



Analysis of Soil Bearing Capacity and Foundation Settlement in the Construction of Gupusmu Puspallad III Jakarta

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ABSTRACT

The ammunition center warehouse and military equipment center are strategically important for Army operations. In the design, an analysis of soil bearing capacity and foundation settlement is required to maximize the structural load of the ammunition center building. Based on this, this study aims to analyze the soil-bearing capacity and potential deformation of the foundation in response to the structural loads applied to the construction of the Ammunition Center Warehouse and Army Equipment Center III in Jakarta. The investigation involved six lightweight sondir points, each with a capacity of 2.5 tons, to obtain a cone value of 250 kg/cm². The information obtained from the sondir test was used to determine the bearing capacity of the soil and the amount of foundation settlement that might occur. Based on the analysis and calculations, a shallow foundation, namely a 2-meter-deep footing, was selected. The allowable soil bearing capacity is 1.18 kg/cm², and the foundation settlement at P1 is about 2.8 cm and 1.3 cm at P2. This research is expected to be the basis for designing ammunition warehouse foundations in military institutions.

Keywords: Ammunition center warehouse, footing foundation, soil bearing capacity, foundation settlement

1. INTRODUCTION

Based on [1] what regulates ammunition maintenance procedures within the Ministry of Defense and the Indonesian Armed Forces, each authorized official is required to carry out ammunition maintenance activities starting from the stockpile warehouse, and transportation, to the user unit. This includes examination, inspection, preventive maintenance, repair, removal and destruction to ensure ammunition is always in good condition and ready for use.

Infrastructure development in the military sector requires careful consideration of the sustainability and safety of building structures. Central ammunition depots and military equipment centers are strategically critical to Army operations. The success of these operations depends heavily on the structural stability and durability of the building. Therefore, this study aims to analyze the bearing capacity of the soil and the potential deformation of the foundation in response to the structural loads applied to the construction of the Ammunition Center Warehouse and Army Equipment Center III in Jakarta.

This study uses geotechnical analysis to examine the geomechanical characteristics of the soil at the construction site. The data used are sondir test data to assess the bearing capacity of the soil. In addition, foundation deformation calculations were performed to determine the potential settlement that could result from the anticipated structural loads.

The analysis of soil-bearing capacity and foundation settlement has significant implications, especially in the aspects of structural planning and risk mitigation. The information obtained is expected to form the basis for developing optimal design strategies and assist in anticipating potential geotechnical risks that may arise during and after construction.

This research provides practical and theoretical contributions to structural sustainability and soil geomechanics in the context of construction sites. The findings are expected to be a valuable reference for further development in the field of geotechnical and construction engineering of military infrastructure.

2. THEORY AND METHODS

2.1 Theory

Soil Investigation

Soil investigation is an important activity in the geotechnical field that aims to obtain soil properties and characteristics for engineering design purposes. According to [2], there are two types of soil investigation: field investigation (in situ tests) and laboratory tests. One of the field investigations (in situ) is the sondir test.

Sondir Test

In accordance with [3], stability analysis and foundation design calculations are often carried out for the design of foundation soil structures using total stress and effective stress parameters. Penetration resistance parameters can be obtained in various ways, including by conducting Sondir or CPT (Cone Penetration Test) [4]. Sondir tests, also known as Cone Penetration Test (CPT), are often conducted to estimate the bearing capacity of deep foundations. However, this method can also be used to estimate the bearing capacity of

shallow foundations. The test involves inserting a cone into the soil and measuring the soil resistance at the tip of the cone, as well as the soil adhesion to the cone shaft and blanket. This gives values for tip resistance (q_c) and blanket attachment (f_s) [5]. Table 1 shows the classification of soil consistency of the cone tip resistance [6].

Table 1 Soil consistency based on conical tip resistance

Consistency	Cone Resistance (q_c) Kg/cm ²
Very Soft	<5
Soft	5-10
Medium Stiff	10-35
Stiff	30-60
Very Stiff	60-120
Hard	>120

Soil Support Using Deep Foundations

Calculation of bearing capacity of deep foundations under vertical load can be done by utilizing soil investigation data (sondir). The bearing capacity of deep foundations can be determined based on field and laboratory data contained in soil investigation reports. One method for this calculation is the Mayerhorf method, which shows that the pile toe resistance is equal to the sondir toe resistance within the range of $2/3 q_c$ to $1.5 q_c$. For practical purposes, $q_p = q_c$ can be used [7]. The blanket resistance of the pile can then be obtained through total friction (Total Sticky Resistance = JHL) multiplied by the circumference of the pile. The method uses equation (1) as follows:

$$q_{ult} = q_p \cdot A_p + JHL \cdot k11 \quad (1)$$

This equation typically uses a safety factor = 3 for end resistance and a safety factor = 5 for friction in order to determine the allowable bearing capacity of the foundation. The calculation is done with the following equation (2).

$$q_{ult} = \frac{q_p \cdot A_p}{3} + \frac{JHL \cdot k11}{5} \quad (2)$$

Where,

A_p = cross-sectional area of the pole

$k11$ = pole circumference

JHL = amount of sticky resistance

q_p = Pole tip resistance

Soil Support using Shallow Foundations

In order to determine the ultimate bearing capacity value of a foundation in both sand and clay soils using sondir data, calculations are made with equations (3) and (4) as follows [4].

$$q_u = \frac{q_c}{15} \quad (3)$$

$$q_i = \frac{q_u}{FK} \quad (4)$$

Where,

- q_c = conus resistant
- q_u = ultimate bearing capacity of soil (ton/m²)
- q_i = soil allowable bearing capacity (ton/m²)
- 15 = reduction factor
- FK = safety factor

Land Subsidence with Pile Foundations

Calculation of safe soil bearing capacity against collapse does not guarantee that the foundation settlement will remain within the specified limits. Therefore, a settlement analysis must be performed. In this regard, it should be considered that buildings are generally sensitive to excessive settlement [8].

Foundation settlement analysis is a complex challenge due to various factors, such as the disturbance of soil stress during the piling process and the uncertainty of load transfer from the pile to the soil. One approach to estimating settlement in pile foundations is the Mayerhorf method, which can be performed using CPT data. When a pile foundation is subjected to a load, the pile will immediately shorten and the surrounding soil compresses [9]. Calculation of foundation settlement is very important to prevent excessive settlement and structural failure [8]. The settlement of the pile foundation can be solved by applying the empirical method, which is obtained using the following equation (5) [5].

$$S = \frac{D}{100} + \frac{Q \cdot L}{A_p \cdot E_p} \quad (5)$$

Where,

- S : total settlement at the masthead (m)
- D : pole diameter (m)
- Q : working load (ton)
- L : pole length (m)
- A_p : cross-sectional area of the pole (m²)
- E_p : modulus of elasticity of the pile (ton/m²)

Land Subsidence Due to Shallow Foundations

The settlement in homogeneous soils of infinite thickness, the equation for the immediate settlement or elastic settlement of a foundation on a uniform ground surface can be written in the form of Equation (6) below [5].

$$S_i = \frac{q \cdot B}{E} (1 - \mu^2) \cdot I_p \quad (6)$$

Where,

- S_i = immediate decline (m)
- q = pressure at the base of the foundation (kN/m²)
- B = foundation width (m)
- E = modulus of elasticity (kN/m²), where Bowles (1977) made calculations from the collection of sondir data, in sandy soil the value of E is 3 q_c (kg/cm²). While in clay soil the value of E is 2 to 8 q_c (kg/cm²).

μ = Poisson's ratio, which for sandy soil is 0.3 while for clay soil is 0.4.

I = influence factor

The influence factors on the foundation can be seen in Table 2 [5].

Table 2 Influence factor on foundation

Foundation Shape		Flexible (I_p)			Stiff	
		Center	Corner	Avarage	I_p	I_m
Circle		1.00	0.64	0.85	0.88	-
Square		1.12	0.36	0.95	0.82	3.70
Rectangle						
L/B	1.5	1.36	0.68	1.20	1.06	4.12
	2.0	1.53	0.77	1.31	1.20	4.38
	5.0	2.10	1.05	1.83	1.70	4.82
	10.0	2.52	1.26	2.52	2.10	4.93
	100.0	3.38	1.69	2.96	3.40	5.06

2.2 Methods

The methodology used in this research is to take a quantitative approach, where data obtained from sondir tests will be collected. The soil investigation in this study includes 6 (six) light sondir points with a capacity of 2.5 tons to obtain a conus value of 250 kg/cm². The essence of the sondir test is to use the static pressure of the penetrometer tool to insert the conus into the soil and record the soil resistance to the entry of the conus, so that the bearing capacity of the soil can be determined. After the sondir test, the value obtained will be processed to determine the recommended foundation, calculate the bearing capacity of the foundation and the settlement of the foundation. For more details can be seen in Figure 1

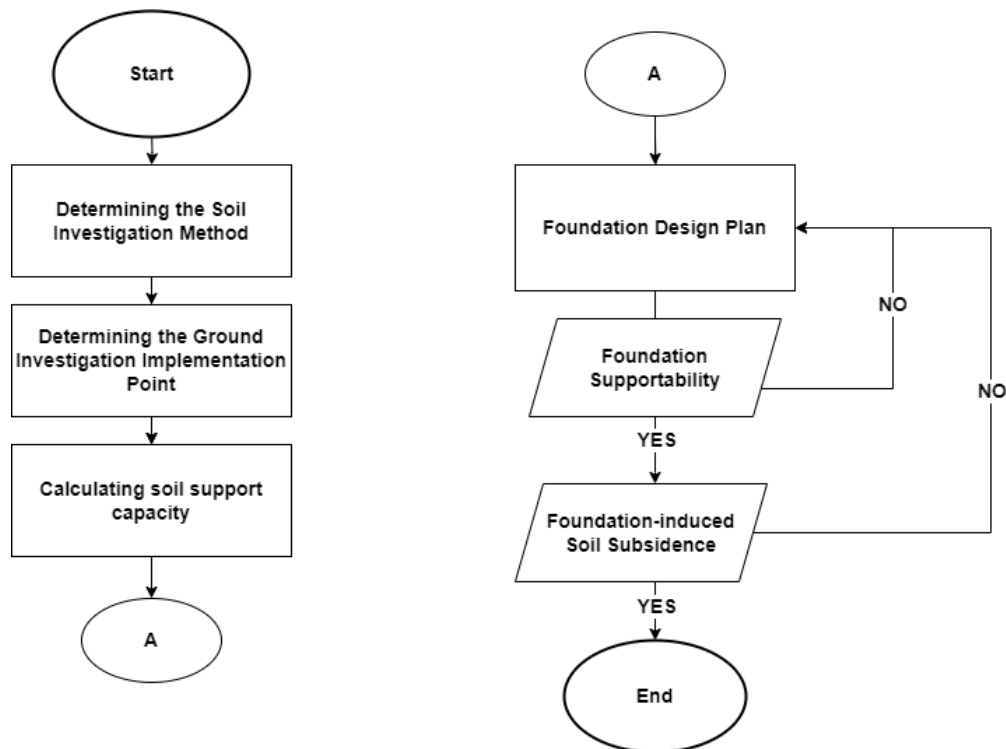


Figure 1 Flowchart of the research methodology

3. RESULT AND DISCUSSION

Sondir Tests Result

Data from the manometer readings on the sondir include the conical tip resistance shown as q_c in kg/cm^2 and the total resistance in kg/cm^2 . Skin friction is calculated with the symbol SF (kg/cm), while total skin friction uses the symbol TSF (kg/cm). The sondir graph illustrates the relationship between conus resistance and depth, and total skin friction and depth. Sondir penetration test results, particularly cone resistance (q_c) data, can be used to determine the relative density of soil layers.

After the soil investigation using the sondir test, some data were obtained in the form of soil type and soil bearing capacity values shown in Table 3.

Table 3 Soil layer arrangement and conus resistance values

Depth (m)	Type of Soil	Consistency	Conus Resistance (q_c) kg/cm^2
0.00-9.00	Silty clay	<i>Medium stiff</i>	≤ 20
9.00-18.00	Silty clay	<i>stiff</i>	20 - 40
18.00-24.00	Silty clay	<i>Very stiff</i>	50 - 200
≥ 24.00	Hard soil	<i>Hard layer</i>	≥ 250

The topsoil layer, down to a depth of 9.00m, is estimated to be of medium stiffness and has a fairly good bearing capacity. Below it, there is a layer of clayey silt with a stiffness ranging from stiff to very stiff, which ends with a hard layer at a depth of 24.00 meters.

Recommended Foundation Design

From the sondir test data conducted, the construction of the ammunition center warehouse uses a shallow foundation, in the form of a site foundation where each warehouse building has two site foundations with different dimensions. The foundation design plan can be seen in Table 4 and Figure 2.

Table 4 Plan foundation dimensions

NO	Foundation	L (mm)	B(mm)
1	P1	2150	2150
2	P2	1000	1000

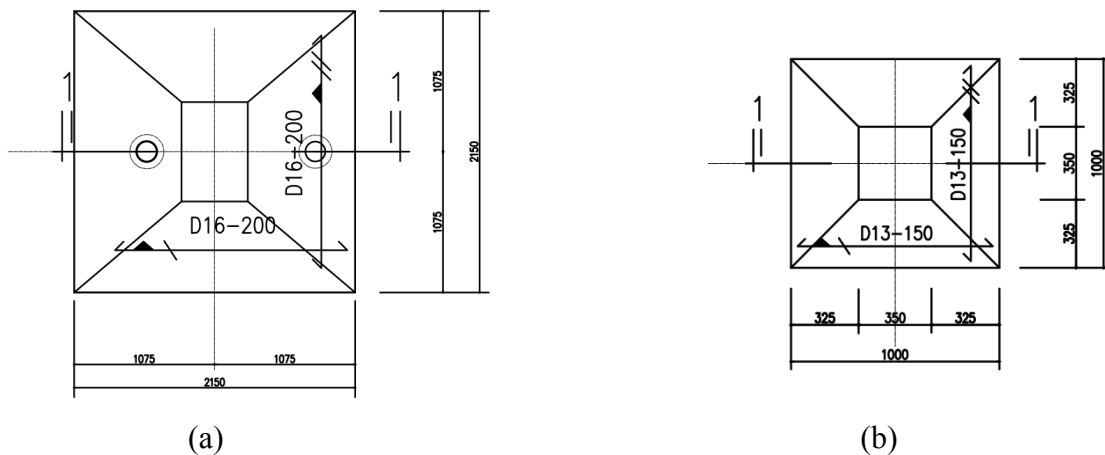


Figure 2 Recommended foundation design (a) P1 foundation, (b) P2 foundation

In the design of the foundation plan used, the footing foundation where the placement of each type of foundation is adjusted so that it can support the load given by the warehouse structure. P1 foundation is a site foundation whose position is around the warehouse, while for P2 foundation is inside the warehouse building. More clearly can be seen in the foundation plan in Figure 3.

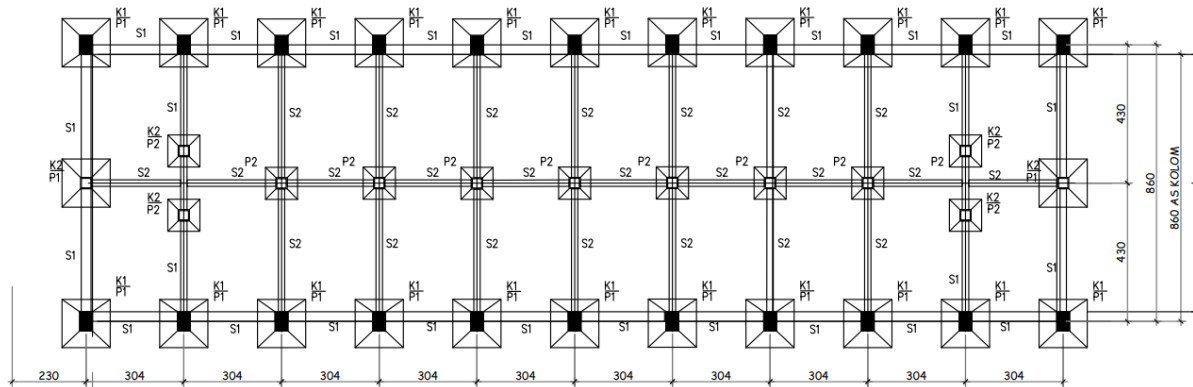


Figure 3 Foundation plan of warehouse building

Foundation Supportability

The recommended bearing capacity of shallow foundations is calculated using equation (1) and the results are shown in Table 5.

Table 5 The q_{all} value at each soil depth

No	Depth (m)	q_c avr (kg/cm)	q_{all} (kg/cm ²)
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1	0.00	0.00	0.00
2	0.50	13.00	0.91
3	1.00	15.83	1.06
4	1.50	15.67	0.98
5	2.00	17.67	1.18

From the analysis, it is found that the recommended foundation depth is at a depth of 2 meters with a bearing capacity of 1.18 kg/cm². A depth of 2 meters was chosen because the planned warehouse building is a 1-story building so the foundation needed does not need to be too deep and the load borne by the foundation is also not too heavy.

Foundation Setback

The foundation settlement is calculated by the equation (6), where from the literature the load on the warehouse is taken as q by summing dead load of 18kg/m² and live load of 600kg/m² [10]. After knowing the value of q , assuming the value of E is 50000 kg/m², μ 0.4 and the influence factor value is 0.95, so we can calculated and displayed in Table 6.

Table 6 Foundation settlement value

No	Foundatio n	Settlement (m)
1	P1	0.021206
2	P2	0.009863

CONCLUSION

From the analysis and calculations carried out, it is found that the recommended foundation is a shallow foundation, namely a footing foundation with a depth of 2 meters where the allowable bearing capacity of the soil is 1.18 kg/cm² and the foundation settlement that occurs is about 2.1 cm at P1 and 0.98 cm at P2. This research is expected to be the basis for designing the ammunition warehouse foundation. In the future, further research is needed with field data observation in the form of soil property data to provide a more optimal foundation design.

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