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EFFECT OF DEEP SOIL MIXING TO INCREASING BEARING CAPACITY ON PEAT SOIL

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ABSTRACT: The peat soils have high compressibility properties and low bearing capacity; therefore, the settlement in peat soils is very significant. The ground improvement, such as deep stabilization needs to be carried out to increase the bearing capacity of the peat soil. The deep stabilization or deep soil mixing (DSM) is a method of soil improvement by the soil column reagent mixed with cement and other pozzolanic materials. This study used the following ingredients: added clay + 12% calcium carbide residue (CCR) and clay + 8% rice husk ash (RHA), which are expected to increase soil carrying capacity because of the properties of silica and lime possessed by pozolan materials that can bind soil particles. The variations in diameter and the number of DSM column test piece are as follows: 4 and 16 column variations with a diameter of 3.75 cm and 1 column with a diameter of 15 cm. The soil mixing column is compacted in a pipe and the concrete cylinder formwork is then pressed for 4 days. The test results showed the increased soil bearing capacity on peat using the DSM. The DSM column (clay + CCR) with a diameter of 15 cm showed the highest bearing capacity of 32.44 kPa with a bearing capacity improvement (BCI) value of 6.151 or a percentage increase in the bearing capacity by 515.09%. On the other hand, the columns (clay + RHA) with a diameter of 3.75 (4 columns) have the lowest bearing capacity, which is equal to 18.67 kPa.

Keywords: DSM, CCR, RHA and Peat Soil Improvement

1. INTRODUCTION

One essential aspect of construction is the bearing capacity of the soil. Therefore, it is important to know the value of the soil bearing capacity, because not all types of soil have properties that support the construction of buildings. The higher the bearing capacity of the soil, the better the ground is used for construction. One type of soil that has low bearing capacity is the peat soil.

The peat soil is a type of soil that is less fertile, wet and soft because it comes from the accumulation of plant residues that have decomposed and has a high content of organic and acidic materials so that it can affect the engineering characteristics of the soil. The peat soil has high compressibility and low bearing capacity, so the settlement in it is very significant. This affects the behavior of foundations in building construction. Therefore, it is necessary to stabilize the peat soil to increase its bearing capacity.

A variety of soil stabilization techniques have been applied to improve the bearing capacity of soft ground, such as fabricated vertical drain, vacuum consolidation, dynamic deep compaction, preloading, stone columns and deep stabilization (such as lime column, deep mixing column).

The chemical stabilization is also used to improve the engineering properties of peat soil through the addition of binder materials, such as a combination of cement and other pozzolanic materials [3], gypsum and fly ash, lime and cement, etc. The mixture can increase the strength, consequently increasing the potential to stabilize the peat.

The use of preloading showed a significant increase in the bearing capacity of the peat soil. The preloading with a height of embankment above 13 cm provides bearing capacity effectively with an increase of 242% [4]. Jadid [5] states that the vibro-replacement method on peat soils can increase the bearing capacity of the shallow foundation. The peat bearing capacity, stabilized with columns, was formed by DMM (deep mixing method). The research results represented that there was a significant increase in peat compressibility with the installation of cement columns [6]. Some soil mixing columns have been shown to increase the soil bearing capacity, such as the pulverized fuel ash (PFA) column-treated peat [7] and soil-cement column [8].

The basic idea for deep stabilization is to produce a stabilized soil that mechanically interacts with the surrounding unstabilized soil. The partially applied loads are carried by columns and partly by the unstable soil between the columns. In this study, presented alternative materials, as a medium of the soil cement column, which is calcium carbide residue (CCR) and rice husk ash (RHA).

The CCR was introduced as a material that can be used as a cement substitute because it contains high calcium ions that have the potential of pozzolanic ingredients when mixed with silica [9]. One of the agricultural wastes containing silica is RHA. It contains about 90%–98% silica [10].

2. THE MATERIAL AND METHOD

This research carried out a peat soil reinforcement by the DSM method which uses laboratory-scale testing. DSM mixture of clay + RHA and clay + CCR are shown in Fig. 1. The peat soil samples were taken from Palem Raya, Ogan Ilir, Indralaya, South Sumatra were disturbed (Fig. 2). The clay sampling was taken from the landfill quarry in Talang Kelapa area, Palembang City (Fig. 3).

(a) (b)

Fig. 1 (a) CCR and (b) RHA samples

Fig. 2 Peat Soil

2.1 Calcium Carbide Residue (CCR)

The CCR is the disposal of remnants from the process of connecting metal with metal (welding), which uses carbide gas (acetylene gas (C_2H_2)) as fuel. The CCR functions well in soil stabilization [11]. It is hardly used in any work and is discharged into the disposal area in the form of slurry and after a few days of silence it will dry out, where this form will harden when reacting with silica, and form a pozzolanic [12]. The CCR has been used in cement substitutes and it can work as a stabilizing material that increases the soil bearing capacity [9].

Fig. 3 Clay sampling.

The CCR, when used as the soil mixture material, is as much as 12% of the dry weight of the peat soil [13]. The chemical contents of the CCR are as follows:

Table 1 Results of CCR chemical analysis testing

Chemical component	Composition (%)
Silicon dioxide (SiO_2)	1.22
Aluminum oxide (Al_2O_3)	1.16
Iron (III) oxide (Fe_2O_3)	0.56
Calcium oxide (CaO)	62.10
Magnesium oxide (MgO)	2.09
Sulfur trioxide (SO_3)	0.86

2.2 Rice Husk Ash (RHA)

The rice husk is a waste obtained from rice mills [14]. It is a waste of all rice-producing countries, most of which are usually discarded or burned. The burning of rice husks produces rice husk ash (RHA). RHA is a high silica-containing material (about 90%) and some slag, such as iron, manganese, calcium, sodium, potassium and magnesium [15].

The RHA, when used as the soil mixture material, is as much as 8% of the dry weight of the peat soil [16]. The chemical contents of the RHA are presented in Table 2.

The sizes of the soil mixture column used are 15 cm and 3.75 cm in diameter with the length of 30 cm each (Fig. 4). The mixture of soil that was used in the column had two variations, namely clay + 8% RHA and clay + 12% CCR.

The test was performed by providing a consolidated load plate placed on the foundation model plate mounted on top of the DSM column. The magnitude of the settlement that occurs on the ground surface was read by a linear variable differential transformer (LVDT) connected to the data logger. The loading was stopped when the load reading in the data logger fell, while the settlement still occurred. It caused a significant settlement and the soil might have collapsed.

Table 2 The chemical components of RHA

Chemical component	Component (%)
Silicon dioxide (SiO_2)	94.68
Aluminum oxide (Al_2O_3)	0.24
Iron (III) oxide (Fe_2O_3)	0.80
Calcium oxide (CaO)	1.77
Magnesium oxide (MgO)	0.00
Sulfur trioxide (SO_3)	0.43
Loss on ignition	2.80

Fig. 4 DSM column samples (a) 3.75 and (b) 15 cm diameter

The following is a variation of the specimen; in this case, the variation in the number and size of the DSM column diameter, used in this study, are as follows:

1) 15 cm diameter with 1 column (Fig 5)

2) 3.75 cm diameter with 4 columns (Fig 6)

3) 3.75 cm diameter with 16 columns (Fig 7)

The test illustration can be seen in the following pictures (Fig. 5-7).

The data obtained from the tests are the value of the load and settlement that occurs because of vertical loads. The ultimate bearing capacity of the soil can be known from the load obtained divided by the width of the foundation model. Then the graph of the behavior of the load and settlement of the peat soil, which is reinforced by the DSM method, is produced based on the method of T. Adams and James G. Collin [17]on each variation of the test. The value of BCI can be calculated from the ratio of the bearing capacity before and after the reinforcement being given

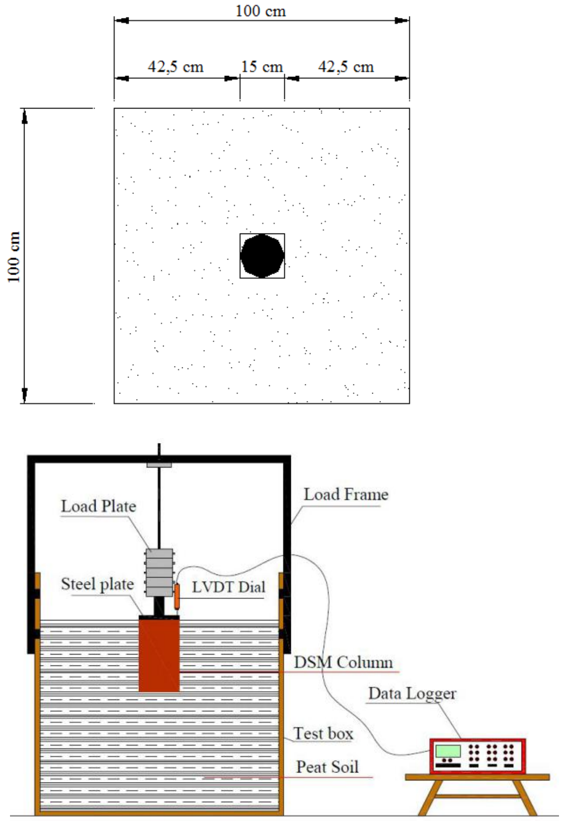

Fig. 5 DSM modeling scheme with 15 cm diameter with 1 column

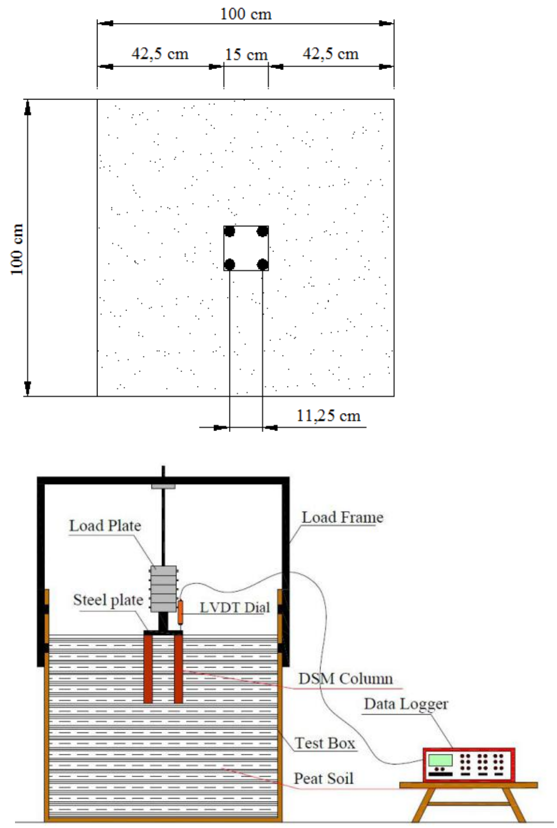

Fig. 6 DSM modeling scheme with 3.75 cm diameter with 4 columns

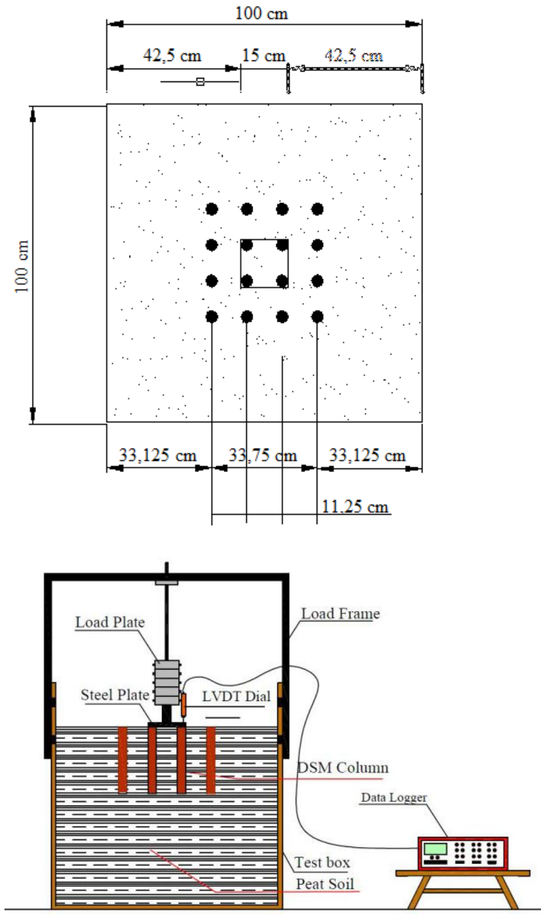

Fig. 7 DSM modeling scheme with 3.75 cm diameter with 16 columns

3. RESULT AND DISCUSSION

3.1 Engineering Properties of Samples

The peat soil used for the study was from Palem Raya, Ogan Ilir, Indralaya, South Sumatra. The properties of peat soil are presented in Table 3. The soil collected was classified as fibrous peat.

Table 3 The properties of peat soil

Properties	Parameters	units
Avg. moisture content (ω)	282.79	%
Specific gravity (Gs)	1.75	-
Density (ρ)	1.63	gr/cm^3
Ash content	18.70	%
Organic content	81.30	%
Liquid limit (LL)	52.00	%
Plastic limit (PL)	37.26	%
Plasticity index (IP)	14.74	%

The visual observation of the peat soil indicated that the soil was dark brown. When the soil was squeezed (passing between the fingers), it can be observed that the soil was rather pale with squeezed muddy water, and the plant structure is not easily identified.

The peat soil above is also classified as peat soil with high organic content (organics content > 75%) and high ash content > 15% (81.30%). The high organic content showed that peat soil consists mostly of composed plants and other destroyed organic matter. The pH test gave a value of 5.37 [18], which indicates that it is acidic.

The mechanical properties of the peat soil were tested from the triaxial test (UU), and the obtained cohesion of soil (cu) = 0.01 kg/cm^2 and internal friction (φ) = 1.57°.

The properties of clay soil are presented in Table 4.

Table 4 The properties of clay soil

Properties	Parameters	units
Liquid limit (LL)	65.50	%
Plastic limit (PL)	40.93	%
Plasticity index (IP)	24.56	%
AASTHO Classification	A - 7- 5	-
USCS Classification	CH	-

The soil collected was classified as CH as per the Unified Soil Classification System. The clay soil used in soil mixing column was classified as the fine-grained soil (inorganic clay with high plasticity).

The mechanical characteristics of the soil mixture, such as optimum moisture content (OMC), maximum dry density (MDD) and unconfined compressive strength (qu) were as follows :

- Clay + 8% RHA : 26.40% (OMC) and
  1.371 gr/cm^3 (MDD)
  1.21 kg/cm^2 = 118.7 kPa (qu)
- Clay + 12% CCR : 21.6% (OMC) and
  1.36 gr/cm^3 (MDD)

  1.55 kg/cm^2 = 152 kPa (qu)

3.2 Bearing Capacity without Reinforcement

The bearing capacity of the peat soil without the reinforcement can be calculated with Terzaghi analysis. Given the soil conditions with undrained shear strength = 0.01 kg/cm^2, φ = 1.570, B = 15 cm, γ = 1.63 kg/cm^3 and Df = 0, the obtained result of the bearing capacity (qu) is 5.274 kPa. It is shown that the peat soil has a low bearing capacity.

3.3 Bearing Capacity with DSM Reinforcement

The results of the laboratory tests for soil reinforced with DSM (clay + CCR) using variations of diameter and number of DSM column indicate an increase in the bearing capacity. The foundation weight was 5.5 kg, the load was 1 kg, therefore, the total weight of the foundation was 6.5 kg. The determination of the bearing capacity value can be observed in Fig. 8, which uses the data interpretation graph between the settlement and loading, and the relationship between the settlement and load increment (DSM with clay + CCR) can be shown in Fig. 9.

For DSM (clay + RHA), the results of the laboratory tests for reinforcement of soil column indicate an increase in the bearing capacity. The graph of the relationship between the settlement and load increment (DSM with clay + RHA) can be shown in Fig. 10. From the two figures above (Fig. 9 and Fig. 10), it is observed that by giving the same load, the settlement that occurs in the 4 column variations was the largest.

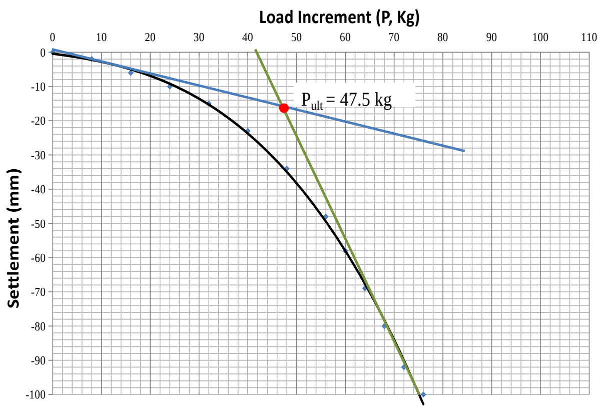

Fig. 8 Graph of load increment versus settlement

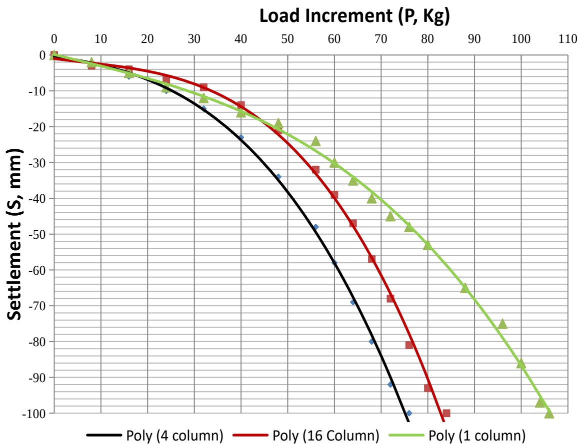

Fig. 9 Graph of load increment versus settlement for each variation (DSM with clay + CCR)

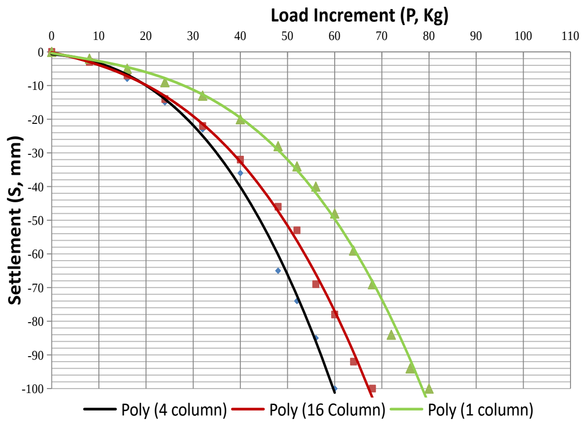

Fig. 10 Graph of load increment versus settlement for each variation (DSM with clay + RHA)

The amount of the ultimate bearing capacity because of the variation of diameter and number of the column can be clearly seen in Table 5. The bearing capacity increase for all variations can be seen in Fig. 11.

Table 5 The value of bearing capacity reinforced with DSM

Variation of size DSM	Soil Mixture	P ultimate (kg)	Q ultimate (kPa)
Without reinforcement			5.27
15 cm dia. with 1 column	Clay + CCR	66.50	32.44
	Clay + RHA	49.00	24.67
3.75 cm dia. with 4 column	Clay + CCR	54.50	24.00
	Clay + RHA	35.50	18.67
3.75 cm dia. with 16 column	Clay + CCR	47.50	27.11
	Clay + RHA	38.00	20.67

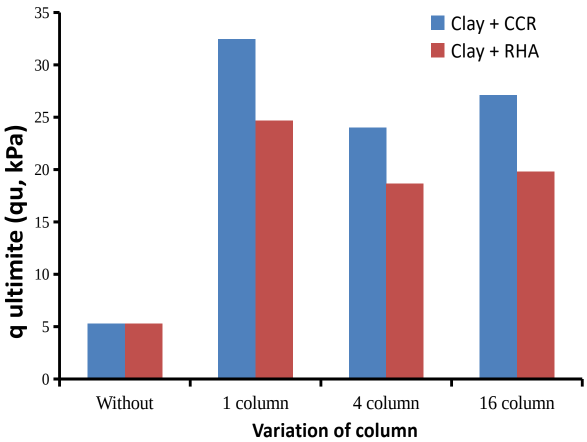

Fig. 11 The value of ultimate bearing capacity for each variation

As observed in Table 5 and Fig.11, the value of the largest bearing capacity is obtained from the DSM column with a diameter of 15 cm for1 column, with a value of 32.44 kPa. The DSM column with a diameter of 3.75 cm has the largest bearing capacity is 16 columns, with an ultimate bearing capacity of 27.11 kPa. Meanwhile, 4 columns of DSM column with a diameter of 3.75 cm have the smallest ultimate bearing capacity, which is 24 kPa. That was because the width of the DSM column blanket with a diameter of 15 cm is greater, causing friction that occurs between the soil and the DSM column, which is greater than the settlement that occurs.

The DSM column with a diameter of 3.75 cm with a variation of 16 columns does not have a large influence on the increase of the bearing capacity of the soil, because the foundation plate used only presses 4 columns. Meanwhile, the remaining 12 columns are located outside the foundation plate. This proves that using more number of DSM columns outside the foundation does not mean giving a significant increase in soil bearing capacity.

3.4 BCI Value

The increased soil characteristic is well known by using bearing capacity ratio or bearing capacity improvement (BCI), that can be determined based on the ultimate bearing capacity without reinforcement and bearing capacity of the reinforced soil (DSM) [19]. This analysis is used as a basis to consider the effectiveness of the reinforcement material, with CCR and RHA as soil mixing medium. The results of the tests carried out by modeling DSM, as a reinforcement media, proved to improve the bearing capacity of the peat soil. The BCI value increases with the increase of the diameter of the column and the number of columns that are used as reinforcement. The maximum value of BCI obtained from the foundation reinforced with DSM (clay + CCR) is 6.151 or 6 times the ultimate bearing capacity without reinforcement, with the increase percentage of 515.09% (Table 6). The improved bearing capacity of the peat soil by using clay + RHA, as the media soil column, was 367.77% or 4 times the bearing capacity without reinforcement.

4. CONCLUSION

Based on the results and discussion, the conclusions are as follows:

1. The DSM column with 15 cm diameter has a greater bearing capacity than the DSM column with a diameter of 3.75 cm with 4 variations, which is equal to 32.44 kPa (clay + CCR) and 24.67 kPa (clay + RHA)
2. The soil mixture with clay + CCR in each variation shows bearing capacity greater than clay + RHA.
3. The DSM column with 3.75 cm diameter, with a variation of 16 columns, does not have a large effect on the bearing capacity of the soil, because the foundation plate used is only able to withstand loads for 4 columns. Meanwhile, the remaining 12 columns are located outside the foundation plate.
4. The bearing capacity improvement (BCI) value is directly proportional to the value of the bearing capacity obtained.
5. The highest BCI value is obtained from the DSM (clay + CCR) column with a diameter of 15 cm for 1 column, which is equal to 6.151, or the percentage increase in the bearing capacity of is 515.09%.

Table 6 The BCI value of the bearing capacity of the foundation reinforced with DSM

Variation of size DSM	Soil mixture	BCI	Increased of BCI %
15 cm dia. with 1 column	Clay + CCR	6.151	515.09
	Clay + RHA	4.678	367.77
3.75 cm dia. with 4 columns	Clay + CCR	4.551	355.06
	Clay + RHA	3.540	254.00
3.75 cm dia. with 16 columns	Clay + CCR	5.140	414.03
	Clay + RHA	3.919	291.92

5. ACKNOWLEDGMENTS

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