ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

IJARMATE
International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
Vol. II, Issue VI, June 2016

Load settlement behavior of square footing rested on clay soil with stone column

Nataraj Palanisamy[1], Getachew Kebede[2], Sadasivam Sasivaradhan[3]
Lecturer, School of Civil and Environmental Engineering, Jimma Institute of Technology, Jimma University, Ethiopia.[1]
Dean, School of Civil and Environmental Engineering, Jimma Institute of Technology, Jimma University, Ethiopia.[2]
Lecturer, School of Civil and Environmental Engineering, Jimma Institute of Technology, Jimma University, Ethiopia.[3]

***Abstract*—Soft clay deposits are extensively located in vast areas and they exhibit poor strength and compressibility. The structure on soft clay has always been associated with problems of stability and settlements. Many construction sites are underline by soils that are both weak and compressible. Ground improvement techniques are normally preferred for economic considerations. Out of several techniques available, stone columns are the most preferable and economic. This ground improvement technique has been successfully used to increase bearing capacity and reduce the settlement of constructions.**

***Index Terms*— Strength, Compressibility, Settlement, Stone column, bearing capacity.**

I. INTRODUCTION

Stone columns have been used extensively in weak deposits to increase the load carrying capacity, reduce settlement of structural foundations and accelerate consolidation settlements due to reduction in flow path lengths. Another major advantage with this technique is the simplicity of its construction method. The type and grain size of stone column material is one of the controlling parameters in the design of stone column. Five materials i.e. stones, gravel, river sand, sea sand and quarry dust, which are stiffer and stronger than the ambient soil were used as column material. The degree of improvement of a soft soil by stone columns is due to two factors. The first one is inclusion of a stiffer column material (such as crushed stones, gravel, etc.) in the soft soil. The second factor is the densification of the surrounding soft soil during the installation of the stone column itself and the subsequent consolidation process occurring in the soft soil before the final loading of improved soil.

II. TECHNIQUES TO IMPROVE STABILITY OF SOIL

A) Removal and replacement method is one of the oldest and simplest methods known on field. However, in weak soil this method might become too expensive.

B) Pre consolidation or preloading through the application of surcharging prefabricated vertical drain or combination of both. Suitable for wide range of soil type.

C) Dynamic consolidation technique is usually used in cohesive soil by heaving and tamping.

D) Reducing the permeability of soil by filling the voids in soil using grouting and injection of cement-soil mixture into the ground. It is not a favourable method in clayey soil.

E) Chemical stabilization by introducing chemical such as lime and fly ash into the soil.

F) Stone column is a type of subsoil structure where a hole is excavated to a certain depth and replaced with aggregate which is then compacted. This method of soil stabilization is also known as vibro-compaction.

III. CHARACTERISTICS OF CLAY SOIL

Generally clay soil particles grain size range from 0.002 mm & less. It has poor strength and compressibility. Clay soil is also prone to shear failure and excessive settlement. It has cohesive bonding and no internal friction.

A) Soil Properties

The properties of the clay were determined by conducting various laboratory tests such as Moisture content test, Specific gravity test, Grain size distribution, Sieve analysis, Atterberg's limit test, Standard proctor test, Unconfined compression test and the results are summarized below

TABLE I Properties of Soil

S.NO	PROPERTIES	RESULTS
1	Initial moisture content	12%
2	Specific Gravity	2.68
3	Percentage of gravel	0%
4	Percentage of sand	32.70%
5	Percentage of Silt	28.94%
6	Percentage of Clay	38.36%
7	Liquid limit	52%
8	Plastic limit	24%
9	Shrinkage limit	12%
10	Plasticity index	28%
11	Soil classification	CH
12	Optimum moisture content	22%
13	Maximum dry density	1.34g/cc

ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
Vol. II, Issue VI, June 2016

14	Unconfined compressive strength	40.5kN/m^2

IV. COARSE AGGREGATES

The coarse aggregates of size 6 to 8 mm are chosen.

TABLE II Properties of Coarse Aggregates

S.NO	PROPERTIES	RESULTS
1	Aggregate crushing strength (%)	20.73
2	Aggregate Impact value (%)	16.11
3	Aggregate Abrasion value (%)	38.3
4	Specific Gravity	2.76
5	Water Absorption (%)	0.6
6	Maximum dry density (kN/m^3)	16.67
7	D10 (mm)	6.83

V. MODEL

A. Model Square Footing

A square steel plate of dimension (150 mm X 150 mm) and thickness 16 mm was used as model footing which is shown in FIG 1

Fig 1 Model Square Footing

B. Model Chamber

The dimension of the model tank was selected based on the dimension of the model footing. As per IS 1888-1982 (METHOD OF LOAD TEST ON SOILS) [2] which includes plate load test, the width of tank was selected as five times the width of footing. Square testing chamber was made in mild steel of (750 mm x 750 mm x 750mm) which is shown in fig 2.

Fig 2 Model Chamber

C. Column Material

Coarse aggregate was used with size range 6 mm to 8 mm. The particle sizes for the column is chosen as per the guidelines of Nayak (1982)[1], which suggest that the size should be in the range of 1/6 to 1/7 diameter of the column.

D. Loading Setup

The Load frame consists of a proving ring (30kN capacity) and two numbers of LVDT to find out settlement.

Fig 3 Entire Loading Setup

VI. TESTING PROGRAM

A. Preparation of Foundation Medium

The soil sample of required quantity passed through 4.75 mm IS Sieve was brought to optimum moisture content by uniform mixing as similar to the Standard Proctor Compaction Test. The number of layers was decided to be 5.

B. Number of Blows

Based on the relationship between the compaction energy, volume of the sample, weight of hammer, height of fall, number of layers and the number of blows the following relation was made for number of blows.

Number of blows (N) = (compactive effort X Volume of mould)/(Number of layers X weight of hammer X height of drop)

From that it was found to be 90 blows using 20 kg hammer for each layer. The foundation medium was prepared by placing the prepared sample in five equal layers with specified no of blows as similar to Standard Proctor Compaction test.

VII. STONE COLUMN INSTALLATION

The centre of the model chamber was properly marked and a GI pipe of 5 cm diameter (1/3 rd of footing size) was placed at the centre of the tank. Around this pipe, clay bed was formed. The clay layer was tamped with a wooden tamper frequently and gently to expel air during the process of filling. The stone required to form the column was carefully charged in the tube in five layers. Each layer was compacted using 12mm diameter rod to achieve a density of 16kN/m^3.

Fig 4 Clay Soil Removed Using GI Pipe

Fig 4a Filling Coarse Aggregate

A. Full Single Stone Column Installation

In the centre of the model chamber to the depth of 700 mm the clay soil was removed and 6 to 8mm coarse aggregate was filled and compacted well.

B. Three Full Stone Columns Installation

150 mm from the centre of the tank two sides the clay soil was removed up to 700 mm and 6 to 8mm coarse aggregate was filled and compacted well.

Fig 4B Three Full Stone Columns Testing

C. Five Full Stone Columns Installation

150 mm from the centre of the tank four sides the clay soil was removed up to 700 mm and 6 to 8mm coarse aggregate was filled and compacted well.

VIII. EXPERIMENTAL PROCEDURE

The model study was carried out similar to the plate load test and it was carried out in loading frame. The experimental test procedure for both the cases i.e. clay with and without stone column was same.

Table III

ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
Vol. II, Issue VI, June 2016

Sl. No	ULTIMATE RESSURE kN/m^2	Settlement (mm)
1	0	0
2	15.177	0.3
3	30.355	0.6
4	45.532	0.9
5	60.710	1.2
6	75.887	1.5
7	91.065	1.8
8	106.243	9
9	121.42	15
10	136.697	19
11	151.775	25

A. Load Test On Square and Circular Footing Resting On Clay

After the preparation of foundation medium the model footing was placed in position. Then the model chamber with footing was placed in position over the Loading frame. The proving Ring and Dial Gauge were placed in position over the footing to acquire the required data. Loading was applied at a strain rate of 1.2 mm/minute in such a way that each load increment was maintained until the footing settlement became less than 0.02mm/hr. The load and the corresponding footing settlements were measured using proving ring and LVDT. The loading was continued till the 25 mm settlement failure occurs. Then the Load-Settlement graph was plotted to those reading.

Note: The same test procedure was carried out with all three cases of stone column (i.e.) single stone column, three stone columns and five stone columns respectively.

IX. RESULTS AND DISCUSSIONS

A. Results of model plate load tests

The results of the model plate load tests conducted for square footing resting on untreated clay and square footing resting on clay reinforced with coarse aggregate full single stone column, three full stone column and five full stone column plotted individually as Load-settlement graph.

B. Load- settlement values for square footing on clay soil

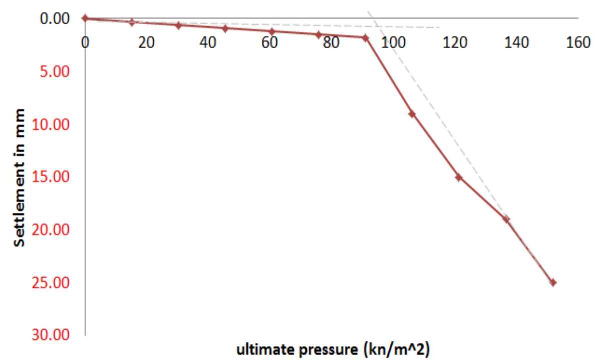


Fig 5 Square footing on clay soil

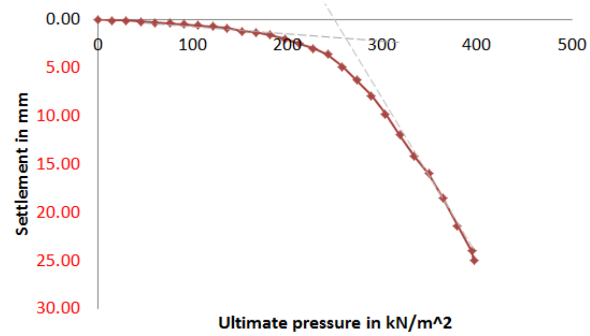


Fig 6 Square footing on single full stone column

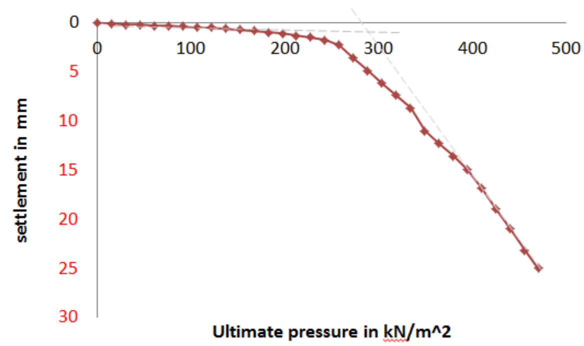
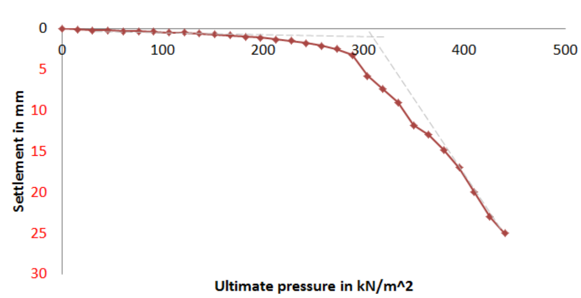


Fig 7 Square footing on three full stone column



ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

IJARMATE
International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
Vol. II, Issue VI, June 2016

Fig 8 Square footing on five full stone column

Table IV Ultimate bearing capacity of square footing

CONDITION	UBC OF SQUARE FOOTING (kN/m^2)
Clay soil only	92.5
With 1 stone column	272.5
With 3 stone column	310.55
With 5 stone column	345.75

X. UBC IMPROVEMENT FACTOR (I_f)

The load-settlement relationship and the ultimate bearing capacity of the footing reinforced with and without stone column have been obtained. The bearing capacity improvement due to the stone column is represented using a dimensionless factor, called the ultimate Bearing Capacity Improvement Factor (I_f). The factor is defined as the ratio of the ultimate bearing capacity of footing reinforced with stone column and the ultimate bearing capacity of footing on untreated clay.

XI. CONCLUSION

In the experimental values, The Bearing Capacity Improvement Factor (I_f).was found to be 2.95 for square footings on single full stone column. The Bearing Capacity Improvement Factor (I_f).was found to be 3.35 for square footing on three full stone columns. The Bearing Capacity Improvement Factor (I_f).was found to be 3.69 for square footing on five full stone columns. The settlement of clay soil decreases with introduction of stone columns.

REFERENCES

[1] N. V. Nayak (1982) "Recent Innovations in Ground Improvement by Stone Columns," *Symposium on Recent Developments in Ground Improvement Techniques, Bangkok*, 1982 S.

[2] "*Method of Load Test on Soils*," IS: 1888-1982.

[3] "*Design Construction for Ground Improvement-Guidelines*," IS: 15824(part1)-2003.

[4] S. Murugesan and K. Rajagopal, "Geo synthetic Encased Stone Columns: Numerical Evaluation", *Geotextiles and Geomembranes*., vol. 24, pp. 349-358, 2006.

[5] Jie Han, "Simplified Method for Consolidation Rate of Stone Column Reinforced Foundations", *Journal of Geotechnical and Geoenvironmental Engineering*., Vol. 127, No. 7, July 2001.

[6] J. T. Shahu and Y. R. Reddy, "Clayey Soil Reinforced with Stone Column Group: Model Tests and Analyses," *Journal of Geotechnical and Geo-environmental Engineering*, vol. 137, No. 12, December 2011.

[7] C. R. Cheeseman, A. Makinde and S. Bethanis, "Properties of light weight aggregates as stone column for soil stabilization," 2004.

[8] J. k. Mitchell and T. R. Huber, "Performance of Stone Column Foundation," *Journal of Geotechnical Engineering*, vol.111, pp. 205-223, 1985.

[9] A. P. Ambily and S. R. Gandhi, "Behaviour of Stone Columns based on Experimental and FEM Analysis," *Journal of Geotechnical and Geo-Environmental Engineering*, vol. 133, pp. 405-415, 2006.

[10] H. Brandl, Long-term behaviour of soil stabilised coarse aggregate as stone column, 1999.

BIOGRAPHY: Author[1] Nataraj Palanisamy lives in Coimbatore,India. Presently working as a Lecturer in Jimma University,Jimma,Ethiopia. Author[1] completed B.E. Civil Engg. in 2010 and M.E. Engg Design in 2013 under Anna University Chennai, India . Author[1] is doing various research activities in the field of advanced development in Civil Engineering

