ash was homogenously mixed with water to get maximum dry density. The omc was taken as 39%.since end bearing columns were used with constant l/d ratio of 4.5. Therefore compacted hard stratum of aggregates mixed with sand was used at the bottom of the tank to adjust depth of the columns. Thoroughly mixed sample was filled in the tank in 3 equal layers each layers so as to achieve a uniform wet density of 0.9 kN/m^3.

2.3 Stone Column Installation: A stone column was installed in the pond ash bed by replacement method. A hollow PVC pipe of required outer diameter was forced into the pond ash bed with the help of rammer blows up to required depth. When the pipe reached required depth it was taken out gently and slowly in order to minimize the disturbance to pond ash bed. The desired amount of aggregates was calculated according to maximum dry density of aggregates. The aggregates were filled in 5 equal layers. Maximum dry density was achieved by compacting aggregates with tamping rod of 16mm diameter. Fig-1 shows the schematic picture of stone column embedded in pond ash bed.

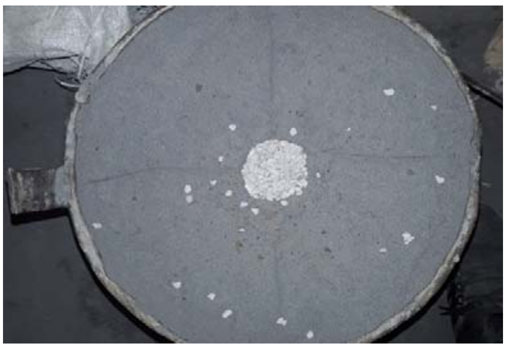

Figure 1: Schematic picture of stone column embedded in pond ash bed.

2.4 Experimental Setup: For the footing Load Test, Tests were conducted on a single stone column having constant l/d ratio but varying diameters. 32, 40 and 50 mm. Both ordinary and encasing stone columns were used keeping l/d ratio as 4.5 throughout. The model test tank test along with sample was placed under a loading frame of tri axial testing machine. Loading was applied through a circular footing of 80 mm diameter resting on the prepared sample bed and resistance offered by the sample bed of virgin pond ash, and sample embedded with different diameter of ordinary and encased stone columns was measured by noting the readings on proving ring. Load was applied till the settlement of 25mm at uniform strain rate of 1.25mm/min. Load corresponding to various deformation was obtained and load vs. settlement curve was plotted. Fig-2 shows the schematic picture of model testing tank under loading frame

Figure 2: Schematic Picture of Model Testing Tank under Loading Frame.

3. RESULTS AND DISCUSSION

The present study is based on model testing, tests were conducted on circular footings resting on virgin pond ash, pond ash reinforced with stone columns and parameters under study were evaluated corresponding to each case The following figures show load versus settlement behavior virgin pond ash and pond ash reinforced with ordinary and encased stone columns. The impact of ordinary and encased stone columns on pond ash bed can be easily examined from the figures below

3.1 Load Settlement Behavior of Virgin Pond Ash

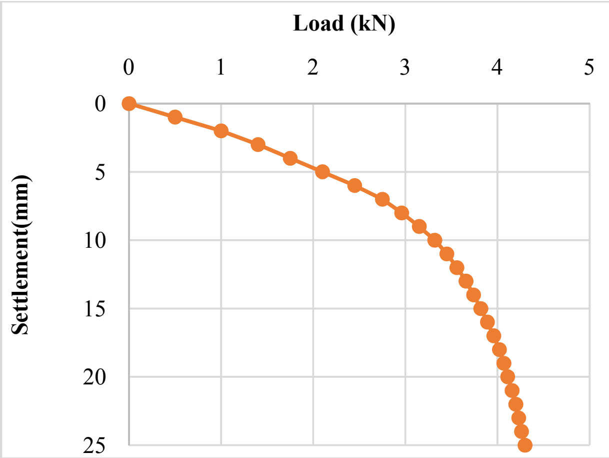

Figure 3 Load vs. Settlement Curve of Pond ash

3.2 Load Settlement Behavior of Pond Ash reinforced with Ordinary and Encased Stone Columns:

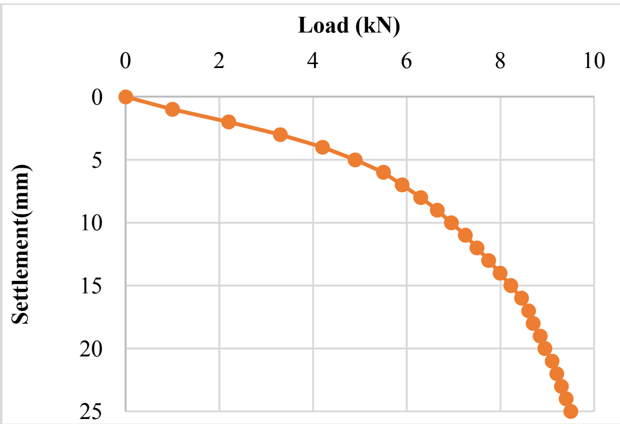

Figure 4 Load vs. Settlement curve of 32mm ord SC

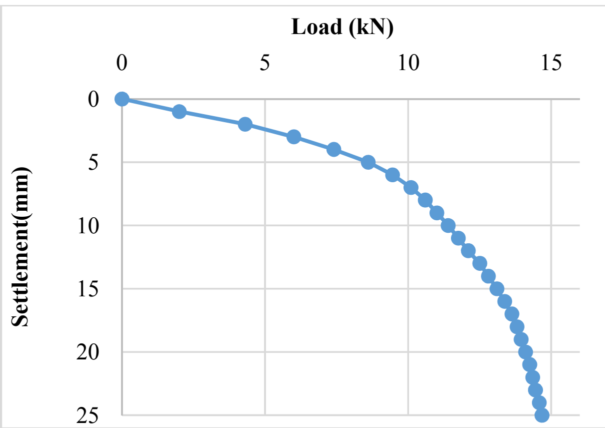

Figure 5 Load vs. Settlement curve of 32mm Enc SC

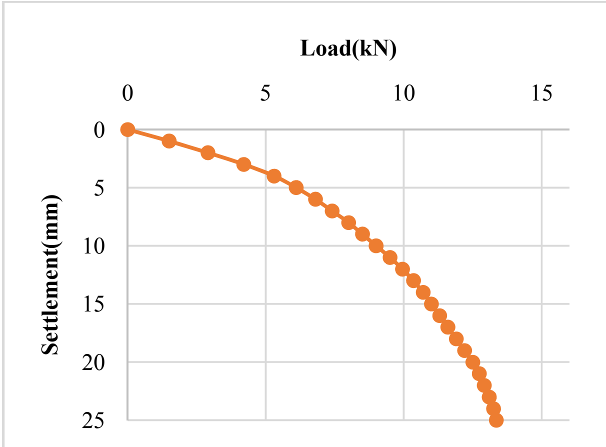

Figure 6 Load vs. Settlement curve of 40mm Ord SC

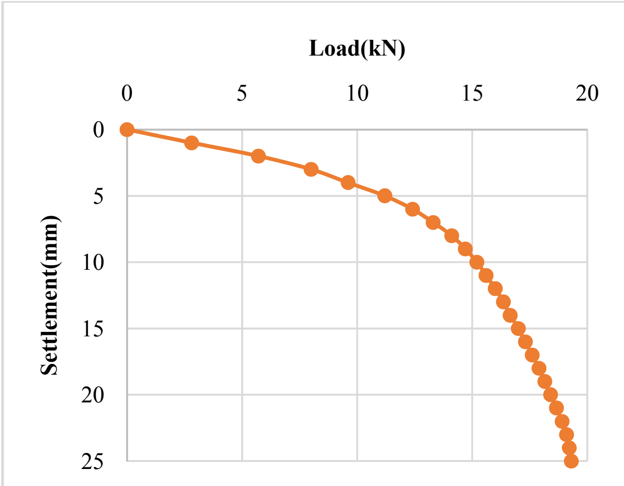

Figure 7 Load vs. Settlement curve of 40mm Enc SC

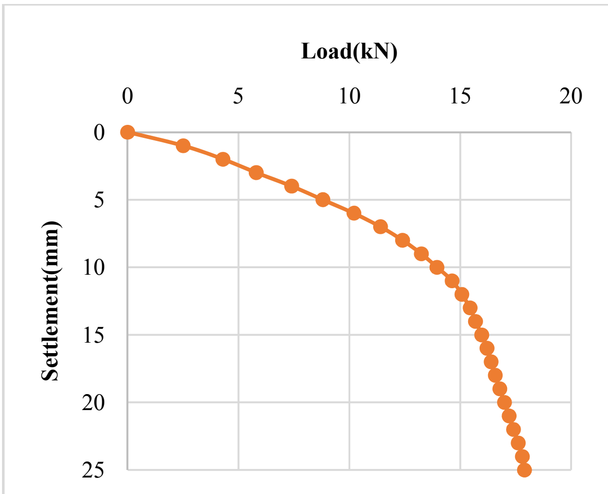

Figure 8 Load vs. Settlement curve of 50mm Ord SC

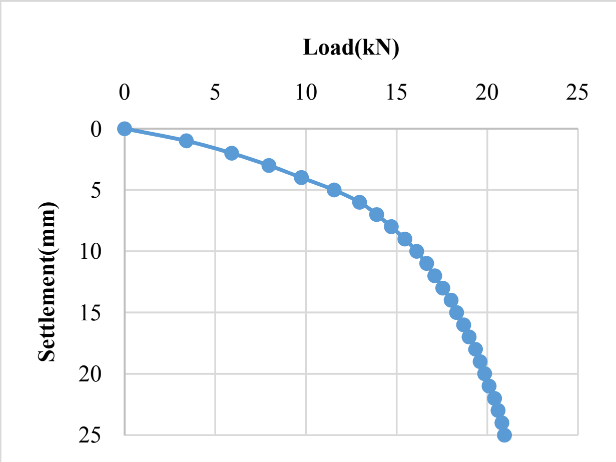

Figure 9 Load vs. Settlement curve of 50 mm Enc SC

4. CONCLUSIONS:

The primary conclusions made from this investigation are as follows.

- On reinforcing the virgin pond ash with stone column, it was observed that load bearing capacity was increased by 2-2.5 times.
- By the provision of encasement load bearing capacity was further increased by 1.5-2 times. This happened because bulging was restrained by encasement
- The effectiveness of ordinary stone column of larger diameter was found elite than that of smaller diameter. It is because of large area ratio we have graver values of friction angle and graver density triggers to low strain.
- In case of encased stone columns, the efficiency of stone columns of smaller diameter was seen superior to that of large ones. It happened because mobilization of higher confining stresses in smaller diameter stone columns.

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