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Behaviour of Ordinary and Encased Stone Columns Embedded in Pond Ash and Pond Ash Mix

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Abstract: *Solid waste is abortive or useless solid material generated from various human activities in residential, commercial& industrial zones. The better and effective management of these wastes is need of hour. The present study focuses on managing the wastes generated from thermal power plants and metal casting foundries. These wastes possess serious problems concerned over various environmental issues. In addition the unavailability of land for suitable disposal has put pressure for the utilization of unused ash ponds. Pond ash deposits are highly compressible and possess low bearing capacity, because of which several hectares of land remains unutilized. The present study focuses on enhancing the load characteristics of ash ponds by inclusion of stone columns. An optimum percentage of waste foundry sand has also been added to ash ponds in order to enhance the compaction and shear characteristics of pond ash. The illustrative research was carried out on stone columns of diameters 32mm, 40mm and 50 mm with constant l/d ratio of 4.5. The diameter of columns was varied and influence of diameter of stone columns on load settlement behaviour was studied. The study was carried out in two phases. In first series of tests stone columns were embedded in virgin pond ash while as in second series the stone columns were embedded in pond ash mix. Load v/s settlement curves for different column diameters in both pond ash and pond ash mix was plotted and the results were compared. It was found that addition of waste foundry sand enhanced the load carrying characteristics of pond ash and second effect was that the ordinary stone columns of larger diameter showed up to be more effective than ordinary stone columns of small diameter and encased columns of smaller diameter were more effective than that of larger diameter encased stone columns. Thus this research work empathizes on making shunned pond ash beds suitable for various structural facilities.*

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I. Introduction

The pond ash is residue that gets produced on ignition of coal for the purpose of energy generation. Coal is burnt to generate electrical energy in coal based thermal power houses. Pond ash, produced by burning of coal for energy output, is an industrialized by-product categorised as toxic waste. Ash produced is unified combination of mixture of bottom ash and fly ash in soaked form. According to the data available 64.6% of all the electricity produced in our country (India) generated from thermal power houses. It is approximated that annually 112 million metric tons of fly ash are conceived in India and out of it just 42 million tons are utilized. The remaining unutilized ash is subjected to disposal on to ash ponds. These ash pond cover almost 65000 acres of land revealing that over and above 80 million metric tons is either accumulated by ash ponds or subjected to land dumps. 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 enhancement practices and facilities. Numerous ground enhancement practices have been advanced and adapted to overcome complications associated with weak soft soil. 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 just increased the load bearing capacity of weak soil deposits but, also reduced the settlement. The embedding of both ordinary as well as encased stone columns in soft cohesive soils have enhanced both load settlement behaviour of the foundation soil, as well as the consolidation characteristics of the neighbouring saturated soft soil.

Literature studies reveal that use of compacted stone column as a stabilitating practice can be applied efficaciously in silty to fines and pond ash is categorized in the same category. So, the current study focuses on effectiveness of foundry sand, ordinary stone column and encased stone column in enhancing the bearing capacity of shunned ash ponds. Here pond ash has been used as soil, foundry sand has been used as stabilizer for additional property improvement of pond ash. Thus in order to achieve enhanced strength of compacted pond ash, a series of experiments and tests were conducted.

Stone columns have past history of several years and different studies 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 slenderness 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. 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 done in stone columns. Amith (2016) in his experimental studies regarding stone columns concluded that load carrying capacity of stone columns increased by increasing un drained strength of clay by provision of geo textile encasement and bulging can be minimized by lime stabilization.

In past few years embeddment of stone columns for enhancing load settlement behavior of soft soil had increased vastly. The present experimental study analyses the impact of type of stone columns and diameter of stone columns on load carrying capacity of pond ash. The impact of PVC mesh as an encasing material has also been studied. Thus current paper ambitions on how to make ash ponds suitable for different civil engineering projects and use of pond ash as embankment fill.

II. Experimental Work

2.1 Materials:

Pond Ash: It is a coal combustion residue released by various manufacturing units and coal based thermal power plants. It is categorised as a waste material and environmental pollutant. The pond ash used in present study was collected from Guru Gobind Singh Super Thermal Power Plant, Ropar Punjab, India. Pond ash was sundried to driest state. The various physical and chemical properties of pond ash are shown in tables.

Waste Foundry Sand: It is a by-product obtained from several metal casting industries. It is categorized as high quality silica sand having sub-angular to round shape and possess high thermal conductivity that makes it suitable for various casting and molding purposes. After being used for several times in casting and molding, these sands have capability of getting recycled, so that they can be again used for casting purposes. But after being recycled and reused several times, they lose suitability of being used again and again. Hence get categorized as waste product. The foundry sand used in current study was collected from Gopal Foundry works, focal point Ludhiana, Punjab, India. The various physical and chemical properties of foundry sand are tabulated in table 3.1.

Stone Aggregates: Crushed stone aggregates of size 2 to 4 mm were used to form stone columns. These aggregates were brought locally. These aggregates were compacted at maximum dry density of $14kN/m^3$.

Encasing Material: PVC Meshwith 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.

Table-3.1 Physical properties of pond ash and waste foundry sand

Physical Parameters	Pond Ash	Waste foundry Sand
Colour	Grey	Light Black
Shape	Round	Round
Uniformity Coefficient (C_u)	3.52	2
Coefficient of Curvature(C_c)	2.16	0.88
Specific Gravity	1.97	2.67

Table-3.2 chemical properties of pond ash and waste foundry sand

Constituents Present	Pond Ash	Waste Foundry Sand
Loss Of Ignition	4.52%	5.15%
Silica (Sio2)	56.32%	87.91%
Alumina(Al2o3)	30.87%	4.70%
Iron Oxide (Feo2)	4.94%	0.94%
Magnesium Oxide (Mgo)	1.58%	0.30%
Calcium Oxide (Cao)	0.70%	0.14%

Table-3.3 Physical properties of demolished concrete waste

Physical Parameters	Stone Aggregates
Colour	Light Grey
Shape	Round/Oval
Size	2-6 mm
Specific Gravity	2.44
ρd,max. & ρd,min.	13kN/m^3& 11kN/m^3

Table-3.4 Physical properties of encasing material

PROPERTIES OF PVC MESH	VALUE
Mass per unit area	8gm/cm^2
Thickness	1.5mm
Apparent opening size	1mm
Diameters used	32,40 and 55mm

III. Experimental Set Up

As present work is based on model tests, a model testing tank of 300 mm diameter and 400 mm height was used. The tank was placed under a loading frame. Vertical load at constant strain rate was applied through a circular footing placed over the center of sample. The stone columns of diameters 32, 40 and 50 mm with constant (L/D) length over depth ratio of 4.5 were used. The stone columns were installed in the compacted bed of ash pond by replacement method. An empty PVC pipe of required external diameter was forced into the bed of pond ash with the help of rammer blows up to required depth. When the pipe reached to 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 maximal dry density of aggregates. The aggregates were filled in 5 equal layers. Maximal dry density was achieved by compacting the aggregates with tamping rod of 16mm diameter. The tests were carried out in two series. In first series the load settlement behavior for virgin pond ash bed and pond ash with ordinary and encased stone columns was examined. In second series of tests load settlement behavior of pond ash mix (mixed with 15% of waste foundry sand), pond ash mix with both ordinary and encased stone columns examined. The load was applied through a proving ring at a constant displacement rate. The settlements corresponding to equal load intervals were noted down. The loading was applied until the settlement of 25 mm. The test is repeated for different diameter of stone column

Figure 1: Stone Column embedded in pond ash **Figure 2:** Model Testing Tank

Figure 3: Bulging of ordinary Stone Column

Figure 4: Bulging of Encased Stone Column

IV. Results and Discussions:

4.1 Influence of Waste Foundry Sand on Settlement Behavior of Pond Ash:

On the behalf of data and results obtained from standard proctor test and direct shear test, it was discovered that optimum quantity of waste foundry sand to be added to pond ash is 15%. Therefore 15% of waste foundry sand was added to pond ash at optimum moisture content of 35%.The prepared bed of compacted pond ash mix was placed under loading frame. The results were obtained by applying load on stone column through a circular footing of 80 mm diameter. The tests have been conducted so as to examine improved load settlement behavior of pond ash. In the graph the comparison between load settlement behavior of pond ash and pond ash mix is shown. The load carrying capacity for 25 mm settlement of pond ash increased by the addition of waste foundry sand. The increment of ultimate load carrying capacity between pond ash and pond ash mix is 18.6 %.

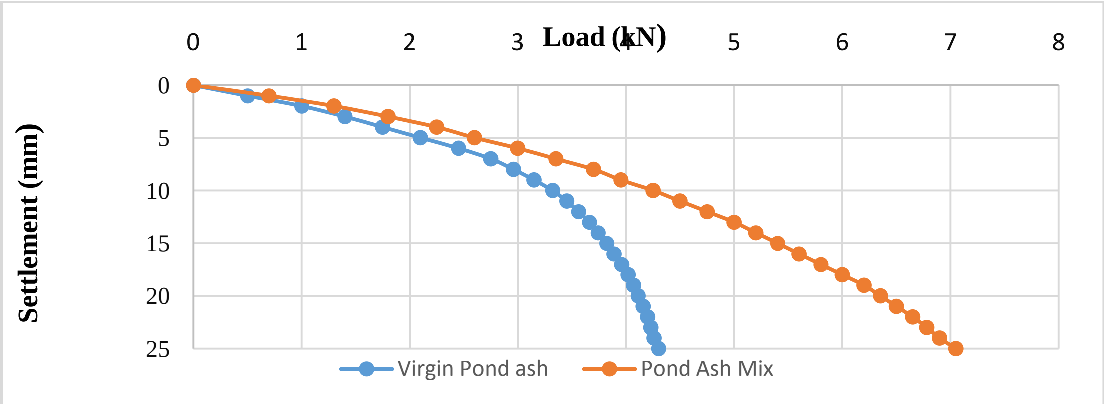

Figure 5: Load v/s Settlement behaviour of pond ash and pond ash mix

4.2 Behavior of Ordinary Stone Columns on Virgin Pond Ash Bed:

Different Test were carried on stone columns of diameters of 32, 40, and 50 mm with varying lengths of 144,180, and 225 mm respectively. The load has been applied vertically by loading frame, and the resulting load versus settlement curves for different diameters were plotted and compared in Figure 6. It was examined from the plotted curves that the load carrying capacity at the settlement of 25 mm was increased by 1.8 to 2.3 times with inclusion of stone columns of different diameters in compacted pond ash bed.

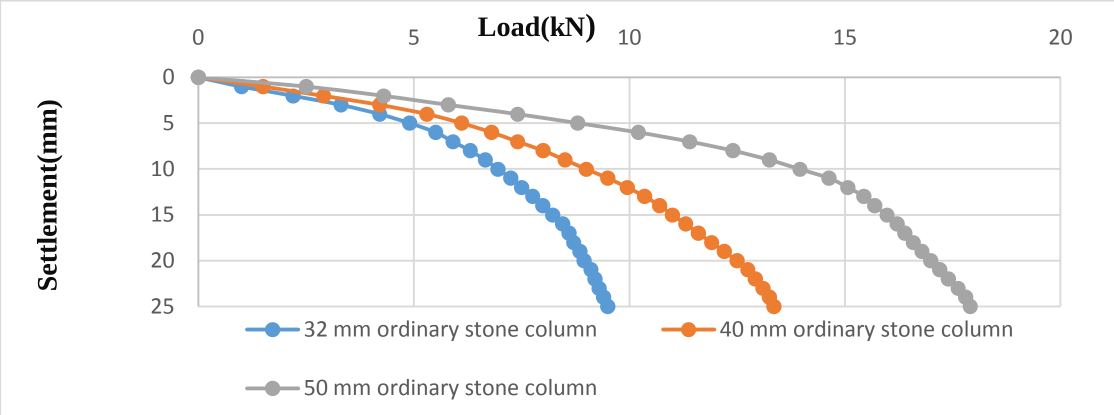

Figure 6: Load v/s Settlement behaviour of Ordinary Stone Columns

4.3 Effect of the diameter of ordinary stone columns on the load settlement behavior of virgin pond ash: The tests have been carried out so as to examine the enhancement in bearing capacity of pond ash due to embedding of stone column. Figure 6: shows load v/s settlement behavior of ordinary stone column for varying diameters of 32, 40 and 55 mm. It was observed that the load carrying capacity for ordinary stone columns increased with increasing the diameter of column. The increment of failure load between 32 mm to 40 mm diameter of stone column is 26.1% and increment of failure load between 40 mm to 50 mm diameter of stone column is 23.8%. It is examined that the responses of stone column with increasing diameter shows a higher failure load at 25mm settlement. Similar trend were revealed from research's evaluated by Murugeson and Rajagopal (2010), Bhattacharyya and Pal (2012), and Marto et al (2013).

4.4 Behavior of encased stone columns on virgin pond ash bed: Test was carried on encased stone columns of diameters of 32, 40, and 50 mm with varying lengths of 144, 180, and 225 mm respectively. The load has been applied vertically by loading frame through the circular footing placed at the center of test tank, and the resulting load versus settlement curves for different diameters were plotted and compared in Figure 7. It was examined from the plotted curves that load carrying capacity at the settlement of 25 mm was further increased by 1.5 to 2 times by encasing the stone columns of different diameters in compacted pond ash bed.

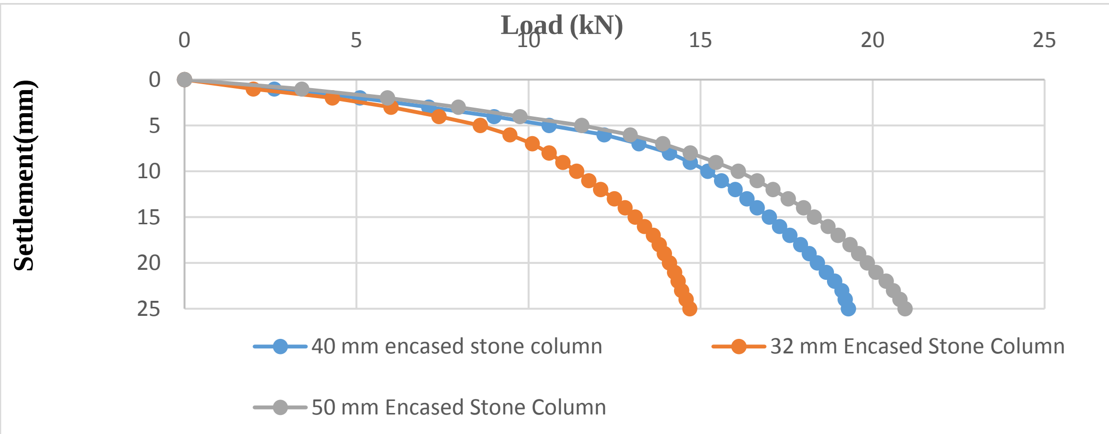

Figure 7: Load v/s Settlement Curve for Encased Stone Columns

4.5 Effect of the diameter of encased stone columns on load settlement behavior of virgin pond ash: Different tests have been carried out so as to examine the enhancement in bearing capacity of pond ash due to embedding of encased stone column. Figure 7 shows load v/s settlement behavior of encased stone column for varying diameters of 32 40 and 55 mm. it is examined that the encased stone columns of lesser dia showed superior performance to that of larger dia for same encasement material. The increment of failure load between 32 mm to 40 mm diameter of stone column is 25.1% and increment of failure load between 40 mm to 50 mm diameter of stone column is 11%.

4.6 Behavior of ordinary stone columns on pond ash mix: Tests were carried over on ordinary stone columns of diameters of 32, 40, and 50 mm with varying lengths of 144, 180, and 225 mm respectively. The load has been applied vertically by loading frame through the circular footing placed at the center of tank, and the resulting load versus settlement curves for different diameters were plotted and compared in Figure 8. It was examined from the plotted curves that load carrying capacity at the settlement of 25 mm was increased by 2.2 to 3 times by embedding of the ordinary stone columns of different diameters in pond ash mix bed.

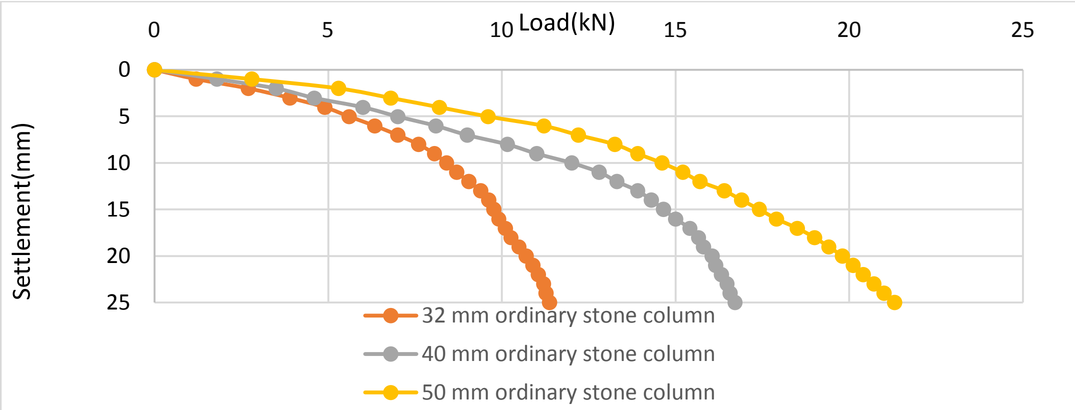

Figure 8: Load v/s Settlement Curve for Ordinary Stone Columns in pond Ash Mix

4.7 Effect of the diameter of ordinary stone columns on load settlement behavior of pond ash mix: Different tests have been carried out so as to examine the enhancement in bearing capacity of pond ash due to embedding of stone column. Figure 8 shows load vs. settlement behavior of ordinary stone column for varying diameters of 32, 40 and 50 mm. it is observed that load carrying capacity for ordinary stone columns increased with increasing the diameter of column. The increment of failure load between 32 mm to 40 mm diameter of stone column is 22% and increment of failure load between 40 mm to 50 mm diameter of stone column is 21.8%. It is examined that the responses of stone column with increasing diameter shows a higher failure load at 25mm settlement.

4.8 Behavior of encased stone columns on pond ash mix: keeping all the parameters same stone columns encased with pvc mesh were embedded in pond ash mix. The load has been applied vertically by loading frame through the circular footing placed at the center of tank, and the resulting load versus settlement curves for different diameters were plotted and compared in Figure 9. It was examined from the plotted curves that load carrying capacity at the settlement of 25 mm was further increased by 1.5 to 2 times by encasing the stone columns of different diameters in compacted pond ash bed.

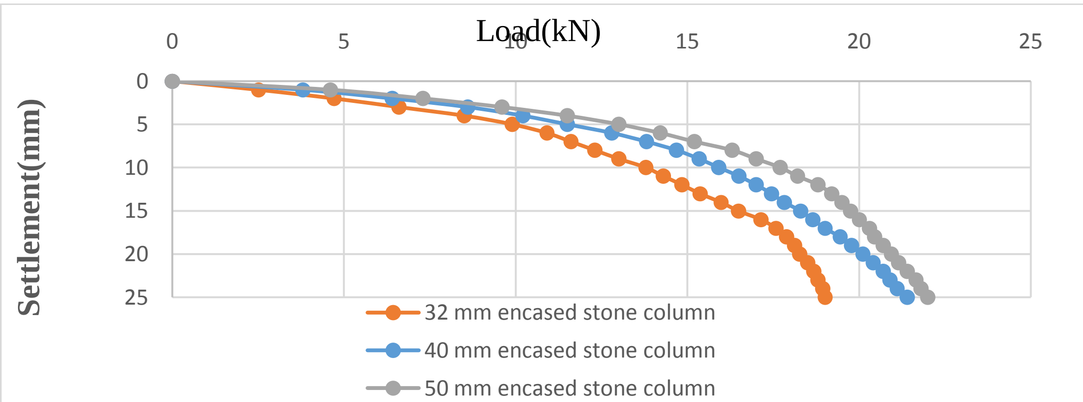

Figure 9 Load vs. Settlement Curve for Encased Stone Columns in pond Ash Mix

4.9 Effect of the diameter of encased stone columns on load settlement behavior of pond ash mix: upon Figure 9 shows load v/s settlement behavior of encased stone column for varying diameters of 32, 40 and 55 mm. It is examined that the encased stone columns of lesser dia showed superior performance to that of larger dia for same encasement material. The increment of failure load between 32 mm to 40 mm diameter of stone column is 24.1% and increment of failure load between 40 mm to 50 mm diameter of stone column is 9 %.

V. Conclusions

- Upon addition of optimum quantity of waste foundry sand, bearing capacity was increased by 15%.
- On reinforcing the virgin pond ash by stone columns the bearing capacity was increased by 1.5 to 2 times.
- On addition of encasement to stone columns bearing capacity was further increased by 1.5 to 2 times.
- In case of pond ash mix bearing capacity was increased by 2.2 to 3 times for ordinary stone columns and for encased ones it was further increased by 1.5 to 2 times.
- The effectiveness of ordinary stone columns of larger diameter was seen superior than that of smaller diameter because of higher area ratio.
- The encased stone columns of lesser diameter was showed superior performance to that of larger diameter for same encasement material because of mobilization of higher confining stresses in smaller diameters.

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