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SHALLOW FOUNDATION ANALYSIS OF A TWO-STORY HOUSE ON A FORMER PADDY FIELD

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ABSTRACT

The foundation becomes an element that receives forces from the building construction above, channels, them to the subsoil, and serves to support the building so that there is no structural failure from the bottom. The sole foundation itself is a foundation that supports structures directly on the ground whose depth is arguably shallow, or generally at most 3 meters above ground level. This shallow foudndation is analyzed and designed in such a way as to be able to support a two-story house building with soil conditions that are former rice fields. This research starts from analyzing existing case studies. Before proceeding with the data calculation process, it is necessary to understand the basic theory and also the formulas that will be used in this research. Afer that, the data calculation process and sondir test results were carried out, which can be concluded that the dominant soil is dense clay. Therefore, a shallow foundation is still feasible to use for lower structure. Next thing is to do the planning and calculation based on bearing capacity and settlement permit. The planning results will then be analyzed to determine the coefficients used in determining the costs in the use of shallow foundations. In this study, the cost calculation that has been carried out has a total of Rp 119,678,664.38. From the total costs, it can be concluded that the use of shallow foundations still makes sense and is one of the best options in the construction of this two story house.

Keywords: *foundation, shallow foundation, dense clay, price*

1. INTRODUCTION

Although Indonesia is a country that has a large area of rice fields, it cannot be denied that not all available rice fields are used for agriculture. Many rice fields are still empty (not used for agricultural activities). Bali is one of the provinces and islands that is very famous for its cultural diversity and tourism. Many tours in Bali are not only entertainment venues but rice fields that become tourist attractions.

Figure 1. Soil Distribution Map in Bali

Image Source: Lokerbali.info

Many rice fields are no longer used or have been converted and many rice fields that are no longer used, are used to build a two-story house. Because of this, this research aims to find out what foundations are suitable for construction in terms of bearing capacity, settlement, and costs required in construction.

Based on what has been presented in the background of the issue, it will result in the formulation of the problem as follows:

- Analyze the bearing capacity generated by shallow foundations. Calculating the amount of settlement that occurs in a different elevation building on single pile and group pile if using a friction piles.
- Analyze the settlement that occurs in shallow foundations based on the design results.
- Calculate the cost required based on the design results at each foundation position.

Based on the formulation of the problem, the objectives of this study are as follows:

- Knowing the bearing capacity produced by shallow foundations.
- Knowing the settlement that occurs in shallow foundations based on design results.
- Knowing the costs required based on the design results at each foundation position.

Literature

The foundation is the initial stage in the construction of a building. The foundation is the lowest structural component of the building that transmits the building to the soil or rock underneath, refers to [1]. In planning the foundation consists of two important parts, namely the ultimate bearing capacity of the soil beneath the foundation and the limit of the largest settlement that meets the applicable requirements without causing collapse of the upper structure. There are many areas that have layered soils of different heights and soil types. There are hard soil layers on top of soft soil layers or vice versa. This needs to be considered during foundation planning.

Soil Bearing Capacity Analysis of Shallow Foundations

This research uses The Terzaghi Method and The Meyerhof Method. According to [2], for The Terzaghi Method can be formulated in equation (1).

$$q_{ult} = c.N_c.\left(1+ 0,3\frac{B}{L}\right) + \gamma.D_f.N_q + 0,5.\gamma.B.N_y.\left(1 - 0,2\frac{B}{L}\right)$$

With q_{ult} = maximum bearing capacity, γ = soil content weight (kN/m^3), c = soil cohesion, B = radius of circular foundation, L = foundation length, D = foundation depth, $N_c N_q N_y$ = bearing capacity factor.

According to [3] The Meyerhof Method can be seen in equation (2).

$$q_{ult} = c.N_c.F_{es}.F_{ed}.F_{ci} + \gamma.D_f.N_q.F_{qs}.F_{qd}.F_{qi} + 0,5.\gamma.B.N_y.F_{ys}.F_{yd}.F_{yi}$$

With q_{ult} = ultimate bearing capacity, c = soil cohesion, B = foundation width, γ = soil content weight, D_f = foundation depth, F_{cs} F_{qs} F_{ys} = form factor, F_{ed} F_{qd} F_{yd} = depth factor, F_{ci} F_{qi} F_{yi} = load slope factor, N_c N_q N_y = bearing capacity factor.

Shallow Foundation Soil Settlement Analysis

The settlement consists of elastic settlement and consolidation settlement. For elastic settlement that occurs in soil occupied by shallow foundations with saturated clay soil types can be seen in equation (3). [4]

$$S_e = A_1 A_2 \frac{q_o B}{E_s}$$

With S_e = Elastic settlement, A_1 = f (H/B, L/B), A_2 = f(Df/B), L = foundation length (m), B = foundation width (m), Ds = foundation depth (m), H = depth of foundation base to stiff layer (m), q_o = net pressure received by the foundation, μs = soil poisson's ratio, E_s = spil elastic modulus.

For the decrease in consolidation can be seenin equation (4).

$$\Delta S_c = \left[\frac{C_c H}{1 + e_0}\right] \mathrm{Log}\left[\frac{\sigma'_0 + \Delta\sigma'_0}{\sigma'_0}\right]$$

With S_c = primary consolidation settlement (m), e_0 = initial pore number of soil, C_c = compressibility index, C_s = expansion index, H_c = thickness of soil layer (m), σ'_0 = effective overburden pressure (kN/m^2), σ'_0 = preconsolidation pressure (kN/m^2) =, $\Delta\sigma'_0$ = pressure change (kN/m^2).

Permission of the settlement

Based on [5] the amount of the settlement that occurs and the difference in the settlement that is permitted based on the function and stability of the structure has the following conditions:

$$\text{Total Settlement} < 15 \text{ cm} + b/600$$

Problem Formulation

Some of the problems that are correlated to this topic are:
1. How is the calculation that will be generated for shallow foundation in the area?
2. How is the foundation settlement for shallow foundation in the area?
3. How is the foundations and dimentions that will be used for design and also calculate coefficient for constructionbudget plan?

2. RESEARCH METHOD

The research methods that can be used in this research are laboratory studies and case studies. Laboratory study is a research method by conducting experiments on a object or material in the laboratory. Case study is a research method by analyzing real cases. In this research, the case study research method will be used.

Before conducting data processing, literature studies need to be sought in order to understand the theoretical basis that needs to be considered and collect the formulas used for analysis. After the literature study is completed, it will be continued with soil data processing.

This research is useful to determine to difference in the cost of foundation placement in the construction of a two-story house building on former rice fields as seen from the bearing capacity of the foundation and soil settlement. This research is conducted by processing soil data to produce final soil parameters. The final soil parameters are used to calculate the bearing capacity and subsidence that occurs. The bearing capacity and soil settlement will be compared with the load per column according to the position. After knowing the design results, a cost analysis will be carried out according to the size and dimentions of the design. After cost is obtained, it will be compared to make conclusions and suggestions based on the result of the analysis.

3. RESULTS AND DISCUSSIONS

Project Data

To calculate the bearing capacity of foundations and ground settlement, project data in the form of sondir data in the Ubud area. Bali is used. The project data consists of 2 points. From this project data, the final parameters will be created that will summarize the soil conditions at the case study site. The final parameters of the soil can be seen in Table 1.

Table 1. Soil Parameters

Elevation (m)		Depth (m)	Type of Soil	Consistention	γ_{sat} (kN/m^3)
3	0	1.5	Clayey	Dens	18
0	1	0.5	Clayey Silt to Silty Clay	Soft	21.8
1	2	1.5	Sandy Silt to Clayey Silt	Soft	21.8
2	3	2.5	Sandy Silt to Clayey Silt	Soft	21.8
Elevation (m)		**Depth (m)**	**Type of Soil**	**Consistention**	**γ_{sat} (kN/m^3)**
3	4	3.5	Sandy Silt to Clayey Silt	Soft	21.8
4	5	4.5	Silt Sand to Sandy Silt	Soft	21.8
5	6	5.5	Silt Sand to Sandy Silt	Soft	21.8
6	7	6.5	Silt Sand to Sandy Silt	Soft	21.8
7	8	7.5	Silt Sand to Sandy Silt	Soft	18.6
8	9	8.5	Sand	Medium Stiff	20.2
9	10	9.5	Sand	Medium Stiff	19.8

Elevation (m)		e_0	C_c	C_s	φ' (°)	S_u (kg/cm²)	C' (kPa)	E_u (MPa)
3	0	0.74	0.196	0.112	31.2	0.6118	24	38
0	1	0.74	0.196	0.112	31.2	0.4589	24	38
1	2	0.74	0.196	0.112	31.6	0.4589	26	38
2	3	0.74	0.196	0.112	31.8	0.4589	26	38
3	4	0.729	0.192	0.1103	32	0.4589	26	38
4	5	0.724	0.189	0.1097	33.4	0.7138	32	46
5	6	0.724	0.189	0.1097	33.4	0.7138	34	50
6	7	0.724	0.189	0.1097	34.8	1.2237	42	58
7	8	0.724	0.189	0.1097	35.8	1.6315	56	86
8	9							
9	10							

Building size and load weight

The different elevation building has a configuration of 40 m × 12 m. All floors of the different elevation buildings use the same building configuration. Configuration illustration can be seen in Figure 2 and the load weight to be used for each floor can be seen in Table 3.

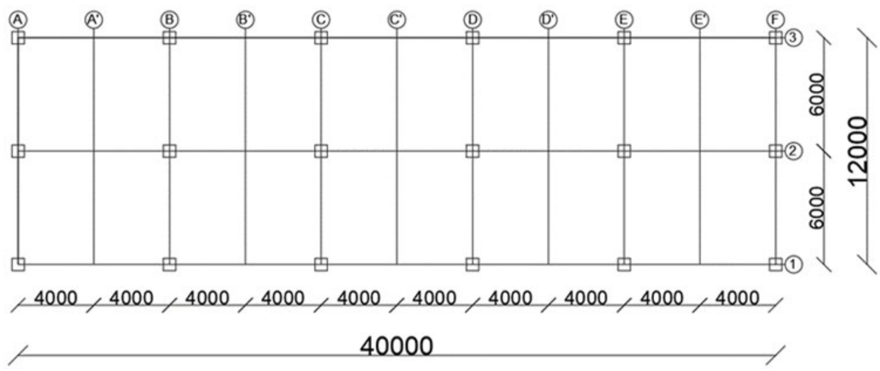

Figure 2. Layout

Table 2. Structure Load

Load Type	**Specific Gravity** (kN/m²)	**Area (m²)**	**Total (kN)**

Plate	4.79	480	2299.2
Dak Roof	0.96	480	460.8
		Total Live Load (kN)	2760

Table 3. Total Dead Load of Two-Story House

Load Type	**Spesific Gravity** kN/m^2	**Area (m^2)**	**Length (m)**	**Wide (m)**	**Height (m)**	**Count**	**Total (kN)**
Roof Plate	24	480			0.13	1	1497.6
Plate 2	24	480			0.13	1	1497.6
Vertical Main Beam	24		144	0.25	0.5	1	432
Horizontal Main Beam	24		240	0.7	0.35	1	1411.2
Secondary Beam	24		120	0.4	0.25	1	288
Hanger	0.068	480				2	65.900688
Floor Covering	0.392	480				2	376.57536
Specs (2 cm)	0.411	480				2	395.404128

Table 3. Total Dead Load of Two-Story House (Continuation)

Load Type	**Spesific Gravity** kN/m^2	**Area (m^2)**	**Length (m)**	**Wide (m)**	**Height (m)**	**Count**	**Total (kN)**
Mechanical & Electrical	0.245	480				2	235.3596
Ceiling	0.107	480				2	103.558224
Column	24		0.65	0.65	4	36	1460.16
		Total (kN)					7763.358

Dead Load	=	7763.358 kN
Live Load	=	2760 kN
Dead + Live	=	10523.358 kN
Total Load Each	=	

Column $= \frac{10523.358 \text{ kN}}{18}$
= 584.631 kN
= 60 Ton
Corner Column Load = 1/4 × 60 ton
= 15 to n
Edge Column Load = ½ × 60 ton
= 30 ton
Inner Column Load = 60 ton

Calculation of bearing capacity and settlement of shallow foundations

Calculation of the bearing capacity of shallow foundations is calculated according to the position of the foundation, namely corner, edge, and depth. For the calculation of carrying capacity using The Terzaghi Method and The Meyerhoff Method. The results of the calculation of carrying capacity and settlement can be presented in Table 4.

Table 4. Results of The Final Calculation of The Point Bearing Capacity

Position	Load (ton)	B (m)	L (m)	qall (ton)	Settlement (mm)	Settlement Permit (mm)
Corner	15	0.7	0.7	46.9	81.50	151.17
Edge	30	1	1	98.9	125.79	151.67
Inner	60	2	2	437	148.76	153.33

Draft cost budget

The cost budget calculation uses an analysis of the unit price of work from the regulation of The Minister of Public Works and Housing of The Republic of Indonesia number 1 of 2022. And for the price of wages and goods taken from the source with the latest prices. The following are the results of the cost analysis shown in Table 5 and 6.

Table 5. Total Cost

Position	Price (Rp)
Corner	16,065,015.29
Edge	53,073,075.79
Inner	50,540,573.30
Total	119,678,664.38

Table 6. Cost of Each Point

Position	Price (Rp)
Corner	4,016,254

Edge	5,307,308
Inner	12,635,143

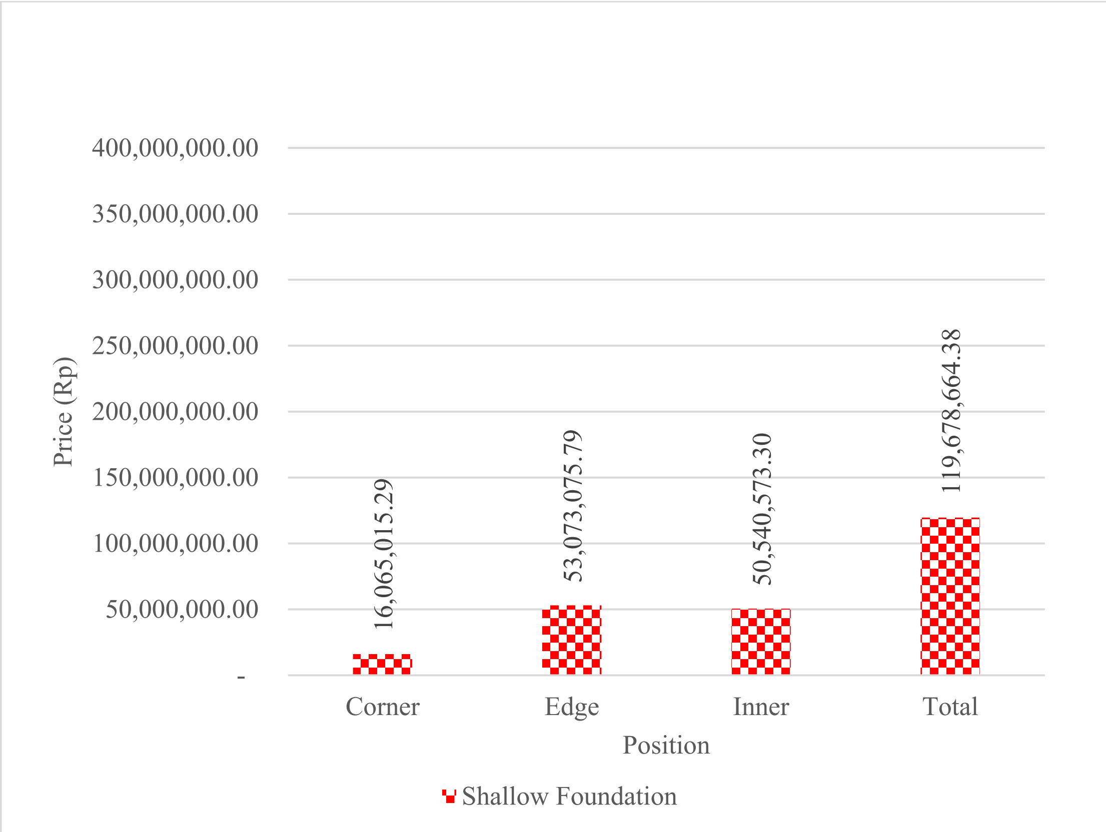

Figure 3. Graph of Foundation Price Each Position

4. CONCLUSIONS AND SUGGESTIONS

Based in the calculations performed, it can be concluded that:

1. Based on the results of the calculation of the bearing capacity, it is obtained that the bearing capacity is able to withstand the centralized load of the structure at each foundation location with the maximum design.
2. Based on the results of the settlement calculation obtained for the shallow foundation settlement has met the permit.
3. Based on the results of the cost comparison, it can be concluded that the shallow foundation has a fairly affordable price.

Based on the results of the research conducted, the authors can provide suggestions:

1. Calculations can be checked using a calculation application to find out accurate results.
2. Because the only available data is sondir data, it is recommended that laboratory tests or boring logs be conducted to complete the design parameters that will be used and improve the accuracy of the calculations.

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