

Correlation of JKR Probe with Undrained Shear Strength

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Abstract. The JKR probe test is a popular field test in Malaysia, and is especially used in soft soil areas to determine bearing capacity. However the correlation of undrained shear strength (S_u) and the JKR probe test is not available at this moment. This study was performed to develop an empirical correlation of JKR probe and undrained shear strength of soft to stiff soil. In order to produce the correlation, the JKR probe test and the vane shear test have been performed at Universiti Tun Hussein Onn Malaysia (UTHM). Six JKR probe tests and 12 field vane shear tests were performed in close proximity to obtain good correlation. The results show that undrained shear strength and JKR probe can be correlated as $S_u=18J^{0.3}$. The proposed correlations will serve as a reference for engineers in estimating undrained shear strength, especially in low-risk construction design.

1 Introduction

The JKR probe is a simple site investigation procedure that is relatively inexpensive. The probe is often used in Malaysia, especially for preliminary site investigation, to assess the subsoil layer and the bearing capacity of soils. It can also be used effectively to identify soft or weak layer materials or slip plane failure [1]. The use of the probe test may reduce the number of bore holes required and reduce the overall cost of the project.

JKR probe is slightly different with the Mackintosh probe in terms of cone angle, diameter of rods and couplings, hammer weight and height of hammer free fall, as shown in Table 1. However, for practical application, the results of JKR Probe and Mackintosh Probe may be considered equivalent [1]. The bearing capacity of the soil can be simply obtained by using a correlation graph, as shown in Fig. 1.

2 Correlations of Mackintosh and JKR Probe

The correlation of JKR probe test with undrained shear strength has not been addressed in detail in the literature. However, there have been several correlations proposed from

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Mackintosh Probe test [2,3]. The detail of correlations of the undrained shear strength, S_u (kN/m^2) and Mackintosh probe (M) is shown in Table 2.

Table 1. Difference between JKR probe and Mackintosh probe

Equipment	Cone angle (°)	Diameter of rods (mm)	Diameter of coupling (mm)	Weight of hammer (kg)	Height of hammer fall (mm)
JKR Probe	60	12	22	5.0	280
Mackintosh Probe	30	13	24	4.5	300

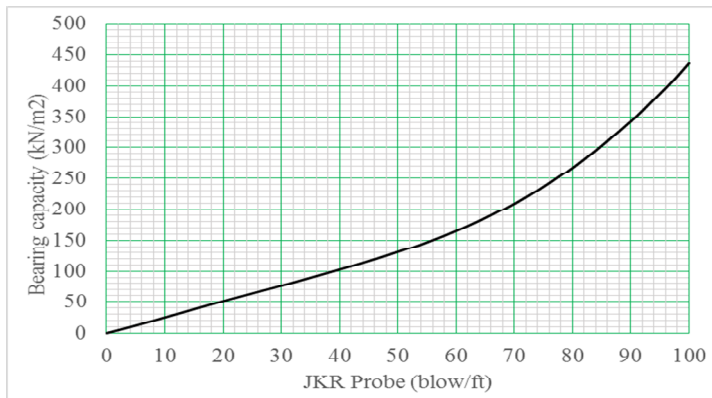


Fig. 1. Estimation chart of bearing capacity

Table 2. Previous correlations between S_u – M (mackintosh probe)

Researcher	Soil types	Location	Equations	Remarks
Hossain & Ali [2]	Soft Clay	Saudi Arabia	S_u (kPa)= K.M	K = 1.59-2.04
	Alluvium	Khazestan province, South of Iran	$S_u = 2.5M$	from vane shear, UU and UCT
Fakher et al. [3]	Alluvium and soft clay	Saudi Arabia and Iran	$S_u = 0.90 M^{0.96}$	from N and M correlation and Equation 1
	Very soft soil		$S_u = 0.64M + 15.35$	
Fatnanta et al. [6]	Soft soil	Indonesia	$S_u = 0.94M + 10.88$	vane shear & Mackintosh probe
	Medium Stiff soil		$S_u = 0.63M + 19.75$	

M represents the number of blows for 100 mm penetration of Mackintosh Probe. The first correlation was proposed by Hossain & Ali [2] in 1990 for soft clay in Sabkha, Saudi Arabia, using field vane shear and Mackintosh probe. Later, Fakher et al. [3] proposed two equations. The first equation was derived from the results of a vane shear test, unconsolidated undrained test (UU) and unconfined compression test (UCT) with a Mackintosh probe. The second equation is based on the correlation of standard penetration test (N) and Mackintosh probe (M) by combining data from Sabtan & Shehata [4]. They proposed a new relationship as follows:

$$N = 0.15M^{0.96} \quad (1)$$

By adopting Terzaghi et al. [5] equation ($S_u = 6N$), they proposed a correlation of S_u and (M) as:

$$S_u = 0.90 M^{0.96} \quad (2)$$

In 2013, Fatnanta et al. [6] proposed a correlation based on field vane shear test and Mackintosh probe test performed at Pekan Baru, Indonesia. They categorized correlations for very soft soil, soft soil, and medium stiff soil. The correlation of very soft soil is questionable because the undrained shear strength of very soft soil is higher than that of soft soil. Furthermore, the proposed equations are not valid if M is equal to zero.

3 Data collection

To develop the correlation of S_u and M , the JKR probe and the vane shear tests were performed at the Research Centre for Soft Soil (RECESS) in Universiti Tun Hussein Onn Malaysia (UTHM). There are six points for the JKR probe test with maximum depth of 6.9 m, while 12 points of vane shear test have been performed in close proximity (less than 0.3 m) to ensure a good correlation obtained as shown in Fig. 2. The number of blows and undrained shear strength for each 300 mm penetration were recorded for JKR probe test. Additionally, a vane shear test was performed at every 0.6 m depth. The vane shear test was pushed statically to the desired depth and torque was applied at a rate of 6° per minute.

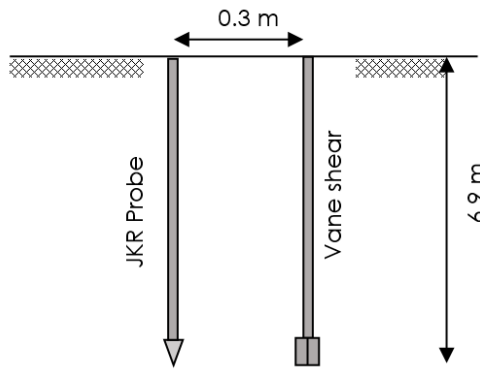


Fig. 2. Details of field testing

4 Results and discussions

4.1 JKR probe test and vane shear test results

The example results of the JKR probe test and vane shear test for point 1 and 2 are shown in Fig. 3 and 4. The results show a good pattern of number of blows and undrained shear strength. This increases with increasing soil depth due to increasing of stress in soil. From Fig. 3 and 4, it is clear that the hard layer exists from the ground surface to a depth of 1 m. This result is due to present of fill material above the existing soft soil layer. These unsaturated fill soils are located above the ground water table, so their behaviors are

influenced by the soil water characteristic curve (SWCC). The SWCC of residual soil or fill material in Malaysia has been discussed in detail by Mohd Fairus *et al.* [7].

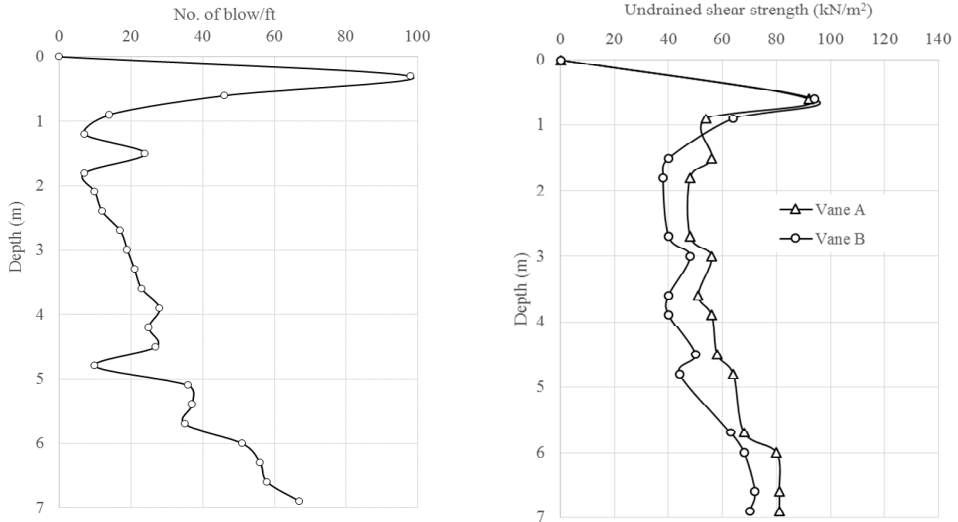


Fig. 3. Number of blow and undrained shear strength versus depth for point 1

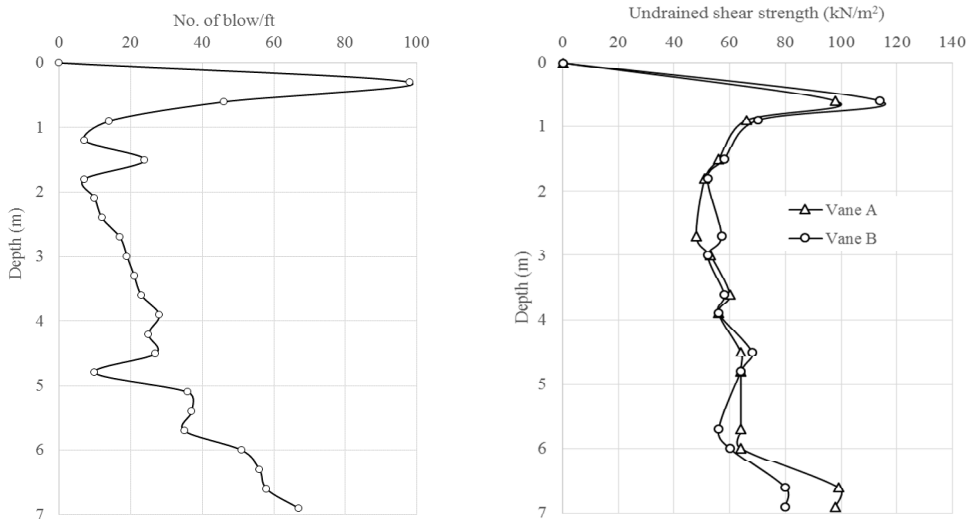


Fig. 4. Number of blow and undrained shear strength versus depth for point 2

4.2 Proposed correlation of JKR probe (J) and undrained shear strength (S_u)

The number of data points obtained from the JKR probe test and the vane shear test were 138 and 168 respectively. The graph of undrained shear strength, S_u versus the number of blows (J-Value) was constructed to develop the correlation.

A graph of undrained shear strength versus the number of blows is shown in Fig. 5. The power correlation was developed and the undrained shear strength could correlate with number of blows using the simplified equation as follows:

$$S_u = 18J^{0.3} \tag{3}$$

where S_u is the undrained shear strength (kN/m^2) and J is the number of JKR probe blow. Referring to the coefficient of determination, $R^2 = 0.5027$ for the proposed equation, it can be categorized as a moderately good correlation [8].

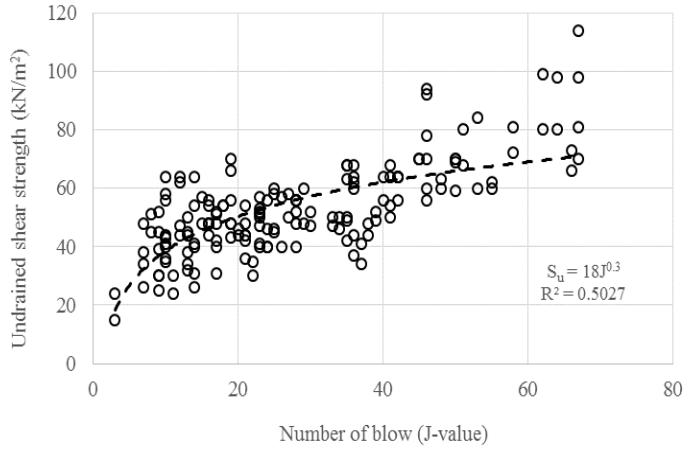


Fig. 5. Correlation of undrained shear strength and J-value

4.3 Parametric studies of proposed correlation

A parametric study was conducted to verify the proposed equation and make comparisons with past researchers. Fig. 6 contains a graph of undrained shear strength versus the number of blows from Mackintosh and JKR probe based on proposed equation. For practical applications, the results from Mackintosh and JKR probe are assumed to be identical.

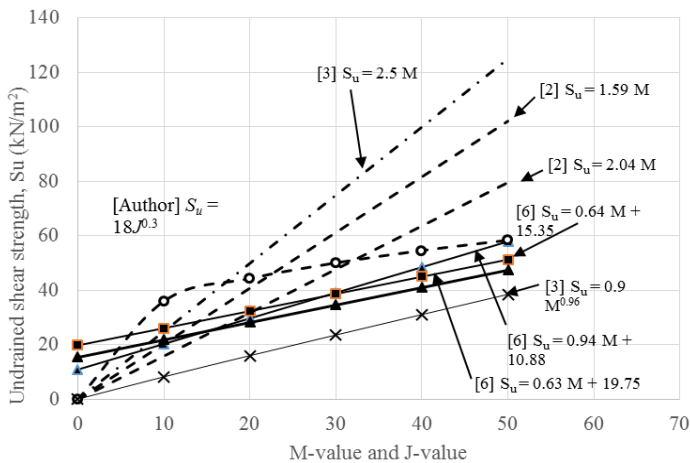


Fig. 6. Comparison of S_u and M or J relationship from proposed equation

5 Conclusion

This study provides a correlation of JKR probe test and undrained shear strength of soft soil. From the study, the undrained shear strength can be predicted as $S_u = 18J^{0.3}$.

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