GROUND IMPROVEMENT USING VIBRO STONE COLUMNS—CAPACITY OF STONE COLUMN

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ABSTRACT: Vibro Stone Columns of 900 mm diameter were installed to improve the safe bearing capacity of the ground to take the loading of heavy container yard. Tests were conducted on the columns to check the load carrying capacity and study the behaviour of the column under loading. The capacity of the column was tested for a single stone column and for group of stone columns. The paper describes the construction of stone columns; set up for the load tests and the test results.

1. INTRODUCTION

1.1 Project

Construction of new container terminal at Vallarpadam Island at Cochin, India is in progress. For design of the proposed container yard the preliminary investigation was carried out during 2006-07 which revealed that the strength of the existing soil was very low and ground improvement is necessary before the actual construction of container terminal.

From the study of these data, the subsurface stratification was identified as –

1. Layer 1: Silty Sand with Shells
2. Layer 2: Soft Clay (Compressible Layer)
3. Layer 3: Loose Silty Sand
4. Layer 4: Soft Clay (Compressible Layer)
5. Layer 5: Dense Sand
6. Layer 6: Stiff Clay

SCPT Tests were also conducted in the area to estimate the depth variation of the soft stratum.

The existing Safe Bearing Capacity (SBC) of the soil was 4 T/m² and the expected settlement of the untreated soil was 1000 to 1500 mm.

1.2 Ground Treatment Using Stone Columns

1.2.1 Design Criteria

The stone columns were designed to provide –

1. Minimum Area Ratio of 0.25
3. Allowable bearing capacity of ground not less than 100 kPa

1.2.2 Design of Stone Column

Based on the criteria the stone columns were designed as per IS 15284. The Salient features of the improvement technique are –

- Dia of Stone Columns: 900 mm, 1100 mm
- Depth of Stone Columns: 20-22 m, 20-22 m
- Grid Pattern: Triangular
- Triangular
- Spacing of stone Columns: 1.70 m, 2.10 m
- Design Capacity of Column: 25 T, 40 T

The depth of the stone column was finalised based on Global Stability Analysis.

2. CONSTRUCTION OF STONE COLUMNS

Stone Columns were installed by vibro-replacement method using Pennine Hydraulic Vibroflot of amplitude 8-11 mm. The columns were installed using top feed wet process. The
method for construction of the stone columns is illustrated in Figure 2.

Fig. 2: Installation of Vibro Stone Columns

The quantity of 900 mm dia stone columns was 2,42,410 Rmt whereas that of 1100 mm dia was 88,256 Rmt.

2.2.3 Material Specification

The back fill stones were clean, durable, angular, hard and resistant to breakage. Stones were quarry crushed, well graded stones of 75 mm down to 12 mm size. The uniformity coefficient was 3.

3. LOAD TESTS ON STONE COLUMNS

Load Tests were performed to study the behaviour of stone columns as single as well as in group. The tests conducted were Initial Load test and hence the load applied was 2.50 times the design load.

The load was applied by operating a hydraulic jack against a suitable kentledge. The load was applied in the range of 10% of safe load (design load). Settlements were recorded for each load increment with the help of 4 dial gauges. Settlements were recorded at every 1, 4, 9, 16, 30 and 60 minutes for each interval. Next loading increment was applied if the rate of settlement was less than 0.05 mm or less in first 15 minutes. The design test load was maintained for a period 24 hours. The test load was removed in 5 to 6 stages. Each unloading stage was maintained till the rebound attained a rate of 1.00 mm in first 15 min. Load-settlement curve was plotted for each test.

3.1 Acceptance Criteria

As per IS 15284, the stone columns are acceptable if meets the following criteria –

1. Settlement of 10–12 mm at design load for single column load test

2. Settlement of 25–30 mm at design load for a three column load test

3.2 Single Column Load Test

For Single column load test, centre column in a group of seven columns was selected as test column. The design load was considered as the safe load on column (excluding the safe load which will be taken by soil) i.e. 25 T.

Hence, the test load was 25 * 2.50 = 62.50 T.

Figures 3 and 6 shows the test set up arrangements.

The total settlement of 28.04 mm and net settlement of 24.97 mm was observed. The settlement at design load of 25 T was 5.22 mm. The load settlement graph is shown in Figures 8 and 9.

Fig. 3: Layout for Single Column Load Test

Fig. 4: Layout for Three Column Load Test
3.3 Three Column Load Test

For Three Column load test, three columns at the centre in a group of fifteen columns were selected as test columns. The design load was considered as the safe load on column (excluding the safe load which will be taken by soil) i.e. 75 T.

Hence, the test load was = 75 * 2.50 = 105 T.

Figures 4 & 7 shows the test set up arrangements.

The total settlement of 24.95 mm and net settlement of 17.57 mm was observed. The settlement at design load of 75 T was 7.51 mm. The load settlement graph is shown in Figures 10 and 11.

3.4 Seven Column Load Test

For seven Column load test, seven columns at the centre in a group of twenty eight columns were selected as test columns. The design load was considered as –

As per the requirement the friction angle of the treated soil shall be 30 degrees.
The ultimate bearing capacity of treated soil was worked out as per Terzaghi’s theory i.e. 
\[ q_{ult} = 1.3 \gamma D f N_q + 0.3 \gamma B N' \gamma \]

For this test; \( C = 0; Df = 0 \) (surface footing); \( B = 4.76 \) & \( N' \gamma = 20 \)

Hence,

\[ q_{ult} = 0.3 \times 18 \times 4.76 \times 20 = 514 \text{ kN/m}^2 \text{ and} \]

Hence the ultimate load = 514 \( \pi / 4 \) \((4.76)^2\) = 988 T

The total settlement of 112 mm and net settlement of 75 mm was observed. The settlement at design load of 385 T was 26 mm. The load settlement graph is shown in Figures 12 and 13.

4. CONCLUSIONS
The Vibro Stone Columns were installed for ground improvement works. The load tests were conducted on single, group of 3 and group of 7 columns upto 2.5 times the design load. The settlements observed at design loads were within the limits specified in IS 15284.

REFERENCES
Greenwood D.A., Mechanical Improvement of soils below Ground surface.