Sriwijaya Journal of Environment
Article
ojs.pps.unsri.ac.id

Reinforcement of Bearing Capacity Foundation using Single Soil Column Method Fixed Diameter 3.2 cm with Calcium Carbide Residue (CCR) and Rice Husk Ash (RHA) Mixed Materials

Dwi Wahyuni*, Ratna Dewi, Yulindasari, Siti Nur Indah Sari

Civil Engineering Department Polythechnic of Srwijaya, Palembang 30137, Indonesia
**Corresponding author: dwi.wahyuni@polsri.ac.id*

Article history

Received	Received in revised form	Accepted	Available online
10 June 2023	19 August 2023	6 September 2023	8 September 2023

Abstract: Soil reinforcement method is one of the efforts to improve the technical properties of soil, such as soil bearing capacity, compressibility and permeability. The soil column method is one of the alternatives to improve physical properties by stabilization to improve soil bearing capacity. This research aims to increase the bearing capacity of the sole foundation by using the soil column method with a mixture of clay, 3% calcium carbide residue (CCR) and 12% Rice Hush Ash (RHA). This research was conducted experimentally in the laboratory using clay test specimens taken from Padamaran Village, OKI, South Sumatra Province, which were put into a test box with 1 m x 1 m x 1.4 m dimensions. The soil column modelling in this research used the soil column method. The soil column modelling in this study used a single column variation with a diameter of 3.2 cm with lengths of 40 cm, 46 cm, and 53 cm, respectively. The results are the clay foundation plate's ultimate soil bearing capacity (qu) before and after reinforcement with the soil column method. The bearing capacity of the footprint foundation plate on the largest clay soil occurs in the soil column variation with a length of 40 cm and a diameter of 3.2 cm, where the bearing capacity of the clay soil, which was originally 140 kPa increased to 21 kPa. In the experimental results of the loading test, the longer the column, the bearing capacity of the column decreases, which may have something to do with the slenderness factor of the column. The slimmer the column, the smaller the compressive strength of the column so that the tendency of the column to bend/collapse becomes greater. It happens because slender columns not only accept axial forces but also consider the addition of secondary moments due to the slenderness of the column. Then, the column cannot withstand the shear load due to the compacted clay soil around the column.
Keywords: Technical properties, stabilization, bearing capacity

1. Introduction

Soft clays have special physical and mechanical properties, including large pore numbers, high water content, small volume weight and large plasticity index, causing soft clays to have low bearing capacity and large compression. Soft clay soils are only technically suitable for constructing roads, houses and buildings with deep foundations. Problems that may often occur if not using deep foundations are cracks on the surface, buildings can collapse, and the road will be a non-uniform decline and even collapse [1]. The method of reinforcing the pile foundation compared to the pile foundation on the bearing capacity value of the footprint foundation from the calculation using the Terzaghi analysis method (1943) shows that the footprint foundation using the reinforced pile on load I and load II is 3339.34 kN and 7785.48 kN. Meanwhile, using the Caisson method, the pile foundation obtained the maximum value of the bearing capacity at load I and load II was 3992.82 kN [2]. The soil column method is one of the alternatives for soil stabilization.

The soil column method is one of the alternatives for soil stabilization. The soil column method's purpose is to increase clay soil's bearing capacity. Calcium carbide residue (CCR) was introduced as a material that can substitute cement because it contains high calcium ions, which have the potential as a pozzolanic material when mixed with silica. Carbide waste (CCR) is the remnants of welding that uses carbide gas (C_2H_2) as fuel [3]. Carbide waste contains about 60% lime hydroxide ($Ca(OH)_2$). Cementation material can be obtained from carbide waste when mixed with silica (SiO_2) because it can form a formation (SiO_2) because it can form pozzolan. Rice Hush Ash (RHA) is rice husk ash waste containing high silica elements; the silica content in rice husk ash ranges from 60% to 95%. These materials can be used as a substitute for cement as a binder.

Based on the description above, the authors conducted a study of the bearing capacity of the reinforced footing foundation using the Soil Column method of a single pile with a fixed diameter of 3.2 cm with a mixture of Calcium Carbide Residue (CCR) and Rice Husk Ash (RHA).

2. Material and Methods

2.1. Materials

The materials used in this research are clay, rice husk ash (RHA) and calcium carbide residue (CCR). The clay was taken from Seriguna Village, Padamaran, Ogan Komering Ilir Regency, South Sumatra. The soil taken is in a state of disturbed soil. Then, RHA obtained residue from burning rice husks in Lahat, South Sumatra and calcium carbide residue (CCR) waste obtained from welding waste in Cinde Market Palembang. The test box used is made of wood with dimensions with a minimum size of 4 times the width of the foundation (B), which is 60 cm. The test box used measures 1 m x 1 m x 1.4 m.The soil column used in this study is made of a mixture of clay soil that has been prepared and then baked and filtered to pass sieve No. 04 mixed with rice husk ash waste (RHA) 12% of the weight of the original clay soil and carbide waste (CCR) 3% of the weight of the original clay soil then mixed with the optimum water content of 37.8%, for the total weight of the mixture to be done 2000 gr. Then the total need for RHA is 12%, CCR 3% of total weight and for clay soil is 2000 gr minus the weight of RHA and CCR, so 1700 gr. Then, it was mixed with 37.8% water, namely 756 mL of water and stirred until the mixture was smooth.

The soil is put into an impermeable plastic with a curing period of 24 hours to prevent evaporation, and the water content is maintained. Then, open the mould uprightly with complete care so that the soil column is not broken, as seen in Figure 1. Variations of single-pile test specimens based on variations in diameter and length of soil column used in this study can be seen in Table 1. The figure for illustrates different tests can be seen in Figure 2.

Figure 1. Columns that have come off the mold

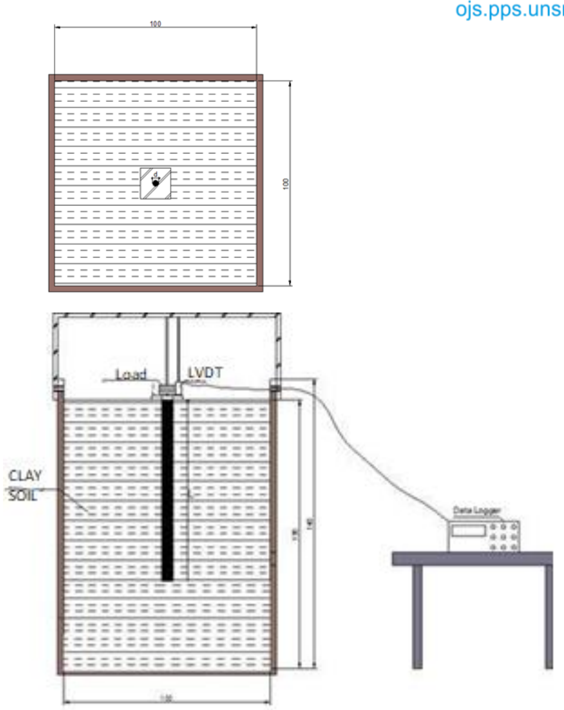

Figure 2. Illustration of the experiment

Tabel 1. Variations of single-pile

No.	d/L	Diameter (d)	Length (L)
1.	0,08	3,2 cm	40 cm
2.	0,07	3,2 cm	46 cm
3.	0,06	3,2 cm	53 cm

2.2. Methods

2.2.1. Sample collection and preparation

A loading test was carried out on the column in a testing box filled with clay soil as high as 1 m and saturated with water for 24 hours to determine the bearing capacity of the soil column. The equipment used in the test included a steel plate load measuring 15 cm x 15 cm x 2 cm, LVDT and data logger. All instruments must be arranged symmetrically so that the resultant load is parallel to the axis of the test pole [4].

2.2.2. Experimental variable and analytical procedures

The loading test carried out in this study was carried out based on using ASTM D-1143 procedures. The loading procedure carried out in this study is included in the Quick Maintained Load Test (QML) type of loading test. This method is relatively faster than other methods required by ASTM. In the QML test, the load increase is carried out gradually every 5% of the plan load until the load collapse is reached. From the calculation of the plan load using the empirical formula, a load of 141.32 kg was obtained, and then 5% of the plan load was 7.066 kg, so for more accurate data, an increase in load of 4 kg was used. The increase in load was held for at least 4 minutes but at most 15 minutes. Recording was done at periods multiple of 5 minutes for each load increase. The loading test in the study was conducted until the pile collapsed. ASTM D 1143 states that the test is stopped if the loading reaches 1.5 to 2x the plan load.

2.3. Data Analysis

After all testing is finished, the data analysis of the load and the decrease that occurs are obtained from the test data results. The following will be done in data analysis. Make a data interpretation graph using the P-Y load method for the relationship between settlement and loading to obtain the bearing capacity of the pile and find the value of the pile bearing capacity from empirical calculations. Look for the BCR (Bearing Capacity Ratio) value in each test variation's single column and group column.

3. Results and Discussion

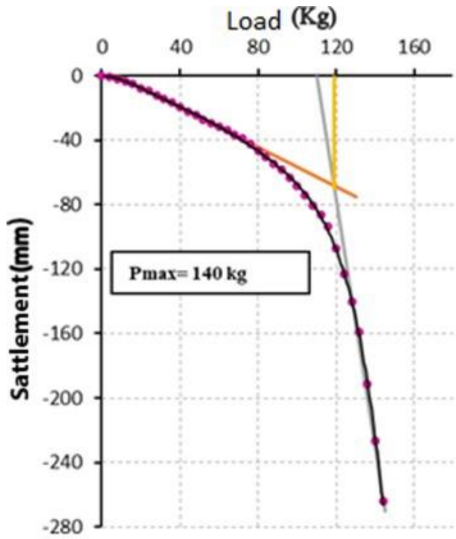

Figure 3. Ultimate load determination graph of foundation plate p-y method.

From the results of the loading test, the maximum load that can be received by the plate is 140 kg as shown in Figure 3 the the calculation shown as:

$$Q_u = \frac{P}{A}$$

$$= \frac{140\ kg}{15\ cm\ x\ 15\ cm}$$

$$= 0,62\ kg/cm^2$$

A = Base area of the foundation – single column area variation 1
= (15 cm x 15 cm) – (0,25 x 3,14 x 3,2 cm x 3,2 cm)
= 225 cm^2 – 8,05 cm^2
= 216,94 cm^2

Q_u = single column area variation 1
= A x q_u (foundation plates)
= 216,94 cm^2 x 0,62 kg/cm^2
= 134,99 kg

In laboratory tests for foundation plates without columns, loading tests were carried out in a box by installing a set of loading test equipment and LVDT, namely frames, data loggers, LVDTs and foundation model plates. It used empirical method to obtain the ultimate bearing capacity value of unreinforced foundation plate using Terzaqhi analysis. Soil data required for empirical calculation of bearing capacity are Cu, Ø and Nc values.

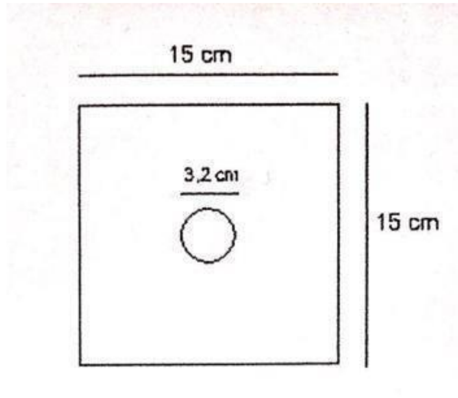

Figure 4. Top view of foundation plate with reinforced single column of 3.2 cm diameter.

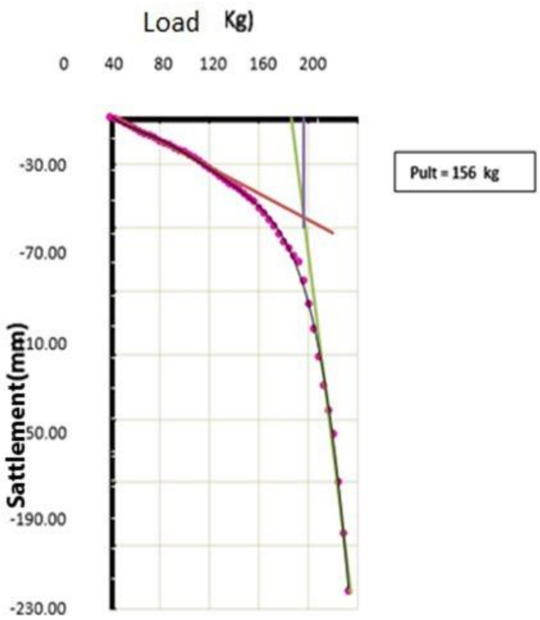

Figure 5. Graph of load and settlement relationship of foundation plate with single column variation 1

The test variations carried out amounted to 3 variations. From the loading test result, a graph of the relationship between settlement and load was obtained. The ultimate load determination uses the method proposed by Michael T. Adams and James G. Collins using an interaction diagram, which is two linear lines that intersect the top and bottom of the graph.

Known As:

qu = C Nc
= (0,11 kg/cm2) (5,71)
= 0,62 kg/cm2

Qu = qu x A
= 0,81 kg/cm2 x (15 cm x 15 cm)
= 141,32 kg

The results of the loading test of the foundation plate with single column variation 1 with soil column size D = 3.2 cm, L = 40 cm, and d/L = 0.08 are shown in Table 2. Top view of foundation plate with single column reinforcement of 3.2 cm diameter. Based on Figure 5, an ultimate load of 156 kg was obtained. So the bearing capacity value of the foundation plate with single column variation 1.

Table 2. Recapitulation of single column bearing capacity values

Variation	Diameter (d)	Length (L)	d/L	Pult (kg)	Qult (kPa)
without	-	-	-	140	141,322
1	3,2 cm	40 cm	0,08	21	51,499
2	3,2 cm	46 cm	0,07	15	62,497
3	3,2 cm	53 cm	0,06	5	79,247

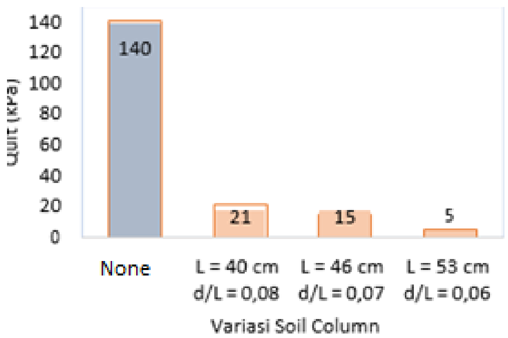

Figure 6. Diagram of bearing capacity value of single column with fixed diameter = 3.2 cm.

The tests carried out on the foundation plate with a single soil column show an increase in the bearing capacity of the foundation plate before and after adding a soil column. The increase in bearing capacity value is generated from various variations of soil columns with different diameters and lengths of soil column. The recapitulation of soil bearing capacity before and after reinforcement for various single-column variations can be seen in Table 2. The diagram of the bearing capacity value of a single column with a fixed diameter of 3.2 cm can be seen in Figure 6.

In the experimental results of the loading test, the longer the column length, the bearing capacity of the column decreases, which may have something to do with the slenderness factor of the column. The slimmer a column is, the smaller the column's compressive strength so that the tendency of the column to bend/collapse becomes greater. This happens because slender columns not only accept axial forces but also consider the addition of secondary moments due to the slenderness of the column. Then, the column cannot withstand the shear load due to the compacted clay soil around the column. The experimental bearing capacity without any single column is 141,322 kPa after using a single column bellow pile foundation.

The maximum increase in the ultimate bearing capacity (qu) value occurred in the column variation with a length of 53 cm and a diameter of 3.2 cm, where the ultimate bearing capacity (qu) value achieved was 70,247 kPa.While using the Caisson method, the pit foundation obtained the maximum value of the bearing capacity at load I and load II was 3992.82kN and reinforcement with the deep soil mixing method with a mixture of clay and 3% carbide waste obtained an increase in the maximum ultimate bearing capacity (qu) value occurred in the column variation with a length of 53 cm with a diameter of 4.8 cm where the ultimate bearing capacity (qu) value achieved was 11.8 kPa, the BCR value was 2.242. The percentage increase in BCR value was 124.2% [5]. The minimum increase in the ultimate bearing capacity (qu) value occurred in the column variation with a length of 53 cm and a diameter of 3.2 cm where the ultimate bearing capacity (qu) value achieved was 7.6 kPa, the BCR value was 1.444, and the percentage increase in BCR value was 44.4% [6].

4. Conclusion

Soil column with a mixture of clay, 12% of rice husk ash (RHA) and 3% carbide waste (CCR) has an effect in increasing the bearing capacity of the foundation plate. Before soil column reinforcement, the bearing capacity of the foundation plate was 140 kg and there was an increase in bearing capacity after reinforcement with soil column in each single and group column variation. Soil column single pile with a diameter of 3.2 cm obtained the largest bearing capacity value of 21 kg in the soil column variation at a length of 40 cm. While the smallest pile bearing capacity with a pile bearing capacity value of 5.00 kg in the soil column variation with a length of 53 cm.

Acknowledgement

We would like to thank to parents, supervising lecturers of Sriwijaya University, examiners and friends who have supported and guided this research.

References

[1] Afrin, H., (2017): A Review on Different Types Soil Stabilization Techniques. International Journal of Transportation Engineering and Technology, 3(2): 19-24.

[2] Rizolla, (2015): “Analysis Of Bearting Capacity Foundations Tread Using Cerucuk Compared With The Caissson Foundation”, Undergraduate thesis, Sriwijaya University, 2015.

[3] Vichan, Songsuda, “Chemical stabilization of soft Bangkok clay using the blend of calcium carbide residue and biomass ash”, Soils and Foundations, Vol.53: 272-281, 2013.

[4] Ferry Fatnanta, Andarsin Ongko., (2018): Bearing capacity analysis of helical pile foundation on peat, MATEC Web of Conferences, 195: 03005.

[5] Oktavia, Dina and Dewi, Ratna and Saloma, Saloma, “Pengaruh Variasi Jarak, Panjang Kolom dan Diameer Deep Soil Mixing Terhadap Perkuatan Daya Dukung Tanah Gambut”, Undergraduate thesis, Sriwijaya University, 2019.

[6] Astusi, Indah and Dewi, Ratna , “Pengaruh Variasi Jarak, Panjang Kolom dan Diameer Deep Soil Mixing (Tanah lempung + 3% CCR) Terhadap Perkuatan Daya Dukung Tanah Gambut”, Undergraduate thesis, Sriwijaya University, 2019.

[7] Bakar, R., A., Yahya, R., Gan, S., N., “ Productionof High Purity Amorphous Silica from Rice Husk”. Prosedia Chemistry”, 19: 189-195, 2016.

[8] Adistia, Yoga (2017): Behaviour Of Fouting Foundation Reinforce By Sand-Lime Column Due to Vertical Loading. Skripsi thesis, Universitas Muhammadiyah Surakarta.

[9] Calcium Carbide Residue”, International Journal of Innovative Research in Science, Engineering and Technology, 5(9): 17023-17030, 2016.

[10] Geetha, D., Ananthiand, A., Ramesh, P., (2016): Preparation and Characterization of Silica Material from Rice Husk Ash-An Economically Viable Method. Journal of Pure and Applied Physics, 4(3): 20-26.

[11] Indera, Rama., enden, Mina., (2016): Stabilisasi Tanah Dengan Menggunakan Fly Ash dan Pengaruhnya Terhadap Nilai Kuat Tekan Bebas. Jurnal Fondasi. Vol 5:1.

[12] Kai Yao a, Zhanyong Yao b., Xiuguang Song., (2016): Settlement evaluation of soft ground reinforced by deep mixed columns, International Journal of Pavement Research and Technology, Vol.9, Issue 6: 460-465.

[13] Kampala, A., Horpibulsuk, S., (2013): Engineering Properties of Silty Clay Stabilizd with Calcium Carbide Residue. Journal of Materials in Civil Engineering, Vol. 25: 632-644.

[14] Kavak, A., (2015): The Effect Of Compaction For A Lime Stabilization Application. International Journal of Advances in Mechanical and Civil Engineering. Vol. 2

[15] Mahdi, T., Ali, A, K., Mahmoud Nazirizad (2017): Experimental Study of Geotextile Effect on Improving Soil Bearing Capacity in Aggregate Surfaced Roads. Engineering and Technology International Journal of Civil and Environmental Engineering. Vol.1: 1

[16] Mana, S., Marli, M., A,J, Chowdhury., (2017): Environmental Characteristics Of Clay And Clay-Based Minerals. GeoloGy, ecoloGy, and landscapes, Vo1. 3:155– 161

[17] Maulana, Gibral., (2016): Stabilisasi Tanah Lempung Ekspansif Menggunakan Campuran Renolith dan Kapur. Jurnal Online Institut Teknologi Nasional. Jurusan Teknik Sipil Itenas. Vol 2:4.

[18] Mishra, B., (2016): A Study on Ground Improvement Techniques and Its Applications. International Journal of Innovative Research in Science, Engineering and Technology, 5(1):72-86.

[19] Mousavi, S., Wong, L., (2015): Mechanical Behavior of Compacted And Stabilized Clay With Kaolin And Cement. Jordan Journal of Civil Engineering. Vol. 9: 4

[20] Norazam, P., N., F., I., Bakar, I., Siang, A., J., L., M., Herman, H., S., (2017):

[21] Pourakbar, S., (2015): Deep Mixing Columns. Pertanika Journal of Scholarly Research Reviews, 1(1): 8-17.

[22] Stabilization of Peat Soil by Using Envirotac. MATEC Web of Conferences, 103.

[23] Wong, Leong., “Mechanical Behavior of Compacted and Stabilized Clay with Kaolin and Cement”. Jordan Journal of Civil Engineering, Vol.9: 10.14525, 2015.