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

Reinforcement Of Soft Soil Using Soil Column Method (Soft Soil + CCR + RHA)

Wahyuni Dwi[1]*, Dewi Ratna[2] and Saloma[3]

[1]Post Graduate Student of Civil Engineering Department, Faculty of Engineering Sriwijaya University, Indonesia
[2]Lecturer in The Civil Engineering Department, Faculty of Engineering Sriwijaya University, Indonesia
[3]Lecturer in The Civil Engineering Department,, Faculty of Engineering Sriwijaya University, Indonesia
**Corresponding Author: dwiwahyuni005@gmail.com*

Received	Received in revised form	Accepted	Available online
13 October 2020	19 December 2020	29 December 2020	31 December 2020

Abstract: Soil reinforcement method is one of the attempts to improve technical characteristic from the soil, such as soil bearing capacity, compressibility and permeability. The Soil Column Method is one of alternatives to enhance physical characteristic by way of stabilization to improve soil bearing capacity. Rice Husk Ash (RHA) contains high silica element, Calcium Carbide Residue (CCR) contains high calcium which is able to form pozzolan when mixed upon silica. This research aims to improve soil bearing capacity by using column soil method with a mixture of soft soil, 3% Calcium Calbide Residue (CCR) and 12% Rice Husk Ash (RHA). Soil column in this research, was applied to a single column variation with a diameter of 3.2 cm in which has 40 cm, 46 cm, and 53 cm in length and also was applied each column with diameter of 3.2 cm, 4.2 cm, and 4.8 cm. Based on the research, ultimate Bearing Capacity (qu) of soft soil without soil column was 54.03 kPa and after being given reinforcement had increased the bearing capacity value (qu). The greatest increase in soil bearing capacity of the soft soil occurred in soil column variation of 53 cm in length with 4.8 cm in diameter where the soil bearing capacity had increased to 75.58 kPa and the percentage increase in BCR was 39.90%. Meanwhile the least of soil bearing capacity occurred in soil column that had 53 cm in length and diameter of 3.2 cm while the soil bearing capacity had increased to 64.47 kPa and BCR only increased to 19.33%.

Keywords: Soil Column, Foundation, Bearing Capacity, Rice Ash Hush (RHA), Calcium Carbide Residue (CCR)

1. Introduction

South Sumatera has diverse ground reliefs such as alluvial soil and sandy soft soil (Palembang. go. id). Soft Soil has low soil bearing capacity and wide range soil shrinkage [1]. Soft soil is an inherently occurring material based on minerals contained in the soil. These properties include cation exchange ability, has plastic behavior when wet, expanding and shrinkage behavior, and very low permeability. Therefore, it is necessary to repair soft soil so that it can be used in building a construction. The method of repairment is an attempt to change or improve the technical properties of the soil, such as bearing capacity, compressibility, permeability, expansion potential and sensitivity to changes in water content, so that it can meet certain technical requirements. Soil stabilization is the conversion of the soil to improve the condition of the soil grain materials, maintain its shear strength, and obtain the desired properties of the soil, so it is suitable for construction or other development related to the soil. Soil stabilization aims to increase bearing capacity and reduce deformation [2].

Reinforcement using the Deep Soil Mixing method with a mixture of soft soil, 12% RHA and 3% CCR. The optimum value of BCR for single column variations with 4.8 cm diameter and 53 cm column length is 4.48. The optimum value of BCR for group column variations with a diameter of 4.8 cm; column length 53 cm and distance between columns 12 cm, which is 6.64 [7].

The Soil Column method is one of the alternatives for soil stabilization. The purpose of using the Soil Column method is to increase the bearing capacity of soft. Calcium Carbide Residue (CCR) was introduced by [8] as a material that can substitute cement because it contains high calcium ions which has the potential as a pozzolan forming material when mixed with silica. Carbide waste (CCR) is the remnants of welding that use carbide gas (C_2H_2) as fuel. Carbide waste contains about 60% lime hydroxide ($Ca(OH)_2$). Cementation material can be obtained from carbide waste when mixed with silica (SiO2) because it can form pozzolan. Rice Husk Ash (RHA) is a waste of rice husk ash containing high silica elements, silica content in rice husk ash ranges from 60% - 95%. Both of these materials can be used as substitute for cement as a binder [6].

Based on the description above, the authors conducted a research of reinforcement soft soil using the Soil Column method 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 were soft soil, Calcium Carbide Residue (CCR) and Rice Husk Ash (RHA), the picture if CCR and RHA can be seen in figure 1. Soft soil for specimens and mixtures from the area of Seriguna Village, Padamaran, Ogan Komering Ilir Regency, South Sumatra. The soil that was taken was disturbed. Therefore, the disturbed soft soil was put into a sack with the aim of maintaining the condition and nature of the soft soil. Retrieval of RHA from the remaining rice husk burning results in Lahat, South Sumatra.

The compressive strength test on various percentages of the soil column mixture used obtained the optimum mixture for clay, RHA and CCR were clay soil, 12% RHA and 3% CCR with an optimum water content of 37.8% and the optimum dry weight of the soil obtained 1.308 gr / cm³ [8]. The mixture is a reference in making soil columns in this study.

Figure 1. Rice Husk Ash

Figure 2. Calcium Carbide Residue

Retrieval of carbide waste obtained from the welding center in Cinde Market, Palembang. Soft with soil properties parameters are as follows:

- Specific Gravity (Gs) : 2.63
- Liquid Limit (LL) : 96.98%
- Plastic Limits (PL) : 41.88 KN/m3
- Plastic Index (IP) : 55.10 KN/m3
- Soil Classification (USCS): CH (Organic Soft)
- Land Classification (AASHTO) : A-7-5 (Soft)
- Optimum Water Content (WOPT): 35%

Experimental box used was made of wood material with dimensions within a minimum size of 4 times the width of the foundation (B) that was 60 cm in order to be able to monitor the movement of the soil due to loading. The experimental box used measuring 1 m x 1 m x 1.4 m. Column test based on the variation in diameter and length of the soil column used in this research can be seen in Table 1, then for illustration of the experiment can be seen in Figure 3.

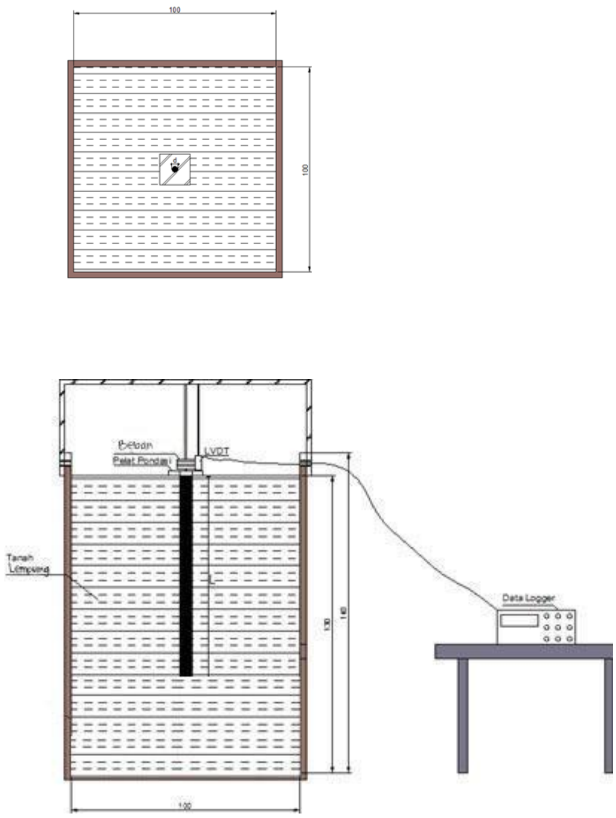

Figure 3. Illustration of the Experiment

2.2. Methods

2.2.1. Sample collection and preparation

Taking soft soil material for the test object and the mixture from the clay soil area in the Padamaran Village area, OKI, South Sumatra Province. RHA from the rest of the combustion from rice husks in the Lahat area, South Sumatra. Calcium carbide residu obtained from welding waste at Cinde Market, Palembang.

2.2.2. Experimental variable and analytical procedures

Soil column used in this research was made from a mixture of soft soil, which passed filter No.4 mixed with 12% rice husk ash (RHA) from the weight of mixture and carbide waste (CCR) was 3% from the weight of the mixture. Then it was mixed with optimum water content that had been obtained from the results of standard soil compaction testing, which was 37.8% and then curing for 24 hours.

The soil column mixture was molded into the pipe according to variations and was compacted according to the standard compaction method, then wrapped in plastic wrap to be airtight and cured of the soil column for 7 days. After the curing was finished, opened the mold in a state of standing upright. The variation of single column test based on the variation in diameter and length of the soil column used in this research can be seen in Table 1.

Table 1. Variations of Test Objects

No.	d/L (cm)	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
4.	0.09	4.8 cm	53 cm
5.	0.08	4.2 cm	53 cm
6.	0.06	3.2 cm	53 cm

2.3. Data Analysis

After all testing is done, data analysis of the load and the decrease that occurs which is obtained from the results of the test data was conducted. 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. Looking for the BCR (Bearing Capacity Ratio) value in the single column and group column of each test variation.

3. Results and Discussion

Soil without reinforcement was carried out by laboratory testing with the method of loading testing in the box the graph of load and settlement of soft without soil column that can be seen in Figure 2. The ultimate load obtained was 116 kg. So the value of the ultimate bearing capacity is as follows:

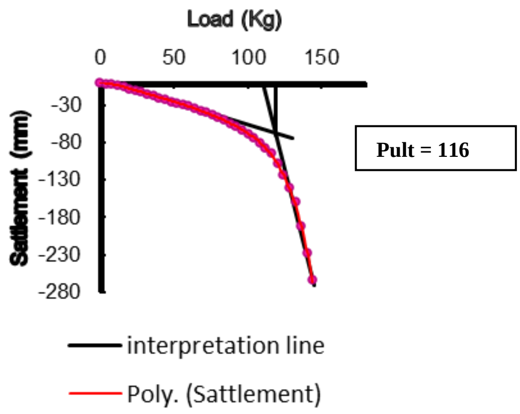

Figure 4. Graph of load and settlement of soft soil without soil column.

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

$$= \frac{\text{The ultimate foundation load} + \text{Own weight foundation}}{\text{Area}}$$

$$= \frac{116 \text{ kg} + 5.0629 \text{ kg}}{15 \text{ cm x } 15 \text{ cm}} = 0.5403 \text{ kg/cm}^2$$

$$= 54.03 \text{ kPa}$$

Based on the experiment that had been carried out on soft soil samples with soil column reinforcement (12% RHA + 3% CCR), it showed an increase in the bearing capacity of soft soil before being given reinforcement and after being given a soil column reinforcement. The increase in bearing capacity is produced from a variety of variations in soil column reinforcement with different lengths and diameters of soil columns. Recapitulation of the bearing capacity of the soil before and after being given reinforcement for a variety of single column variations can be seen in Table 3. The diagram of the bearing capacity of a single column with a fixed diameter of 3.2 cm can be seen in Figure 3.

Table 3. Recapitulation of the bearing capacity of a single column

Diameter (mm)	Length (mm)	d/L	Pult (kg)	Qult (kPa)
-	-	-	116	54.03
3.2 cm	40 cm	0.08	156	71.58
3.2 cm	46 cm	0.07	150	68.92
3.2 cm	53 cm	0.06	140	64.47
4.8 cm	53 cm	0.09	165	75.58
4.2 cm	53 cm	0.08	160	73.36

3.2 cm	53 cm	0.06	140	64.47

Based on Table 3 the length of soil column affects the bearing capacity of soft soil. From the research results, the longer the column, the lower the bearing capacity of the soil. Decrease in bearing capacity was obtained from this research because compacting at the end of the column so that the greater the vertical load given to the column can make the column become fractured resulting in decreased bearing capacity. The decrease can also be caused by a column that cannot withstand the shear force obtained from a given load. So this research is similar to a study conducted by [12] who conducted a study of single column bearing capacity with a mixture of clay and 3% CCR on peat soil, this indicates that the increase in bearing capacity is directly proportional to the d / L ratio. In the single column variation loading test with 53 cm long and 4.2 cm in diameter, the carrying capacity of the peat soil has increased to 21.5 kg. Meanwhile, in the single column variation loading test with a length of 53 cm and a diameter of 4.8 cm, the carrying capacity of the peat soil increased to 20 kg.

Based on the results of testing a single column with a fixed diameter 3.2 cm, the largest carrying value was obtained in the first variation of soil column which had a diameter of 3.2 cm; length of 40 cm and ratio d / L = 0.08 that is equal to 71.58 kPa. The smallest bearing capacity value was obtained in the third variation soil column which had a diameter of 3.2 cm; 53 cm length and ratio d / L = 0.06 which was 64.47 kPa. For the diagram of the bearing capacity of a single column with a fixed length of 53 cm can be seen in Figure 6.

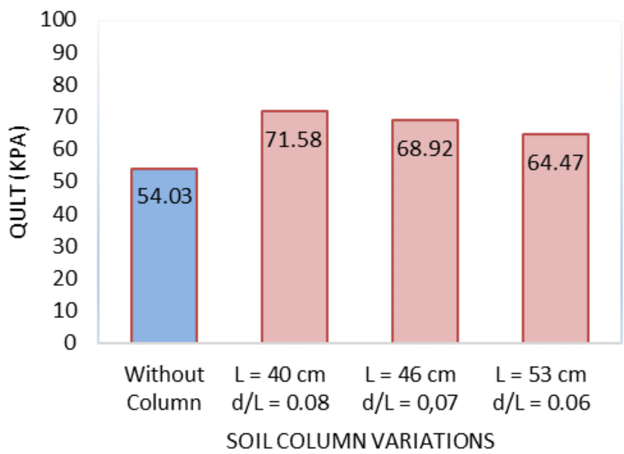

Figure 5. Diagram of bearing capacity of a single column with a fixed diameter = 3.2 cm

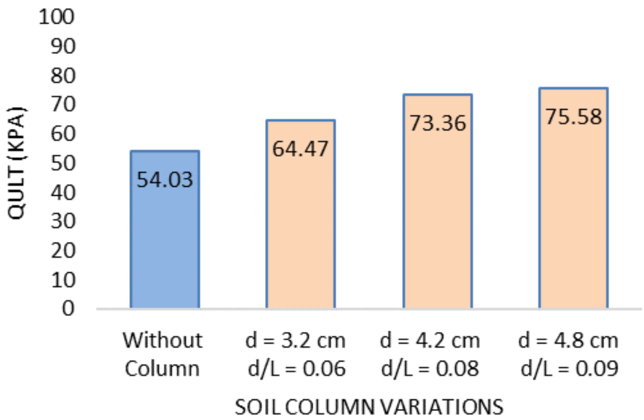

Figure 6. Diagram of bearing capacity of a single column with a fixed length of 53 cm

Based on Figure 5 and Figure 6 for the same d / L ratio of 0.08 however with different diameters and lengths. The bearing capacity with a diameter of 4.2 cm and a length of 53 cm is greater than the column with a diameter of 3.2 cm and a length of 40 cm. This showed that the diameter had a greater influence in increasing the bearing capacity even though the ratio d / L was the same. The increase in the bearing capacity was directly proportional to the ratio d / L, where the greater the value of the d / L ratio, the value of the bearing capacity of the soil also increases. The increase occurs because with a large d / L value, the possibility of a broken column was smaller and smaller so that the column was able to withstand the load. The largest bearing capacity was obtained with a 4.8 cm diameter column; 53 cm length and ratio d/L = 0.09 which was 75.58 kPa. Recapitulations of the single column ultimate load can be seen in Table 4.

Table 4. Recapitulations of the single column ultimate load

Diameter (mm)	Panjang (mm)	d/L	Q_{ult} (kPa)	q_u (kPa)	q_u (kg/cm2)	Pu (Kg)
3,2	40	0.08	71.58	17.56	0.18	40
3,2	46	0.07	68.92	14.89	0.15	34
3,2	53	0.06	64.47	10.44	0.10	24
4,8	53	0.09	75.58	10.44	0.25	24
4,2	53	0.08	73.36	21.56	0.22	49
3,2	53	0.06	64.47	19.33	0.10	44

Based on Table 4 it can be seen that there was a decrease in the value of the single column ultimit load (Pu) directly proportional to the increase in soil column length. While the greater the diameter of the soil column, the increase in the value of the single column ultimate load (Pu). The decrease and increase were the same as those shown by the results of the bearing capacity of the ultimate soil with reinforcement (Qult). Recapitulation of soil column friction resistance can be seen in Table 5.

Table 5. Recapitulation of soil column friction resistance

d	L	d/L	P_u (kg)	V (cm^3)	W (kg)	(As)	f_s (kg/cm^2) .1cm'
3.2	40	0.08	40	321.70	0.58	402.12	0.09
3.2	46	0.07	34	369.95	0.67	462.44	0.07
3.2	53	0.06	24	426.25	0.77	532.81	0.04
4.8	53	0.09	24	959.07	1.73	799.22	0.03
4.2	53	0.08	49	734.28	1.32	699.32	0.07
3.2	53	0.06	44	426.25	0.77	532.81	0.08

where
d = Diameter (cm)
L = Length (cm)
Pult = Ultimate load (kg)
Qult = Bearing capacity (kPa)
As = Circumference (cm2)
Fs = Frictions capacity ((kg/cm2).1cm')

Soil column friction resistance (fs) is the bearing capacity of the foundation obtained from the friction of the column with the ground. The ultimate bearing capacity of the soil column was the sum of the tip resistance, the friction resistance and the weight of the column itself. Because the cross section of the column was very small, then the end resistance of the column was ignored, so the ultimate bearing capacity was considered only determined by the amount of friction resistance and weight of the column itself.

Concluded that the bearing capacity of the column cover or friction resistance depends on the dimensions of the column and the load given. Columns with the same diameter, the frictional resistance increases directly with the increase in ultimate load. Friction resistance also increases proportionally with increasing diameter of the soil column. Meanwhile, as the column length increases the friction resistance decreases.

The recapitulation of BCR values and the percentage increase in single column BCR values can be seen in Table 5 and the diagram of BCR single column values can be seen in Figure 7.

Table 6. BCR values and percentage increase in single column BCR values

Diameter (d)	Length (L)	BCR	Percentage Increase (%)
-	-	1	-
3.2 cm	40 cm	1.32	32.49%
3.2 cm	46 cm	1.28	27.56%
3.2 cm	53 cm	1.19	19.33%
4.8 cm	53 cm	1.40	39.90%
4.2 cm	53 cm	1.36	35.78%
3.2 cm	53 cm	1.19	19.33%

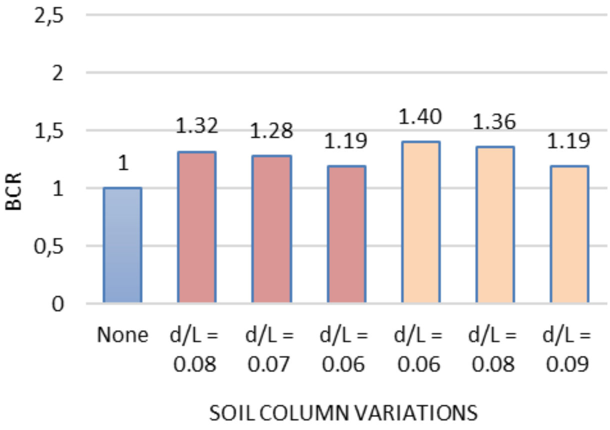

Figure 7. Diagram of BCR value single column

Comparison between the bearing capacities without reinforcement with the bearing capacity however with reinforcement was the value of BCR. Calculation of BCR value served as an indicator to determine the amount of soil bearing capacity increase based on variations in diameter, column length and distance between soil columns.

Based on Table 5 and Figure 7, the BCR value and the largest percentage increase for a single column were obtained in variation 4, with a diameter of 4.8 cm and a length of 53 cm. The highest BCR value was 1.40 with a percentage increase of 39.90%. While the BCR value and the smallest percentage increase for a single column were obtained in variations with a diameter of 3.2 cm and column length of 53 cm. The smallest BCR value was 1.19 with a percentage increase of 19.33%.

4. Conclusion

From this research, there are several conclusions that can be concluded, such as:

a. The value of the ultimate bearing capacity (qu) of soft soil before being given reinforcement was 54.03 kPa and an increase after being given strength with the soil column method with Soil Column method with a mixture of Soil, 3 % Calcium Carbide Residue (CCR) and 12 % Rice Husk Ash (RHA)

b. The largest increase in bearing capacity of soft occurred in the variation of soil column with a length of 53 cm with a diameter of 4.8 cm where the carrying capacity of soft which originally was 53.81 kPa rose to 75.58 kPa and the percentage increase in BCR increased by 39.90%. While the smallest increase in soil bearing capacity occurred in soil columns with a length of 53 cm with a diameter of 3.2 cm where the bearing capacity of the soil increased to 64.47 kPa and the percentage increase in BCR rose by 19.33%.

Acknowledgement

We would like to thank to the head of department of Magister Civil Engineering, lecturers of Sriwijaya University, and Head of Geotechnical Laboratory of Sriwijaya University who have supported and guided this research

References

[1] Mana, S., Marli, M., A,J, Chowdhury, "Environmental Characteristics Of Clay And Clay-Based Minerals",GeoloGy, ecoloGy, and landscapes, Vo1. 3:155–161R,2017.
[2] Wong, Leong., " Mechanical Behavior of Compacted and Stabilized Clay with Kaolin and Cement". Jordan Journal of Civil Engineering, Vol.9: 10.14525, 2015.
[3] Afrin, H., "A Review on Different Types Soil Stabilization Techniques", International Journal of Transportation Engineering and Technology, 3(2): 19-24,2017.
[4] Kamala, A., Horpibulsuk, S., "Engineering Properties of Silty Clay Stabilizd with Calcium Carbide Residue", Journal of Materials in Civil Engineering, Vol. 25: 632-644, 2013.
[5] Bandyopadhyay, T., S., Singh, A., K., Pandey, V., Singh, J., P., "Stabilization of Soil using GGBS and
[6] Calcium Carbide Residue", International Journal of Innovative Research in Science, Engineering and Technology, 5(9): 17023-17030, 2016.
[7] Bakar, R., A., Yahya, R., Gan, S., N., " Productionof High Purity Amorphous Silica from Rice Husk". Prosedia Chemistry", 19: 189-195, 2016.
[8] 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.
[9] 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.
[10] Ferry Fatnanta, AndarsinOngko, "Bearing capacity analysis of helical pile foundation on peat", MATEC Web of Conferences, 195: 03005, 2018.
[11] Kai Yao a, Zhanyong Yao b, Xiuguang Song, "Settlement evaluation of soft ground reinforced by deep mixed columns", International Journal of Pavement Research and Technology, Vol.9, Issue 6: 460-465, 2016.
[12] 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.