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Soil Improvement Using the Stone Column Method at the International Port of Tibar, Timor-Leste

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Abstract

Stone column (stone column) is one of the soil improvement methods that fall into the category of "reinforcement" or soil strengthening which uses aggregate in the form of gravel or crushed stone to make columns with a certain diameter and depth in the soil layer with the aim of increasing the carrying capacity of the soil and reducing settlement. . The stone column method is intended to detail the soil improvement work in this project both on land and at sea. The stone column method has been used to improve weak soils since the 1950s. The rigid granular elements of the stone column increase the stiffness and shear resistance of the weak soil and the permeable nature of the column accelerates consolidation settlement so that residual settlement can be limited to a tolerable value. Various design methods have been used to design stone columns over the years ranging from simple hand calculations to complex and highly complex numerical models. Important considerations include the type of structure to be supported, in-situ soil properties of stone column material parameters, area replacement ratio, stress concentration and consolidation time. Like other geotechnical methods, the stone column method requires stability checks and workability checks. Not only the stone column method but there are several design methods that will be discussed in this journal paper and will highlight some of the advantages and disadvantages of each approach. Importantly, all soil improvement methods, whether simple or complex, must be verified by post-treatment testing with field measurements.

Keywords:
Another Design Method, Stone Column

1. Introduction

Stone column(stone column) is one of the soil improvement methods that fall into the category of "reinforcement" or soil strengthening which uses aggregate in the form of gravel or crushed stone to make columns with a certain diameter and depth in the soil layer with the aim of increasing the carrying capacity of the soil and reducing settlement. . The stone column method is intended to detail the soil improvement work in this project both on land and at sea. In the case of the dry feed-bottom method, the vibrator penetrates deep into the soil using its own weight, a 'pull-down' force and compressed air. Once the required depth is reached, a vibrator with a depth is extracted gradually, accompanied by an up-and-down motion, allowing the stone to flow into the void that has been created. The up-and-down movement of the vibrator inward allows the formation of a compacted granular column. The column formed is larger than the initial hole created by the penetration process. The stone column construction with a depth vibrator ensures the rock column is properly compacted to the required diameter and depth and compacts the surrounding soil.

2. Research methods

The research was conducted for three months starting on August 24, 2020 until December 4, 2020, the location of this research was carried out at an international port located in Tibar, Timor-Leste. The data collection technique was carried out by collecting data at the location and getting help from the owner, namely PMU-TBPP, looking for references from journals on the internet, and getting support from supervisors.

3. Results and Discussion

Compared to rigid concrete or steel piles, the vibro stone column (VSC) load-carrying mechanism is different. Instead of shaft friction and end bearing resistance, VSC transmits loads to the ground primarily by bulging and mobilizing lateral soil stresses. Usually a VSC is designed as a group of columns that work together, not as individual columns that work separately. Typical column diameters range from 0.6 m to 1.1 m, and column standards. Columns are triangular or rectangular, with center-to-center distances ranging from 1.5 m to 2.5 m. When the columns are placed at a reasonable distance, they influence each other and act as a group. When uniform loading is applied to the treated soil, especially where there is a granular platform.

Volume 6 Number 1 September 2022

3.1. Soil Classification

Soil can be classified into several parts as follows:

1. gravel (gravel)

Gravel is a coarse-grained soil because the grains are more than 2 mm. Ideally using compaction soil reinforcement techniques.

2. sand (sand)

Same with gravel but what distinguishes it is in its size, sand with a size of 0.6 mm – 2 mm. Ideally using compaction soil reinforcement techniques.

3. Clay (clay)

It consists of very small grains and exhibits the properties of plasticity and cohesion. Particle size <0.002 mm, very suitable for using consolidation and reinforcement soil reinforcement techniques.

4. silt (silt)

It is a transition between clay and fine sand. The particle size is 0.002 mm – 0.06 mm. It is very suitable to use consolidation and reinforcement soil reinforcement techniques.

3.2. Soil Reinforcement Technique

3.2.1. Consolidation

It is a consolidation technique to drain the water content in the soil and reduce the pore water pressure. This technique will be very effective for use on fine-grained soil types. Soil improvement is carried out by accelerating the consolidation process, namely by providing drainage (vertical or horizontal) on the soil so that it is possible to reduce or eliminate pore water pressure.

3.2.2. Reinforcement

It is a reinforcement technique by adding another material that is more rigid to improve soil properties in the field. This technique is intended for soils that behave non-granular. Soil improvement is carried out by increasing the shear strength of the soil by providing a stiffer soil reinforcement element to increase soil mass and can be combined with providing drainage to reduce pore water pressure.

3.2.3. Compaction

It is a soil improvement technique using compaction energy. This technique will be very effective for use on granular soil types. Increased soil density, bearing capacity, and liquefaction mitigation by using energy from rollers, vibrators, or impacts.

3.3. Work at outdoor

3.3.1. Preparation

The stone column drive is equipped with a pile frame and steel tube with the valve end at the bottom, the tube diameter will be slightly smaller than the design diameter of the stone column. This work uses a rock column vibrating tube from a manufacturer named Ruian Bada Engineering Machinery Co., Ltd, and a vibroflot from a manufacturer named Beijing Vibro-flotation Engineering Machinery Co., Ltd. The types of rock column vibrating tubes that will be used in this trial are ZJB-200A-DZ240A and BJZC-BFS-400-180 from vibroflot.

Table 1. Ruian Bada Pile Frame System Information

SN	Items	Parameter
1	Mobile Mode	Walking Type
2	Moving Step(mm)	2500
3	Tube Diameter (mm)	560 and 760
4	Penetration Depth (m)	27
5	Main Hoist Tensile Stiffness (KN)	100
6	Main Hoist Pulling Speed (m/min)	19
7	Auxiliary Hoist Tensile Force (KN)	50
8	Auxiliary Hoist Pulling Speed (m/min)	18
9	Steel Wire Rope	39/Φ28/Φ24
10	Pile Height(m)	31
11	Overall Size(m)	14x6.5x35
12	Weight (kg) excluding vibro-hammer and tube	80000

Volume 6 Number 1 September 2022

Table 2. Ruian Bada Vibro-Hammer Information

SN	Items	Parameter
1	Type	DZ-240A
2	Start Mode	Variable Frequency Start
3	Power (KW)	240
4	Vibration Frequency (r/min)	0-680
5	Eccentric Torque	3525
6	Vibration Strength(KN)	0-1822
7	Area (mm)	0-23.8
8	Weight (kg)	18500

Table 3. Vibroflot Information from Beijing Vibroflotation

No	Items	BZJC-BFS-400-180
1	Motor Power (kW)	180
2	Vibrating Strength (kN)	20-30
3	Rotation Speed (rpm)	1200-1800
4	Hopper Capacity (m3)	1.2
5	System Pressure (bar)	6
6	Stone Tube Diameter (mm)	DN250
7	Vibroflot Size (mm)	2600 x 600 x 700
8	Vibroflot Weight (kg)	2860

Table 4. SPT point coordinates

SPT Coordinates in the Experimental Area					
No	Area	ID of SPT	X	Y	Remark
1	Experiment Area 1	Pre-BL09	9051362.634	772147,353	
2		Post-BL09-1	9051363.836	772148.042	
3		Post-BL09-2	9051362.236	772148,047	
4		Post-BL09-3	9051361.434	772147,356	
5	Experiment Area 2	Pre-BL08	9051391.153	772151.000	
6		Post-BL08-1	9051392.155	772151.574	
7		Post-BL08-2	9051390.821	772151,578	
8		Post-BL08-3	9051390.153	772151.003	
9	Experiment Area 4	Pre-BL11	9051360.2721	772159.8386	
10		Post-BL11-1	9051361.4678	772159.1382	
11		Post-BL11-2	9051360.8656	772158.7956	
12		Post-BL11-3	9051362.2340	772159.0756	
13	Experiment Area 5	Post-TA5-1	9051394.429	772143.306	
14		Post-TA5-2	9051393.778	772142,938	
15		Post-TA5-3	9051395.296	772143.309	

3.3.2. Stone Column Operation

This section defines the operations relevant to moving the rock column in the experimental area. Before moving the stone column, determine the center point of each stone column based on the RTK-GPS tool.

1. Move the rock column vibrating tube to the marked area, aligning the vibrating tube to the design point. The vibrating tube must be perpendicular to the ground.
2. Turn on the vibrating tube, lower the vibrating tube into the ground at a speed of 1-2 m/min. The monitor will record current during penetration, and usually higher values will indicate hard layers and lower values will indicate loose areas. Then the area of relative looseness will be identified by

Volume 6 Number 1 September 2022

the penetration current. A range value will be selected for the identification of the layer for the official SC construction after completion of the experimental area.

3. Load rocks around1.5m3-3m3into the hopper then send it to the top of the vibrating tube, open the tube valve and slowly the stone which is in the hopper is released and into the hole through the vibrating tube. Keep vibrating for one minute, then lift the tube and keep vibrating.
4. To compact the soil layer to the required density, the vibrating tube will be lifted up to 1.5m at each step and penetrated back into the soil to a depth of 0.6m. The 1.5m lift will be divided into two sub-steps to free up enough rock to fill the hole. A lift of 0.75m and a shaking time of about 10 seconds must be ensured for each substep. When re-penetrating, the entire time to a depth of 0.6m is about 5-10 seconds to ensure sufficient compaction. When the current reaches the specified value then the depth is considered solid. The time period and depth will be recorded by the monitor automatically.
5. Repeat processes (3) and (4) until the column is complete.
6. During SC construction, check SC length, SC diameter, stone volume, with monitor guide.

The recommended formula for estimating the relative density of standard penetration resistance as measured by the SPT is shown below:

$$DR = \sqrt{\frac{(N1)60}{46}}$$

$$(N1)60 = N * CN * CE * CB * CR * CS$$

Where:

N = standard rated penetration resistance
CN = factor to normalize N
CE = correction for hammer energy ratio
CB = borehole diameter correction factor
CR = correction factor for rod length
CS = correction for sampler with or without linear

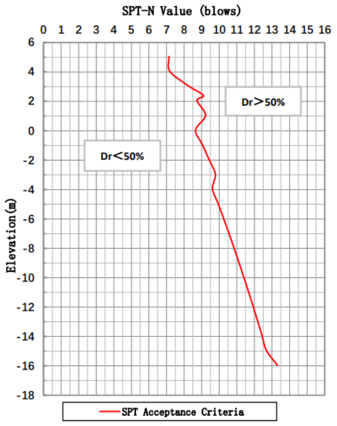

Figure 1. SPT curve for 6.05m elevation (TBPP-PMU)

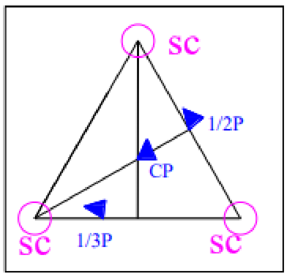

Figure 2. SPT Scheme (TBPP-PMU)

1/2P = at the midpoint between adjacent stone columns
1/3P = at a third of the distance from the stone column
CP = center of mass of rock column network

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Volume 6 Number 1 September 2022

4. Conclusions and recommendations

4.1. Conclusion

Based on the results of research that has been carried out at the Tibar International Port, more precisely in the stone column section, there are conclusions as follows:

1. All SPT values meet Dr 50% as determined by design.
2. The coordinates of the stone column in each experimental area have shown good results, so they can carry out the process or work of the stone column.
3. Supervision carried out on stone column work is very strict, to minimize non-compliance with the standards that have been set together.
4. The level of safety especially in stone column work has met the established standards, and the workers complied with them.

4.2. Suggestion

From the conclusions that have been given above, the suggestions given are:

1. The coordinates of the stone column in the experimental area must be reproduced, so that the data obtained is even more accurate.
2. The control system for the damaged stone column machine must be better, so that the stone column work is not delayed too long.

Set aside a certain area on the construction site to store trash that must be disposed of after the daily work is done.

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Biography

Raimundo Novena Maria Tito Gomes, was born on September 4, 1999 in Laclo, Atsabe District, Ermera Timor-Leste. The eldest of four children. The author started school in elementary to junior high school in Externato De Sao Jose, Dili Timor-Leste. In 2014 the author decided to continue his education at the Frater Senior High School Makassar. Currently the author is studying for a bachelor's degree at Narotama University Surabaya majoring in Civil Engineering.