Numerical Modeling of Foot Plate Foundation Located on Peat Soil

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Abstract. Peat soil can be found in several place in Indonesia, one of them in Kalimantan. Peat soils with its characteristic have highest compressibility among than other soil types. The experimental modeling of foot plate foundations in peat areas was too difficult to be performed. Numerical modeling can be one of the efforts to determine the optimum results with a relatively more economical cost. This study modeled the foot plate foundation structure where located on peatland with different elevation of peat soil into the elevation of the foundation. Peat soil elevation had been determined successively below the foundation elevation, the same level of the foundation elevation and above the foundation elevation. All geometric and material data had been obtained from field data. The analysis performed in static analysis with in 2D shell idealization by utilizing Abaqus software version 6.14-2. Numerical results had been also compared with analytic results. The result of the research showed that there is a match between numerical result and analytic result. The stress occurred at the base of the foundation for each peat soil elevation difference correspondently 16.53 MPa, 9.34 MPa and 3.59 MPa. The lowest stresses occurred when the peat soil elevation located above the foundation elevation (78.28%).

Keywords: peat, soil, foundation, foot plate, model

1. Introduction

Peat soil can be found in several place in Indonesia. The Kalimantan is one of them. [6] said that peatlands area in Indonesia had been recorded in 20.1 million Ha or about 70% of total peatland area in Southeast Asia. Furthermore, the 4th level of the largest peatlands area in the world after Canada, Russia and USA. The Kalimantan island has 4.778.005 Ha peatlands area [7]. [4] said that reduction of water content is accompanied by reduction of its void ratio and its compressibility; in addition, strength of the peat soil increases with the decrease of water content. The absorbent capacity of the peat decreases with the increase of water content reduction. When its water content reduction reaches 80% of the initial ones, the peat soil does not have ability to re-absorb water. The peat soils with its characteristic have lower soil bearing capacity than other soil types. The test results show that the stabilizer was environmentally friendly. The values of specific gravity and wet unit weight increase with the increase of stabilizer percentage and curing time period; water content and void ratio are decreasing with the increase of stabilizer percentage and curing time period. Consequently, the compression behavior of stabilized peat soil is also altered, that is, the increment of the stabilizer percentage and curing period.
are able to decrease the total compression of the stabilized peat soil but not affect its compression behavior. Hence, the experimental modeling of foot plate foundations in peat soil condition was too difficult to be performed. It was caused by so many variables that should be evaluated and involved in the modeling.

The numerical modeling can be one of the efforts to determine the optimum results with a relatively more economical cost. [5] A simple method, for practical use in 2D, to determine this shear layer model’s parameters are developed that the shear layer’s stiffness can be determined independently of the superstructure’s geometry. There are so many numerical applications were based on finite element methods such as Abaqus. This application was very possible to model the foundation in many soil layers with their characteristics. The availability of stress criterion features in this application allowed the modeling of foot plate foundations in peat soil to be optimally performed.

[1] explained that the main function of the foundation is to pass the construction load to the subsoil under the foundation. The bearing capacity of the foot plate foundation soil was safe if the settlement had been justifiable and the collapse did not occur. [2] gives an equation of soil bearing capacity by involving \(N_c\), \(N_q\), and \(N_{\gamma}\) parameter. The parameters had been called as the bearing capacity factor (Eq. 1). This equation also considers the soil weight volume effect, cohesion, and external load.

\[
\gamma'_{ave} = \gamma' + \left( \frac{z}{B} \right) (\gamma'_{b} - \gamma')
\]  

(1)

Where \(q_u\), \(c\), \(q\), \(\gamma\), and \(B\) respectively are bearing capacity of ultimate soil, cohesion, the weight of soil on the foundation of each unit of length, the weight volume of soil, and the width of the foundation. The Equation 1 is a bearing capacity equation for a square foot plate foundation [1].

[3] evaluated the mechanical behavior of structures which in contact with the soil. The behavior is influenced by the interaction between the soil and the structure. This interaction is called the Soil-Structure Interaction (SSI). This study explained that some of the structures in which SSI is important to consider are mainly on building, bridges and oil drilling constructions. This research also used finite element method to model soil behavior as nonlinear springs.

This study modeled the numerical behavior of the foot plate foundation with the varying elevation of peat soil. The variation of the soil layer is determined by the variation of water level. The foot plate foundation had been modeled in 2D shell idealization.

2. Research Method

This study modeled the structure of the foot plate foundation where located on peat soil with difference elevation into the foundation level. All geometric and material data had been determined from actual condition. Modeling had been performed in two models, namely, foundation model and soil model. The analysis performed is static structure analysis with 2D shell model. All numerical modeling had been performed by utilizing Abaqus 6.14-2 version.

Figure 1 showed the prototype of the foot plate foundation to be modelled. This study used the dimension of foot plate foundation \((B = L)\) was specified in 1500 mm x 1500 mm foot plate. The depth of foundation had been noticed in \(D_f\). The model scale has been determined 1 : 1. The variations specified
in this model were the peat soil elevation variations (thickness of peatland = 1.00 m). Successive at the elevation below the foundation, at same level the foundation elevation, and above the foundation surface.

This study also observed the effect of the settlement of foundation that was indicated by the displacement (u_z) of the foundation. The strength and stability of the foundation structure had been also considered in this research. Table 1 showed the geometric data from the foundation dimension used as the model in this study.

| Table 1. Dimension |
|---------------------|
| **Section** | **Dimension** |
| | **B (mm)** | **L (mm)** | **D'f (mm)** |
| Foot plate | 1500 | 1500 | 400 |
| Concrete column | 400 | 400 | 900 |
| Soil | 6750 | 6750 | 1950 |
| Peat | 6750 | 6750 | 1000 |

Table 1 showed the geometric data of the structure modelled in this study. The dimensions of the structure had been expressed successively: Area (A), width (B), length (L), thickness of foot plate foundation structure (D’f). All dimensions are expressed in International Standard Units. The model was consisted foot plate, concrete column, soil and peat soil.

Every model had been determined its mechanical properties such in modulus of elasticity (E) and Poisson ratio (ν) based on the codes as shown in Table 2. The density of the material had been also specified based on the characteristic of the material. The material data of the structure model consists of data of elastic modulus (E) and Poisson ratio (ν) which recorded in International Standard Unit. All material data was obtained based on the result of standardized measurement table.

| Table 2. Material properties |
|-----------------------------|
| **Section** | **Material properties** |
| | **Γ (N/mm³)** | **E (MPa)** | **ν** |
| Foot plate | 2,35E-5 | 23500 | 0,2 |
| Concrete column | 2,35E-5 | 23500 | 0,2 |
| Soil | 16,48 | 2574 | 0,45 |
| Peat | 8,91 | 2 | 0,35 |

2.1 Numerical Model

2.1.1 The Peat Soil Under the Foundation

The modeling of the foundation structure with the peat soil lies beneath the foundation used the prototype of the foot plate foundation as shown in Fig. 3 and Fig. 4.
Figure 3 showed that there is peat soil at 1950 mm below the foundation. The dimensions of the foundation of foot plate had been considered in 1500 mm x 1500 mm. The depth of the foundation was considered in 1100 mm from the surface. The foundation thickness is 400 mm. Weight of concrete volume \( \gamma_{\text{beton}} = 2.4 \text{ T} / \text{m}^3 \) with Poisson ratio \( v = 0.2 \).

Soil properties 1 is the weight of wet soil volume \( \gamma_{\text{wet}} = 1.81 \text{ T}/\text{m}^3 \), soil shear angle \( \phi_r = 350 \), soil cohesion \( c = 0 \text{ T}/\text{m}^2 \). The second soil layer was considered as peat soil. The second soil layer properties correspondently \( \gamma = 8.91 \text{ N}/\text{mm}^3 \), \( E = 2 \text{ MPa} \) and \( v = 0.35 \).

**Figure 2.** Peat soil under the foundation

Figure 4. Showed the foundation modeling with 2D shell elements in Abaqus. The peat soil layer elevation lies below the foundation elevation at -1950 mm depth from the ground elevation with 1000 mm thickness. The modeling of the elements on the foundation uses a plane stress model while in soil modeling using the plane strain model. The green zone showed the peat soil layer.

Figure 4 showed the meshing gradation in the first model. The elements had been used in this model were consisted in two elements. They were quadrilateral elements and triangle shell element which was dominated by quadrilateral elements. The second layer of soil is a layer of peat soil with peat properties had been involved. All elements used in this model were linear with reduced integration.

2.1.2 The Peat Soil Level at Foundation Elevation

This model used peat soil elevation where placed equal to the elevation of the foundation base. Foundation elevation had been determined equal to -1100 mm from the ground elevation.
Figure 4. The peat soil level in model 2

Figure 6. showed the modeling of the foot plate foundation with the peat soil elevation at the foundation elevation (Model 2). The peat soil lied at the foundation elevation (-1100 mm) with the layer thickness being 850 mm (2D). Idealization of the interaction condition between the foot plate and peat layer is tie constraint. The green zone in Fig. 5 showed the peat soil layer (thickness = 1000 mm).

2.1.3 The Peat Soil Level on The Foundation Surface
The third model defined in a foot plate foundation model which the peat soil elevation lied above foundation elevation. The peat soil elevation defined at -400 mm from the soil surface elevation. The peat soil layer was lied above the foundation elevation with 400 mm thick layer.

Figure 5. The peat soil elevation in Model 3

Figure 6. showed the modeling of a foundation structure with the peat soil level above the foundation elevation. As with the previous two models the idealization of the boundary condition used on the foundation structure is a simple supported. The structure of the foundation is given a centralized load on both nodal concrete column models.

Figure 6. The meshing in model 3
Figure 7 showed the deformation and stress contour in the foot plate foundation structure of the third model. The deformation of foot plate foundation in model 3 equals the deformation in both previous models. Nevertheless, the soil layers above the foundations (peat soil) showed relatively larger deformations of the two previous models. The grey zone showed the peat soil layer where located on the foot plate foundation.

3. Results and Discussion

3.1 The Peat Soil Under the Foundation

Based on the numerical results that have been made the foundation structure surface with the the peat soil level located below the foundation elevation has a relatively smaller stress than the other two models.

Figure 7. The peat soil under the foundation (Model 1)

Figure 8 shows that the soil moisture layer did not have a significant effect on the deformation of the foot plate foundation structure. This is indicated by the soil below the foundation elevation.

3.2 The Peat Soil at Foundation Elevation

Based on the numerical results that have been made advance the foundation structure with the groundwater face located below the foundation elevation has a relatively smaller stress than the other two models.

Figure 8. The peat soil level in model 2

Figure 9 showed that the soil moisture layer did not have any significant effect on the deformation of the foot plate foundation structure significantly. This is indicated by the soil below the foundation elevation.
3.3 The Peat Soil Level on The Foundation Surface

Based on the numerical results that have been made the surface of the foundation structure with the peat soil where located below the foundation elevation has a relatively larger stress than the other two models. This is indicated by the soil response that is below the foundation elevation.

![Figure 9. Groundwater level in model 3](image)

The deformation of the foot plate foundation structure due to gravity load. The deformation in the second model was similar into the deformation that occurs in the first model. The stress contours that occur in second model. The stress was occurring at foot plate foundation of model 2 is relatively larger than the first model. The soil layer under the foundation did not show significant deformation as is the case with the first model.

4. Conclusion

Based on the results of numerical modeling it can be concluded several things as follows

- Peatland elevation to the foundation elevation significantly affects in soil deformation and foundation structure response
- The stress occurred at the base of the foundation for each peat soil elevation difference is 16.53 MPa, 9.34 MPa and 3.59 MPa
- The lowest stresses occurred in peat soil elevation conditions located above the foundation elevation (78.28%)
- The numerical modeling of the 2D shell model provided good results for a review of the foundation structure, but the stress on the soil layer needs to be evaluated considering the interaction conditions between the soil layers by soil surface interaction (SSI)

5. References

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