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# Effect of Geogrid Layer on Sand and Clay Soil Deformation Under The Site Foundation

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**Abstract.** Two things must be evaluated when planning a shallow foundation: sufficient bearing capacity and non-excessive settlement. In theory, foundation-bearing capacity analysis is based on Terzaghi or Meyerhoff's theory. Terzaghi's theory assumes that the soil under the foundation is uniform to an infinite depth and has sufficient strength to withstand the applied load (Gofar & Kassim, 2007). In reality, the soil beneath the foundation does not always have adequate bearing capacity, which results in excessive settlement (Shahin et al., 2017). Soil replacement using good quality soil is commonly used to improve the bearing capacity of soft soils in a particular location. Many soil improvement methods have been used, including soil compaction, additives, hydraulic methods such as PVD installation, and inclusion methods. Another alternative is to install a layer of geotextile or geogrid under the foundation to increase bearing capacity and reduce deformation. Several studies on improving soil bearing capacity under footing foundations show a significant increase in bearing capacity due to installing geotextile or geogrid layers at a certain distance under the footing foundation. This research uses a numerical method where the analysis is carried out on a hypothetical model with a geometry comparison that matches the laboratory-scale model research conducted by Ambhita (2020). Numerical analysis was performed using SIGMA/W (Geoslope International, 2018). The results showed that the foundation settlement on the medium clay layer without geogrid reinforcement was more significant than on the sand layer with geogrid reinforcement. Using geogrid layers increases the stiffness of the soil so that the deformation (settlement) is more minor, and the placement pattern of the geogrid layer affects the deformation that occurs.

Keywords: Site Foundation, Sand, Medium Clay, Soft Clay, Geostudio SIGMA/W

## INTRODUCTION

When planning a shallow foundation, two things need to be evaluated: sufficient bearing capacity and small settlement. In theory, foundation-bearing capacity analysis is based on Terzaghi or Meyerhoff's theory. Terzaghi's theory assumes that the soil under the foundation is uniform to an infinite depth and has sufficient strength to withstand the applied load (Gofar & Kassim, 2007). In reality, the soil under the foundation does not always have sufficient bearing capacity, which results in excessive settlement (Shahin et al., 2017). Soil replacement using good quality soil is commonly used to improve the bearing capacity of soft soils in a given location. Many soil improvement methods have been used, including soil compaction, additives, hydraulic methods such as PVD installation, and inclusion methods. Another alternative is to install a geotextile layer under the foundation to improve bearing capacity and reduce deformation.

Several studies related to the improvement of soil bearing capacity under the footprint foundation include the behavior of the ultimate bearing capacity of shallow foundations on geogrid-reinforced soft soil (Nugroho, 2010), modeling of shallow foundations using three layers of geotextiles on soft clay soil (Subianto, 2012), the effect of geotextiles and bamboo arrays on the bearing capacity of shallow foundations on peat soil (Agus Nugroho, 2012), deformation analysis of soft soil against geogrid reinforcement using the finite element method (Dewi S., 2018), testing the bearing capacity of sand soil with geogrid reinforcement (Sarah A., 2021), analysis of geogrids as reinforcement in retaining walls (Johan Oberlyn, 2021), 2018), and soil bearing capacity testing with geogrid reinforcement (Sarah A., 2021), geogrid analysis as reinforcement in retaining walls (Johan Oberlyn, 2021).

Based on the background description above, research will be conducted on modeling the footprint foundation, scaling the conditions according to what happens in the field, and analyzing the decline that occurs using the SIGMA/W geostudio program without and with geogrids as reinforcement.

Based on the literature study, several research questions can be asked, namely:

1. What is the effect of soil characteristics on the foundation collapse mechanism?
2. What is the effect of soil layering on the foundation collapse mechanism?
3. What is the effect of geogrid installation on increasing the bearing capacity of foundations in sand and clay soils?

The research objectives are as follows:

1. Identify the soil type's effect on the deformation under the foundation.
2. Evaluate the geogrid layer's effect on the deformation under the foundation.
3. Evaluate the placement pattern of the geogrid layer that affects the deformation that occurs.
4. The benefit of this research is to provide input for construction implementers regarding the effect of soil type, soil coating, and geogrid installation on increasing soil-bearing capacity.

## MATERIALS, INSTRUMENTS, APPROACHES, AND METHODS

The research uses a numerical method, where the analysis is carried out on a hypothetical model, and a comparison of geometry and soil data is made following laboratory-scale model research conducted by *Ambhita (2020)*. Numerical analysis was carried out using SIGMA/W *(Geoslope International, 2018)*.

One of the programs commonly used for foundation design is the “GEOSTUDIO” program, an application package for geotechnical and geo-environmental modeling, which is integrated so that it is possible to use the results of one product in another. SIGMA/W is a program used for stress and strain analysis. Its application in embankment dams is to analyze the deformation due to gradual loading and deformation during reservoir operation. SIGMA/W is capable of modeling the following conditions:

1. Deformation analysis with linear elastic or nonlinear elastic-plastic soil models.
2. Boundary conditions are transitions or stresses which change with time.
3. Embankment or excavation construction.
4. Soil-structure interaction.
5. Consolidation analysis.

The inputs required by SIGMA/W to analyze stress and deformation with the Linear Elastic soil model are E Modulus (kPa), Cohesion (kPa), Poisson Ratio, Phi, and Soil Content Weight (kN/m$^3$).

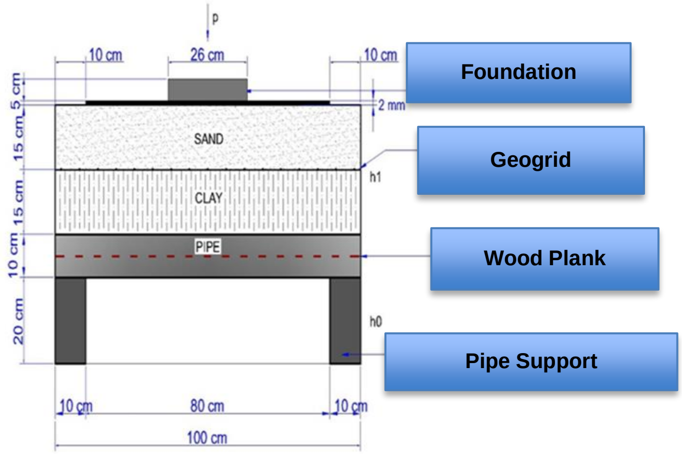


**Figure 1.** Laboratory-scale Modeling

The shape of the reviewed geometry is shown in figure 2 below with four conditions, namely:

1. Sand layer
2. Medium clay and sand layer
3. Medium clay layer
4. Sand and medium clay layer

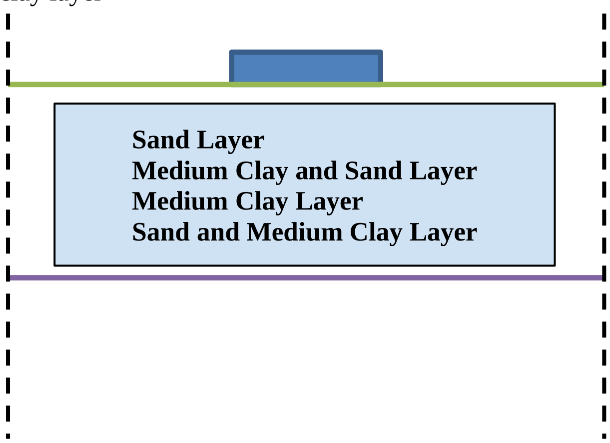


**Figure 2.** Laboratory-scale Modeling

- Reviewed geometry

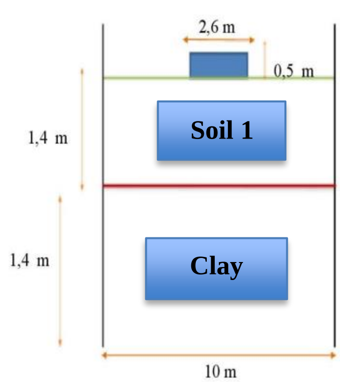


**Figure 3.** Geometry reviewed with soil characteristics

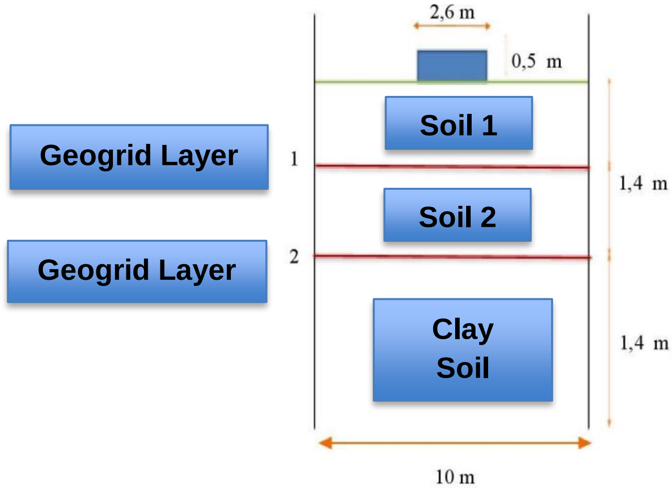


**Figure 4.** Geometry reviewed with Geogrid reinforce

- Modeling and parameters in SIGMA/W

The foundation load applied was 30.43 kPa for each condition, and multiples increased the load until the maximum settlement was reached.

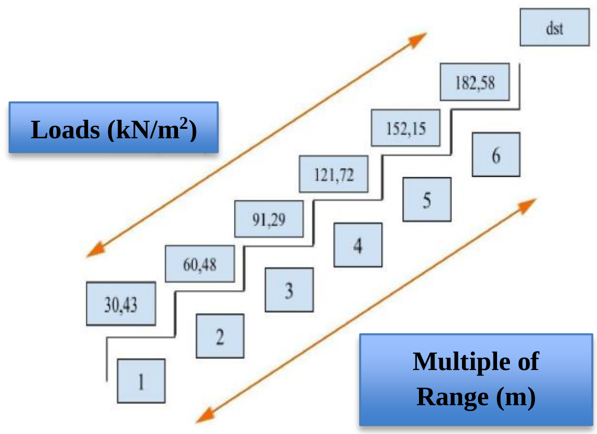


**Figure 5.** Foundation loading

- Geometry reviewed with mesh modeling and boundary conditions

Boundary conditions for the left and proper boundaries are given restraints on the X-axis, while restraints are given at the base on the XY-axis.

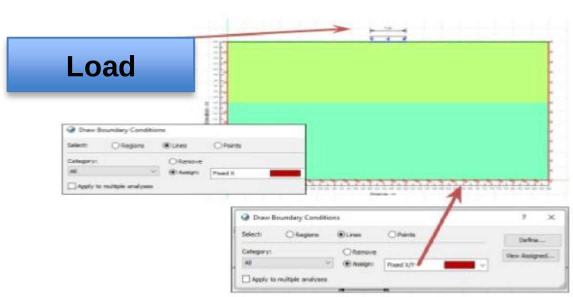


**Figure 6.** Boundary conditions on the XY axis

- Conditions reviewed for foundation modeling in SIGMA/W

1. Condition 1 (sand layer).
2. Condition 2 (medium clay layer).
3. Condition 3 (sand and medium clay layer).
4. Condition 4 (medium clay and sand layer).
5. Condition 5 (sand layer with geogrid reinforcement below).
6. Condition 6 (medium clay layer with geogrid reinforcement below).
7. Condition 7 (sand and medium clay layer with geogrid reinforcement in the middle).
8. Condition 8 (medium clay and sand layer with geogrid reinforcement in the middle).
9. Condition H (medium sand and clay layer with geogrid reinforcement below).
10. Condition F (medium clay and sand layer with geogrid reinforcement below).

- Mesh modeling in SIGMA/W

The numerical modeling of the footing foundation in the SIGMA/W program is made of a square iron plate with a size of 2.6 m² and a thickness of 0.5 meters, where under the footing foundation, there are two different soil layers, namely sand and medium clay layers. The sand and medium clay layer depth is 1.4 m, while underneath is a layer of soft clay (native soil) with a depth of 1.4 m and a distance of 10 m. In the boundary condition in the right and left directions of fixed X is a moving roller pedestal that can withstand the vertical forces acting, while in the fixed XY direction is a fixed / not moving joint pedestal that can resist vertical and horizontal forces.

The numerical modeling of the site foundation can be seen in Figure 7 below:

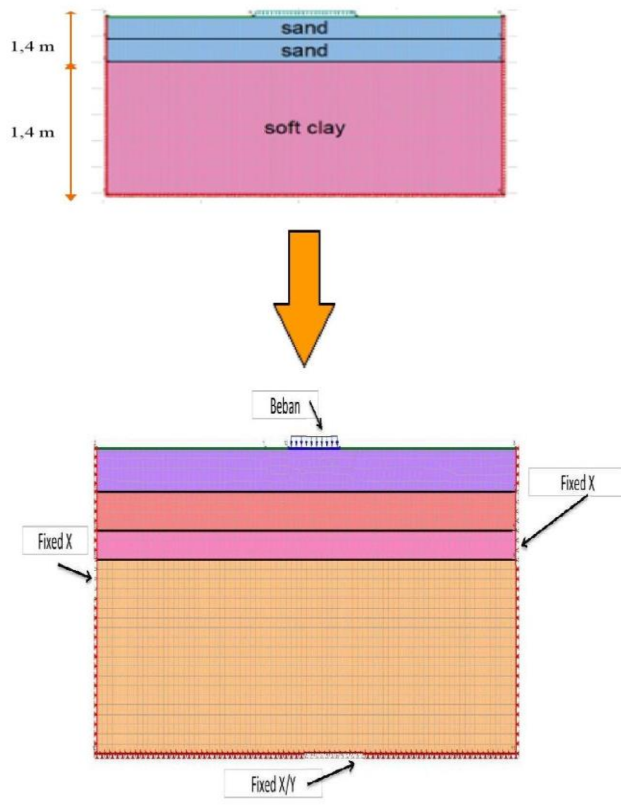


**Figure 7.** Undeformed mesh

- Input soil material, load, and geogrid parameter data to the program

SIGMA/W supports various types of analysis, including static and dynamic soil movement analysis, soil deformation analysis, consolidation analysis, etc.

- Sand

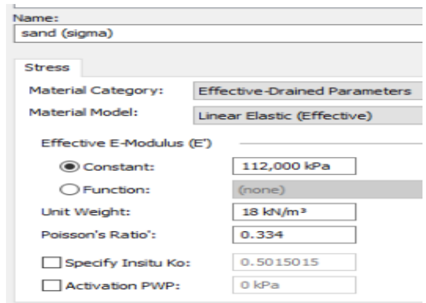


**Figure 8.** Inputting sand parameters to the program

- Medium clay

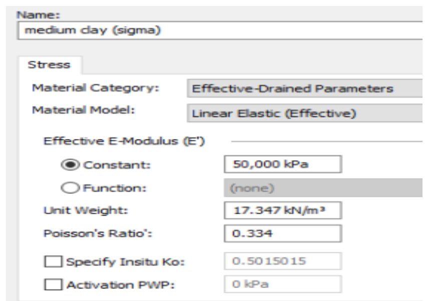


**Figure 9.** Inputting medium clay parameters into the program

- Soft clay

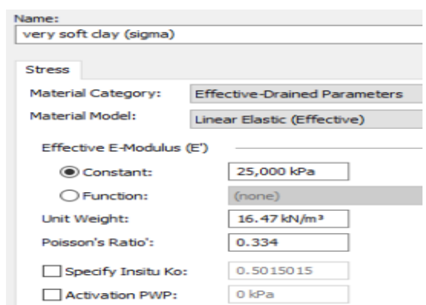


**Figure 10.** Inputting soft clay parameters to the program

- Loads

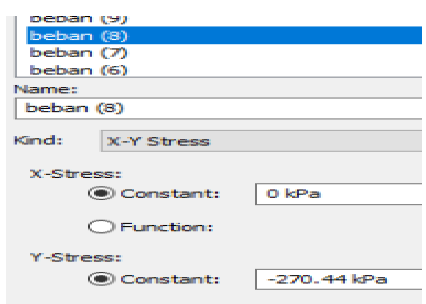


**Figure 11.** Inputting load parameters into the program

The expected results of this research are:

- Effect of soil characteristics on foundation collapse mechanism.
- The effect of the geogrid layer in increasing foundation-bearing capacity and reducing settlement.

## RESULTS AND DISCUSSION

Some of the material property values estimated using the SIGMA/W geostudio program for the soil property parameters can be seen in Table 1, while the reinforcement property parameters are in Table 2. and the foundation property parameters are in Table 3.

**Table 1.** Soil properties

| Type of soils | Clay | Medium Clay | Soft Clay |
|---|---|---|---|
| Modulus of elasticity (E) | 112000 kPa | 50000 kPa | 25000 kPa |
| Unit weight ($\gamma$) | 18 kN/m³ | 17,347 kN/m³ | 16,47 kN/m³ |
| Poisson ratio (v) | 0,334 | 0,45 | 0,45 |

**Table 2.** Reinforcement properties

| Material type | Geogrid |
|---|---|
| Modulus of elasticity (E) | 4730 kPa |

**Table 3.** Site foundation properties

| Material type | Iron plate |
|---|---|
| Modulus of elasticity (E) | 210 kPa |

- Calculation results of condition one and condition two without geogrid reinforcement

The maximum settlement in the sand layer without geogrid reinforcement of 18 mm can be seen in Figure 1. The maximum settlement in the medium clay layer without geogrid reinforcement of 20 mm can be seen in Figure 2. Then, the comparison of the maximum settlement in condition one and condition two without geogrid reinforcement can be seen in Figure 3 below:

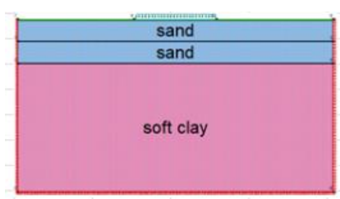


**Figure 12.** Condition 1 at sand layer

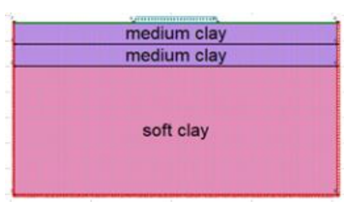


**Figure 13.** Condition 1 at medium clay layer

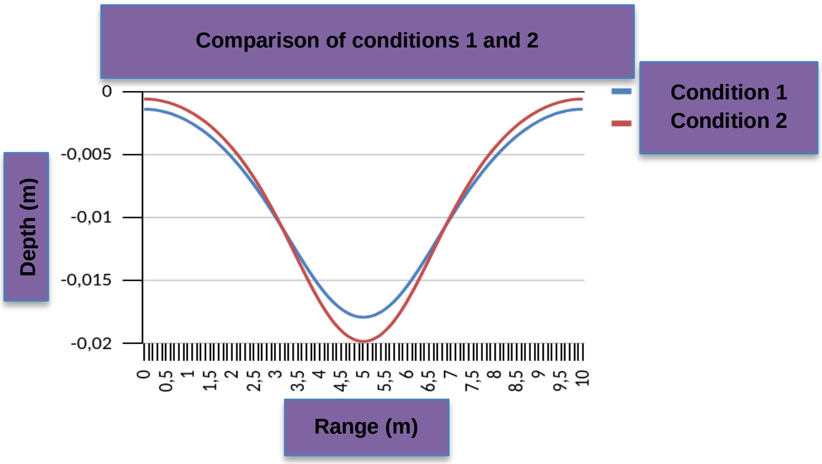


**Figure 14.** Comparison of maximum settlement in Condition 1 and Condition 2

- Calculation results of condition three and condition four without geogrid reinforcement

The maximum settlement in the sand and medium clay layer without geogrid reinforcement of 18 mm can be seen in Figure 4. The maximum settlement in the medium clay and sand layer without geogrid reinforcement of 19 mm can be seen in Figure 5. Then, the comparison of the maximum settlement in condition one and condition two without geogrid reinforcement can be seen in Figure 6 below:

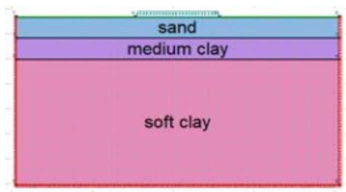


**Figure 15.** Condition 3 at sand and medium clay layer

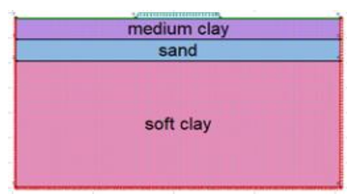


**Figure 16.** Condition 4 at sand and medium clay layer

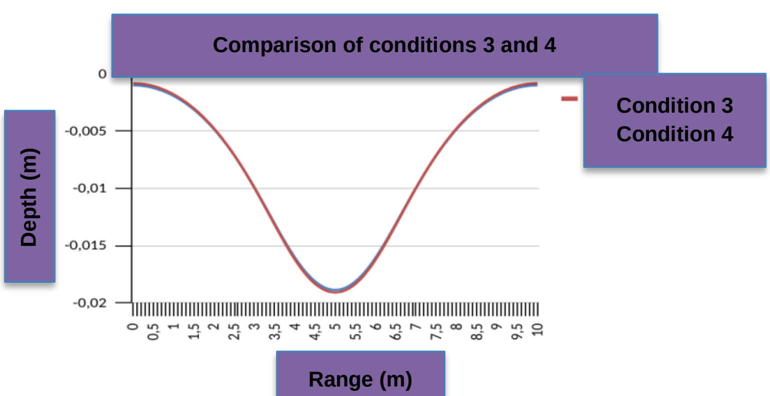


**Figure 17.** Comparison of maximum settlement in Condition 1 and Condition 2

The deformed mesh in condition 1 (sand layer), condition 2 (medium clay layer), condition 3 (sand and medium clay layer), and condition 4 (medium clay and sand layer) can be seen in Figure 7, Figure 8, Figure 9, and Figure 10 below:

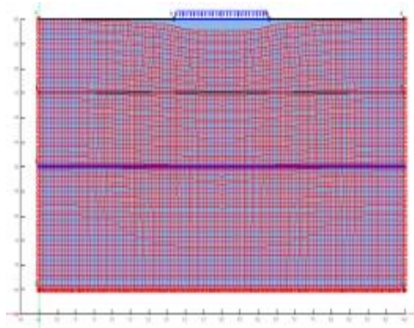

**Figure 18.** Deformed mesh in condition 1

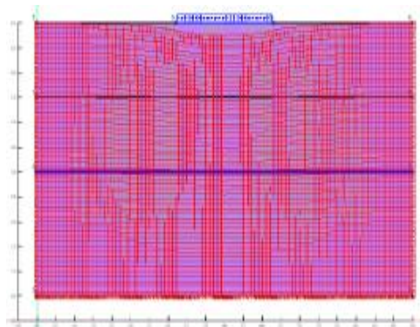

**Figure 19.** Deformed mesh in condition 2

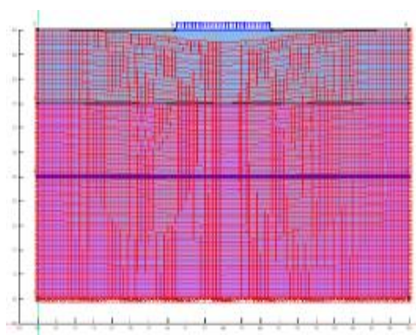

**Figure 20.** Deformed mesh in condition 3

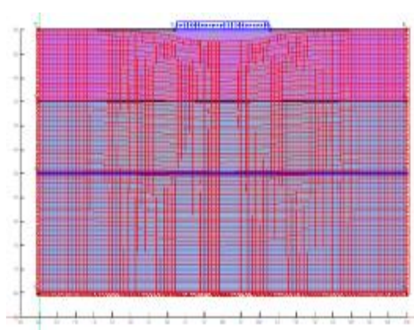

**Figure 21.** Deformed mesh in condition 4

- Calculation results of conditions 5 (sand layer) and 6 (medium clay layer) with geogrid reinforcement.

The maximum settlement in the sand layer with geogrid reinforcement over the soft clay layer was 17 mm, as seen in Figure 11. Maximum settlement in medium clay layer with geogrid reinforcement over soft clay layer of 20 mm in Figure 12. Then, the maximum settlement in the medium sand and clay layer with geogrid reinforcement in the center is 20 mm, as seen in Figure 13, and the maximum settlement in the medium clay and sand layer with geogrid reinforcement in the center was 19 mm in Figure 14.

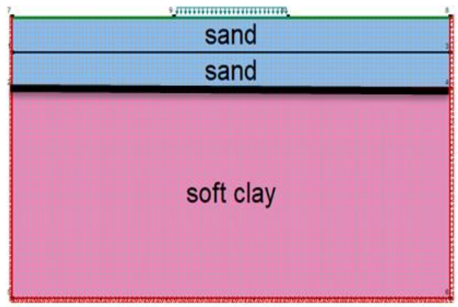


**Figure 22.** Condition 5 on the sand layer with geogrid reinforcement below


**Figure 23.** Condition 6 on medium clay layer with geogrid reinforcement below

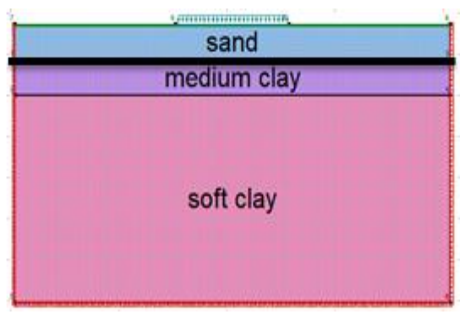


**Figure 24.** Condition 7 on sand and medium clay with geogrid reinforcement in the center

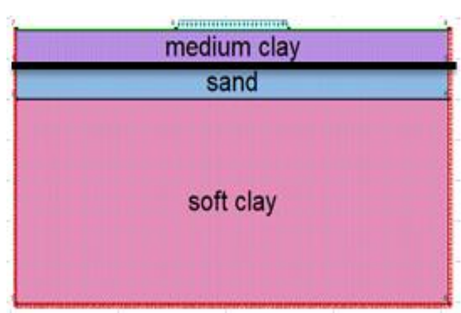


**Figure 25.** Condition 8 on medium clay and sand with geogrid reinforcement in the center

Condition H shows a decrease of 18 mm where the installation of geogrids under two layers of soil (sand and medium clay) can minimize the decline that occurred previously, can be seen in Figure 15 below:

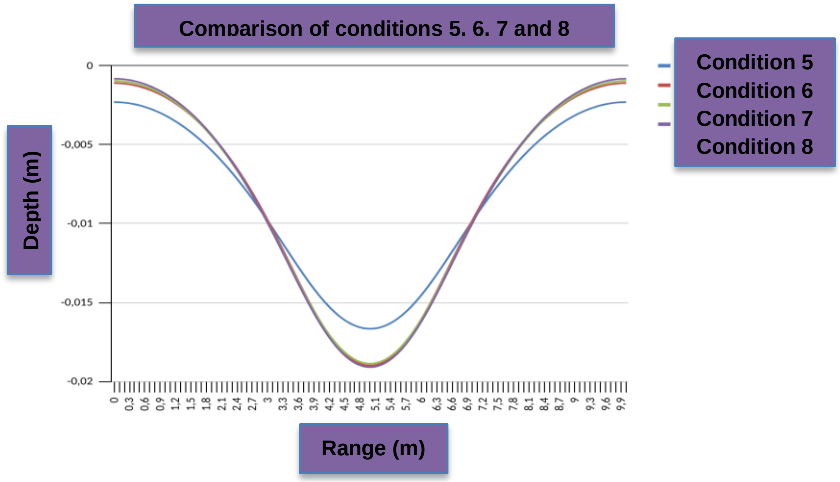


**Figure 26.** Comparison of maximum settlement in conditions 5, 6, 7, and condition 8 with geogrid reinforcement

- Calculation results of condition 3, condition 7, condition H, condition 4, condition 8, and condition F (if geogrid layers are installed under two different layers).

The settlement of condition 3, condition seven, and condition H if the geogrid layer is installed under two different layers in Figure 16, Figure 17, and Figure 18. Condition H shows a decrease of 18 mm, where geogrids are installed under two layers of sand and clay, which can minimize the previous decline in Figure 19.

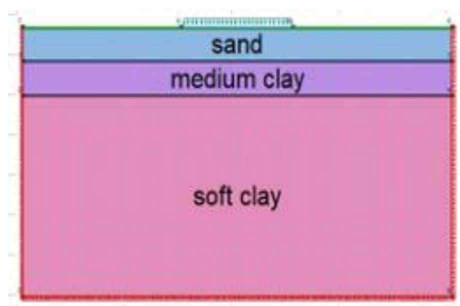


**Figure 27.** Condition 3 without geogrid reinforcement

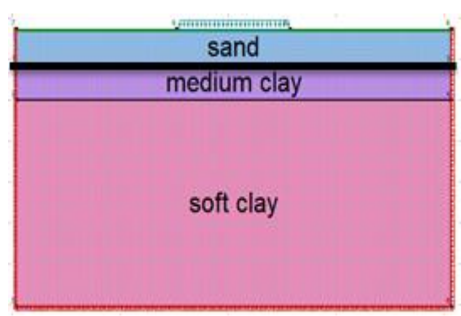


**Figure 28.** Condition 7 with geogrid reinforcement in the center

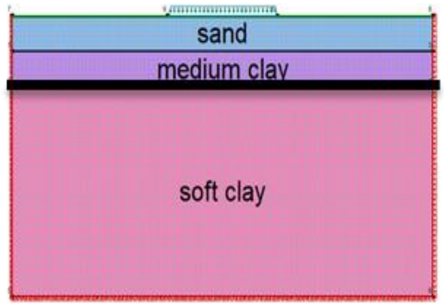


**Figure 29.** Condition H with geogrid reinforcement below

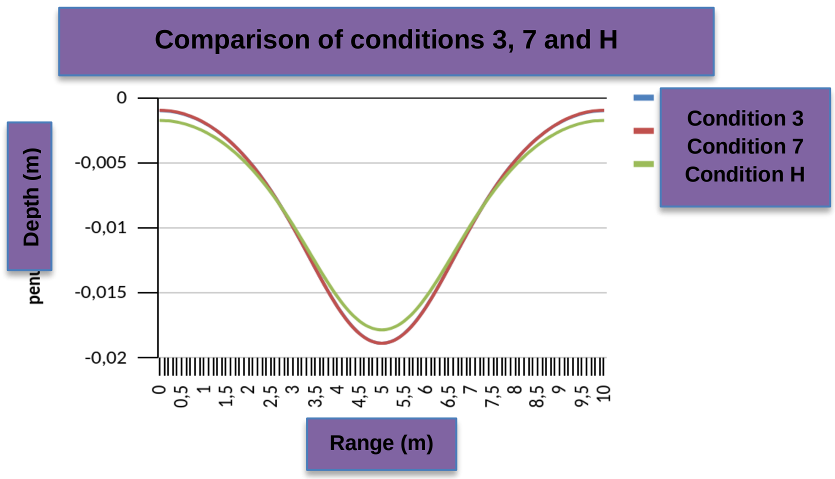


**Figure 30.** Comparison of maximum settlement in conditions 3, 7, and condition H with geogrid reinforcement below

- The settlement of Condition 4, Condition 8, and Condition H when the geogrid layer is installed under two different layers in Figure 20, Figure 21, and Figure 22. Condition H shows a decrease of 18 mm where the geogrid is installed under two layers of medium clay and sand in Figure 23.

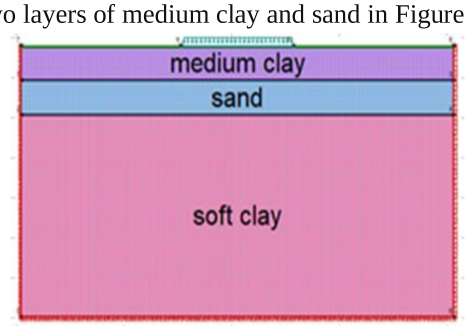


**Figure 31.** Condition 4 without geogrid reinforcement

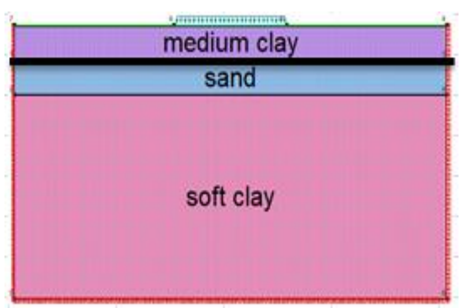


**Figure 32.** Condition 8 with geogrid reinforcement in the center

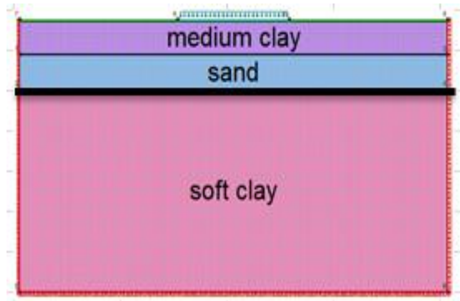


**Figure 33.** Condition F with geogrid reinforcement under

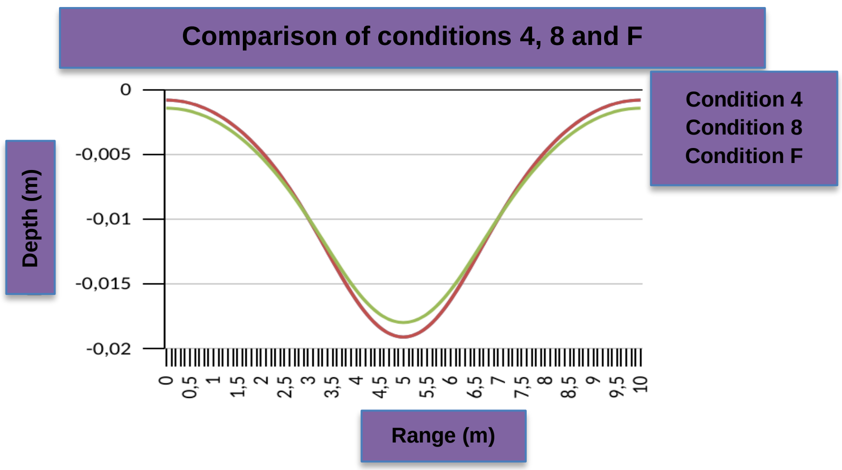


**Figure 34.** Condition F with geogrid reinforcement under

- Recapitulation of the results of the decrease that occurs in each condition

The overall decrease that occurs in each condition can be seen in Table 4 below:

**Table 4.** Recap of derivation results with SIGMA/W program

| Condition | The Max Settlement (mm) | Description |
|---|---|---|
| 1 | 18 | |
| 2 | 20 | Most medium clays - without geogrid |
| 3 | 18 | |
| 4 | 19 | |
| 5 | 17 | Smallest sand - sand - geogrid |
| 6 | 20 | |
| 7 | 20 | |
| 8 | 19 | |
| H | 18 | |
| F | 18 | |

## CONCLUSIONS

1. The foundation settlement on the medium clay layer without geogrid reinforcement is more significant than on the sand layer with geogrid reinforcement.
2. The use of a geogrid layer increases the stiffness of the soil so that the deformation that occurs (settlement) is more minor.
3. The geogrid layer placement pattern affects the deformation that occurs.

- The suggestions in this research are that the subsequent research can use other reinforcement layers with the same method, and different soil types can also use geostudio to be modeled in the laboratory or the field.

## REFERENCES


[1] Hardiyatmo, H.C. (1994). Soil Mechanics 2. First Edition. Publisher PT Gramedia Pustaka Utama. Jakarta.

[2] Beyene Negesa, Adamu. Settlement Analysis of Pipe Culvert Situated in Soft Clay Treated with Prefabricated Vertical Drained. Department of Civil Engineering, Jimma of Technology, Jimma University, Jimma, Ethiopia.

[3] Wesley, L. D. (1997). Soil Mechanics. Jakarta. Public Works Publishing House.

[4] Subianto (2002). Shallow Foundation Modeling Using Three Layers of Geotextile on Soft Clay. Journal of Faculty of Civil Engineering and Planning, Petra Christian University Vol. 4 No. 1 Page 15 - 18.

[5] Gofar, N. & K.A. Kassim (2007) Introduction to Geotechnical Engineering Part 1 & Part 2. Pearson Prentice Hall. Singapore.

[6] Gerscovich, D.M.S., Sieira, A.C.C.F., Ferreira, A.M. Numerical Simulation of the Mechanical Behavior of Buried Pipes in Trench. Foundation and Structure Engineering, State University of Rio de Janeiro, UERJ, Brazil.

[7] Nugroho (2010). Ultimate Support Behavior of Shallow Foundation on Soft Soil Reinforced by Geogrid. Journal of Civil Engineering Media Vol. X pp. 22 - 27.

[8] National Standardization Agency, SNI 8460: (2017). Geotechnical Design Requirements.

[9] Agus Nugroho, (2012). Effect of Geotextile and Bamboo Arrangement on the Support Capacity of Shallow Foundation on Peat Soil. Journal of Geomechanics 1st pp. 38 - 44, 2012.Dewi S, (2018). Deformation Analysis of Soft Soil against Geogrid Reinforcement Using Finite Element Method. Siimo Engineering Journal Vol. 2 Edition 1. pp. 01 - 08, 2018.

[10] Ambhita, (2020). An analysis of the effect of pressure above clay and sand layers on the deformation of pipes using LVDT sensors.

[11] Sarah Alwiyah, (2021). Testing the Support Capacity of Sand Soil with Geogrid Reinforcement. Journal of Saintis Vol. 21 No. 01 pp. 01 - 10, 2021.

[12] Johan Oberlyn, (2021). Analysis of Geogrid as Reinforcement in Retaining Wall. Journal of Exata Vision Vol. 2 No. 1 pp. 111 - 118, 2021.

[13] Bambang Setiawan, Galuh Chrismaningwang, Dicky Adi Renaldi, (2023). Analysis of Soft Soil Consolidation Acceleration with Preloading Method Using Geostudio 2018 R2 Software. Journal of Civil Engineering Matrix Vol 11, No 3 (2023): September.

[14] Tiorivaldi, Bangun Marpaung, Proceeding (2024). Numerical Study of Anchored Piles Using Geostudio Sigma/W Modeling. In Proceedings of the 4th International Seminar and Call for Paper (ISCP UTA ’45 JAKARTA 2023), pages 422 - 426 ISBN: 978-989-758-691-0; ISSN: 2828-853X.

[15] M. Aziz Komarudin, (2024). Effect of Adding Surcharge Load Stress on the Acceleration of Soft Soil Consolidation. Civil Building Management and Engineering Journal Vol: 1, No 4 Page 1 - 8.

[16] M. Sahrul R. (2024). Numerical Modeling of Soil Embankment on Soft Soil Using Variation of Expanded Polystyrene (EPS) Geofoam Material Type. Civil Building Management and Engineering Journal Vol: 1, No 4 Page 1 - 8.