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Bearing Capacity and Settlement Behavior of Peat Soil Improve by Stone Column

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Abstract: The stone column is the standard ground improvement method used on the peat soil but, there are no clear guidelines to use the stone column, so this study be conducted to achieve the objective. This study aims to model the stone column in the peat soil by using the PLAXIS Software to determine the peat soil's bearing capacity and settlement and compare the bearing capacity and settlement with various stone columns; geometry, and properties. By using the PLAXIS 2D Software, to model the stone column and the peat soil in order to analyse the behavior of the peat soil with different geometry of the stone column. This findings from the results of settlements and bearing capacity shows that encased stone column have better performance compared to the uncased stone column. The smaller the diameter of the stone column, the peat will be easier to collapsed. Besides, the larger the spacing between stone columns, the higher the settlement and the lower the bearing capacity. The 100% of the maximum length will act better compared to 50% of the maximum length. This research justifies the need for suitable geometry of stone column can be applied to the peat soil and become common options of ground improvement techniques.

Keywords: Peat Soil, Stone Column, PLAXIS Software, PLAXIS 2D Software,

1. Introduction

The peat soil is one of the softest soils with low shear strength and has high settlement [7][8][9]. Peat soil unable resist construction loads put on it. Therefore, the stone column is the standard ground improvement method used on the peat soil but, there are no clear guidelines to use the stone column, so this study will be conducted to achieve the objective.

This study aims to model the stone column in the peat soil by using the PLAXIS Software to determine the peat soil's bearing capacity and settlement and compare the bearing capacity and settlement with various stone columns; geometry, and properties. This research study various geometry of the cased and uncased stone columns (diameter, depth, and spacing) that will affect the peat soil's behavior using the PLAXIS Software. It is expected that the peat soil with encased stone columns shows

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low settlements compared to the peat soil without encased stone column. There have less findings of researches and real case studies using the stone column in the peat soil. The situation may considered deficiency of the stone column as ground improvement method. Weak deposits including peat, have lack lateral support and may have implications upon to the stone column cause the stone column to be fail [10]. The stone column may not suitable as the ground improvement method in peat soil. Therefore, there have no clear guidelines to use the stone column, so this study conducted to achieve the objective.

2. Materials and Methods

This topic aim to concentrate on the method used to perform this study by using the stone column, specifically to improve the load bearing capacity and the settlement behaviour of the peat soil. By using the PLAXIS 2D Software, to model the stone column and the peat soil in order to analyse the behavior of the peat soil with different geometry of the stone column.

2.1 Soil and Embankment Properties used in FEM Analysis

The soil properties that will be used in this study is based on the case study of the improvement of the existing railway line Hamburg-Berlin, have very soft soil layers (peat and mud) and inadequate bearing capacity [3].

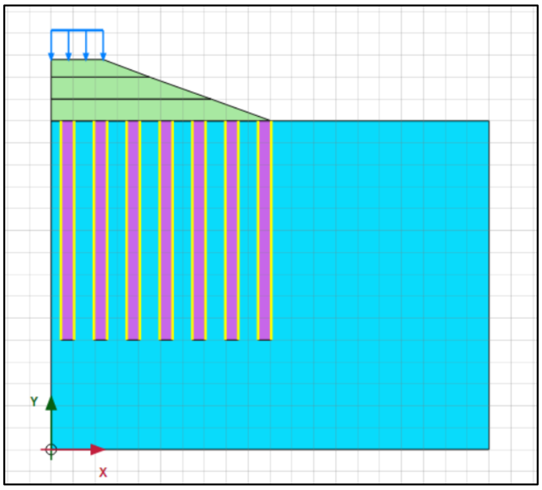


Figure 1: The soil profile that will be use in this study.

This is the soil profile that will be use in this modelling study. The height of the embankment is 2.80 m, the height of the peat soil that use is 15 m. The peat soil is known with high settlement, have low load bearing capacity and not appropriate to be foundation for construction. Therefore, this study by using the stone column is one of the initiatives or way to improve the settlement and the load bearing capacity.

2.2 Parameters used in FEM Analysis.

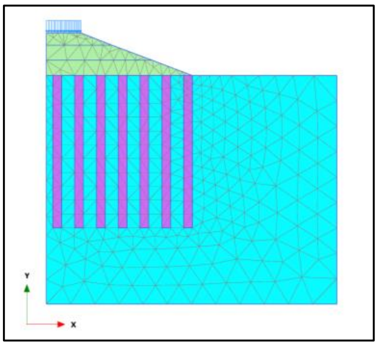
The Table 1 below shows the parameters that used in modelling. The material model that will be used for the peat soil is soft soil creep (SSC), Mohr-Coulomb for the stone column and embankment fill, while the geogrid use the elastic model [6]. The type of behaviour of the peat soil is undrained meanwhile, the stone column and the embankment fill are drained behaviour. The bulk density for the peat soil, stone column and the embankment fill which are 815 kg/m^3, 2000 kg/m^3 and 1955 kg/m^3 respectively. The Elastic Modulus for the peat soil is 800 kN/m^2, the stone column is 30,000 kN/m^2 and for the embankment is 25,000 kN/m^2. The Poisson Ratio for the peat soil is 0.35, and 0.3 for both stone column and embankment fill. The Modified Compression Index for the peat soil is 0.2. The Cohesion use in peat soil is 8 kN/m^2 while the stone column is 0.01 kN/m^2 and 1 kN/m^2 for the embankment. The friction angle for the peat soil is 20°**,** the stone column is 42°, and the embankment fill is 30°. The dilatancy angle for stone column is 10°**.** The hydraulic conductivity for the stone column is 100 m/day, for the peat soil 0.005 m/day while for the embankment fill is 3 m/day. Stiffness of the geogrid encasement use is 5000 kN/m and the unit weight for peat soil, the stone column and the embankment fill, are 11 kN/m, 20 kN/m and 19 kN/m separately. The installation pattern of stone column will be triangular [6].

Table 1: Material properties used in modelling, Prasad [4].

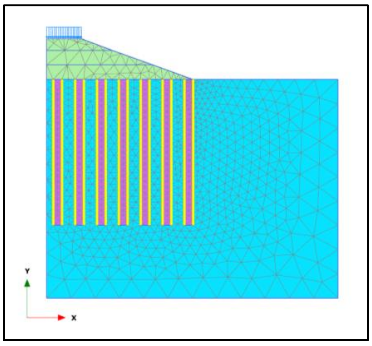
Materials	Peat	Stone Column	Geogrid	Embankment
Material model	Soft Soil Creep	Mohr-Coulomb	Elastic	Mohr Coulomb
Type of behavior	Undrained	Drained	-	Drained
Bulk density, (kg/m^3)	815	2000	-	1955
Elastic modulus, E	800	30,000	-	25,000
Poisson's ratio, v	0.35	0.3	-	0.3
Modified Compression Index, λ*	0.2	-	-	-
Modified Swelling Index, κ*	0.01	-	-	-
Cohesion, c (kN/m^2)	8	0.01	-	1
Friction angle, φ (°)	20	42	-	30
Dilatancy angle,ψ (°)	0	10	-	0
Hydraulic conductivity, k (m/day)	0.005	100	-	3
Stiffness, EI (kN/m)	-	-	5000	-
Unit weight, (kN/m^3)	11	20	-	19

2.3 Proposed Model of Peat Soil with different geometry of stone column

In this study we proposed design model of the peat soil improved stone column using PLAXIS 2D to get the result of bearing capacity and settlement of peat soil based on different conditions stated below.

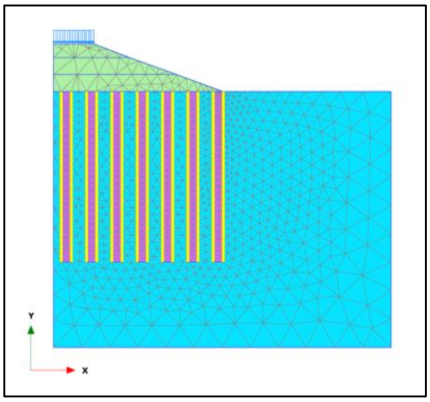


(a): Uncased Stone Column

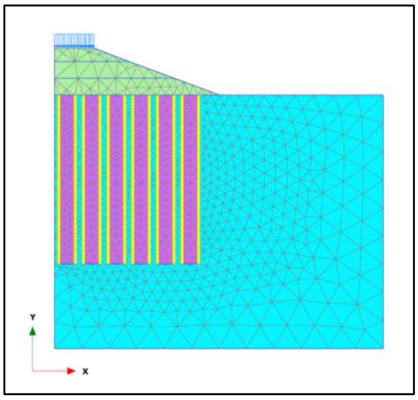


(b): Encased Stone Column

Figure 2: Uncased and Encased Stone Column, Malarvizhi [6]

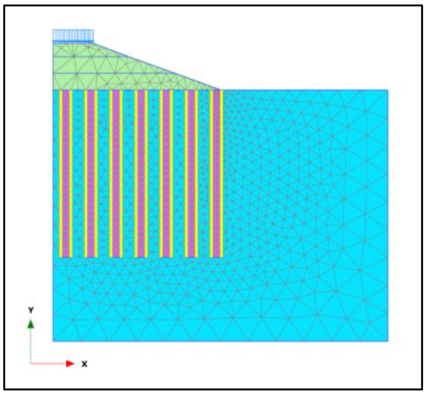


(a): With 0.6m diameter

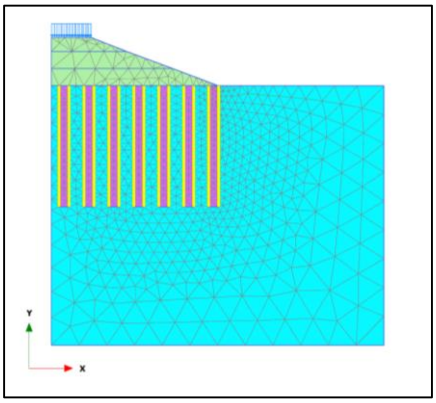


(b): With 1.0m diameter

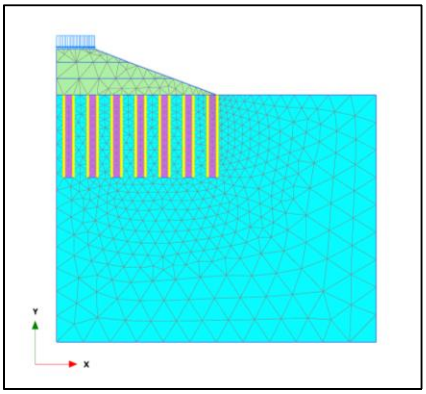
Figure 3: Different diameter of Stone Column, Aljanabi [1] & Kempfert [3]



(a): With 100% length

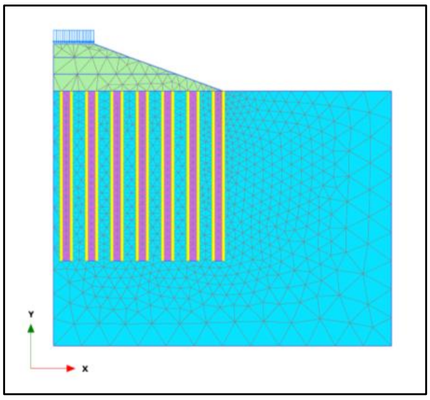


(b): With 70% length

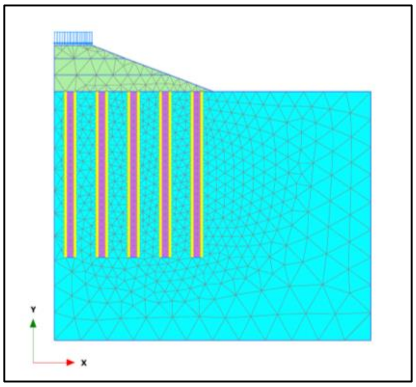


(c): With 50% length

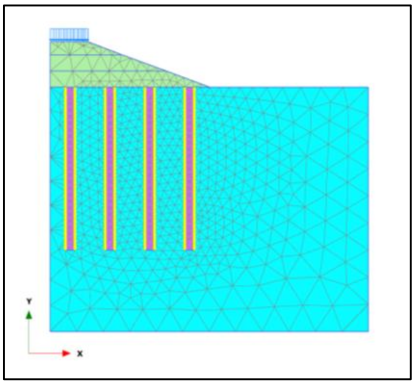
Figure 4: Different length of Stone Column, Malarvizhi [6]



(a) : With 1.5m spacing



(b) : With 2.0m spacing



(c) : With 2.5m spacing

Figure 5: Different spacing of Stone Column, Prasad [4]

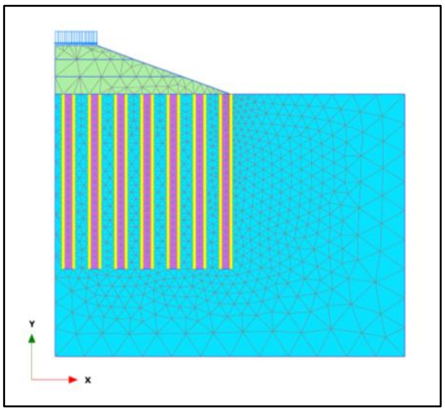


Figure 6: Different Stiffness of Geogrid, Ambily [2] & Prasad [4]
(a): 5000 kN/m^2 (b): 500 kN/m^2 (c): 50 kN/m^2

3. Results and Discussion

The result of expected outcomes is to achieve the objective of this project. Plaxis Software can be utilize to model the stone column in the peat soil. The software also use to determine the results of settlement and bearing capacity of the peat soil model with different geometry of stone column. The settlement will be evaluate by results from the deformation and pore water pressure curve, meanwhile, the bearing capacity will be examine by the maximum stresses of the peat soil.

3.1 Settlements

The results will compare between different geometry of stone column in peat soil, which is more suitable and more efficiency in improve settlements of peat soil.

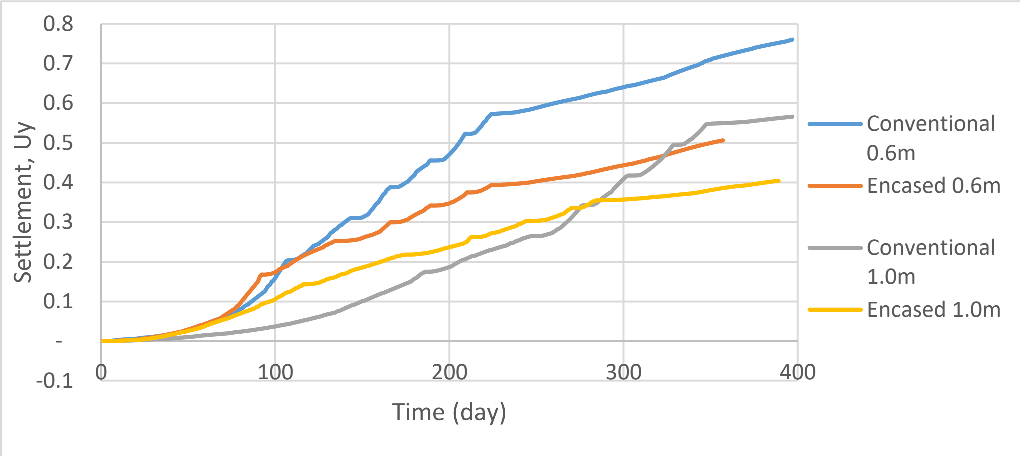


Figure 7: Settlement of the peat soil by using different diameter

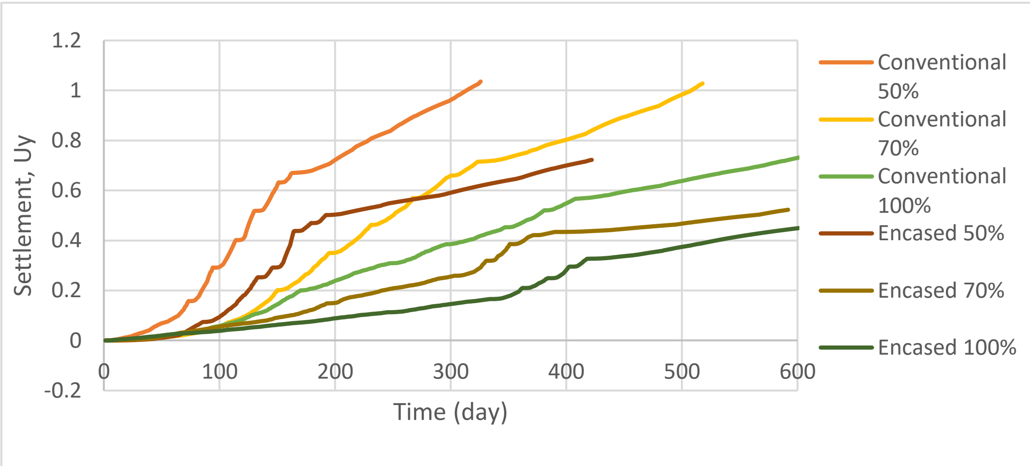


Figure 8: Settlement of the peat soil by using different length

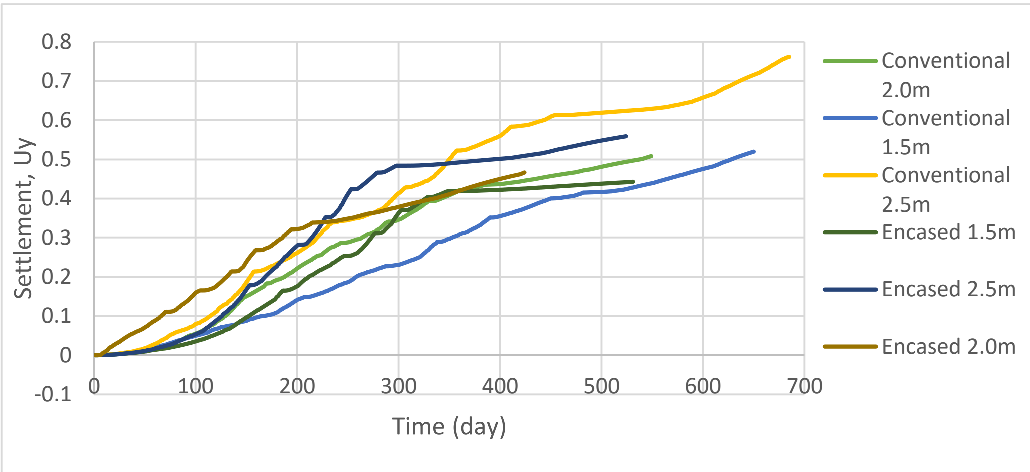


Figure 9: Settlement of the peat soil by using different spacing

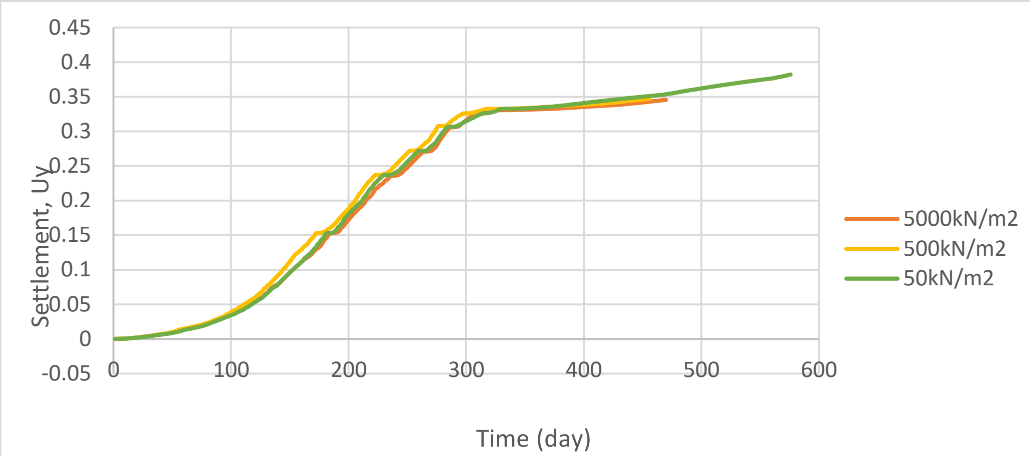


Figure 10: Settlement of the peat soil by using different stiffness of geogrid

From the results, the performance of encased stone column is better compared to the uncased stone column. From Malarzhivi [6] researches, encasing stone column increases the stress concentration on the column, thereby reducing the load on soil, consequently reducing the settlement. In aspect of diameter with different nodes, it can be summarized that the smaller diameter is more prone to settled compared to the bigger diameter [2]. In aspect of spacing, the larger the spacing, the larger the deformation, the higher the settlement [2]. The length that tested in this study which are 50%, 70% and 100% from the maximum length, the 100% have the least deformation compared to the 50% and 70% length. Based on the results, indicate that the stiffness of geogrid stone column is not affected to the settlement of the peat soil. Referring to Malarzhivi [6] study, when the stiffness is increased beyond 2000 kN/m^2/m, the contribution to settlement reduction ratio becomes insignificant for the conditions analyzed.

3.2 Bearing Capacity

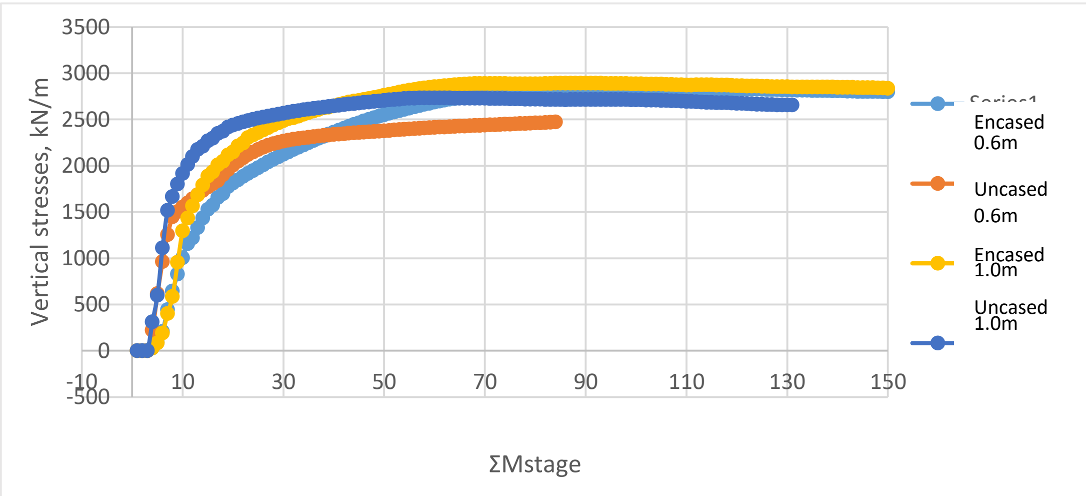


Figure 11: The full results of bearing capacity of the peat soil with the different diameter of stone column

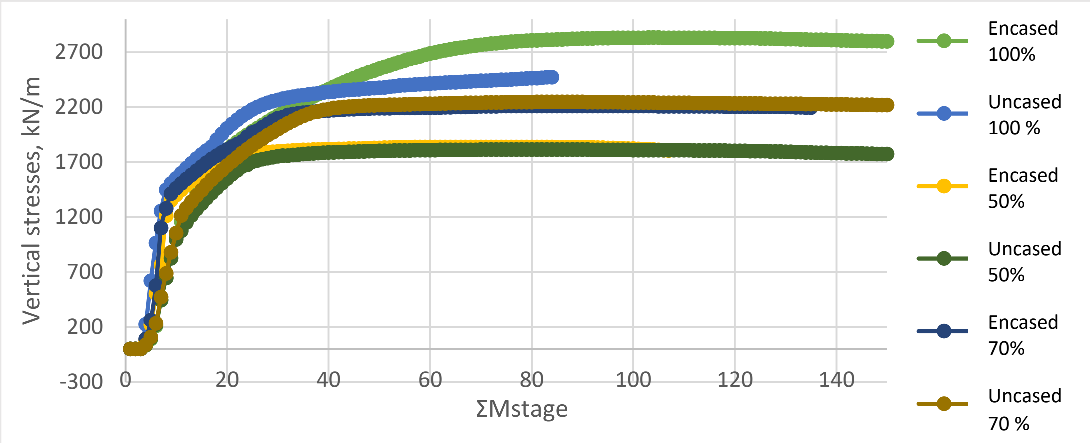


Figure 12: The full results of bearing capacity of the peat soil with the different length of stone column

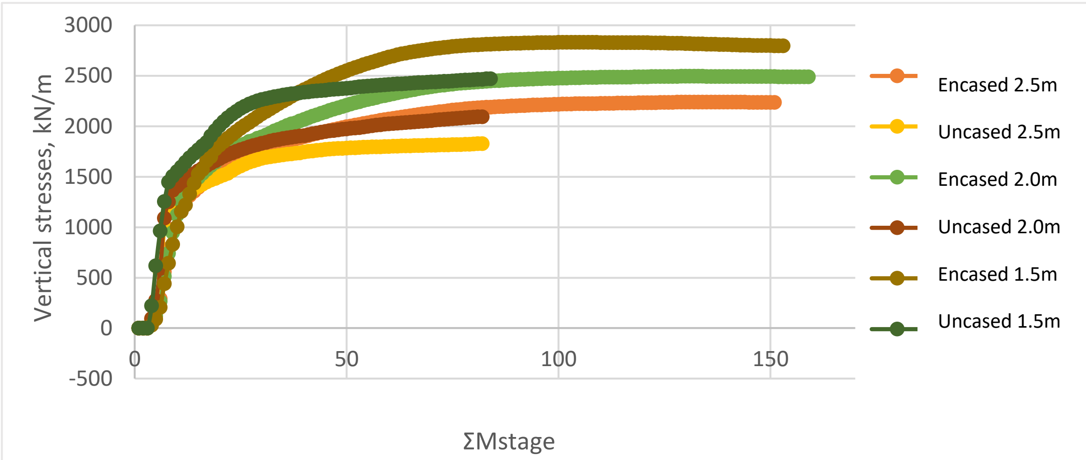


Figure 13: The full results of bearing capacity of the peat soil with the different spacing between both stone column

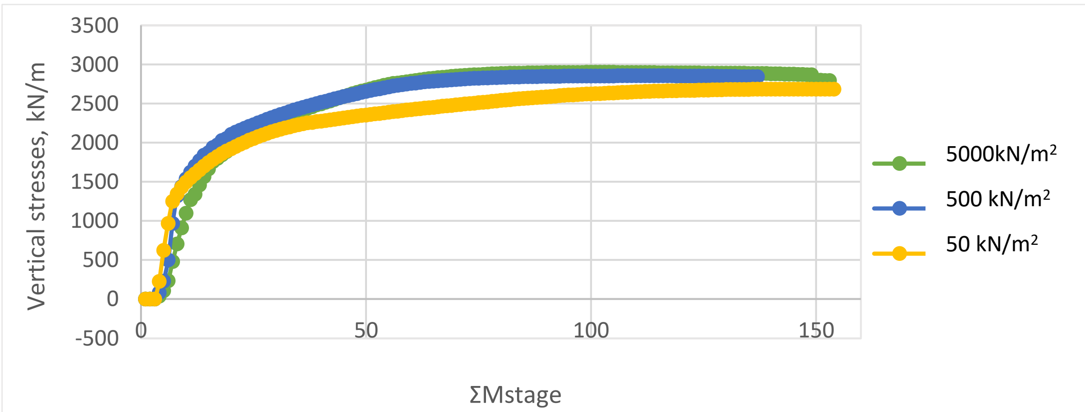


Figure 14: The full results of bearing capacity of the peat soil with the different stiffness geogrid encased stone column

Based on the results, it can be concluded that encased stone column have better performance compared to the uncased stone column [6]. In terms of diameter, the result shows that the more bigger the diameter, the higher the value of bearing capacity [2]. As for different length that have been applied in this study, the 100% length have have the highest bearing capacity compared to the 70% and 50%

length. According to Malarzhivi [6], column have shared high load by the passive resistance against bulging. For the spacing, the smaller the spacing, the greater the bearing capacity [2]. In respect to the stiffness of geogrid encased stone column, the results indicate no big differs of bearing capacity between the stiffness of geogrid have been carried out [2][6]. Thus, by referring to this study, the hypothesis about encased stone column have high bearing capacity compared to the uncased stone column is acceptable.

4. Conclusion

In conclusion, the aim of this research is to acquire a better understanding in modelling the structures in PLAXIS software. From this research, the bearing capacity and settlement have been determined and the results of bearing capacity and settlement with different geometry of stone column have been compared. Hence, suitable geometry of stone column can be applied and became common options of ground improvement techniques besides preloading and vertical drains (PVD).

Based on the analysis of the results, it shows that the encased stone column have better performance compared to the uncased stone column. The smaller the diameter of the stone column, the peat will be easier to collapsed. Besides, the larger the spacing between stone columns, the higher the settlement and the lower the bearing capacity. The 100% of the maximum length will act better compared to 50% of the maximum length. The stiffness of geogrid stone column is not affected the settlement of peat soil.

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