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Proceedings of the Second International Conference on the Future of ASEAN (ICoFA) 2017 – Volume 2

Science and Technology

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About this book

This book examines how business, the social sciences, science and technology will impact the future of ASEAN. Following the ASEAN VISION 2020, it analyses the issues faced by ASEAN countries, which are diverse, while also positioning ASEAN as a competitive entity through partnerships. On the 30th anniversary of ASEAN, all ASEAN leaders agreed to the establishment of the ASEAN VISION 2020, which delineates the formation of a peaceful, stable and dynamically developed region while maintaining a community of caring societies in Malaysia, Indonesia, Singapore, Brunei, Vietnam, Thailand, the Philippines, Myanmar, Laos and Cambodia. In keeping with this aspiration, Universiti Teknologi MARA Perlis took the initial steps to organise conferences and activities that highlight the role of the ASEAN region. The Second International Conference on the Future of ASEAN (ICoFA) 2017 was organised by the Office of Academic Affairs, Universiti Teknologi MARA Perlis, to promote more comprehensive integration among ASEAN members. This book, divided into two volumes, offers a useful guide for all those engaged in research on business, the social sciences, science and technology. It will also benefit researchers worldwide who want to gain more knowledge about ASEAN countries

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Differentiation of Displacement Factor for Stiff and Soft Clay in Additional Modulus of Subgrade Reaction of Nailed-slab Pavement System

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Abstract. Displacement factor was proposed to use in calculation of additional modulus of subgrade reaction. The moduli is used in designing the Nailed-slab Pavement System. A curve of displacement factor was proposed by Puri (2017) for soft clay and the inverse one was recomended by Hardiyatmo (2011b) for stiff clay. This paper is aimed to develop displacement factor for stiff clay based on Hardiyatmo data and compared to Puri’s curve. Results show that there is no significant differentaition of displacement factor between both clay consistencies. It can be concluded that the curve of dispalcement factor for soft clay from Puri’s curve can be used for stiff clay.

Keywords: rigid pavement, Nailed-slab System, subgrade, displacement factor, clay

1 Introduction

Hardiyatmo (2008) introduced a new proposed method that is called Nailed-slab System. It was developed from the pavement of the *Sistem Cakar Ayam Modifikasi* (CAM) by changing the cylindrical foundation with short micro piles. Hardiyatmo (2008) conducted several studies on a nailed slab under dynamic loads, and studies on vertical loadings were done by Hardiyatmo (2009; 2011a), Nasibu (2009), Dewi (2009), Taa (2010), Somantri (2013), and Puri et al. (2011a, 2011b, 2012a, 2012b, 2013a, 2013b, 2013c, 2013d). Nailed-slab System due to tension loading was studied by Puri, et.al. (2015) and Puri (2016). Hardiyatmo (2011a) proposed an analysis method for determining the additional modulus of subgrade reaction. The additional modulus of subgrade reaction is the additional modulus developed by a pile. Meanwhile, the modulus of subgrade reaction is the modulus considered from a slab. Puri et al. (2012a) modified the Hardiyatmo method by considering the tolerable deflection or allowable deflection of a pavement slab (δ_a) as an approach to safety construction.

Hardiyatmo (2011b) used the inverse of the displacement factor which developed from full scale test in stiff clay. The displacement factor is the ratio between the relative displacement between the pile and soil (δ_0) and the displacement of the pile head (δ_p). Since the δ_p is assumed to be similar with slab deflection (δ_s), then this factor is written as

$$\alpha = \frac{\delta_0}{\delta_s} \tag{1}$$

Puri (2017) proposed a curve of displacement factor (δ_0/δ_s) for soft clay. In this paper, the curve of the δ_0/δ_s ratio for stiff clay based on Hardiyatmo data (2011b) will be developed and will be compared to Puri's curve (2017).

Hardiyatmo (2011a) proposed Eq. (2) in determining the additional modulus of subgrade reaction (Δk). The relative displacement between the pile and soil is considered.

$$\Delta k = \frac{\delta_0 A_s}{\delta_s^2 s^2}\left(a_d c_u + p_0 K_d \tan \varphi_d\right) \tag{2}$$

Where δ_0 : relative displacement between pile and soil (m), δ_s : deflection of surface of slab (m), A_s : surface area of pile shaft (m^2), s : pile spacing (m), a_d : adhesion factor (non-dimensional), c_u : undrained cohesion (kN/m^2), p_o' : average effective overburden pressure along pile (kN/m^2), K_d : coefficient of lateral earth pressure in pile surroundings (non-dimensional), and ϕ_d : soil internal friction angle (degree).

Figure 1 shows the curve of the inverse of the displacement factor (δ_s/δ_0) based on the full-scale test of a single pile in stiff clay. The pile and slab were connected by bolts. The pile diameter was 20 cm, and the length of the pile varied between 1.0 m and 2.0 m.

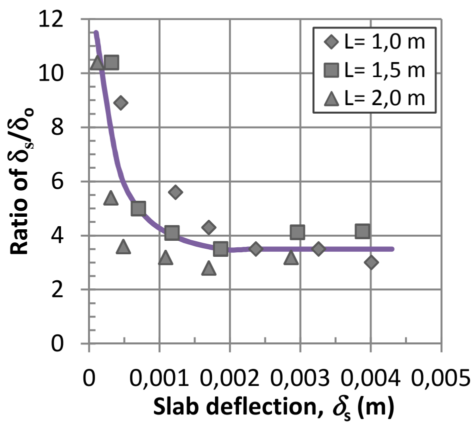

Fig. 1 Relationships of δ_s/δ_0 ratio vs. slab deflection (Hardiyatmo, 2011b)

Figure 2 shows the curve of displacement factor (δ_0/δ_s) for soft clay according to Puri (2017). This curve was based on full scale test on single pile Nailed-slab System in soft clay. The slab and pile was connected monolithically.

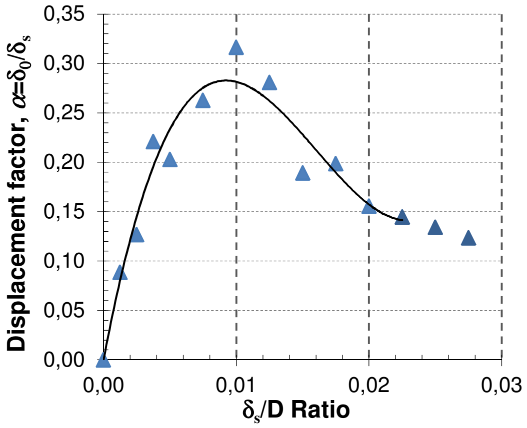

Fig. 2 Curve of displacement factor (α) for soft clay (Puri, 2017)

The additional modulus of subgarde reaction (Δk) is used in determining the equivalent modulus of subgrade reaction (k') as given as Eq. (3) (Hardiyatmo, 2011a; Dewi, 2009; Puri et al., 2012a):

$$k' = k + \Delta k \tag{3}$$

Where k : modulus of subgrade reaction from plate load test (kN/m^3) and Δk: additional modulus of subgrade reaction due to pile installation under slab (kN/m^3). The modulus of subgrade reaction from a plate load test (k) is usually taken by using a circular plate, and it should be corrected to the slab shape of the nailed slab. The secant modulus is recommended.

2 Methodology

The object of this research is the inverse of displacement factor from Hardiyatmo (2011b) as shown in Figure 1 and the curve of displacement factor from Puri (2017) as in Figure 2. Hardiyatmo (2011b) used data from Dewi (2009) to develop Figure 1. Dewi (2009) conducted Nailed-slab System with single pile by using reinforced concrete. The used slab was circular slab with 1.00 m in diameter and 0.15 m in thickness. There was no lean concrete under the slab. The used pile was 0.20 m in diamater and 1.00 m, 1.50 m, and 2.00 m in length variation respectively. Slabs and piles were connected by using some bolts. The Nailed-slab was constructed in stiff clay. The unconfined compression strength q_u of clay was 120.28 kN/m^2. The characteristic strength of concrete was 21.97 MPa.

Puri (2017) also conducted Nailed-slab System with single pile by using reinforced concrete. The used slab was rectangular slab with 1.20 m width and 0.15 m in thickness. There was 0.05 m lean concrete under the slab. The used pile was 0.20 m in diamater and 1.50 m in length. Slabs and piles were connected monolithicaly. The Nailed-slab was constructed in soft clay. The unconfined compression strength q_u of clay was 40.28 kN/m^2. The characteristic strength of concretes were 29.21 MPa, 17.4 MPa and 14.5 MPa for slab, pile, and lean concrete respectively. Table 1 shows clay properties from both researchers.

Table 1. Clay properties

No.	Parameter	Unit	Stiff clay (Dewi, 2009)	Soft clay (Puri et al., 2013c)
1	Specific gravity, G_s	-	2,45	2.55
2	Consistency limits:			
	- Liquid limit, *LL*	%	88,46	80.50
	- Plastic limit, *PL*	%	24.43	28.48
	- Shrinkage limit, *SL*	%	n/a	9.34
	- Plasticity index, *PI*	%	56.05	59.98
3	Water content, *w*	%	24.60 – 36.10	54.87
4	Fines content	%	92.93	92.29
5	Sand content	%	7.30	6.89
6	Gravel content	%	0.41	0
7	Bulk density, γ	kN/m^3	17.00	16.32
8	Dry density, γ_d	kN/m^3	12.52	10.90
9	Undrained shear strength, s_u	kN/m^2	60.14	20.14
10	CBR	%	n/a	0.83
11	Soil classification:			
	- AASHTO	-	A-7-6	A-7-6
	- USCS	-	CH	CH

The displacement factor for stiff clay will be defined by using Figure 1. The value of δ_s/δ_0 will be inversed become displacement factor ($\alpha = \delta_0/\delta_s$) and compared to Puri (2017).

3 Results and Discussion

Displacement factor for stiff clay based on Hardiyatmo (2011b)—only for 1.50 m pile length—is shown in Figure 3 and combined to Puri (2017). It seen that there is no differentiation between both soil consistency up to 0.01 in δ_s/D ratio. Significant defferentiation came up after 0.01 in δ_s/D ratio. Figure 4 shows curve of displacement factor for all data and is compared to Puri (2017). It is can be concluded for both cases that there is no effect of soil consistency. Allthought there are some differents between both cases. Puri (2017) used lean concrete, larger and rectangular slab while Hardiyatmo (2011b) used circular and smaller slab without lean concrete. And there was also differed on slab-pile connection type. These factors can be neglected, because of the relative displacement between pile and soil was response of these conditions.

According to Figure 4, it can be concluded that the curve of dispalcement factor for soft clay from Puri (2017) can be used for stiff clay.

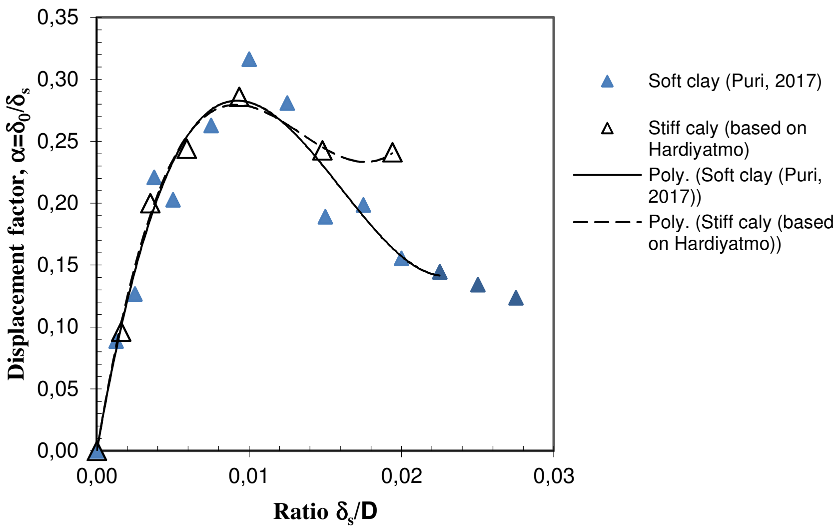

Fig. 3 Displacement factor for soft and stiff clay

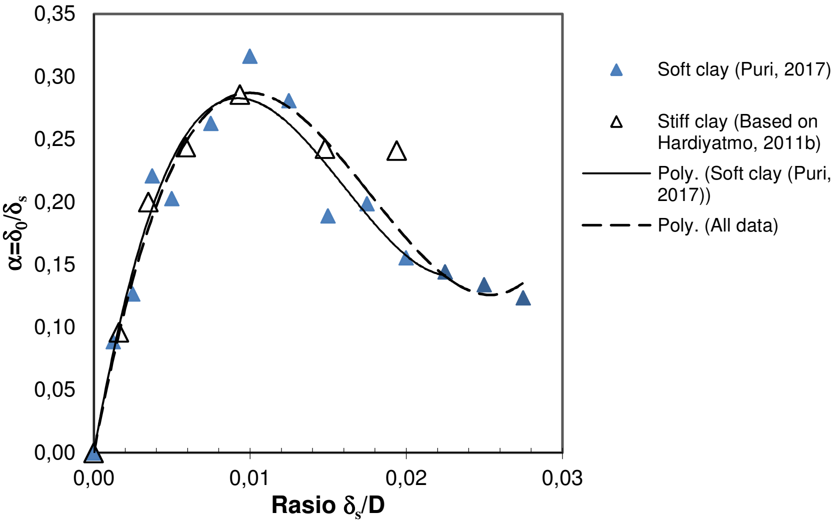

Fig. 4 Displacement factor for all data

4 Conclusion

Curve of dispalcement factor for stiff clay was developed and compared to dispalcement factor for soft clay. It is seem that there is no significant differentaition between both clay consistencies. It can be concluded that the curve of dispalcement factor for soft clay from Puri (2017) can be used for stiff clay. In this case, effect of lean concrete, slab shape and dimension, and slab-pile connection type were neglected, because of the relative displacement between pile and soil was response of these conditions.

Acknowledgements

This work is partially supported by Universitas Islam Riau. The author also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

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