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Effects of Model Scale Due to Displacement Factor for Nailed-slab Pavement System

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ABSTRACT

The Nailed-slab pavement system can be analyzed by using equivalent modulus of sub grade reaction. This modulus consists of modulus of subgrade reaction contributes by slab and additional modulus of subgrade reaction contributes by pile which installed under the slab. The displacement on the surface of loading plate is always larger than the relative displacement between pile and soil. Since the relative vertical displacement between the pile and surrounding soil is very small, ultimate pile shaft resistance has not been fully mobilized yet. The mobilized unit pile shaft resistance can be reduced by applying dispalcement factor. Some researcher conducted small scale test and others conducted full scale test. This research is aimed to study the effect of different model scale to the dispalcement factor. Results show that the model scale affects the value of dispalcement factor. Displacement factor for full scale model very small than small scale model. In other case, pile length can also affect this factor.

Keywords: rigid pavement, soft clay, Nailed-slab System, modulus of subgrade reaction, displacement factor, model scale.

1 INTRODUCTION

Nailed-slab pavement system is a method to improve the performance of rigid pevement on soft subgrade in case this system constructed on the ground (Puri, 2015a, 2015b, 2016, 2017a, 2017b; Puri, et.al 2011a, 2011b, 2012a, 2012b, 2013a, 2013b, 2013c, 2013d, 2015, 2015; Hardiyatmo, 2008, 2009, 2011a, 2011b; Dewi, 2009; Nasibu, 2009; Taa, 2010; Somantri, 2013; Diana, et.al, 2016, 2017). The slab have double functions; as a pile cap, and as a pavement slab at the same time. This system can be also as a soil reinforcement if it is contructed under embankment (Waruwu, et.al 2017).

Hardiyatmo (2011a) proposed the method to analyze Nailed-slab pavement system by using equivalent modulus of sub grade reaction. This modulus consists of modulus of subgrade reaction contributes by slab and additional modulus of subgrade reaction contributes by pile which installed under the slab. Pile and slab should be connected monolithically (Puri, 2015).

According to Hardiyatmo (2011a), the displacement of the loading plate is different from the relative displacement between soil and pile. When the pile moves down due to loading, the soil under the plate also goes down. The displacement on the surface of loading plate (δ_s) is always larger than the relative displacement between pile and soil (δ_0). Since the relative vertical displacement between the pile and surrounding soil is very small, ultimate pile shaft resistance (Q_s) has not been fully mobilized yet. The mobilized unit pile shaft resistance can be reduced by applying dispalcement factor ($\alpha = \delta_0 / \delta_s$).

Hardiyatmo (2011a) conducted small scale model test (1 : 5) on soft clay and proposed curve of inverse displacement factor. Puri (2015) also proposed similar curve based on small scale model test (1 : 5) on soft clay. Hardiyatmo continued to propose the same curve of inverse displacement factor based on full scale model on stiff clay (Hardiyatmo, 2011b). Puri (2017a) proposed a curve of displacement factor for soft clay based on full scale model.

This research is aimed to study the effect of different model scale to the dispalcement factor.

2 DISPLACEMENT FACTOR

The analytical approach in determining the equivalent modulus of subgrade reaction (k') is given as follows (Hardiyatmo, 2011a; Dewi, 2009; Puri et al., 2012a):

$$k' = k + \Delta k \qquad (1)$$

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.

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

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

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).

Hardiyatmo (2011a) published Figure 1 the inverse of dispalcement factor (δ_s/δ_0) based on small scale tests (1 : 5). The model used was 4 cm pile diameter and 40 cm in length. Hardiyatmo (2011b) re-published the relation between δ_s/δ_0 and slab deflection for a full-scale model (Figure 2) while the pile and slab were connected by a bolt. The pile diameter was 20 cm, and the length of the pile varied between 1.0 m and 2.0 m. Puri (2015) developed the curve of dispalcement factor (δ_0/δ_s) based on small scale tests (1 : 5). The model used was 4 cm pile diameter and 20 cm in length.

Puri (2017a) peoposed a curve of displacement factor ($\alpha = \delta_0 / \delta_s$) as shown in Figure 3, based on full scale model on soft clay. The pile and slab was connected monolitichally.

Based on Hardiyatmo work (2011b) and Dewi (2009), the curve of displacement factor is shown in Figure 4 (Puri, 2017b).

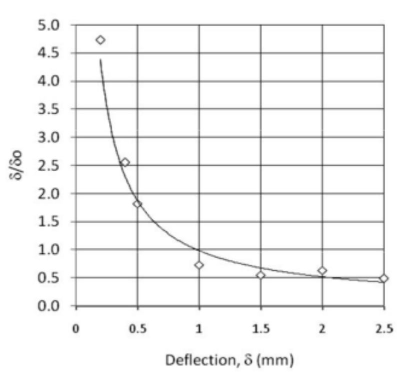

Figure 1 Relationships of δ_s/δ_0 ratio vs. slab deflection based on small scale model test (Hardiyatmo, 2011a).

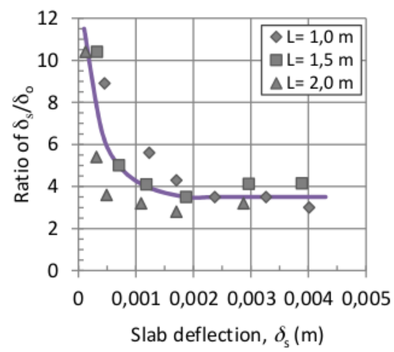

Figure 2 Relationships of δ_s/δ_0 ratio vs. slab deflection (Hardiyatmo, 2011b) based on full scale model test.

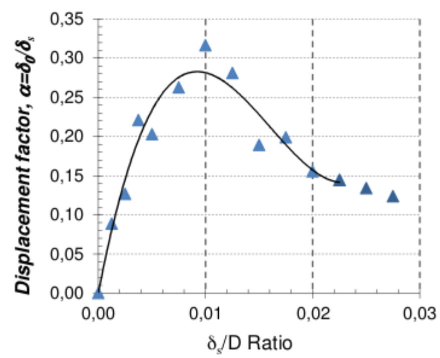

Figure 3 Curve of displacement factor, α based on full scale model test (Puri, 2017a).

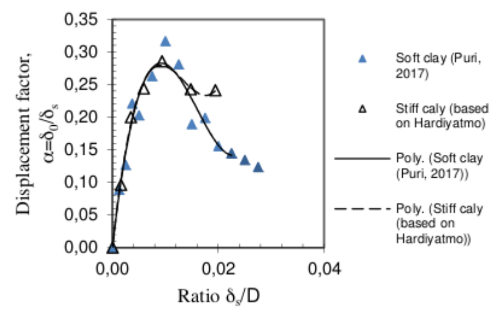

Figure 4 Displacement factor for soft and stiff clay based on full scale model test (Puri, 2017b).

Figure 4 shows the displacement factor for stiff clay based on Hardiyatmo (2011b)—only for 1.50 m pile length—and combined to Puri (2017a). 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. It is can be also concluded for both cases that there is no effect of soil consistency at least up to 0.01 in δ_s/D ratio. Althought there are some differents between both cases. Puri (2017a) 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.

3 RESEARCH METHOD

Data was taken from work of Hardiyatmo (2011a) and Puri (2015) in form of inverse dispalcement factor (δ_0/δ_s), and Hardiyatmo (2011b) for small scale and full scale model test respectively. Those inverse of dispalcement factor (δ_0/δ_s) re-inverse to dispalcement factor ($\alpha = \delta_s/\delta_0$). Data also taken from Puri (2017a, 2017b) for dispalcement factor ($\alpha = \delta_s/\delta_0$) for full scale model test. Those all of dispalcement factor were compare eacth other and to find the effect of model scale due to this factor. The structural dimension of model and soil data are presented in Table 1. Hardiyatmo (2011a) and Puri (2015) are for small scale model in soft clay. Hardiyatmo (2011b) and Puri (2017) are for full scale model in stiff clay and soft clay respectively.

Table 1 Nailed-slab dimension and soil data

Description	Unit	Hardiyatmo (2011a)	Puri (2015)	Hardiyatmo (2011b)	Puri (2017)
Pile:					
- Diameter, D	cm	4	4	20	20
- Length, L_p	cm	40	20	150	150
Slab:					
- Width, B	cm	20	20	120	120
- Thickness, h	cm	4	4	15	15
- Shape	-	Rectangular	Rectangular	Circular	Rectangular
Soil:					
- Undrained cohesion	kPa	21	21	60	20
- Soil Classification		CH	CH	CH	CH

4 RESULTS AND DISCUSSION

Dispalcement factor ($\alpha = \delta_s/\delta_0$) for small scale model test is shown in Figure 5. The maximum α value tend to be similar between shorter pile and longer pile, while the ratio of δ_s/D for shorter pile tend to be in small range compare to longer pile.

There are very significant effect of model scale as shown in Figure 6. Displacement factor for full scale model very small than small scale model. It can influence the result of analysis. Displacement factor for small scale model should be used for small scale and the same thing for full scale model. According to Hardiyatmo (2011a) and Waruwu et.al (2017), by using inverse of displacement factor for small scale in calculation of small scale Nailed-slab model was good agreement with the observed deflection. According to Puri (2017a), displacement factor for full scale model in calculation of full scale Nailed-slab model was very good agreement with the observed deflection.

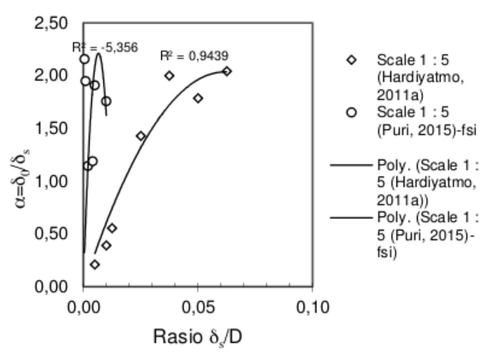

Figure 5 Displacement factor for soft clay based on small scale model test.

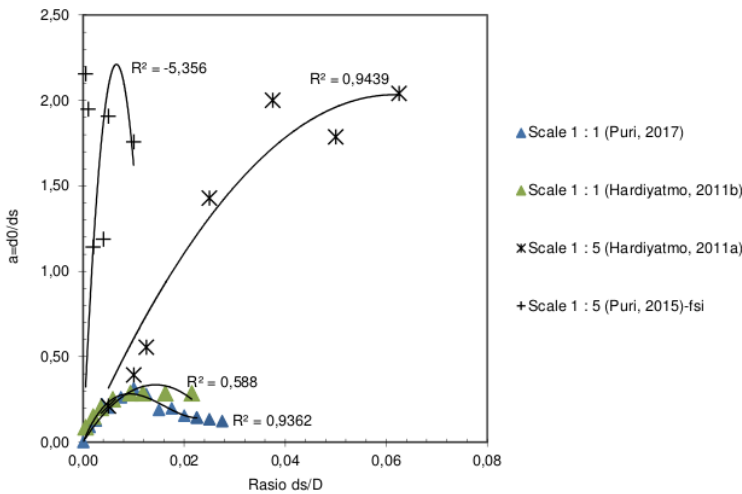

Figure 6 Displacement factor based on all scale model test.

5 CONCLUSIONS

Displacement factor was discussed by considering the model scale. It can be concluded that the model scale affects the value of dispalcement factor. Displacement factor for full scale model very small than small scale model. In other case, pile length can also affect this factor. It is recommended using each displacement factor approriate with dimension scale of Nailed-slab.

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