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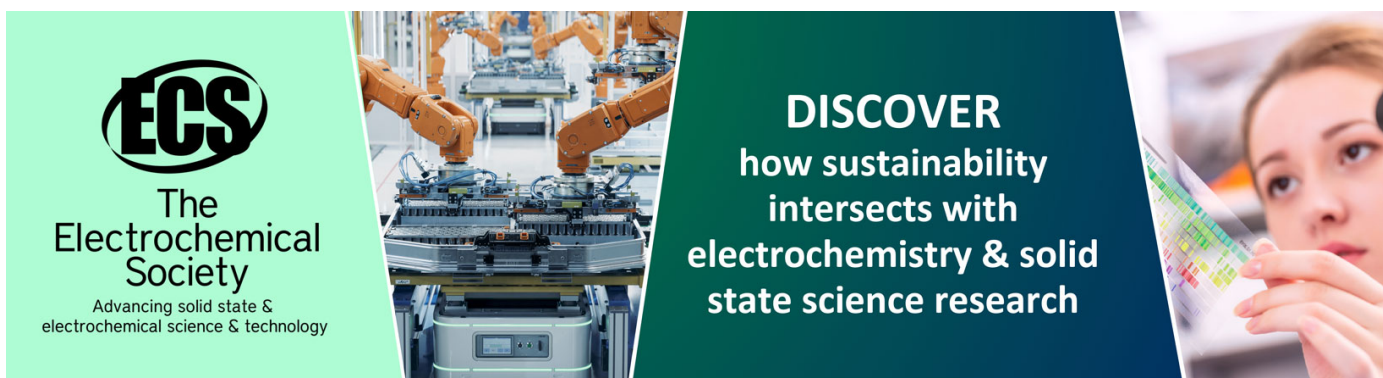
Influence of bamboo pile clusters in the pile mattress bamboo construction systems as reinforcement of soft subgrade that support embankment load

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Influence of bamboo pile clusters in the pile mattress bamboo construction systems as reinforcement of soft subgrade that support embankment load

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Abstract. One of the problems that arise in building land transport infrastructure located on soft soil is the making of the road construction. The completion of the road construction issue is carried out by the engineering that the road is safe and stable. The main long-term goal of this research is to provide a method of handling embankment construction that is above soft soil, complementing the existing methods, by using the main bamboo material. This study discussed the influence of bamboo pile clusters on a bamboo mattress construction system to support the embankment load on soft soil. The method of this research is to make a bamboo cluster containing 3 bamboo sticks, 4 bamboo sticks, and 7 bamboo sticks. The cluster is inserted into the soft soil. Bamboo pile clusters are gradually loaded until the soil collapses. Data that is investigated in the area of the cluster and the force given to suppress the cluster. The results of the study show the relationship of bamboo pile clusters with P_{ult} . The value of the P_{ult} depends on the area of the cluster with the formula: $P_{ult} = 840 L_n (X) - 3044$ with X is the cluster area.

1. Introduction

1.1 Background

Soft ground in Indonesia is estimated to cover about 20 million hectares or about 10 percent of Indonesia's total land area [4]. Soft soil found in the area around the beach, and many cities in Indonesia is located on the waterfront and most of its territory is essentially soft soil areas with high water surface, as shown in Figure 1. The city is a center of the economy of the area concerned, so that the necessary facilities and infrastructure to support the smooth running of the event. One of the facilities and infrastructure that is needed is a means of land transportation, good highways and railroads

Urban areas located on soft soil, the means of land transportation must pass through the soft ground. One of the problems that arise in building land transport infrastructure located on soft soil is the making of the construction of the road. The completion of the road construction issue is done with engineering so that the road is safe and stable.



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Kimpraswil [4], gives five methods of solution work pile located on soft soil that has been accepted and applied in Indonesia, is replacement material, counterweight berms, addition of load (surcharging), staged construction, use of lightweight materials.

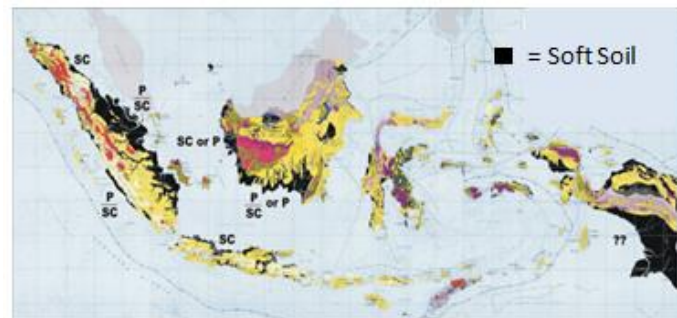


Figure 1. Soft Soil Map in Indonesia [8].

Irsyam [3] featuring research full-scale test embankment with reinforcement pile mattress bamboo for toll roads in Tambak Oso, Surabaya (Figure. 2). The study states that embankment with the pile mattress Bamboo system shows sufficient stability against slope failure and the failure of the bearing capacity, the actual settlement was also approaching the predicted settlement. Therefore, the pile mattress bamboo system proved reliable as a reinforcement of embankment and can distribute more uniform settlement.



(a) Insert Bamboo Pile Into the Ground



(b) Arrange of Mattress Bamboo.

Figure 2. Pile mattress Bamboo for Toll Road Embankment Tambak Oso Surabaya [3].

1.2 Problems and objectives of research

Problems in the construction design of pile mattress bamboo for reinforcement of soft soil is to determine the number of layers of the mattress and the distance of pile associated with the existing soil conditions. At a certain soil conditions, the number of layers of the mattress can be determined if the data rigidity of mattress is known, so is the distance pile can be determined if the data of the ultimate force that causes deformation so that the ground collapses (spring constant) is known. Issues that will be examined is limited to the effect of bamboo pile which is part of the pile mattress construction system in supporting the embankment load. This problem can be solved by the proposed research. The results of the proposed research is pile bamboo spring constants parameters. The parameter is required in numerical analysis with Plaxis 2D. Numerical analysis can determine the influence of the distance of pile on the pile mattress bamboo construction in support of embankment load.

2. Theories and concepts

2.1 Spring constant

Determination of the spring constant of pile bamboo by Irsyam [3] which is illustrated in Figure 3 is as follows: Bamboo is considered to have a diameter of 8 cm. Pile hold ultimate force suit bearing capacity of soft soil that is working on the pile with equation (1).

$$P_{ult} = K_{ll} \cdot (c_1 \cdot h_1 + c_2 \cdot h_2 + c_3 \cdot h_3 + \dots c_i \cdot h_i) + 9 \cdot A_b \cdot c_i \quad (1)$$

With: k_{ll} = average circumference of bamboo; $c_1, c_2, \dots c_i$ = cohesion undrained appropriate layers, and $h_1, h_2, \dots h_i$ = height of each layer of soil in accordance of pile depth, A_b : sectional area of bamboo pile. The maximum bearing capacity of the soil transferred to the bamboo is expressed in equation (2).

$$F_{max} = P_{ult} / F_s \quad (2)$$

With: F_s is the safety factor. The amount of ground deformation (δ) so f_{max} immobilized, assumed $\delta = 0.1 \times d$, with d is the diameter of the bamboo. The magnitude of the spring constant (k) defined by equation (3).

$$k = F_{max} / \delta \quad (3)$$

Sectional stiffness parameter value (EA) of pile is obtained by taking the value of the modulus of elasticity (E) of bamboo by reference.

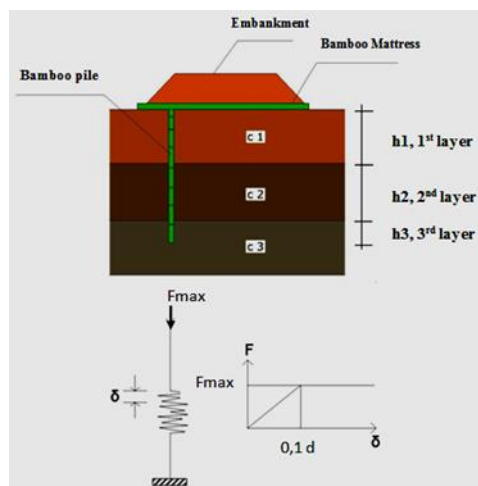


Figure 3. The determination of F_{max} and Spring Stiffness of Bamboo Pile [5].

2.2 Bearing capacity of single pile in clay

Ultimate bearing capacity (Q_u) of the pile foundation on clay soil can be expressed by equation (4).

$$Q_u = \alpha \bar{c}_u \cdot A_s + N_c \cdot C_u \cdot A_b \quad (4)$$

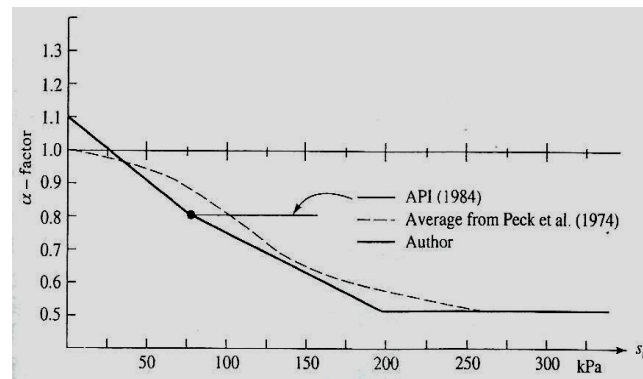


Figure 4. Relation of S_u and Adhesion [2].

With : α = is an adhesion factors derived from an empirical relationship with shear strength (Figure 4.), C_u = is an average undrained cohesion along the pole blankets, A_s = is an area of the pile, N_c = is a bearing capacity factor (~ 9.0), c_u = is an undrained cohesion base of the pile, A_b = is an area of base pile.

2.3 Bearing capacity of pile mattress bamboo on soft soil

Bearing Capacity of pile mattress bamboo soft soil, can be considered as a combination between the carrying beams / plates and piles. The workload on it (q) through the mat first be distributed into piles. Load acting on pile will be retained by the soft soil. Because piles rigidity much greater than the soil that supports it, then the soil will decline to collapse. The amount of support for the soil to collapse (Q_u) can be calculated by equation (4).

Figure 5. shows that the magnitude of the soil deformation to pile collapsed in general there are two concepts, the first is the concept of capacity with controlled deformation (controlled deformation capacity), $P_{F0.1}$, and the second is the concept of ultimate capacity, P_u . The first concept states that pile collapse if the amount of deformation of pile has reached 10% of the pile diameter [1].

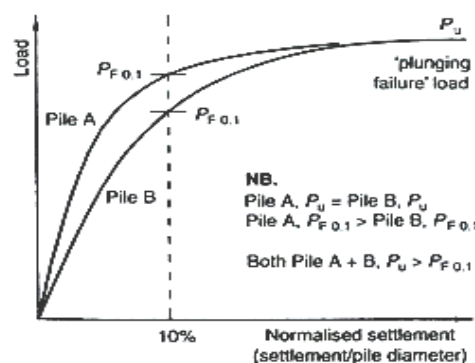


Figure 5. Definition of Failure Pile [1].

After the soil that supports pile collapse, then the residual loads is supported by the mat (q_m). load transfer on the pile mattress bamboo can be illustrated as in Figure 6. The Load of pile is displayed with equation (5).

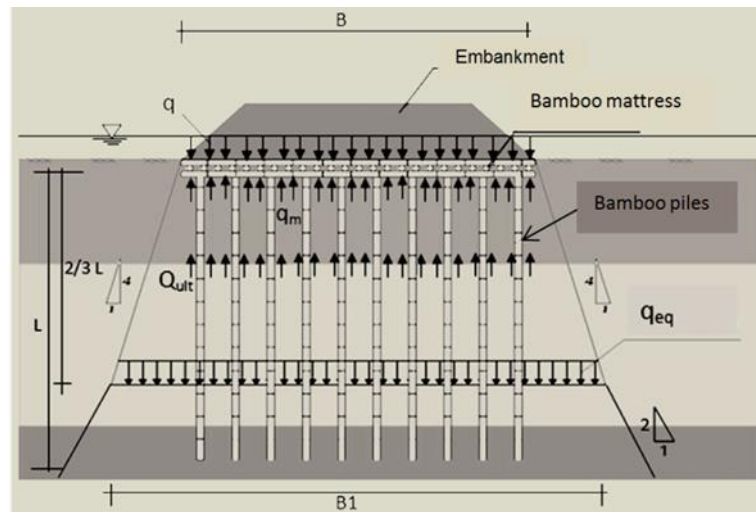


Figure 6. Load Transfer on Pile Mattress Bamboo System [5].

$$Q_{tot} = n \cdot Q_{ult} \quad (5)$$

With: Q_{tot} = is the total load pile, n = is the number pile per meter length embankment, Q_{ult} = is the ultimate load of pile. Distributed load received the mat can be written by equation (6).

$$q_m = q - n \cdot Q_{ult} \quad (6)$$

With, q_m = is the distributed load which received the mat, q = is the total distributed load that work on the mat, B = is the width of the mat.

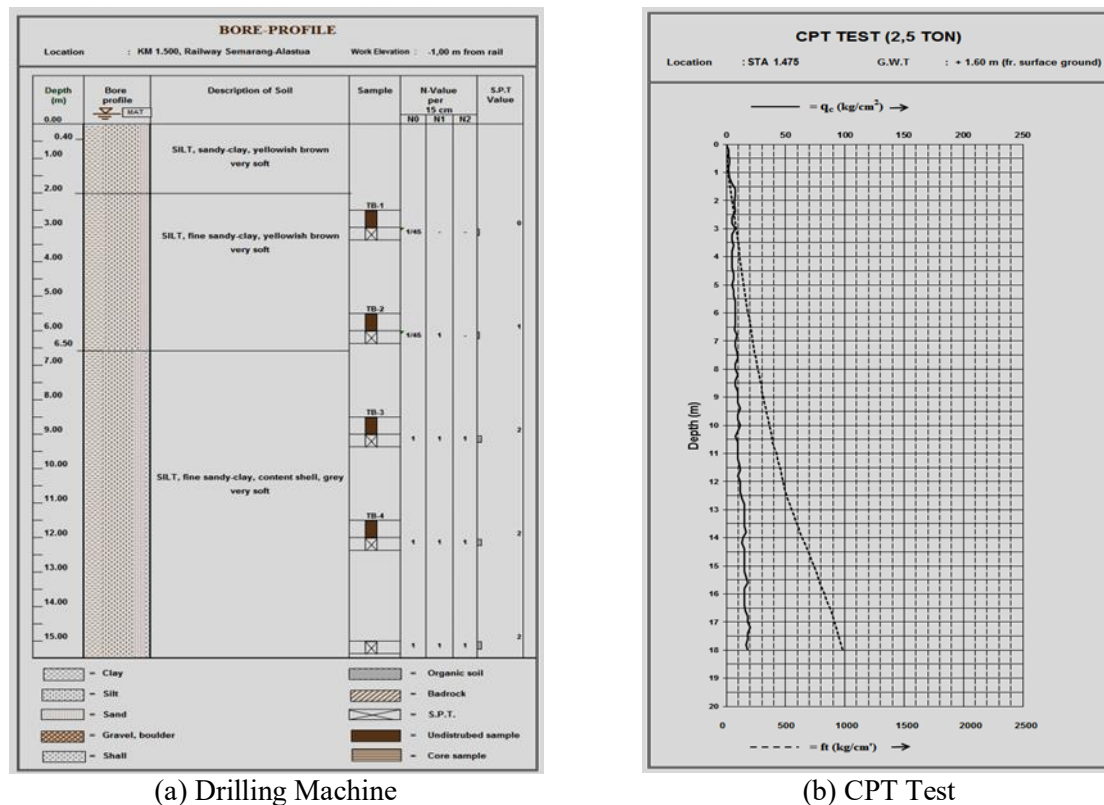
Load mat is supplied to the ground with spread 4v: 1h, provide additional stress to the ground by q_{eq} , q_{eq} work at a depth of 2/3 the length of pile, an additional amount of stress in the soil can be written by equation (7).

$$q_{eq} = q_m \cdot B / B1 \quad (7)$$

3. Subgrade condition and materials testing

3.1 Sub grade Conditions

The location of testing model in the Cilosari village Semarang, Central Java, namely in the double railway track Semarang-Bojonegoro KM: 1,500. Subgrade condition is known by testing Drilling Machines and Test Sondir. Results drill machine and sondir test as shown in Figure (7).



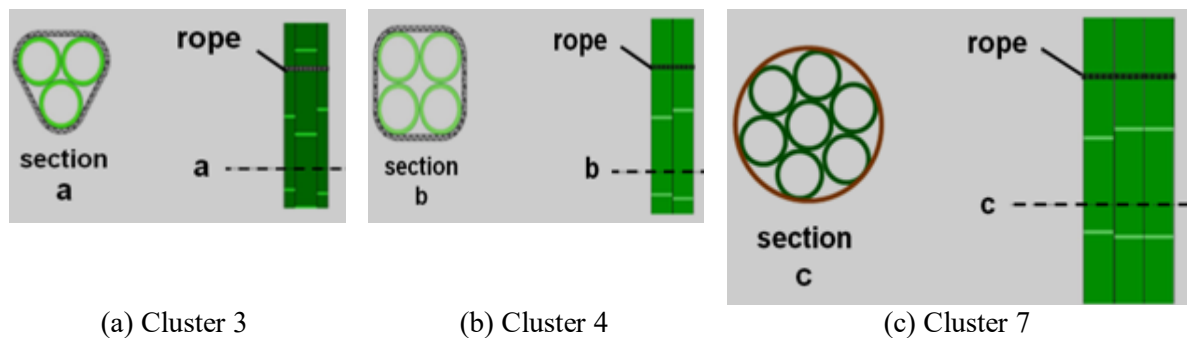
(a) Drilling Machine

(b) CPT Test

Figure 7. Results Drill Machine And Sondir Test.

3.2 Material test

Pile a bamboo tied into a particular cluster with a plastic strip or wire rope. The necessary data of bamboo pile is a cross-section stiffness (AE) cluster and spring constants. Pile of bamboo that are planned in the study were 3 clusters, 4 clusters and 7 clusters, as shown in Figure 8.



(a) Cluster 3

(b) Cluster 4

(c) Cluster 7

Figure 8. Arrangement of Bamboo Pile.

4. Setting model and testing program

4.1 Setting model

Bamboo pile testing are located in areas of ponds with stagnant water approximately 1.50 meters. Framework is needed to test. Framework for testing shown in Figure 9(a), after the framework is completed pile erection as in shown in Figure 9(b).



Figure 9. (a) Setting Cluster, (b) Cluster Piling.

Piling of bamboo into the ground by using a load of 63 kg free falling with the steering pipe. Free fall height of about 100 cm. Piling done to position the cluster as shown in Figure 10.

4.2 Testing program

Testing is done for each clusters as many as 3 trials. Type clusters there are 3 types namely clusters 3, clusters 4, and the clusters 7. Example of position clusters 3 and clusters 7 are ready to be tested is shown in Figure 10.

The Concept Testing of spring constant is doing add load gradually (Figure 11.) until the cluster down because the soil is not able to support the load that is given. The main data is recorded is the magnitude of the force applied and the magnitude of the deformation.



Figure 10. Clusters Ready to Be Tested.

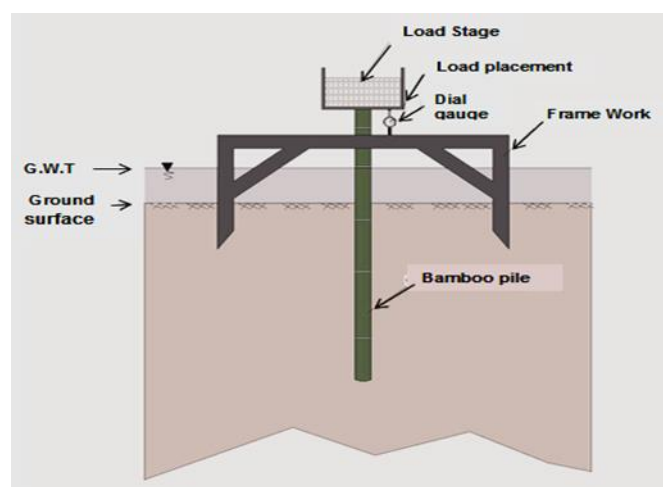


Figure 11. Set Up Test Constant Spring of Bamboo Clusters.

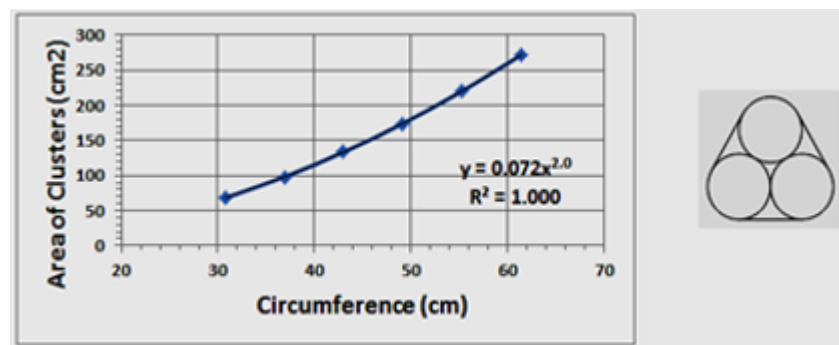
5. Experimental data and analysis

5.1 The cluster area

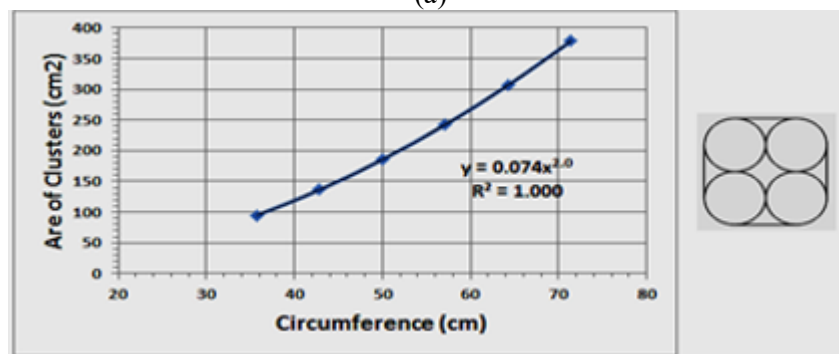
The ultimate force of each cluster type is obtained by loading tests on each cluster. This ultimate force works on the actual cluster which has an area that varies according to the diameter of the bamboo. The area of the cluster is determined by measuring the circumference of the cluster tie. Based on the circumference of the clusters tie and cluster configuration, then with the mathematical trial Autocad, the formula can be determined as follows: Cluster 3, cluster area = $0,072 \cdot X^2$ (Figure 12.a); cluster 4, cluster area = $0,074 \cdot X^2$ (Figure 12.b), and cluster 7, cluster area = $0,076 \cdot X^2$ (Figure 12.c) with X is circumference of cluster.

5.2 Force and cluster displacement data

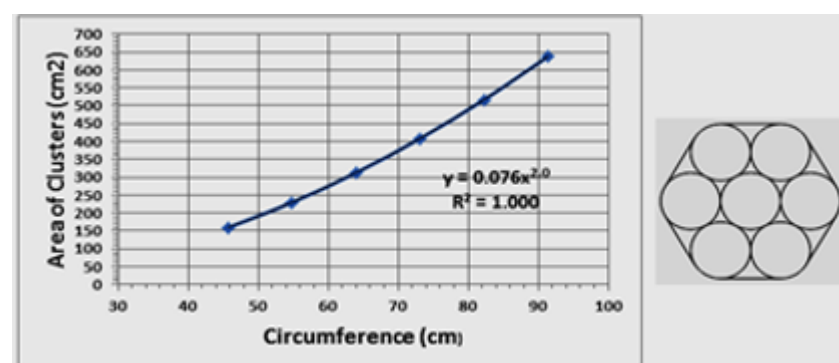
Bamboo used for testing consists of a variety of sizes, therefore, in order to equalize the influence of the bamboo pile, the actual cluster area is converted to an equivalent cluster area with a minimum diameter of the allowed bamboo (5 cm diameter). For example cluter 3, it contains 3 coulumn of bamboo, each 5 cm in diameter. The compressive force of the three cluster types with bamboo contents 5 cm in diameter is shown in Figure 13 to Figure 15.



(a)



(b)

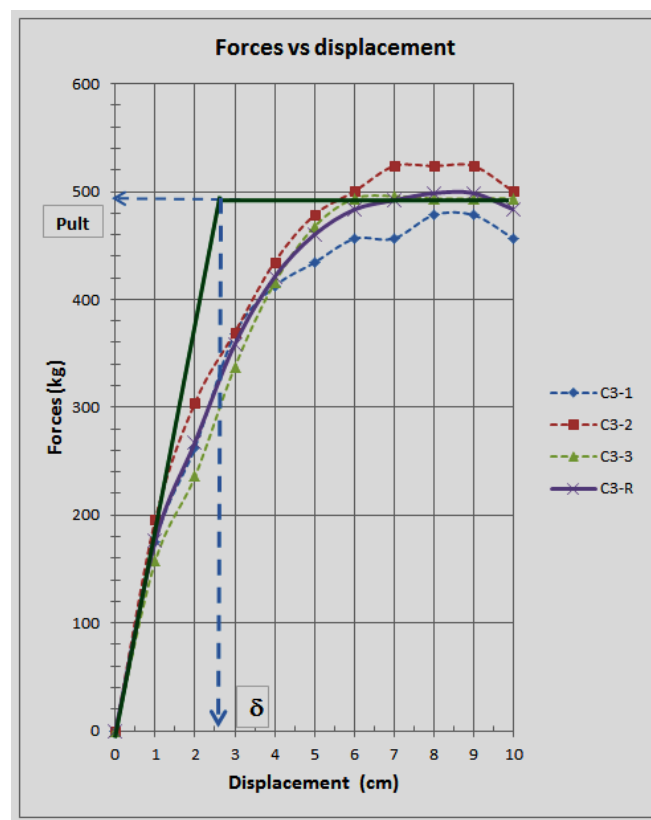


(c)

Figure 12. Circumference VS Clusters Area: (a) clusters 3, (b) clusters 4, (c) clusters 7.

With the correlation between the circumference and the area of the cluster, it will be able to easily determine the cluster area with various sizes of bamboo.

From similar figures, the determination of force ultimate, P_{ult} for clusters also had been obtained. The method used was initially has two assumptions; the first is by assuming the force that the ultimate force acting will cause deformation (δ) = of $0.1 d$, with d is the cluster diameter. The second assumption is by assuming the force applied causing the supporting soil completely collapsed. From those two theories, the ultimate force cluster is taken. For results cluster 3 was reported obtained P_{ult} of 490 kg with recorded deformation of 2.6 cm ($0.28 d$).

**Figure 13.** Determination of P Ultimate Cluster 3, $P_{ult} = 490$ kg, Deformation 2.6 cm ($0.28 d$).

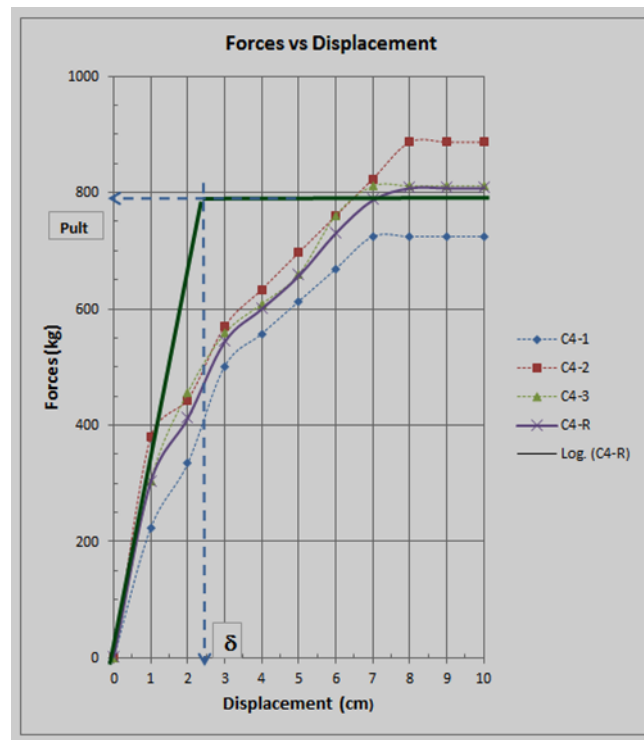


Figure 14. Determination of P Ultimate Cluster 4, $P_{ult} = 790$ kg, Deformation 2.5 cm (0.22 d).

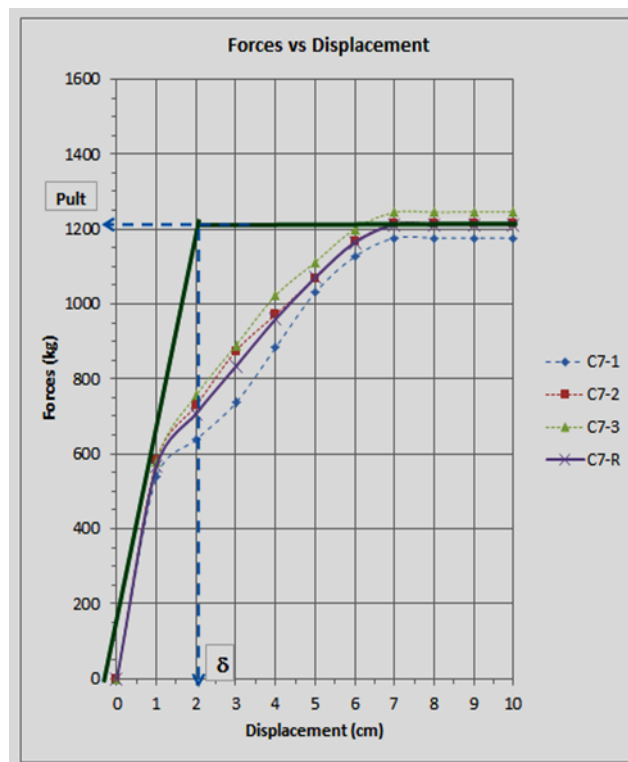


Figure 15. Determination of P Ultimate Cluster 7, $P_{ult} = 1210$ kg, Deformation 2.6 cm (0.16 d).

Based on the three P_{ult} values for the three types of clusters it can be determined the influence of clusters on the construction of bamboo mattress structures in supporting the load of embankment. The influence is shown in Figure 16.

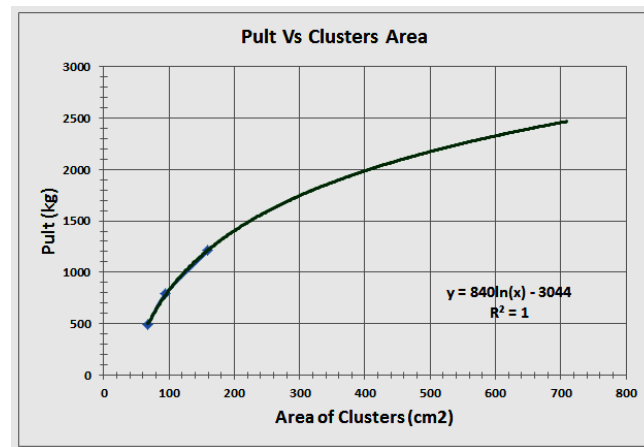


Figure 16. Influence Area of Cluster Vs P_{ult} .

The influence of cluster area on P_{ult} in Figure 16 above, if logarithmic regression is carried out, it will produce a relationship between the area of the cluster and the ability of support in Pile mattress bambo construction system with the formula $P_{ult} = 840 \ln(X) - 3044$ with $X = \text{Cluster Area}$. This value will be used as input for various bamboo pile spacing configurations in numerical analysis so that it can be seen the influence of cluster distance on fill height.

6. Conclusion

Based on the discussion above, the influence of cluster areas in supporting the load in The Pile Mattress Bamboo Construction Systems as Reinforcement of Soft Subgrade That Support Embankment Load, can be formulated as $P_{ult} = 840 \ln(x) - 3044$, with $X = \text{Area of cluster}$.

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