

A Major Project II

on

**Comparative study of load deformation behaviour of silty clay bed
reinforced with stone column of different depth and gradation**

Submitted in partial fulfillment for the award of the degree of

MASTERS OF TECHNOLOGY

IN

CIVIL ENGINEERING

With Specialization in

GEOTECHNICAL ENGINEERING

By

Darin Baruah

(Roll No. 2K12/GTE/04)

Under The Guidance of

Prof. Anil Kumar Sahu

Department of Civil Engineering



Delhi Technological University, Delhi 110042



Department of Civil Engineering

DELHI TECHNOLOGICAL UNIVERSITY

CERTIFICATE

This is to certify that the major project report entitled “Comparative study of load deformation behaviour of silty clay bed reinforced with stone column of different depth and gradation” is a bonafide record of work carried out by Mr. Darin Baruah under my guidance and supervision, during the session 2013-14 in partial fulfillment of the requirement for the degree of Master of Technology (Geotechnical Engineering) from Delhi Technological University, Delhi.

Dr. Anil Kumar Sahu

Professor,

Department of Civil Engineering,

Delhi Technological University

Delhi - 42



DELHI TECHNOLOGICAL UNIVERSITY

ACKNOWLEDGEMENT

I wish to convey my sincere gratitude to Prof. Pankaj Jalote, Vice Chancellor, Delhi Technological University and Prof. A. Trivedi, Head, Department of Civil Engineering for providing me with the necessary facilities for conducting experiments.

I would like to express my deepest sense of gratitude and indebtedness to my guide and motivator Prof. Anil Kumar Sahu, Civil Engineering Department, Delhi Technological University for his valuable guidance and support in all the phases from conceptualization to experimentation and final completion of the project. I also thank all the faculty members of Civil Engineering Department, Delhi Technological University who have enlightened me during my project.

I am deeply thankful towards all the lab assistants of my university who have helped me to conduct the experiments and also my helper Mr Karan who has helped me in lifting all the heavy equipment.

I would also like to thank my parents for their encouragement and persistent support which has helped me to do better in all of my endeavours.

(Darin Baruah)

Roll No: 2K12/GTE/04

INDEX

CONTENTS	PAGE No.
List of abbreviations	vi
List of figures	vii
List of tables	ix
List of pictures	x
List of symbols	xi
Abstract	1
Chapter 1	
1.0 Introduction	3
1.1 Objectives of present investigation	5
Chapter 2	
2.0 Review of Literature	7
2.1 Methods of stone column installation	7
2.1.1 Vibro-compaction method	7
2.1.2 Vibro-replacement method	8
2.1.3 Cased- borehole method	9
2.2 Design concept	10
2.3 Failure mechanism of stone column	10
2.4 Ultimate bearing capacity of single isolated granular piles	11
2.5 Settlement calculation of single isolated granular piles	12
2.6 Experimental and numerical studies	14
Chapter 3 Material and methods	
3.0 Materials and equipment	18
3.1 Loading system	19
3.2 Geotextile used for encasement	20
3.3 Stone column installation	20
3.4 Method used	21
Chapter 4 Experimental investigations on soil	
4.0 Moisture content determination	23

4.1 Specific gravity test	23
4.2 Particle size distribution	24
4.3 Particle size distribution using hydrometer analysis	26
4.4 Atterberg's limits test	29
4.5 Compaction characteristics	32
4.6 Direct shear test	34
4.7 Unconfined Compressive Strength test	40
4.8 Specific gravity and water absorption test on aggregate	43
4.9 Particle size analysis of aggregates	44
4.10 Aggregate impact test	44
Chapter 5 Experiments on silty clay bed	46
Chapter 6 Experiments on stone column with and without encasement	50
Chapter 7 Theoretical bearing capacity values	65
Chapter 8 Results and discussion	65
Chapter 9 Conclusion and Recommendations for future	68
Reference	69

List of Abbreviations

Sl. No.	Abbreviation	Full form
1	ASCE	American Society of Civil Engineers
2	BCIF	Bearing Capacity Improvement factor
3	BIS	Bureau of Indian Standard
4	Conf.	Conference
5	ESC	Encased stone column
6	Fig.	Figure
7	IS	Indian Standard
8	IGS	Indian Geotechnical Society
9	No.	Number
10	pp.	Page number
11	PVC	Poly Vinyl Chloride
12	SMFE	Soil Mechanics and Foundation engineering
13	Vol.	Volume
14	Wt.	Weight

LIST OF FIGURES

Fig. No.	Title of figure	Page No.
1	Wet top feed system of stone column construction	8
2	Dry bottom feed system	9
3	Cased rammed stone column	10
4	Different modes of failure of stone column	11
5	Set up of stone column in rectangular tank	19
6	Grain size distribution of soil particle	25
7	Calibration curve of hydrometer	27
8	Grain size distribution based on hydrometer analysis	29
9	No. of blows v/s water content graph	31
10	Water content v/s dry density graph	34
11	Shear stress v/s horizontal displacement graph for a normal loading of 50kN/m^2	38
12	Shear stress v/s horizontal displacement graph for a normal loading of 100kN/m^2	38
13	Shear stress v/s horizontal displacement graph for a normal loading of 150kN/m^2	39
14	Shear stress v/s Normal stress graph	39
15	Stress v/s strain plot of pure soil	42
16	Load v/s deformation graph for unreinforced silty sand bed	49
17	Loading of bed reinforced with stone column	51
18	Load v/s deformation graph for stone column with 20mm aggregate and 250 mm depth	55

Fig. No.	Title of figure	Page No.
19	Load v/s deformation graph for stone column with 20mm aggregate and 500 mm depth	56
20	Load v/s deformation graph for stone column with 20mm aggregate and 750 mm depth	56
21	Load v/s deformation graph for stone column with 10mm aggregate and 250 mm depth	57
22	Load v/s deformation graph for stone column with 10mm aggregate and 500 mm depth	57
23	Load v/s deformation graph for stone column with 10mm aggregate and 750 mm depth	58
24	Load v/s deformation graph for stone column with 10mm + 20mm aggregate in ratio 1:1 by weight and 250 mm depth	58
25	Load v/s deformation graph for stone column with 10mm + 20mm aggregate in ratio 1:1 by weight and 500 mm depth	59
26	Load v/s deformation graph for stone column with 10mm + 20mm aggregate in ratio 1:1 by weight and 750 mm depth	59
27	Load v/s deformation graph for encased stone column with 20mm aggregate and 750 mm depth	60
28	Load v/s deformation graph for encased stone column with 10mm aggregate and 750 mm depth	60
29	Load v/s deformation graph for stone column with 10mm + 20mm aggregate in ratio 1:1 by weight and 750 mm depth	61
30	Comparison of load v/s settlement behaviour for 250mm depth stone column having different gradation	61
31	Comparison of load v/s settlement behaviour for 500mm depth stone column having different gradation	62
32	Comparison of load v/s settlement behaviour for 750mm depth stone column having different gradation with and without encasement	62

LIST OF TABLES

Table No.	Title of table	Page No.
1	Moisture content of soil	23
2	Calculation of specific gravity	24
3	Grain size distribution calculation	24
4	Calibration of hydrometer	27
5	Data sheet for hydrometer test	28
6	Liquid limit determination	30
7	Calculation of plastic limit	32
8	Optimum Moisture Content Calculation	33
9	Data Sheet for shear stress calculation under 50kN/m ² normal loading	35
10	Data Sheet for shear stress calculation under 100kN/m ² normal loading	36
11	Data Sheet for shear stress calculation under 150kN/m ² normal loading	37
12	Unconfined compressive strength determination	41
13	Table for specific gravity and water absorption test of coarse aggregate	43
14	Sieve analysis for coarse aggregate	44
15	Observation table for impact test on coarse aggregate	44
16	Density of stone for different gradation and depth of column	52
17	Comparison of load carrying capacity at 25mm settlement for different stone columns	63
18	Comparison of settlements at 50kN load for different stone columns	63
19	Comparison of bearing capacities at 25mm settlement	64

LIST OF PICTURES

Picture No.	Title of Picture	Page No.
1	Rectangular tank used for soil bed preparation (1.5m×0.6m×0.9m)	18
2	Truss used for loading	19
3	Hydraulic jack used for loading	19
4	Hydrometer analysis	26
5	Rectangular tank soil filling (1.5m×0.6m×0.9m)	46
6	Mixing and weighing of soil with water in batches upto optimum moisture content	47
7	1125 kilograms of soil filled in tank volume 1.5m×0.6m×0.75m	47
8	Loading applied on silty clay bed	48
9	Load at failure in hydraulic jack	53
10	Sieves used for gradation of aggregates	53
11	Stone column with 20mm aggregate and sand layer on top of stone column	54
12	Stone column with 10mm aggregate and sand layer on top of stone column	54
13	Load application on stone column and stone column after failure	55

LIST OF SYMBOLS

q_{ult} = ultimate bearing capacity

φ_s = angle of internal friction of soil

φ_{column} = angle of internal friction of column material

C_u = original undrained shear strength of clay

γ = unit weight of soil

Z = depth from surface of composite foundation

K_p = soil coefficient of passive earth pressure

σ_{r0} = initial radial stress along granular pile

S_t = settlement of composite foundation

m_v = modulus of volume compressibility

μ_c = reduction in stress coefficient of clay

σ_v = limiting vertical stress

D = diameter of stone column