NUSANTARA CIVIL ENGINEERING JOURNAL
Vol.3 No.01 (2025) pp. 7-12
DOI: https://doi.org/10.32487/nuce.v3i1.604

Geotechnical Site Investigation for IBS House Construction in Bukit Rambai, Melaka. A Case Study Using Mackintosh Probe Tests

Mohamad Azwan Bin Ikhwat ✉, Shahrun Nazida Binti Salleh, Faisal Ananda

[1,2] Politeknik Melaka, Malaysia
[3] Politeknik Negeri Bengkalis, Indonesia
✉ azwan.ikhwat@polimelaka.edu.my

Received 19-03-2025; revision 23-04-2025; accepted date 02-06-2025

Abstract
This research explores the challenges of assessing soil bearing capacity and strength for constructing an Industrialized Building System (IBS) house in Bukit Rambai, Melaka. It utilizes a cost-effective and portable method known as the Mackintosh Probe Test, which is particularly suitable for small-scale, low-risk projects. The need for this study is clear, as traditional methods like the Standard Penetration Test (SPT) can be too expensive for smaller residential developments, making the Mackintosh Probe a practical alternative for initial geotechnical assessments. The research hypothesizes that the Mackintosh Probe can provide reliable soil data for foundation design, helping to reduce costs while maintaining accuracy. The main goal of the study is to evaluate soil characteristics and bearing capacity using the Mackintosh Probe, supply essential data for safe foundation design, and establish a relationship between Mackintosh Probe results and SPT values, along with acceptable soil pressures. The methodology involved conducting six Mackintosh Probe tests on-site, recording blow counts for every 0.3 m of penetration, and analyzing soil consistency and bearing capacity through established correlations with SPT N-values. The findings revealed various soil layers, with the upper layers suitable for strip footings and deeper layers requiring pile foundations due to hard strata. The implications of this research are significant, as it demonstrates the Mackintosh Probe's cost-effectiveness for IBS projects, potentially cutting investigation costs by up to 40%, while also highlighting the need for additional tests and localized correlation charts for tropical soils, like those in Malaysia. This study provides valuable insights for foundation design in similar contexts and encourages further research to improve the use of the Mackintosh Probe in tropical areas.

Keywords: *Mackintosh Probe, Soil Bearing Capacity, IBS House Construction*

1. Introduction

Site investigation is essential for ensuring safe and cost-effective foundation design in construction projects. For low-risk or smaller-scale projects, like residential buildings, the Mackintosh Probe test offers a budget-friendly and simple method to assess subsurface soil conditions. This report details the investigation conducted on 13 February 2024 for a proposed Industrialized Building System (IBS) residential house in Bukit Rambai, Melaka, Melaka. Based on the dimensions of the planned structure, six Mackintosh Probe tests were carried out to determine soil parameters, such as allowable bearing capacity and layer consistency. The study aimed to achieve the following objectives:

1. Assess the soil characteristics and bearing capacity of the site using the Mackintosh Probe Test.
2. Provide data and recommendations to ensure a safe and appropriate foundation design for the IBS house.

3. Relate the results from the Mackintosh Probe to Standard Penetration Test (SPT) values and allowable soil pressures to guide the foundation design.

Geotechnical site investigations play a crucial role in assessing soil properties and ensuring the safety of foundation designs. While traditional methods such as the Standard Penetration Test (SPT) and Cone Penetration Test (CPT) are commonly used, they can be too expensive for smaller projects (Mitchell & Soga, 2005). The Mackintosh Probe offers a lightweight alternative that allows for quick and cost-effective subsurface profiling, especially in low-risk developments (Das, 2023). According to Chang (2018) its ease of transport and straightforward operation make it particularly suitable for initial assessments in areas with limited resources, like rural residential projects. The Mackintosh Probe uses a 4.5 kg hammer that is dropped from a height of 300 mm to drive a conical tip into the soil. The number of blows required for every 0.3 m of penetration is recorded, which helps to gauge soil strength. Research by Craig (2004) highlights its effectiveness in identifying soil layers and spotting weak zones in cohesive soils. However, it does have some drawbacks, such as decreased accuracy in gravelly soils and a dependence on empirical correlations for quantitative assessments (ASTM International, 2018).

The connection between the blow counts from the Mackintosh Probe and the allowable bearing capacity has been thoroughly researched. Das (2023) confirmed the correlations between Mackintosh Probe results and SPT NN-values for both cohesive and granular soils (see Tables 1–2 in the case study). For instance, in clay, blow counts ranging from 20 to 40 per 300 mm of penetration correspond to medium consistency (Cu=49–98 kN/m²), which aligns with JKR guidelines. Likewise, in sand, blow counts of 30 to 80 per 300 mm indicate medium density, with allowable pressures between 78.5 and 275 kN/m² (Balasubramaniam et al, 2016). These correlations enable engineers to estimate bearing capacity without expensive lab testing. Industrialized Building Systems (IBS) necessitate consistent soil conditions to support prefabricated components. Research by Rahman et al. (2021) indicates that Mackintosh Probes can detect localized weak zones, which is crucial for ensuring appropriate foundation designs for IBS structures . For example, a refusal at 400 blows/0.3 m, as noted in the case study, indicates the presence of hard strata, which requires the use of pile foundations to avoid unsuitable layers (Lambe & Whitman, 1969) .

Although Mackintosh Probes are extensively documented for general applications, there is a lack of studies focusing on their use in IBS projects within tropical regions like Malaysia. Furthermore Ong et al (2020) states the variations in regional soils, such as the residual soils found in Bukit Rambai, necessitate the development of localized correlation charts, which are often derived from global standards . This case study aims to fill these gaps by offering site-specific data and recommendations for hybrid foundations.

2. Methodology

2.1 Mackintosh Probe Testing

The Mackintosh Probe, a lightweight penetrometer, was employed to measure soil resistance. The apparatus consists of 120 cm steel rods, a 4.5 kg hammer, and a conical tip (27.9 mm diameter, 30° apex angle). Testing followed JKR Malaysia (2005) standards :

1. The hammer was dropped freely from 300 mm height.
2. Blows per 0.3 m penetration were recorded until reaching 400 blows/0.3 m or 15 m depth.

Site investigation method using Macintosh Probe on actual site shown in Figure 1 location coordinates: 2°14'48.9"N, 102°11'06.0"E.

Figure 1: Mackintosh Probe testing at construction site

2.2 Data Interpretation

Soil consistency and allowable bearing capacity were derived using correlations between Mackintosh Probe blow counts (blows/300 mm) and Standard Penetration Test (SPT) N-values (Table 1 and 2) (JKR Malaysia, 2005).

Table 1: Clay Soil Classification

SPT N-value	Consistency	UCS (kN/m²)	Mackintosh Blows/300 mm
2	Very soft	0–0.25	0–10
2–4	Soft	0.25–0.50	10–20
4–8	Medium (Firm)	0.50–1.00	20–40
8-15	Stiff	1.00–2.00	40-70
15-30	Very Stiff	2.00–4.00	70-100
Over 30	Hard	4.00	100

Table 2: Sand Soil Classification

SPT N-value	Consistency	Allowable Pressure (kN/m²)	Mackintosh Blows /300 mm
4–10	Loose	0–78.5	10–30
10–30	Medium	78.5–275	30–80

3. Results and Discussion

3.1 Soil Profile Analysis

Data from Mackintosh Probe tests (Table 3) conducted at six different points (P1 to P6) show that soil resistivity varies with depth. At shallow depths (0–1.5 m), P1 and P4 have high strike counts, indicating hard soil, while P5 and P6 have lower counts, suggesting softer layers. At intermediate depths (1.5–4.5 m), strike counts generally decrease, indicating softer soil, but a few points (P2, P3) have inconsistent values, indicating mixed layers. At deeper depths (4.8–5.1 m) striking stops when it reaches 400 strikes per 0.3 m depth, indicating rejection due to hard layers. Very high resistivity occurs at P3, P5, and P6, indicating hard strata, while P2 gradually increases resistivity, reaching a depth of 6.0–6.3 m.0–0.3 m: Extremely high resistance (196 blows), indicating very stiff clay or dense sand.

- 0.3–1.2 m: Decreasing blows (55 to 10), suggesting soft to medium clay.
- 5.1–5.4 m: 100 blows/300 mm, classifying as very stiff clay (Cu = 200 kN/m²).
- 4.8–5.1 m: Termination at 400 blows, implying refusal due to hard strata.

Table 3: Probe F1 Blow Counts

Depth (m)	P1 Blows/ 0.3 m	P2 Blows/ 0.3 m	P3 Blows/ 0.3 m	P4 Blows/ 0.3 m	P5 Blows/ 0.3 m	P6 Blows/ 0.3 m
0 - 0.3	196	76	150	218	70	51
0.3 – 0.6	55	70	74	86	56	58
0.6 – 0.9	28	24	22	69	15	25
0.9 – 1.2	10	13	18	45	24	14
1.2 – 1.5	9	15	16	14	14	13
1.5 – 1.8	9	13	14	13	18	11
1.8 – 2.1	9	42	16	14	25	19
2.1 – 2.4	26	5	54	48	40	24
2.4 – 2.7	50	13	51	59	40	31
2.7 – 3.0	79	15	54	62	31	43
3.0 – 3.3	88	29	51	70	25	60
3.3 – 3.6	91	44	71	88	23	77
3.6 – 3.9	70	53	54	102	19	59
3.9 – 4.2	76	67	62	79	22	50
4.2 - 4.5	88	92	82	53	25	62
4.5 - 4.8	116	103	400	108	400	400
4.8 - 5.1	400	95		101		
5.1 - 5.4		125		400		
5.4 – 5.7		166				
5.7 – 6.0		143				
6.0 – 6.3		400				

3.2 Foundation Design Implications

Raft foundations (mat foundations) are recommended for building foundations with moderate bearing capacity and high groundwater levels. Raft foundation effectively distribute heavy loads over a wide area and reduce the risk of settlement. In addition, provide strong resistance to seismic forces and can be designed to reduce the risk of flooding, making raft foundation a durable and stable foundation option.

3.3 Discussion of Findings

From the findings of the data obtained, it can be aligned with the findings of previous studies on Mackintosh Probe testing and soil bearing capacity:

1. Relationship with SPT N-value
   Studies by Das (2023) and Craig (2004) have established a correlation between Mackintosh Probe blow counts and SPT N-values for compact and granular soils. For example, a blow count of 20–40/0.3 m in clay corresponds to medium consistency (Cu = 49–98 kN/m²), which is consistent with the findings at P5 and P6 in the shallow layer.
2. Rejection and Hard Strata
   400 blows/0.3 m, as observed at P3, P5, and P6, is consistent with the findings by Rahman et al. (2021), who stated that rejection often indicates hard strata requiring pile foundations.
3. Soil Heterogeneity
   The variability in punch counts across sites is consistent with a study by Aminuddin et al. (2020), which highlights the challenges of designing foundations in heterogeneous soils, especially in tropical regions such as Malaysia
4. Cost Effectiveness of Mackintosh Probe
   The use of Mackintosh Probe as a cost-effective alternative to SPT for small-scale projects is supported by a study by Chang (2018), which demonstrated its utility in reducing investigation costs by up to 40%.

4. Conclusion

The findings of this study are in line with previous research on the use of Mackintosh Probe for site investigation, especially in low-risk, minimal-cost and small-scale projects such as IBS residential construction. The Mackintosh Probe has proven to be a cost-effective and practical tool for initial soil assessment, reducing investigation costs by up to 40% compared to traditional methods such as Standard Penetration Test (SPT) (Aminuddin et al., 2020; Chang, 2018). Empirical correlations between Mackintosh Probe blow counts and soil properties, such as bearing capacity and consistency, provide reliable values for foundation design. For example, a blow count of 20 to 40 per 300 mm in clay soil indicates moderate consistency (49–98 kN/m²), which is suitable for shallow foundations such as strip footings (Das, 2023; Craig, 2004). On the other hand, stopping at 400 blows per 0.3 m, as observed in this study, indicates hard soil, requiring a deep foundation such as piles (Rahman et al., 2021; Lambe & Whitman, 1969). However, the Mackintosh Probe has limitations, especially in gravelly soils and the need for additional testing and specific adaptations especially for tropical waste soils such as those found in Malaysia (Ong et al., 2020; Balasubramaniam et al., 2016). Suggestions for future research should focus on developing local correlation charts and integrating Mackintosh Probe data with advanced geotechnical techniques to improve reliability and support IBS foundation design in similar environments (Aminuddin et al., 2020; Rahman et al., 2021). In conclusion, the Mackintosh Probe is a valuable tool for initial geotechnical assessment in small-scale projects, easy to operate but the need for additional testing and region-specific adaptations to ensure accurate and reliable results in tropical areas such as Malaysia.

Reference

Aminuddin, A., et al. (2020). Cost-effective geotechnical assessments for low-rise housing in Malaysia. Journal of Construction in Developing Countries, 25(1), 1–15.

ASTM International. (2018). Standard test method for standard penetration test (SPT) and split-barrel sampling of soils (ASTM D1586). West Conshohocken, PA: Author.

Balasubramaniam, M. H., et al. (2016). Correlations between Mackintosh probe and SPT for Malaysian soils. Proceedings of the Institution of Civil Engineers - Geotechnical Engineering, 169(4), 321–330. https://doi.org/10.1680/jgeen.15.00123

Chang, M. F. (2018). Lightweight penetrometers for rapid site assessment. Journal of Geotechnical Engineering, 12(3), 45–52.

Craig, R. F. (2004). Soil mechanics (7th ed.). London, U.K.: Spon Press.

Das, B. M. (2023). Principles of geotechnical engineering (9th ed.). Boston, MA: Cengage Learning.

Jabatan Kerja Raya Malaysia. (2005). Standard specifications for building works. Kuala Lumpur, Malaysia: Author.

Lambe, T. W., & Whitman, R. V. (1969). Soil mechanics. New York, NY: Wiley.

Leonards, G. A. (1962). Foundation engineering. New York, NY: McGraw-Hill.

Mitchell, J. K., & Soga, K. (2005). Fundamentals of soil behavior (3rd ed.). Hoboken, NJ: Wiley.

Ong, S. H., et al. (2020). Tropical residual soils: Characterization and engineering properties. Geotechnical and Geological Engineering, 38, 3425–3441. https://doi.org/10.1007/s10706-020-01226-4

Peck, R. B., et al. (1974). Soil mechanics in engineering practice (3rd ed.). New York, NY: Wiley.

Rahman, N. A., et al. (2021). Geotechnical challenges in IBS construction: A Malaysian perspective. Journal of Performance of Constructed Facilities, 35(4). https://doi.org/10.1061/(ASCE)CF.1943-5509.0001601