Poll Res. 40 (3) : 913-917 (2021)

ISSN 0257–8050

UTILIZING COPPER SLAG AND CONSTRUCTION WASTE IN PROBLEMATIC SOIL IMPROVEMENT

BHARATH M.

Department of Civil Engineering, Veltech Rangarajan Dr. Sagunthala R & D Institute of Science and Technology, Chennai 600 052, India

(Received 30 January, 2021; Accepted 4 May, 2021)

ABSTRACT

Copper slag a byproduct from copper extraction and construction demolition wastes should be reused because these waste materials occupy larger area and reusing these materials leads to sustainable development. In this study, compressive test on column were conducted to ensure the suitability of waste as column materials for reducing settlement and void ratio (to achieve increased density). Waste material encased with geo composites is also analyzed. Hence it is concluded that even some slippage happens due to the texture of copper slag it may be used as better replacement material for conventional stones.

KEY WORDS : Stone column, Geocomposite, Construction waste, Copper slag

INTRODUCTION

Generally, the soft clay deposits found along the coastal plains worldwide which have low shear strength, low permeability and high compressibility Installation of stone columns is one of the most popular methods used to improve the strength of soft soil like peat or sludge (undrained shear strength less then 5kN/m^2) since it has been properly documented in the middle of last century. Owing to the presence of pores in the stone column, it acts as vertical drains for seepage of water from the soil during consolidation so it can accelerate the consolidation. Foundation settlements are reduced due to increases in compression modulus compared to the surrounding soil and also it contributes as a supporting structure. Ling Zhan (2013) analyzed the settlement calculation of composite foundation reinforced with stone columns by using the unit cell approach with the assumption like settlement is uniform; column material is treated as an elastic material.

Deb and Shiyamala (2014) studied the effect of clogging on rate of consolidation of stone column-improved by considering particle migration. Ambily and Gandhi (2007) studied on single column and group of seven columns in clay of high plasticity and that stiffness improvement factor is found to be independent of shear strength of surrounding soil and it mainly depends on column spacing and angle of internal friction of stones. Ambily and Gandhi (2007) evaluated the behavior of stone column by varying column spacing, shear strength of clay and consistency of clay through experiments on model stone columns.

Murugesan and Rajagopal (2010) conducted laboratory model test on single and group of stone columns with and without encasement. Lay used in the test was low plasticity. Clay bed was prepared by consolidating slurry under the pressure of 10kpa. It was found that effectiveness of decreased as geo-synthetic increases in diameter of stone column and hoop strains in the geo-synthetic encasement were highest near the top and decreases towards the depth of the column. Shahu and Reddy (2011) conducted drained tests on small scale models of floating stone column group placed in slurry deposited clayey soil. Stalin (2004) studied the concrete waste as column material for the improvement of soft clay and concluded that the time required for the 75% of consolidation (t75) in case of clay+ concrete waste columns are much closer to clay + stone aggregate column irrespective of number of columns.

Upon using the stone aggregate as column material, the cost for the project is moderately high, so the geotechnical engineers must go for the alternate material. Hence, an attempt is made in this paper to study the performance of waste as column material in the place of conventional stone aggregate.

MATERIALS AND METHODOLOGY

Natural soil

The soil collected from Chennai, Tamilnadu was air dried and tested for gradation, Atterberg limits and specific gravity were measured as per relevant IS specifications. The details of physical properties of natural soil are summarized in Table 1.

Properties	Values
Silt (%)	12
Sand (%)	22
Clay (%)	66
Liquid Limit (%)	67
Plastic Limit (%)	31
Plasticity Index (%)	36
Shrinkage Limit (%)	12
Free swell index (%)	60
Classification	CH

Geo-synthetics

Geo-composite was used to encase the aggregate column in the present study. In case of geo-composite, the columns encased with non-woven geotextile are additionally encased with a geogrid to allow for drainage without clogging of soil in the aperture. The geo textile was stitched to form the tube for encasing the column. The geogrid encasement was tied by using commercially available cable ties. The properties of geogrid and geotextile are tabulated in Table 2(a) and 2(b).

Table 2(a). Properties of Geogrid

Description	Values
Aperture size	25mm x25mm
Tensile strength (kN/m)	40.5
Type	Uniaxial

Table 2(b). Properties of Geotextiles

Properties	Values	Units
Mass/Unit Area	150	Gms/Sq.Mt
Thickness	1.3	Mm
Tensile Strength	4.5	kN/m
Elongation	55	%
Opening Size	160	Microns
Permittivity	2.0	Sec

Conventional coarse aggregate, Construction waste aggregate and copper slag

Conventional coarse aggregate and construction waste aggregate of size varying from 5 to 10mm had been used to form the columns. Particle size for the columns are as per the guidelines of Nayak (1983), which suggest that it should be in the range of 1/6 to1/7 of the diameter of the column.

The construction waste was collected from the nearby construction site. The waste was broken and it was sieved to get sizes ranging from 5mm to 10mm.The crushing percentage of construction waste is 34% and for conventional coarse aggregate is 23%.

Load test on model tank in softclay

Load test was performed in a model tank as shown in Figure 1 on the prepared clay with conventional coarse aggregate, construction waste and copper slag as column materials by varying number of columns and encasement.

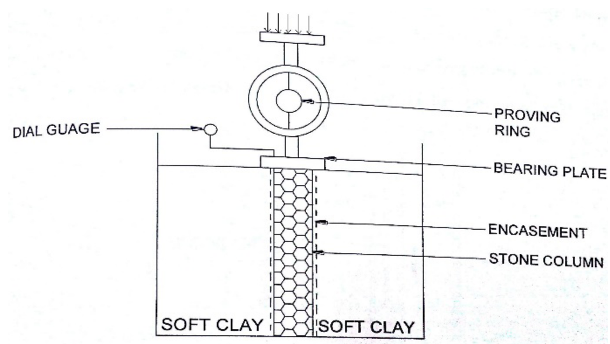

Fig. 1. Schematic view of Load test setup arrangement

Vane Shear Strength Test on Clay

Using vane shear apparatus, shear strength test was done for clay. As per IS: 2720(Part 30)-1980, and undrained shear strength of remoulded clay is 1.2 kN/m^2.

RESULTS AND DISCUSSION

Load-Settlement Behavior of Virgin Clay

Fig. 2 shows the load-settlement curve of virgin clay, where in ultimate failure load is found as 60N corresponding to settlement of 7mm. Fig. 3 and 4 present the load settlement curves of 1, 2 and 3 columns of conventional stone and construction waste aggregate columns respectively. At a settlement of 5mm, the load carrying capacity of one, two and three conventional stone aggregate columns are 98N, 120N and 132N respectively (Fig. 2) and for the same settlement, the load capacities of one, two and three columns of Construction Waste Columns (CWC) exhibited a load capacity of 70N, 98N and 129N respectively (Fig. 3). This results imply that construction waste material can be utilized as column material in the place of conventional stone aggregate.

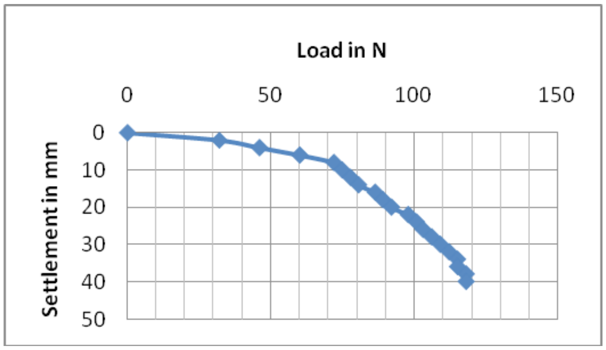

Fig. 2. Load Vs Settlement Curve for Virgin Clay

Comparison of load carrying capacity of Conventional Stone Column (CSC), Construction Waste Column (CWC), Copper slag Column (CuC), Copper slag with Stone Column (CuSC) and Copper slag with Construction Waste Column (CuCWC) (No encasement)

In case of 5mm settlement, one, two and three Construction Waste Columns (CWC) exhibited a load capacity of 70N, 98N and 129N respectively, which is corresponding to a percentage increases of 16% to 115% when compared to that of soil without

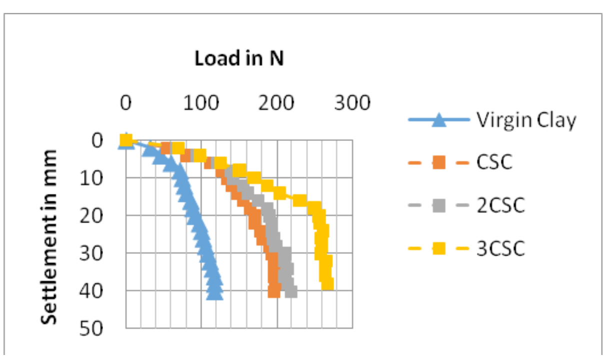

Fig. 3. Load Vs Settlement curves of soft clay with Conventional Stone Column (without encasement)

column. The same is 63% to 120% in case of Conventional Stone Column (CSC) (Fig. 5). In case of Copper slag Columns (CuC) the percentage increases from 43% to 101%. While for Copper slag with conventional Stone Columns (CuSC) the percentage increase ranges from 130% to 193%, for Copper slag with Construction Waste Column (CuCWC) the percentage increase is from 43% to 125% as seen in Fig. 5.

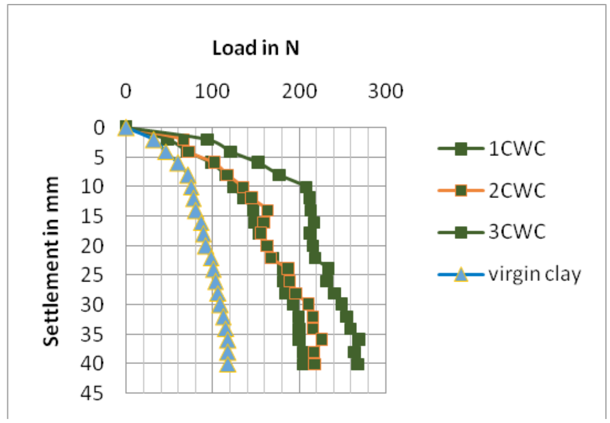

Fig. 4. Load Vs Settlement curves of soft clay with Copper Slag with Construction Waste Column (Without encasement)

The two Copper slag with conventional Stone Columns (CuSC) yielded a load capacity value of 118N, 168N and 216N for 5mm, 10mm and 20mm settlement respectively. Whereas for the same amount of settlement, the load capacity of two Copper slag Columns (CuC) is 112N, 114N and 167N. Here the percentage reduction in settlement is in the range of 5% to 22%. In case of Conventional Stone Column (CSC), the percentage reduction in settlement is in the range of 4% to 35%. However, the Copper slag with Construction Waste Columns (CuCWC) offered 10% to 24% reduction in settlement when compared with the Copper slag with conventional Stone Columns (CuSC). Further

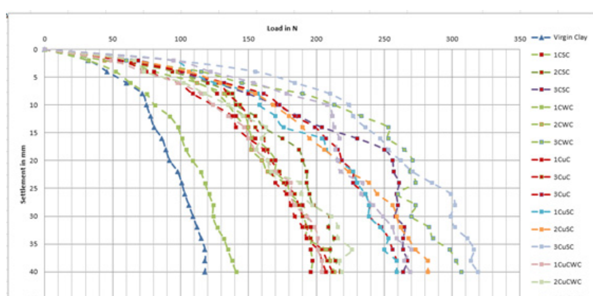

Fig. 5. Load Vs Settlement curves of Soft clay with Various Column (Without Encasement)

when the results of Construction Waste Columns (CWC) are compared with CuSC the reduction in settlement is found to be in the range of 17% to 26%.

Load-Settlement characteristics of soft clay with geo composite encased Column of Stone, Construction, Waste, Copper slag and their mixtures (With encasement)

Fig. 6 and 7 shows the load settlement behaviour of 1, 2 and 3 stone columns copper slag and construction waste column mix respectively with geocomposite encasement. For a settlement of 5mm, 124N, 126N and 206N are the load carrying capacity values for stone aggregate column respectively for 1, 2 and 3 columns. On the other side, for the same 5 mm settlement, the capacity is 86N, 92N and 156N in the case of copper slag and construction waste mix column materials respectively for 1, 2 and 3 columns. For any settlement encased stone column gives always higher capacity compared to uncased columns.

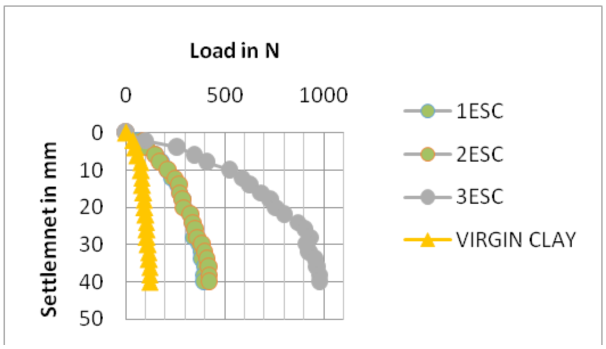

Fig. 6. Load Vs Settlement curves of soft clay with Encased Stone Column (with encasement)

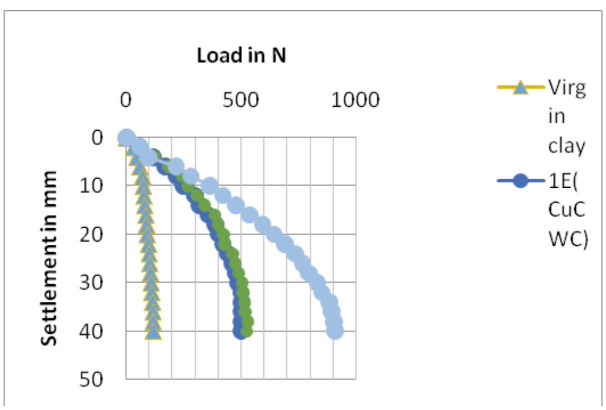

Fig. 7. Load Vs Settlement curves of soft clay with E (CuCWC) (With encasement)

CONCLUSION

Load carrying capacity of soft clay with one, two, three columns of stone aggregate, construction waste aggregate, copper slag, copper slag with stone aggregate and copper slag with construction waste are studied. The effect of number of columns and the performance of encasement also examined. Conclusions drawn from the experimental results are discussed below.

1. Stone columns improved the load carrying capacity and reduced settlement of soft clay bed. Encased columns are much stiffer and stronger than the non-encased columns. The shape of load settlement curve is independent of number of column and materials used.
2. The order of increase of capacity of single column is as follows: Conventional Stone Column (CSC)> Copper slag with Stone Column (CuSC)>Copper slag with Construction Waste Column (CuCWC)> Construction Waste Column (CWC)>Copper slag Column (CuC).
3. The load carrying capacity of encased column is higher than the column without encasement. The order of increases of capacity of encased column is as follows: Encased Stone Column (ESC)>Encased Copper slag with Stone Column (ECuSC)>Encased Copper slag Column (ECuC)>Encased Copper slag with Construction Waste Column (ECuCWC)> Encased Construction Waste Column (ECWC).
4. Even though the copper slag is heavier material than the conventional stone aggregate the glassy structure affects the frictional properties. Due to the glassy smooth surface slipping occurred in non-encased columns. Provision of encasement controls the slipping.
5. The column using construction waste performs better without encasement but the column using copper slag become a suitable material when the encasement was provided.

It is hence concluded that the copper slag/ construction waste with the stone column may be effectively utilized as column material in the place of the conventional stone aggregate in the improvement of clay.

REFERENCES

Ambily, A.R. and Gandhi, S. R. 2004. Experimental and theoretical evaluation of stone column in soft clay. *International Conference on Geosynthetic and Geo Environmental Engineering.* 113 : 201-206.

Ambily, A.R. and Gandhi, S. R. 2007. Behavior of stone columns based on experimental and fem analysis. *Journal of Geotechnical and Geo Environmental Engineering.* 113 : 405-415.

Deb, K. and Shiyamala, S. 2014. Effect of clogging on rate of consolidation of stone column-improved ground by considering particle migration. *International Journal of Geomechanics*. 40 : 17-26.

IS: 12584 Part 1,Design and Construction for ground Improvement-Guide line.

IS: 2386 Part IV-1963, Indian Standard Methods of test for Aggregates for concrete.

IS: 2720 Part 30-1980, Methods of test for soils, Part 30: Laboratory vane shear test

Ling Zhan, 2013. Settlement calculation of composite foundation reinforced with stone column. *International Journals of Geomechanics*. 13 : 248-256.

Murugesan, S. and Rajagopal, K. 2010. Studies on the behavior of single and group of geosynthetic encased stone columns, *Journal of Geotechnical and Geo Environmental Engineering.* 9 : 129-139.

Nayak, N.V. 1983 Recent advances in ground improvements by stone column. *Proceedings of the Indian Geotechnical Conference*, Chennai, India.

Shahu, J. and Reddy, Y. 2011, Clayey soil reinforced with stone column, *Journal of Geotechnical and Geo environmental Engineering*. 137 : 1265-1274.

Stalin, V. K. 2004. Concrete waste as column material for the improvement of soft clay', *Proceedings of 5th International Conference on Ground Improvement Techniques*, Malaysia, 1:293-296.