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Peat Soil Improvement Method Using Woven Bamboo and *Cerucuk*

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***Abstract*—Most of the land in South Sumatera is the problematic soil, one of that is peat. Peat has low soil bearing capacity, and it becomes a problem when construction is built. Before the installation process, it is necessary to handle that soil. Soil improvement that can be done on peat to increase the bearing capacity value is the reinforcement method or physical stabilization. The results of research on woven bamboo and *cerucuk* are used as reinforcement material, which is expected to be an alternative to improve soil bearing capacity. The research methodology used was on the scale of the laboratory and analyzed by comparing the soil bearing capacity without reinforcement in bearing capacity ratio (BCR). The maximum bearing capacity with *cerucuk* reinforcement and without woven bamboo is 39.33 kPa with variations of the two outer rods of the left and right sides from 750 angle toward the foundation plane. However, using the 3 layers of reinforcement woven bamboo that is combined with *cerucuk*, which has diameter 1,5 cm and length 60 cm generates the highest soil bearing capacity value. The maximum of bearing capacity is 58 kPa. The BCR is 10,88 or in percentage is 988,2%, or 10 times greater than bearing capacity without reinforcement. So, it can be inferred that woven bamboo and *cerucuk* are used as an alternative to improve bearing capacity on peat soil.**

***Keywords*— *cerucuk;* woven bamboo; peat soil improvement; problematic soil.**

I. Introduction

From time to time, the residents' population is increasing. The growth in population is equivalent to the increasing need for shelter, which leads to the high demand for lands. South Sumatera almost majorly consists of vacant land with a low quality of soil/problems (such as lowland/swamp), one of the problems is the peat soil. The development of the peat area, accompanied by the urgent needs of residential land makes the area utilization of peat soil conditions inevitable. Some issues that occur in peat soils are high groundwater level, the low bearing capacity of peat soil, high compressibility, and long-lasting secondary consolidation—similarly, the condition of peat soil in Ogan Ilir regency [1]. Therefore, on peat soil, it is mandatory to conduct the improvement first before starting construction on top of the soil, so that improves the quality and bearing capacity of the soil. This will culminate in an issue of the excessive difference in soil settlement.

Research on bearing capacity improvement on peat soil has been done, such as peat stabilized by DMM [2]. By the addition of the ratio of the cement, column can improve Peat soil compaction parameters. The experimental results show that cement and the addition of another Pozzolanic object improved the strength characteristics of peat soil. Peat soil improvement in this research using Chemical stabilization. The chemical admixtures such as: fly ash and well-graded sand [3], pond ash, and hydrated lime [4], shredded waste tire chips [5], and others. Strength increases due to the mixture, so it becomes the potential to stabilize the peat.

The method of Vibro-Replacement in peat soil based on Jadid [6] explained that the method could increase the bearing capacity parameters for shallow foundations analysis. Similarly, preloading methods can improve the parameters of bearing capacity of the peat soil [7]. That can be implemented to solve the problems on peat soil that could be carried out by the using of *cerucuk* (wood). The implementation of *cerucuk* is an effort to increase the bearing capacity of the fibrous peat soil in a simple way which has several advantages, for instance, the relatively inexpensive cost, the material that is easy to get, the simple implementation, access to control and the short time implementation [8]. The material used is *cajelput* wood. With the usage of *cajelput* wood as an alternative reinforcement, people can get advantages of existing natural resources [9]. Based on the description that previously described, it becomes important to conduct research which is used to import the bearing capacity value of shallow foundation of fibrous peat soil at *cerucuk* reinforcement a long with or without the woven bamboo. Wherein the previous research, with only woven bamboo reinforcement only, it can upgrade the bearing capacity of shallow foundations in peat soil [10].

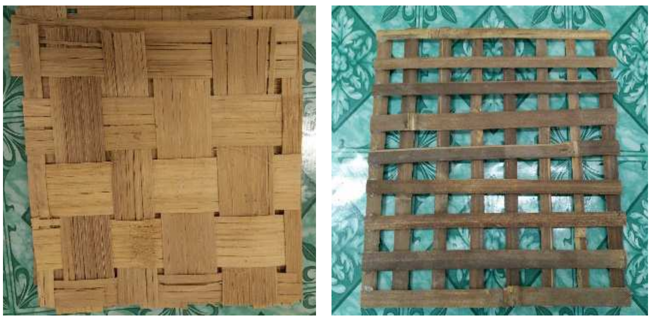
II. Materials and Method

This research shows the outcomes of the research conducted using laboratory testing methods. The test performed is the modeling of shallow foundation reinforced with *cajelput cerucuk* and without the woven bamboo. Palem Raya, Ogan Ilir, Indralaya, South Sumatera is a peat soil sampling location (Fig. 1).

Fig. 1 Peat soil

The size of *cajelput cerucuk* reinforcement used is 1.5 cm and 2 cm diameter at the length variation of 40 cm, 50 cm, and 60 cm, while the width of the woven bamboo used is 2B size with 3 layers of reinforcement (Fig. 2).

(a) ***Cerucuk***



(b) Woven bamboo
Fig. 2 Reinforcement

The test is performed for each predetermined variation by giving the load to the ground through the load plate. LVDT reads the settlement value through a data logger. The weight addition is done by adding 8 kg for every 15 minutes. The test will be stopped in case of foundation collapse, which is when the foundation is disrupted, and LVDT can no longer read the occurred settlement.

The test of bearing capacity shallow foundation which reinforced by *cajelput cerucuk* without the woven bamboo is conducted in several variations below:

- The arrangement of all perpendicular rods (Fig. 3)
- The arrangement of one outer rod at the left and right sides form an angle of 85^o (Fig. 4)
- The arrangement of two outer rods at the left and right sides form an angle of 85o
- The arrangement of one outer rod at the left and right sides form an angle of 75o
- The arrangement of two outer rods at the left and right sides form an angle of 75o (Fig. 5).

Figure 3 explains the testing method as follows:

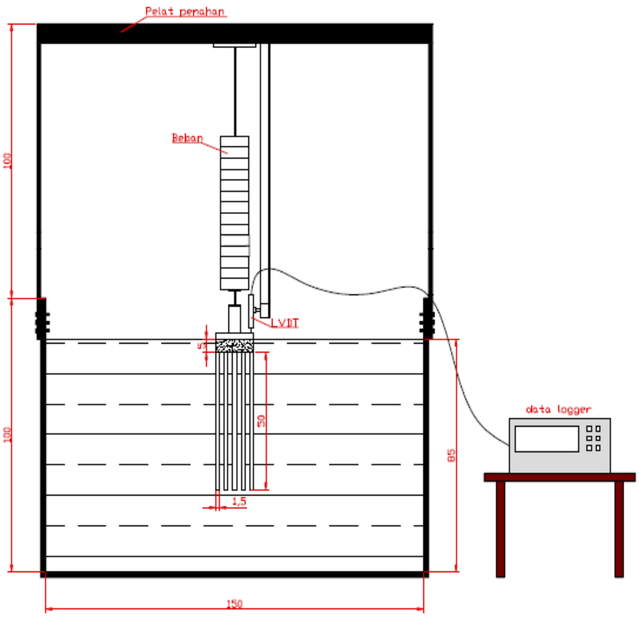


Fig. 3 The sketch of the test with all perpendicular rods

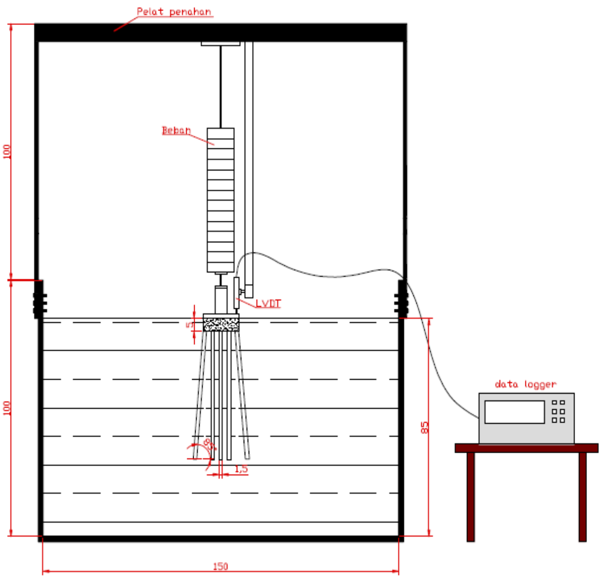


Fig. 4 The sketch of the test with one outer rod forms 85^o angle

Testing the bearing capacity of shallow foundations is modeled using reinforcement *cajelput cerucuk* and woven bamboo will be performed in 6 variations, namely the variation in the variation of length, and the variation of *cerucuk* diameter (Table I). The data obtained from this test are the settlement and load data. The bearing capacity value is obtained by correlating the values between the two by using the method from Collin and Adams [11]. The value of BCR could be counted after the value of the bearing capacity of the soil with reinforcement obtained by way of comparing the value of bearing capacity after using reinforcement and without reinforcement.

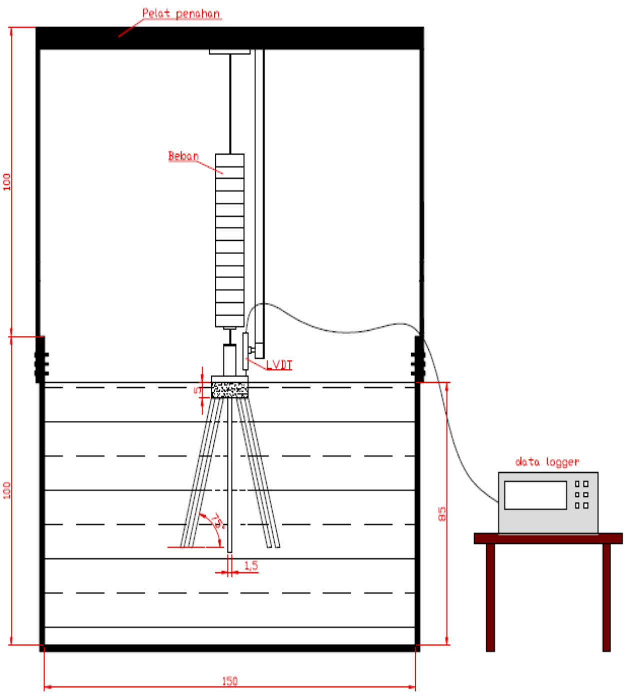


Fig. 5 The sketch of the test with two outer rods form the 75° angle.

TABLE I
THE VARIATION OF SHALLOW FOUNDATION REINFORCED BY *CAJELPUT CERUCUK* AND WOVEN BAMBOO

Variation of *Cerucuk*	Length (cm)	Woven bamboo
Diameter 1.5cm (7x7)	40	3 Layers
	50	
	60	
Diameter 2 cm (5x5)	40	
	50	
	60	
Diameter 1.5cm (7x7)	40	Without woven bamboo
	50	
	60	

Test sketch illustrations modeled using reinforcement *cajelput cerucuk* and woven bamboo can be observed in Fig. 6.

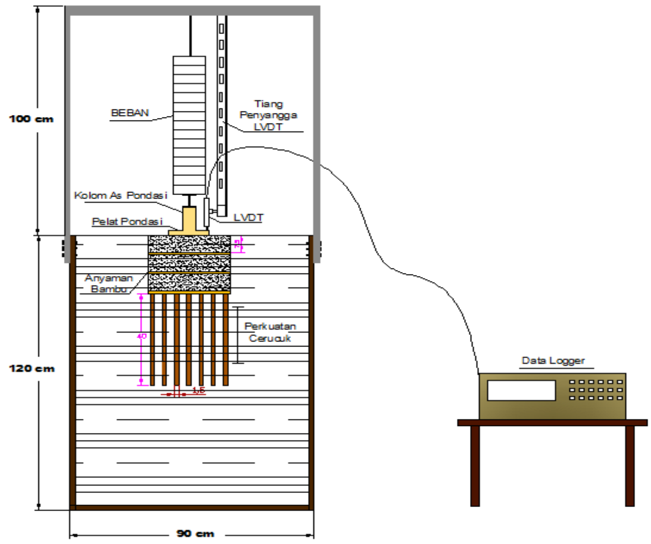


Fig. 6 The sketch of the test with 40 m of *cerucuk* length and 1,5 cm of *cerucuk* diameter

III. RESULTS AND DISCUSSION

A. Engineering Properties of Peat Soil

The sample of the peat soil was taken from Palem Raya, Ogan Ilir (OI), Indralaya. From the results of physical tests showed that:

- Average of moisture content : 362.516 (ω, %)
- Specific Gravity : 1.75 (Gs)
- Unit Weight : 1.63 (gr/cm3)
- Plastic Limit : 37.26 (PL, %)
- Liquid Limit : 52.00 (LL, %)
- Plasticity Index : 14.74 (IP, %)
- Ash Content : 18.70 (AC, %)
- Organic Content : 81.30 (OC, %)

Therefore, peat soil was classified as fabric-peat soil with the ash content (AC) more than 15%. Peat soil at the large organic content (OC) more than 75%, and fibrous peat, the peat soil with fiber content (FC) more than 20%. The results based on the Triaxial (UU) received the value of cohesion is 0.01 kg/cm^2 (c_u), and the value of internal friction is 1.57° (φ). The average of the coefficient of the vertical permeability (k_v) is 5.30 x 10^{-4} m/s, and the horizontal permeability (k_h) is 9.93 x 10^{-4} m/s. Based on the above, the fibrous peat soil has a high or medium low permeability value. This is also indicated by a k_h value higher than the k_v value.

B. Bearing Capacity without Reinforcement

Terzaghi analysis was used to analyze the bearing capacity of peat soil before it is given the reinforcement. The data of the soil: c_u = 0.01 (kg/cm^2), Df = 0, B = 15 (cm), φ = 0^0, and γ = 1.63 (kg/cm^3). The bearing capacity (q_u) result is 5.33 kPa. According to Wawuru [10], bearing capacity without the reinforcement of peat soil at Selingsing Village, District Medang Kampai, Dumai, Riau Province is 0.0175 kg/cm$^{2\ a}$ or 1.715 kPa. The results of the calculation of fibrous peat soil have low bearing capacity.

C. *Bearing Capacity with Cerucuk Reinforcement and without Woven Bamboo*

The soil reinforced with *cajelput cerucuk* with variations of inclination angle and the rows number of *cerucuk* slopes shows an increase in the bearing capacity of the peat. The analysis of soil reinforced of peat soil with *cajelput cerucuk* using variations of inclination angle and the rows number of *cerucuk* slopes indicating the parameter of bearing capacity increased. Fibrous peat soil in the box was excavated as deep as 5 cm with the same width as the foundation plate that is 15 cm x 15 cm. Then install the *cerucuk* into the excavation. After that, sand was covered with a thickness of 5 cm to equal the ground level, the weight of the foundation itself = 5.5 kg, 1 kg load of the pole, so the sum of the weight of the foundation =6.5 kg.

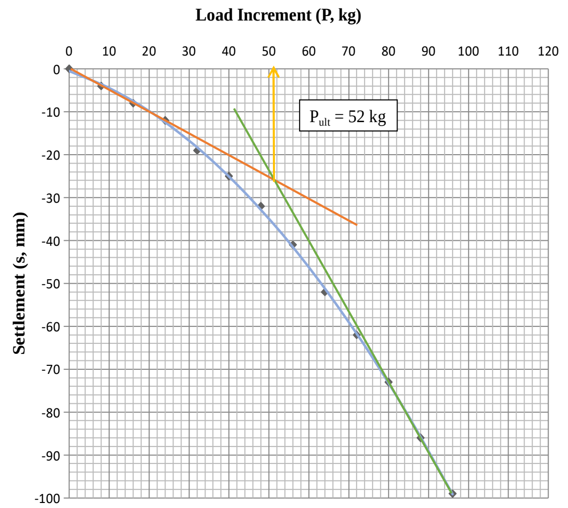


Fig. 7 Graph of load increment (P, kg) and the settlement (s, mm)

Based on Fig.7, the bearing capacity value can be obtained by using an analysis of the graph of settlement and loading (Adams and Collin methods) [8]. Fig. 8 shows the relationship between load increment (P, kg) and the settlement (s, mm).

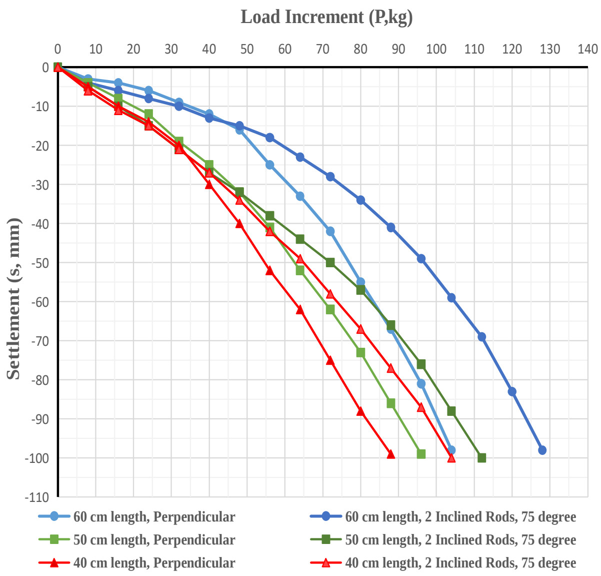


Fig. 8 Graph of load increment versus settlement for each variation

The total of the ultimate bearing capacity due to the oblique *cerucuk* number and the variation of slope of peat soil reinforcement could be seen in Table II, whereas for the graph of the bearing capacity for all variations increase (Fig. 9).

TABLE II
THE VALUE OF FOUNDATION BEARING CAPACITY REINFORCED WITH *CERUCUK* WITHOUT WOVEN BAMBOO

Variation of *Cerucuk*	***Cerucuk* Length**	**Arrangement Number of Outer *Cerucuk* at the Left-Right Side**	**$q_{ultimit}$ (kPa)**
Without reinforcement			5.33
Perpendicular *Cerucuk*	40 cm		18.89
	50 cm		25.56
	60 cm		31.77
Cerucuk with 85-degree slope	40 cm	1 Inclined Rod	23.33
	50 cm		29.56
	60 cm		33.56
	40 cm	2 Inclined Rods	28.67
	50 cm		35.33
	60 cm		41.11
Cerucuk with 75-degree slope	40 cm	1 Inclined Rod	26.89
	50 cm		33.11
	60 cm		38.44
	40 cm	2 Inclined Rods	30.44
	50 cm		37.56
	60 cm		42.44

As seen in Table II and Fig.9, it can be stated that the augmentation in bearing capacity of the peat soil is equivalent to the number of *cerucuk* rows installed in oblique position and inversely proportional to the number of *cerucuk* inclination angle toward the foundation plane.

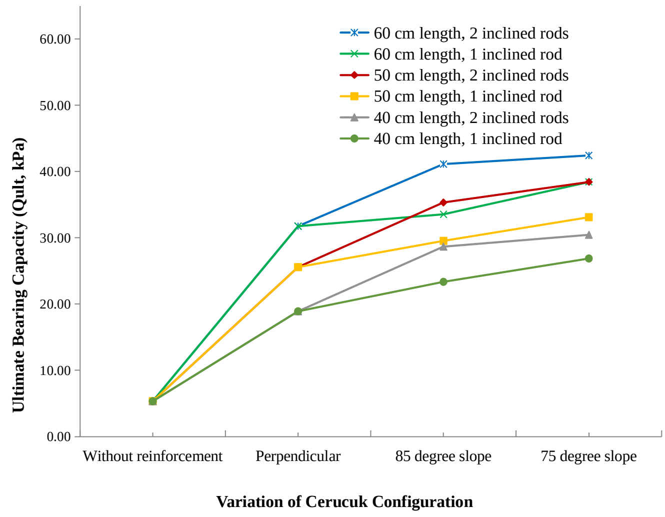


Fig. 9 The value of ultimate bearing capacity for each variation

This is due to the application of Newton's Law of action and reaction, i.e., the forces of two objects at each other are always equal and opposite. The greater the force applied to the foundation, the higher the value of the pile end resistance, and vice versa. The outer force applied to the inclined pile foundation will be larger than the perpendicular pile, the higher the value of the pile end resistance. This is what causes the value of the bearing capacity is higher than the perpendicular pile.

The maximum bearing capacity is obtained at the arrangement variation of two outer rods at the left and right-side form 75^0 angle toward the foundation plane with 60cm *cerucuk* length, which the value is 39.33 kPa. From research result, Rika Deni et al., The bearing capacity of peat soil by using pra-consolidation can be the increase of 9.01 kPa or the percentage increase of 242 % (without reinforcement was 2.64 kPa).

Ultimate bearing capacity for the all perpendicular rods variation was also calculated analytically, as follows. It is given a soil condition with $\varphi = 1{,}57^o$, $\gamma = 1.63$ gr/cm^3 = 1.63 x10^{-3} kg/cm^3, c_u = 0,01 kg/cm^2, and group piles parameter (piles length 60cm):
d.= 1.5 cm, z = 60 cm, B = 15 cm, L = 15 cm,
n' = 5, m = 5, n = 25

It got, $Q_u = Q_s + Q_b$ = 4.343 kg + 0.35 kg
Q_u = 4.693 kg (for single pile)

For the group piles,

$$E_g = 1 - \left[\left(\tan^{-1} \left(\frac{d}{s} \right) \right) \frac{(n'-1)m + (m-1)n'}{90 m n'} \right]$$

$$= 1 - \left[\left(\tan^{-1} \left(\frac{1.5cm}{3.75cm} \right) \right) \frac{(5-1)5 + (5-1)5}{90 x 5 x 5} \right]$$

= 0,612

So, Q_g = n x E_g x Q_u
= 25 x 0.612 x 4.693 kg = 71,8029 kg

$$q_u = \frac{Q_g}{A_{Pondasi}} = \frac{71.8029\ kg}{15cm \times 15cm}$$

= 0.319 kg/cm^2 = 31.9 kPa

From the above calculation (Table III) shows that bearing capacity value is due to the addition of reinforcement by using the analytical method obtained results close to the same as the laboratory testing as in q ultimate to a length (L) =60 cm. The analytical bearing capacity of 31.90 kPa when compared to the bearing capacity using the graph method with a value of 31.77 kPa can be seen as having a value close to the same Similarly, for the length of the *cerucuk* 40 cm and 50 cm.

TABLE III
THE VALUE OF FOUNDATION BEARING CAPACITY WITHOUT REINFORCED

Variation of *Cerucuk*	Length (cm)	$q_{ultimit}$ (kPa)	
		Analytics	Lab. Test result
Diameter 1.5 cm (5x5)	40	19.08	18.89
	50	25.09	25.56
	60	31.90	31.77

D. Bearing Capacity with Cerucuk Reinforcement and Woven Bamboo

The loading test was performed with the variation of the length of *cerucuk* (40 cm, 50 cm, 60 cm) and *cerucuk* diameter variation (1.5 cm and 2 cm). Peat soil with reinforcement excavated with size 30 cm x 30 cm as deep as 19 cm. Then do the installation of *cerucuk* and woven bamboo first followed by the addition of a layer of sand on second and third with bamboo reinforcement spacing (0,5B) 7.5 cm. In the first layer of the foundation base distance to the reinforcement is 0.25B (3.75cm). Then place the foundation plate and column for loading. Lastly installed LVDT tools with LVDT tool ends are in the foundation plate. Figure 10 shown that relationship in load increment (P, kg) and the settlement (s, mm) for foundation reinforced *cerucuk* and woven bamboo. The test result of the reinforced foundation with a variation of *cerucuk* length and diameter and with 3 layers of woven bamboo reinforcement showed an increase in soil bearing capacity.

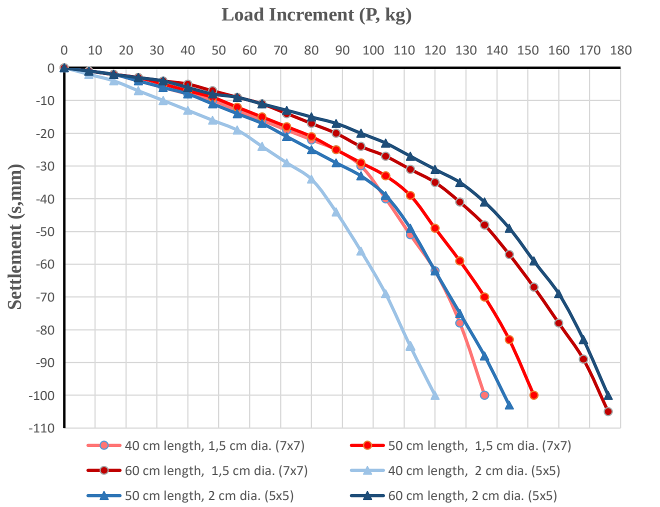


Fig. 10 Graph between load increment and settlement (test result of foundation reinforced *cerucuk* and woven bamboo)

The value of ultimate bearing capacity can be seen in Table IV. and Fig. 11 below. Table IV shows the test results of bearing capacity. It can be said that a diameter *cerucuk* of 1.5 cm with a longer *cerucuk* will provide greater bearing capacity and the more *cerucuk* that sustains the load, the greater the bearing capacity.

TABLE IV
THE VALUE OF FOUNDATION BEARING CAPACITY REINFORCED WITH *CERUCUK* AND WOVEN BAMBOO

Variation of *Cerucuk*	Length (cm)	$q_{ultimit}$ (kPa)
Diameter 1.5cm (7x7)	40	42.89
	50	49.11
	60	58.00
Diameter 2 cm (5x5)	40	37.56
	50	42.00
	60	53.56
Diameter 1.5cm (7x7) without woven	40	18.00
	50	24.67
	60	32.67

Based on Table IV and Figure 11, with the formation and diameter of the *cerucuk* being equal to and without woven bamboo. For the foundation, the difference in the bearing capacity is significant, which is 2 times larger when using woven bamboo. From Table II and IV, it can be analyzed that with the reinforced foundation without woven bamboo with the same length of *cerucuk* and diameter, but with different arrangement which the first one is 5x5 where all *cerucuk* are positioned below the foundation and the second one, 7x7 with one *cerucuk* rod at the left and right side gave five kPa greater amount of bearing capacity if compared with the previous formation. It can be explained that the influence *cerucuk* beyond the foundation is not too significant to improving the bearing capacity of peat soil.

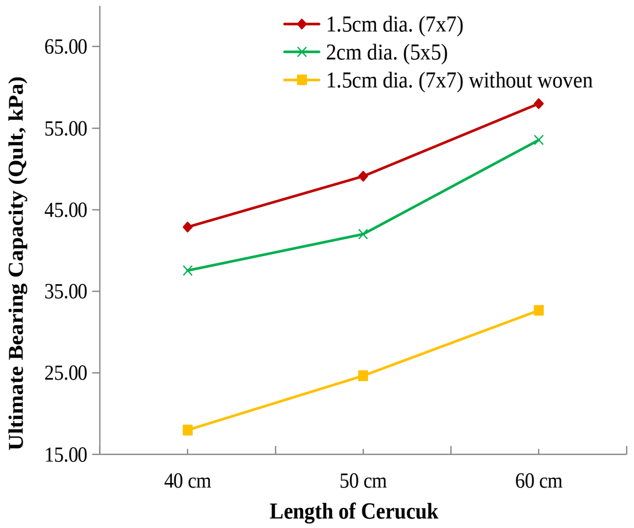


Fig. 11 The value of ultimate bearing capacity (for each variation with woven bamboo)

E. BCR Value

The value of the Bearing capacity Ratio (BCR) is the value obtained from the comparison between the bearing capacity of the reinforced soil (qu) and without reinforcement (qo) which in this study is used as a benchmark to measure how much effect of the variables used in the reinforcement [12]. The results of the tests applied the reinforcement of *cajelput cerucuk* material can increase the value of BCR.

The results of the value of BCR (maximum) from the foundation reinforced at *cerucuk* without woven bamboo is 7.379 or 7 times of the ultimate bearing capacity without reinforcement. Table V Table 5 explains the increasing percentage is about 637.899%. Based on the delivered results, the installation of inclined *cerucuk* has very significant results on the bearing capacity value of the foundation and the longer *cerucuk* rod with the same formation and diameter size; then the bearing capacity will be higher as well.

The foundation reinforced with *cerucuk* and three layers of woven bamboo is 10.88 or 10 times larger than the value of soil bearing capacity without reinforcement, with the number of percentage increase is 988.18% as shown in Table VI. The improvement bearing capacity of peat soil by using bamboo reinforcement only was 279% for 3 layers of bamboo reinforcement from bearing capacity without reinforcement [10].

If the foundation reinforced with *cerucuk* and 3 layers of bamboo compared to Waruwu's research is 3 - 4 times larger than the use of bamboo only. However, the usage of woven bamboo greatly affected the value of bearing capacity ratio that is reinforced with *cajelput cerucuk*, where the value of its Bearing Capacity Ratio can be increased 2 - 3 times larger without 3 layers of woven bamboo.

TABLE V
THE BCR VALUE OF BEARING CAPACITY OF FOUNDATION REINFORCED WITH *CERUCUK* WITHOUT WOVEN BAMBOO

Variation of *Cerucuk*	***Cerucuk* Length**	**Arrangement Number of Outer *Cerucuk* at the Left-Right Side**	**BCR**	**Increased (%)**
Without reinforcement			1.00	
Perpendicular *Cerucuk*	40 cm		3.54	254.41
	50 cm		4.80	379.55
	60 cm		5.96	496.06
Cerucuk with 85-degree slope	40 cm	1 Inclined Rod	4.38	337.77
	50 cm		5.55	454.51
	60 cm		6.30	529.56
	40 cm	2 Inclined Rods	5.38	437.84
	50 cm		6.63	562.91
	60 cm		7.71	671.32
Cerucuk with 75-degree slope	40 cm	1 Inclined Rod	5.04	404.48
	50 cm		6.21	521.22
	60 cm		7.21	621.28
	40 cm	2 Inclined Rods	5.71	471.19
	50 cm		7.05	604.61
	60 cm		7.96	696.33

TABLE VI
THE BCR VALUE OF BEARING CAPACITY OF FOUNDATION REINFORCED WITH *CERUCUK* AND WOVEN BAMBOO

Variation of *Cerucuk*	**Length (cm)**	**BCR**	**Increased (%)**
Diameter 1.5cm (7x7)	40	8.047	704.69
	50	9.214	821.39
	60	10.882	988.18
Diameter 2 cm (5x5)	40	7.045	604.50
	50	7.880	687.99
	60	10.047	904.69
Diameter 1.5cm (7x7) without woven	40	3.377	237.71
	50	4.628	362.79
	60	6.129	512.88

IV. CONCLUSION

It can be concluded based on this research because of this as follows: The maximum value of bearing capacity is obtained at the variation of two *cerucuk* rods at the left and right side forming 75^0 angles to the foundation plane, where the value is 39.33 kPa with the BCR value is 7x of bearing capacity value before it is given a reinforcement with *cerucuk* without woven bamboo. The maximum value of bearing capacity is obtained at the variation of with 60 m of *cerucuk* length and 1,5 cm of *cerucuk* diameter, where the value is 58 kPa with the BCR value is 10x of bearing capacity value before it is given a reinforcement with *cerucuk* and woven bamboo. Woven bamboo and *cerucuk* used as an alternative to peat soil reinforcement provide the bearing capacity value of peat soil rises. This is proportional to the addition of the length and the amount of cerucuk used.

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