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Comparative study of the bearing capacity of square and rectangular shallow foundations based on Terzaghi and Meyerhof methods

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ABSTRACT

Foundation integrity is paramount in evaluating building reliability. This research investigates Building X, a two-story structure with shallow footing foundations on soft soil in East Jakarta. The study compares bearing capacity using Terzaghi and Meyerhof methods, with structural loads modeled in ETABS. Results show Terzaghi's ultimate bearing capacity (qu) is 15076.00 kg/m², while Meyerhof's is 22017.68 kg/m². Consequently, Terzaghi provides a more conservative Safety Factor (SF). The technical implications are critical for decisions: Terzaghi's results serve as a lower-bound safety limit to prevent catastrophic shear failure, while Meyerhof offers comprehensive geometry-based parameters. Many points exhibit an SF below the 3.00 standard, with several below 1.00 under Terzaghi analysis. This study contributes to building audits by bridging classical theories with practical Building Functionality Certificate (SLF) requirements in soft soil regions. The findings underscore the necessity for future numerical validation using Plaxis 2D to account for complex non-linear soil-structure interactions and precise settlement behavior.

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1. INTRODUCTION

(Sarifah et al., 2023) The foundation is one of the building structures located at the lowest part of the construction. Its existence cannot be separated from the building structure, as the foundation functions to transfer the forces or loads acting on the superstructure to the underlying soil with sufficient bearing capacity. The method for calculating or evaluating classical bearing capacity methods is based on the theory of Terzaghi and Meyerhof (Pantelidis, 2024). Foundation structures are generally divided into two categories: shallow foundations and deep foundations. Shallow foundations are used when hard soil or layers with high bearing capacity are at a relatively shallow depth, generally less than 3.00 meters. These types of foundations include square footings, continuous footings (strip), and raft foundations. Shallow foundations are often chosen for low-rise buildings, such as schools, because they are more economical, easier to construct, and effective enough to support loads at that depth. The use of shallow footings, longitudinal footings (strip), and square footings is expected to support building loads with adequate stability and be economical during construction. (Nurokhman et al., 2023) Soil tests report for hard soil located at a certain depth will determine the selection of the building's foundation type. For buildings with more than three floors, a deep foundation, such as bore piles or driven piles, is selected. The research aims to determine the bearing capacity of shallow foundations using the Terzaghi and Meyerhof methods on building X, which functions as a school building in East Jakarta. The background of this research is the existence of a building feasibility inspection of Certificate of Functionality (SLF) on the research object building that has been constructed to evaluate the feasibility of the lower structure, especially the foundation. Every five years, a building's functional feasibility evaluation study and periodic inspection are required by Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 27/PRT/M/2018 Concerning Certificates of Building Functionality (Nugroho & Ayu Hapsari, 2022).

In foundation structural planning, the Terzaghi and Meyerhof theory can be used to calculate the bearing capacity of shallow foundations. Several factors influence the soil bearing capacity factor, including the depth of the foundation, the shape of the foundation, the width of the foundation, and the location of the groundwater table (Aisah & Dhiniati, 2023). (Aksoy & Küçükay Kayaalp, 2025) The value of lateral stresses decreased with increasing depth beneath the foundation for all foundation sizes. Bearing capacity analysis studied the soil's ability to support the foundation load from the structure above it. Foundation design must also consider shear failure and excessive settlement. Therefore, two criteria must be met: stability criteria and settlement criteria. The requirements that must be met in foundation design are: A safety factor against collapse due to exceeding the bearing capacity must be met. In bearing capacity calculations, a safety factor of 3.00 is generally used, and the foundation settlement must remain within tolerable limits, especially non-uniform settlement (differential settlement), which must not cause damage to the structure.

The analysis of shallow foundation bearing capacity using the Terzaghi and Meyerhof methods has become a classic standard in soil mechanics; its application has thus far been predominantly focused on the design phase of new buildings. This research fills the gap in the technical evaluation aspects of existing buildings, specifically regarding the fulfillment of the Certificate of Functionality (SLF) regulation, based on The Minister of Public Works and Public Housing of the Republic of Indonesia Number 27/PRT/M/2018. The novelty of this research lies in the substructure audit approach, a comparative study between the Terzaghi and Meyerhof methods to determine the sensitivity of the Safety Factor (SF) in low-rise buildings within the East Jakarta area. To achieve this, the research is structured into several stages: it begins with structural modeling and load extraction using ETABS, followed by the analytical calculation of bearing capacity for both square and rectangular footings. Finally, a comparative sensitivity analysis of the Safety Factors is performed to provide technical recommendations for SLF compliance in soft soil conditions.

2. RESEARCH METHOD

This study collected and analyzed data to evaluate the bearing capacity of shallow square and strip foundations. The data required for this study include: soil test reports on soil characteristics at the research site, and As-Built Drawings, which are drawing documents that describe the actual condition of the existing building. The research method used in this study is a quantitative method. The following research steps are depicted in the flowchart (Figure 1).

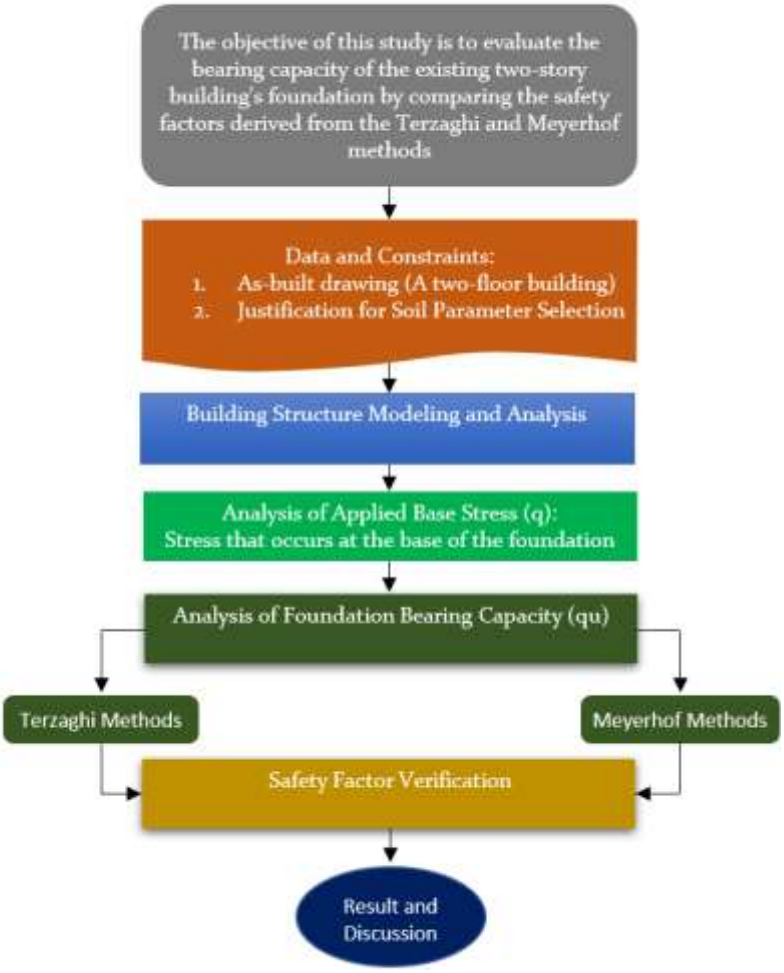

Figure 1. Research Flowchart
Source: Author Data, 2025

2.1. Data and Constraints

To ensure a focused and accurate evaluation, several simplifying assumptions are established. The object of the research is a two-story school building in the East Jakarta area. The object of this research is a two-story school building using shallow foundation structures, including square (square) and rectangular (continuous) foundations. The loads calculated through ETABS are assumed to be concentrated static loads and moments at the foundation's center of gravity. The effects of dynamic loads (earthquake) are accounted for through load combinations in accordance with SNI 1726:2019, specific liquefaction analysis was not performed. The foundation is assumed to be a rigid plate, such that the contact pressure distribution on the soil is linear.

2.2. As-Built Drawing

The data collected included information on the building's condition, including the lowest floor elevation of -1.20 m, the highest floor elevation of +7.05 m, the number of floors (2 stories and 1 roof floor), the floor height of 4.00 m, the roof structure consisting of concrete slabs and IWF and C-profile trusses, and the building's foundation structure consist of square or rectangular footings and continuous rectangular footings (strips)(Figure 2).

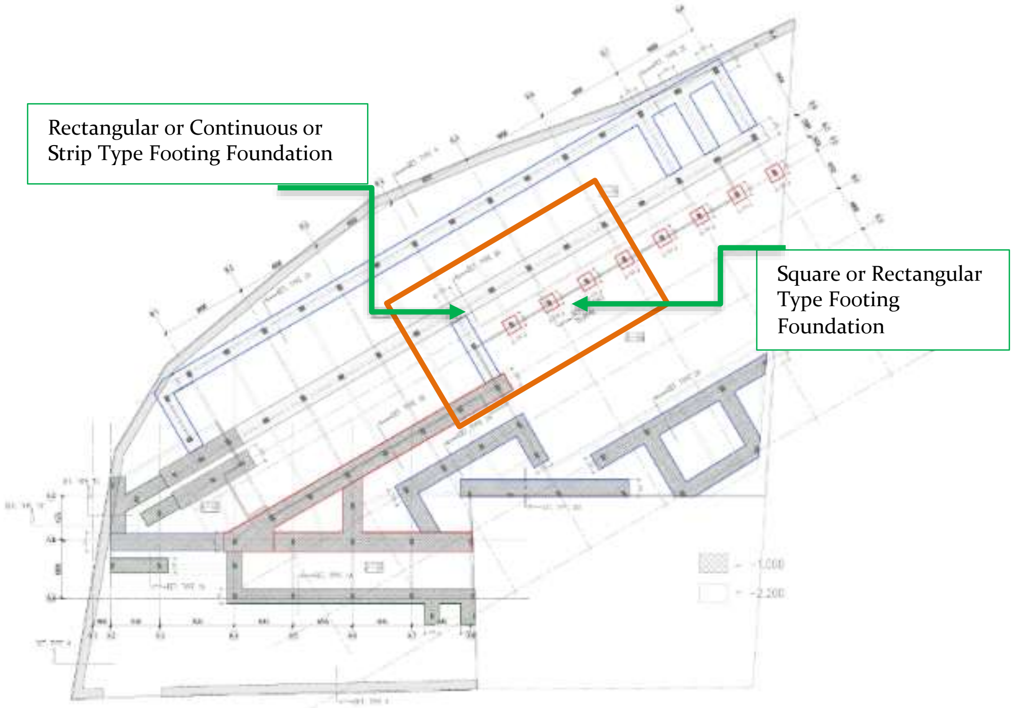

Figure 2. Foundation Structure Plan (Reviewed Area)
Source: Author Data, 2025

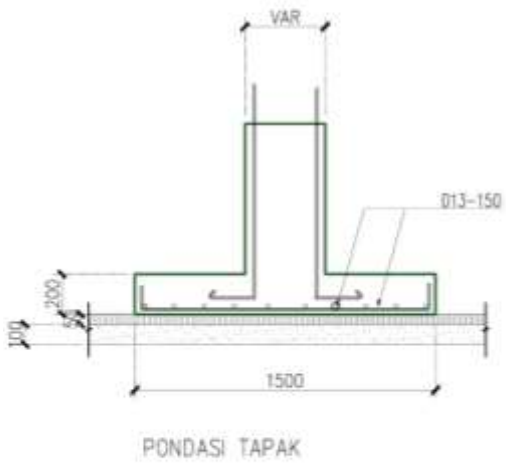

Figure 3. Type 1a Foundation: Square Foundation at A Depth of – 2.20 M
Source: Author Data, 2025

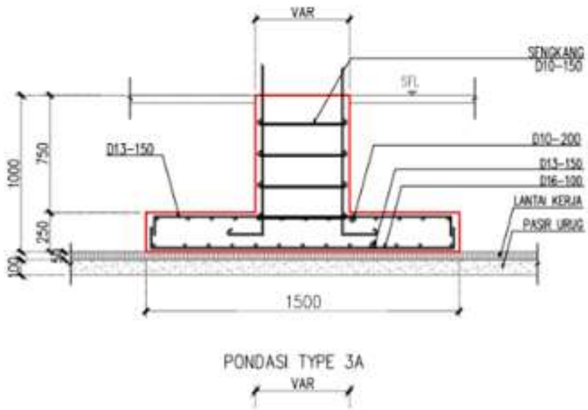

Figure 4. Type 3a Foundation: Longitudinal or Continuous (Strip) at A Depth of -2.20 M
Source: Author Data, 2025

2.3. Justification for Soil Parameter Selection

The selection of soil parameters in this study is based on the soil investigation report (soil test) at the location of Building X, East Jakarta, with the following considerations: CPT Data Report and regional geology. The soil data is derived from field CPT testing, shear strength parameters such as the internal friction angle (ϕ) and cohesion (c). Based on regional geology, the East Jakarta area is dominated by alluvial deposits consisting of clay and silt layers. East Jakarta was selected because the soil conditions in several areas are identified as soft soil, necessitating a more rigorous and conservative bearing capacity evaluation.

Cone Penetration Testing (CPT) continuously obtains data as the cone penetrates soil layers. In this method, a cone with standardized dimensions is pushed into the ground at a predetermined rate. During penetration, the device simultaneously measures tip resistance, sleeve friction, and dynamic pore pressure. The combination of these parameters provides an accurate depiction of soil stratigraphy and behavior. Furthermore, the obtained measurements can be applied in various correlations to estimate a wide range of soil properties. (Kurniawan & Suhendra, 2020) The comparative analysis of the ultimate bearing capacity for square and rectangular foundations under varying friction angle values indicates that an increase in the friction angle leads to a corresponding increase in both the ultimate bearing capacity and the elastic settlement. The soil test report in this study was conducted using the Cone Penetration Testing (CPT) method at 3 points, marked S1, S2, and S3 (Figure 5). The results of the soil investigation obtained a cohesion value of 20 and a friction angle of 15 °.

Figure 5. CPT Point Location
Source: Author Data, 2025

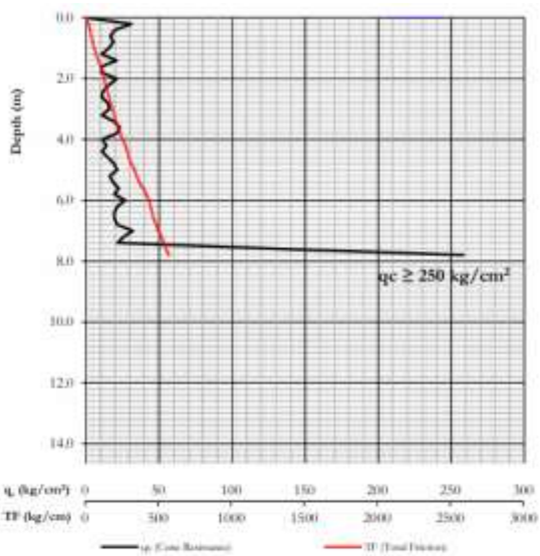

Figure 6. qc Graph Value vs Soil Depth at Point Location S2 based on CPT
Source: Author Data, 2025

2.4. Building Structure Modeling and Analysis

(Yelmeli & Verma, 2024) ETABS is a software for structural analysis that can be used to model high-rise buildings. (Babu et al., 2023) ETABS can analyze story shear forces, inter-story drifts, moments, and displacements, which are then tabulated and examined. It provides a comprehensive platform for modeling, analyzing, and designing building structures under various loading conditions, including seismic loads. With advanced features such as response spectrum analysis, time history analysis, and pushover analysis, ETABS enables engineers to accurately and thoroughly evaluate the seismic response of irregular structures.

This study also utilized ETABS, a software tool that helps identify internal output forces in structures, such as moment, axial, shear, and torsion forces. (Sinarta et al., 2024) The following regulations are used in foundation structure design in Indonesia:

a) SNI 1726:2019, which regulates earthquake resistance planning procedures, explains that soil-structure interaction can be calculated in equivalent lateral force analysis, dynamic linear analysis, or earthquake response history analysis when the structure is located in site class C, D, E, or F.

b) SNI 1727:2020, which regulates concerns minimum loads for building design, such as live load, dead load, and wind load.
c) SNI 8460:2017, which regulates geotechnical design requirements.
d) SNI 2847:2019, which regulates structural concrete requirements for buildings.

The purpose of 3D building modeling using analysis software is to obtain internal forces. The 3D portal system is modeled based on As-Built Drawing data to ensure accuracy with the existing building conditions. The data required for this research analysis includes architectural, mechanical, electrical, and structural drawings. The foundation support system is assumed to be a fixed support capable of resisting vertical, horizontal, and moment forces received from the superstructure. (Silalahi et al., 2024) The research on building modeling requires several types of data, including: general information about the building, structural as-built drawings, data on the quality of concrete, and results from hammer testing. The concrete compressive strength (f'c) for beams and floor slabs is 25 MPa, and for columns is 30 MPa. The quality of reinforcing steel yield strength (fy) for deformed reinforcement (BJTS) is 420 MPa, and for plain reinforcement (BJTP) is 280 MPa. According to SNI 2052:2024, the use of concrete reinforcing steel in building construction must meet quality standards to ensure structural integrity and safety.

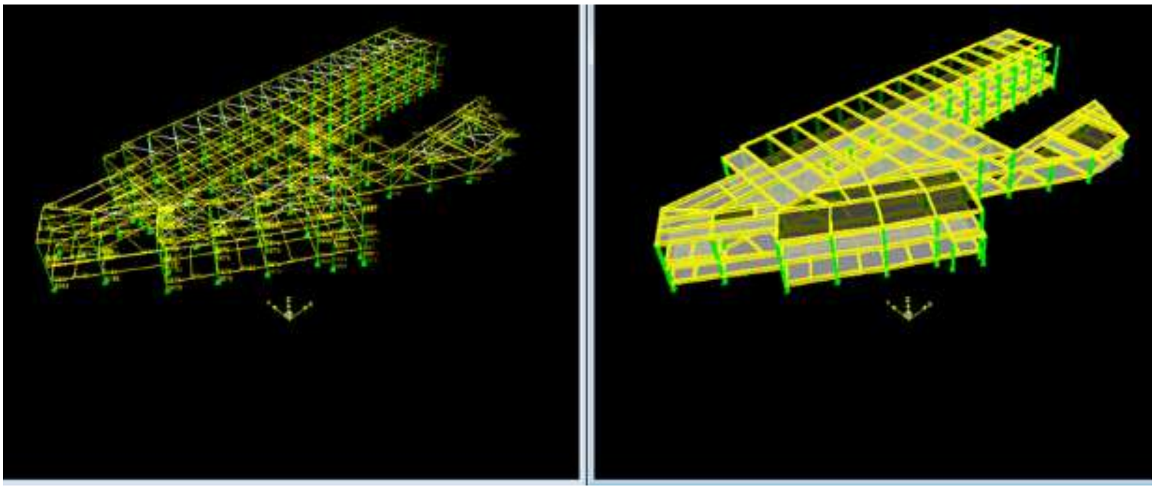

Figure 7. Building Structure Modeling
Source: Author Data, 2025

2.4.1. Dead and live loads

Dead and live loads acting on the structure are included in ETABS according to the SNI 1727-2020 standard (Table 1). In this study, wind loads were not considered because wind speeds were considered low in the research area.

Table 1. Loads Types

Load Types	Load Information	Wight (kg/m²)
Dead Loads (DL)	Speci/Screed, thickness = 20 mm	42.00
	Ceramic, thickness = 10 mm	24.00
	Mechanical, electrical, and ceiling	12.00
	Sanitation + Plumbing	12.00
Live Loads (LL)	Classroom	1.92
	Corridor on the ground floor	4.79
	Corridor upstairs	3.83
	Rooftop	0.92
	Corridor on the ground floor	2.87

Source: Author Data, 2025

2.4.2. Seismic Loading

In this research, earthquake loads are based on the Indonesian building code of SNI 1729 2019. The response spectrum graph is developed based on spectral acceleration at a certain period by considering seismic location factors, soil type, and structural response modification coefficients. Soft soils generally have low bearing capacity and tend to experience significant settlement due to their characteristics, such as high water content, large void ratio, and weak interparticle bonds. These conditions cause the soil to be unable to support loads optimally. The application of loads reduces the void ratio and results in ground surface settlement. Therefore, the greater the applied load, the greater the settlement that occurs (Isnaniati & Mochtar, 2023).

In this study, the soft soil class was also selected in determining S_{D1} and S_{Ds}. Then, the earthquake loading was calculated based on the project location in East Jakarta, with seismic response spectra of SDs = 0.69 (g) and SD1 = 0.64 (g) for the soft soil category. This data was obtained from the website https://rsa.ciptakarya.pu.go.id/2021/. Building structure modeling based on SNI 03-1726-2019 takes into account the earthquake priority factor value, Seismic Design Category (SDC), and S_{D1} values. The risk category for school buildings is included in category IV at 1.50. The Seismic Design Category (SDC) used is type D. The selection of this SDC is based on the S_{DS} and S_{D1} values.

2.4.3. Load Combination

(Maheshwari, 2024) Both the static equivalent method and the dynamic response spectrum method are essential approaches in seismic analysis of buildings. The selection between the two depends on the complexity and specific characteristics of the structure, with the dynamic response spectrum method generally providing a more comprehensive and accurate evaluation, especially for complex and high-rise buildings. The load combination applied in the building structure modeling is the gravity load and strong earthquake load with a redundancy value of 1.00.

a) 1.4 DL
b) 1.2 DL + 1.6 LL
c) $(1.2 + 0.2\ S_{Ds})DL + \rho.Q_{ey} + LL = 1.34\ DL + Q_{ey} + LL$
d) $(1.2 + 0.2\ S_{Ds})DL + \rho.Q_{ex} + LL = 1.34\ DL + Q_{ex} + LL$
e) $(0.9 - 0.2\ S_{Ds})DL + \rho.Q_{ey} + LL = 0.76\ DL + Q_{ey} + LL$
f) $(0.9 - 0.2\ S_{Ds})DL + \rho.Q_{ex} + LL = 0.76\ DL + Q_{ex} + LL$

where:

DL = Dead Load
LL = Live Load
Q_{ex} = Load Response Spectra in x-direction
Q_{ey} = Load Response Spectra in y-direction
S_{DS} = Short Period Spectral Acceleration
S_{D1} = 1-Second Period Spectral Acceleration
ρ = Redundancy Factor

2.5. Stress Analysis of Applied Base Stress (q)

(Luévanos-Rojas, 2023) The applied loads and resulting moments are derived from structural analysis, which may be performed using established methods such as the stiffness method, slope-deflection method, or Hardy Cross method, incorporating dead, live, wind, and seismic loads. The study considers a rectangular isolated footing resting on elastic soil, subjected to biaxial bending, with the column potentially positioned anywhere on the footing. A general analytical expression for footings under biaxial bending is used, assuming a linear pressure distribution beneath the foundation. The stress or pressure that occurs at the base of the foundation due to the loading of the ultimate axial force and the bending moment in the x- and y-directions, and taking into account the magnitude of the inertia in the x- and y-directions and the center of gravity in the x- and y-directions of the cross-section can be calculated based on equation (1).

$$q = \frac{P}{A} + \frac{Mx.Y}{Ix} + \frac{My.X}{Iy} - (Df\,\gamma) \qquad (1)$$

where:

q = Stress or pressure occurring between the foundation base and the subgrade, or the stress occurring in the soil due to the load on the foundation area (kg/m²)
P = Ultimate axial force (kg)
A = Cross-sectional area of the footing (m²)
Mx = X-direction moment force (kg· m)
My = Moment force in the y-direction (kg· m)
Y = Center of gravity of the y-direction section (m⁴)
X = Center of gravity of the x-direction section (m⁴)
Df = Foundation depth (m)
γ = Soil density (kg/m³)

2.6. Analysis of Foundation Bearing Capacity (qu)

2.6.1. Foundation Bearing Capacity According to Terzaghi

(Jabar & Shakir, 2025) Based on Terzaghi's Method, the bearing capacity of a square foundation located on homogeneous soil can be calculated using equation 2, and the bearing capacity of a rectangular foundation located on homogeneous soil can be calculated using equation 3.

$$qu = 1.3c\,Nc + Df\,\gamma\,Nq + 0.4\,\gamma\,B\,N_\gamma \qquad (2)$$

$$qu = cNc + Df\,\gamma\,Nq + 0.5\,\gamma\,B\,N_\gamma\,(1-0.2B/L) \qquad (3)$$

where:

qu = Ultimate bearing capacity (kg/m²)
c = Cohesion
Df = Foundation depth (m)
B = Foundation width (m)
L = Foundation length (m)
γ = Soil density (kg/m³)
Nc, Nq, N_γ = Soil bearing capacity factor that depends on the angle of friction in the soil

Table 2. Bearing Capacity Factor of Foundation Soil based on Terzaghi for General Shear Failure (ϕ)

ϕ	Nc	Nq	N_γ
0	5.7	1.0	0.0
5	7.3	1.6	0.5
10	9.6	2.7	1.2
15	12.9	4.4	2.5
20	17.7	7.4	5.0
25	25.1	12.7	9.7
30	37.2	22.5	19.7
34	52.6	36.5	35.0
35	57.8	41.4	42.4
40	95.7	81.3	100.4
45	172.3	173.3	297.5
48	258.3	287.9	780.1
50	347.6	415.1	1153.2

Source: Hardiyatmo, 2011

Terzaghi's foundation bearing capacity equation can be applied to shallow foundations provided Df < B. Terzaghi's theory is used to calculate the bearing capacity of granular soils and soils with cohesion (c) and an internal friction angle (ϕ). Soils are generally classified as cohesive or fine-grained soils, such as clay; cohesionless or coarse-grained soils, such as sand; and cohesive-friction soils, such as silt, which have cohesion and internal friction angles. (Pantelidis, 2024) Terzaghi's 1943 bearing capacity equation developed Pradtl's 1920 bearing capacity theory, incorporating plasticity theory, for analyzing the driving of a rigid base into softer soil. (Kilic, 2025) Terzaghi’s approach is considered more straightforward compared to other methods for determining the ultimate and allowable bearing capacities of foundations on soil, due to its minimal use of complex equations. It serves as a valuable benchmark for comparison with alternative methods and is often regarded as a foundational basis for the development of bearing capacity theories.

2.6.2. Foundation Bearing Capacity According to Meyerhof

The foundation bearing capacity equation must consider the foundation shape, foundation depth, and load slope. According to Meyerhof, the foundation bearing capacity can be calculated using equation 4 (Trinanda, 2021).

$$qu = c\,Nc(S_c\, d_c\, i_c) + Df\,\gamma\, Nq(S_q\, d_q\, i_q) + (1/2)\, B\, \gamma\, N_\gamma\,(S_\gamma\, d_\gamma\, i_\gamma) \quad (4)$$

where:

qu = Ultimate bearing capacity (kg/m^2)
Nc, Nq, Nɣ = Bearing capacity factor for the foundation
Sc, Sq, Sɣ = Foundation shape factor
dc, dq, dɣ = Foundation depth factor
ic, iq, iɣ = Load slope factor
Df γ = Overburden pressure at the base of the foundation (kg/m^2)
B = Foundation width (m)
γ = Soil density (kg/m^3)
c = Cohesion

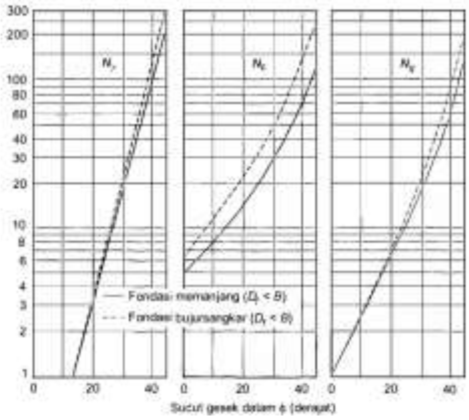

Figure 8. Bearing Capacity Factor of Foundation Soil According to Meyerhof
Source: Hardiyatmo, 2011

Table 3. Foundation Form Factor According to Meyerhof Methods

Form Factor	Factors of Foundation Form	Note
S_c	1+0.2 (B/L) tg² (45+ϕ/2)	for any ϕ
$S_q = S_\gamma$	1+0.1 (B/L) tg² (45+ϕ/2)	for $\phi \geq 10^o$
$S_q = S_\gamma$	1	for $\phi > 0^o$

Source: Hardiyatmo, 2011

Table 4. Foundation Depth Factor According to Meyerhof Methods

Depth Factor	Foundation Depth Factor	Note
d_c	1+0.1 (D/B) tg² (45+ϕ/2)	for any ϕ
$d_c = d_\gamma$	1+0.1 (D/B) tg² (45+ϕ/2)	for $\phi \geq 10^o$
$d_c = d_\gamma$	1	for $\phi > 0^o$

Source: Hardiyatmo, 2011

Table 5. Load Slope Factor According to Meyerhof Methods

Load Slope Factor	Load Slope Factor	Note
$i_c = i_q$	$(1- \delta^o/90^o)^2$	for any ϕ
i_γ	$(1- \delta^o/\phi)^2$	for $\phi \geq 10^o$
i_γ	1	for $\phi > 0^o$

Source: Hardiyatmo, 2011

2.7. Safety Factor Analysis for the Bearing Capacity of Shallow Foundations

The safety of a foundation's bearing capacity can be expressed by the ratio between the foundation's bearing capacity on the subgrade (qu) and the stress at the base of the foundation due to the axial load on the foundation area (q). In planning the design of the foundation structure, this must be greater than the safety factor in equation (5). The Safety Factor (SF) value that can be used in the analysis is 3.00.

$$\frac{qu-\gamma\,Df}{q-\gamma\,Df} > SF \quad (5)$$

where:

qu = Soil bearing capacity for the foundation (kg/m²)
q = Stress at the base of the foundation (kg/m²)
γ = Soil density (kg/m³)
Df = Foundation depth (m)

(Asngari et al., 2021) Previous research showed that the bearing capacity analysis of foundations using the Terzaghi method yielded lower results than the Meyerhof method for square (rectangular) foundations. In this study, the authors examined the bearing capacity evaluation of foundations not only for squares but also for rectangular ones, whereas previous research only examined rectangular shapes.

3. RESULTS AND DISCUSSIONS

3.1. Foundation Bearing Capacity Analysis based on Modeling

The foundation bearing capacity assessment area examined in this study was the foundation area at the CPT S2 test point. Continuous square and rectangular foundations (strips) were constructed at a depth of -2.20 m. Based on the soil investigation report at point S2, the soil density was 1600 kg/m³, and the qc value at the -2.20 m elevation was 20 kg/cm² according to Figure 6, and then the soil friction angle (ϕ) was 15°. The area examined included seven type 3A foundations: a continuous rectangular footing (strip) and three square or rectangular footings (footprint). The dimensions of the Type 3A foundation are rectangular in shape, with a width of 1.50 m. However, the length is considered a partitioned or separate section in each area, resulting in two area sizes: 1.50 m x 3.00 m and 1.50 m x 6.00 m. Then, the dimensions of the square type foundation (footprint) have dimensions of 1.50 m x 1.50 m (Figure 2), and the values of internal forces in foundations based on the modeling structure of the building are based on Table 5. The area reviewed in this study is based on the As-Built Drawing and the ETABS modeling base point (Figure 9). In the ETABS modeling for the reviewed foundation point, it is type 3A measuring 1.50 m x 3.00 m, located on the foundation column base points of 5476, 5478 and 5485. Then, for type 3A measuring 1.50 m x 6.00 m, situated at base points of 5477, and 5486, as well as for the footing type measuring 1.50 m x 1.50 m located at base points of 5494, 5495, 5496, 5497, 5498, and 5499. The analysis of the foundation bearing capacity is shown in the calculation example, which is then displayed in the Table.

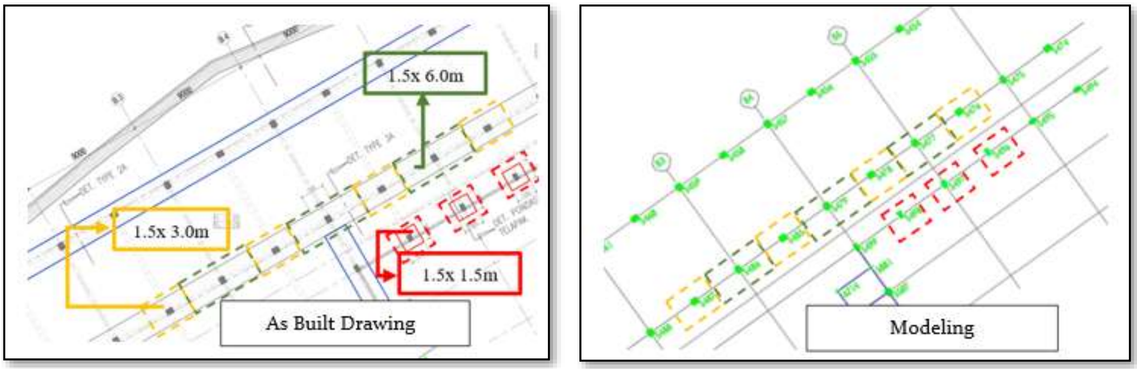

Figure 9. Foundation Points Reviewed Based on The As-Built Drawing and The Location of The ETABS Modeling Base Point
Source: Author Data, 2025

3.2. Structural Analysis Results

The structural analysis results from the structural modeling of building X in East Jakarta, reviewed in this study, were limited to the CPT area at point S2. A continuous or longitudinal footing (type 3A) and a rectangular footing have been constructed in this area. At this point, the internal forces resulting from the reactions of the column structure connected to the continuous shallow strip foundation and footing were obtained. The internal forces analyzed included the largest or ultimate forces, such as the axial force (symbolized as FZ) and the x- and y-directional moments (symbolized as MY and MY). Based on the internal force analysis results in the modeling, the axial force acting on the foundation columns can be determined based on the ground floor base point support (Table 6).

Table 6. The Internal Forces in Foundations based on the Modeling Structure of the Building

Base Point	Foundation Types	FZ (kg. m)	MX (kg· m)	MY (kg. m)
5494	Footing	20155.16	198.77	5434.10
5495	Footing	19310.06	519.78	5607.67
5496	Footing	19069.99	909.06	5664.55
5497	Footing	18910.22	706.30	5655.68
5498	Footing	19032.31	128.87	5561.33
5499	Footing	36612.47	2459.15	2288.56
5476	3A	92489.07	1913.09	4096.63
5477	3A	104660.69	1269.19	2879.52
5478	3A	89323.33	1638.32	4078.17
5479	3A	105718.56	1971.85	3685.16
5485	3A	114412.60	1507.64	4255.51
5486	3A	127166.18	1809.94	3049.54
5487	3A	112524.74	1333.42	4274.48
5476	3A	92489.07	1913.09	4096.63

Source: Author Data, 2025

3.3. Stress at the base of the foundation (q)

3.3.1. Stress at the base of a rectangular footing measuring 1.50 m x 1.50 m located at the base point of 5497

A = B = L = 1.50 m

Ix = $1/12.b.h^3 = 1/12(1.50)(1.50^3) = 0.42\ m^4$

Iy = $1/12.b^3.h = 1/12(1.50^3)(1.50) = 0.42\ m^4$

P = 19032.30 kg

Mx = 128.87 kg· m

My = 5561.33 kg. m
X = 0.75 m
Y = 0.75 m
γ = 1600 kg/m³
Df = 2.20 m

$$q = \frac{P}{A} + \frac{Mx.Y}{Ix} + \frac{My.X}{Iy} - (Df\,\gamma)$$

$$= \frac{19032.3}{1.5\ x\ 1.5} + \frac{128.87\ x\ 0.75}{0.42} + \frac{5561.33\ x\ 0.75}{0.42} - 3520$$

= 15054.72 kg/m²

3.3.2. The stress that occurs at the base of the continuous rectangular footing foundation type 3A measuring 1.50 m x 3.00 m located at the base point of 5487

A = B.L = 1.50 m x 3.00 m
Ix = 1/12.b.h³ = 1/12(1.50)(3.00³) = 3.38 m⁴
Iy = 1/12.b³.h = 1/12(1.50³)(3.00) = 0.84 m⁴
P = 112524.74 kg
Mx = 333.42 kg. m
My = 4274.48 kg. m
X = 1.50 m
Y = 0.75 m
γ = 1600 kg/m³
Df = 2.20 m

$$q = \frac{P}{A} + \frac{Mx.Y}{Ix} + \frac{My.X}{Iy} - (Df\,\gamma)$$

$$= \frac{112524.74}{1.50\ x\ 3.00} + \frac{333.42\ x\ 0.75}{3.38} + \frac{4274.48\ x\ 1.5}{0.84} - 3520$$

= 29158.67 kg/m²

3.3.3. The stress that occurs at the base of the continuous rectangular footing foundation type 3A measuring 1.50 m x 6.00 m located at the base point of 5486

A = B.L = 1.50 m x 6.00 m
Ix = 1/12.b.h³ = 1/12(1.50)(6.00)³ = 27.00 m⁴
Iy = 1/12.b³.h = 1/12(1.50³)(6.00) = 1.69 m⁴
P = 127166.18 kg
Mx = 1809.94 kg. m
My = 3049.54 kg. m
X = 3.00 m
Y = 0.75 m
γ = 1600 kg/m³
Df = 2.20 m

$$q = \frac{P}{A} + \frac{Mx.Y}{Ix} + \frac{My.X}{Iy} - (Df\,\gamma)$$

$$= \frac{127166.18}{1.50 \text{ x } 6.00} + \frac{1809.94 \text{ x } 0.75}{27.00} + \frac{3049.54 \text{ x } 3.00}{1.69} - 3520$$

= 27500.13 kg/m²

3.4. Comparative Study of The Analysis of The Foundation Bearing Capacity

The calculation results presented in Table 7 and Table 8 reveal a significant discrepancy between the Terzaghi and Meyerhof methods in evaluating the structural safety of Building X.

Table 7. Comparison Between Foundation Bearing Capacity (qu) and Applied Base Stress (q) Using the Terzaghi Method

Base Point	Foundation Type	Dimensions (m)		$q_{u\ Terzaghi}$ (kg/m²)	q (kg/m²)	SF
		Width	Length			
5494	Footing	1.50	1.50	14703.40	15955.51	0.92
5495	Footing	1.50	1.50	14703.40	16641.96	0.88
5496	Footing	1.50	1.50	14703.40	16194.74	0.91
5497	Footing	1.50	1.50	14703.40	15054.72	0.98
5498	Footing	1.50	1.50	14703.40	21192.59	0.69
5499	Footing	1.50	1.50	14703.40	15955.51	0.92
5476	3A	1.50	3.00	14926.00	24741.16	0.60
5477	3A	1.50	6.00	15076.00	22332.76	0.68
5478	3A	1.50	3.00	14926.00	23943.79	0.62
5485	3A	1.50	3.00	14926.00	29805.40	0.50
5486	3A	1.50	6.00	15076.00	27500.13	0.55

Source: Author Data, 2025

Table 8. Comparison Between Foundation Bearing Capacity (qu) and Applied Base Stress (q) Using the Meyerhof Method

Base Point	Foundation Type	Dimensions (m)		$q_{u\ Meyerhof}$ (kg/m²)	q (kg/m²)	SF
		Width	Length			
5494	Footing	1.50	1.50	22017.68	15451.84	1.42
5495	Footing	1.50	1.50	22017.68	15955.51	1.38
5496	Footing	1.50	1.50	22017.68	16641.96	1.32
5497	Footing	1.50	1.50	22017.68	16194.74	1.36
5498	Footing	1.50	1.50	22017.68	15054.72	1.46
5499	Footing	1.50	1.50	22017.68	21192.59	1.04
5476	3A	1.50	3.00	21808.72	24741.16	0.88
5477	3A	1.50	6.00	21298.43	22332.76	0.95
5478	3A	1.50	3.00	21808.72	23943.79	0.91
5485	3A	1.50	3.00	21808.72	29805.40	0.73
5486	3A	1.50	6.00	21298.43	27500.13	0.77

Source: Author Data, 2025

3.4.1. Sensitivity Comparison of Safety Factor (SF) Values

There is a stark contrast in the Safety Factor (SF) results between the two methods. The Terzaghi method yields substantially lower qu values, ranging from 14703 to 15076 kg/m², resulting in SF values below 1.0 (unsafe) for nearly all observed points. Conversely, the Meyerhof method provides more optimistic qu values, ranging from 21298.43 to 22017.68 kg/m², which produce SF values above 1.0 for square footings. This discrepancy arises because the Meyerhof method incorporates more comprehensive shape and depth factors, as well as load eccentricity, which are not as detailed in Terzaghi's classical theory. This confirms that the choice of method is a decisive factor in determining a building's eligibility for a Certificate of Functionality (SLF).

3.4.2. Influence of Foundation Geometry and Dimensions

The data indicate that shifting from square footings (1.50 x 1.50 m) to elongated footings (1.50 x 6.00 m) significantly impacts stability. In the Meyerhof analysis, the qu value tends to decrease as the foundation length increases from 22017.68 to 21298.43 kg/m². This phenomenon is closely linked to the soft soil characteristics in East Jakarta. In cohesive-dominant soils, longer foundations distribute stress over a wider area but may reach shear limits faster than square footings, which benefit from better lateral confinement effects on all sides.

3.4.3. Correlation with Soft Soil Characteristics

Based on the field data and the justification for selecting East Jakarta as the study site, the actual stress (q) at several points reaches values exceeding 29000 kg/m², which far surpasses the soil's ultimate bearing capacity. The presence of soft soil significantly restricts the ultimate bearing capacity (qu). The prevalence of SF values below the standard requirement of 3.00 suggests that while the building remains standing, it faces high risks of excessive settlement or local shear failure. This reinforces the urgency of periodic SLF inspections to detect structural distress before catastrophic failure occurs. Certain limitations may affect the comprehensiveness of these findings, such as the influence of the homogeneous soil assumption and the non-consideration of settlement. The analysis in this study focuses strictly on bearing capacity stability and does not yet account for soil settlement. In the soft soil conditions of East Jakarta, settlement can often be a more decisive factor in structural failure, therefore further research regarding soil settlement analysis is highly recommended.

4. CONCLUSION

Based on the bearing capacity analysis of the foundations for Building X in East Jakarta, it can be concluded that a significant discrepancy exists between the Terzaghi and Meyerhof methods. The Terzaghi method consistently yields lower ultimate bearing capacity (qu) and more conservative Safety Factor (SF) results compared to the Meyerhof approach. Most observed points on the existing foundation show SF values that do not meet the ideal standard requirements (SF < 3.00). Consequently, soil reinforcement is necessary to comply with SLF (Certificate of Functionality) standards. For this existing structure, Micropiles (Underpinning) or Jet Grouting are recommended, as they can significantly enhance bearing capacity and mitigate settlement risks with minimal disturbance to the existing structure. These measures are vital for ensuring structural reliability and regulatory compliance. The soft soil conditions in East Jakarta act as a primary limiting factor, causing the applied stress (q) at several points to exceed the allowable bearing capacity, particularly in elongated foundations, which are highly sensitive to settlement. This study suggests utilizing the Terzaghi approach as the primary conservative baseline for shallow foundation design, while the Meyerhof results should serve as a secondary comparison. Furthermore, the fact that the building remains standing despite low SF values can be attributed to the condition where qu > q, and the original design likely incorporated high load combination factors. To enhance evaluation accuracy, further research is recommended to validate these findings using numerical methods such as Plaxis 2D. This is essential for modeling non-linear soil-structure interactions and verifying precise settlement behavior in complex soft soil characteristics. (Alzabeebee et al., 2025) One of the finite element methods that can be used to analyze foundation bearing capacity is Plaxis 2D. (Çevik, 2023) Beyond analytical theories, studies emphasize that finite element methods provide superior results when detailed data, such as multi-layered soil profiles, precise groundwater table levels, and accurate deformation parameters, are available.

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