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EFFECT OF SAFETY FACTORS ON THE CALCULATED DEFLECTION OF 1-PILE ROW FULL SCALE

2**NAILED-SLAB** PAVEMENT **SYSTEM RESTING ON SOFT CLAY DUE TO** CONCENTRIC **LOADINGS**

Anas Puri 1 Associate Professor Department of Civil Engineering,

16**Universitas Islam Riau, Email:** anaspuri@eng **.uir.ac.id** **Abstract**

7**The Nailed-slab** Pavement **System** was **proposed as an alternative** improving **for rigid pavement** performance on **soft soils.**

Puri, et.al. (2012a) proposed a new approach for practical purpose in designing

1where pile friction resistance is fully mobilized and the tolerable settlement is considered.

The

1additional modulus of subgrade reaction due to pile installing is defined by

using safety factor 2.5. Effect of variation in safety factors (SF) were not considered yet. In this paper, effect of SF variation due to slab deflection will be considered by using SF 1.0 to 3.0. The slab

2deflection will be calculated by using beam on elastic foundation

theory. Analysis will use data of loading test

3on 1-pile row full scale Nailed-slab by Puri, et.al.

(2013). Observed deflection data will be used to determine the

1additional modulus of subgrade reaction. Calculated deflection based on the additional modulus of subgrade reaction is compared to the

observed deflection. Results show that SF variation affects the calculated deflections.

1Good results are obtained in the sense that the calculated settlement is in good agreement with observation.

The SF = 1.0 is adequate for analysis. The Nailed-slab in the field will have extensive area and alot of number of installed pile under the slab. Hence,

4the performance of this system would be better due to reduction on the slab deflection.

Keywords: Deflection, Nailed-Slab Pavement System, Safety Factor, Soft Clay, Subgrade Modulus . 1. INTRODUCTION

7The Nailed-slab System was proposed as an alternative improving for rigid pavement performance on soft soils. It is

also

2to gain the efficiency of construction implementation. The changing of the shell of fondasi cakar ayam (hen's claw foundation) by short-friction piles was proposed by Hardiyatmo (2008). The rigid pavement slab is nailed to the subgrade by installing the short piles underneath. The

1slab has double functions: as pavement structures and all at once as pile cap.

The composite system is developed which consist of slab, piles, and soils surrounding the piles and

4slab. The installed piles under the slab make the slab keeps contact with the soils and increase the

slab stiffness (Puri, et.al., 2011a).

2Then the slab height can be decreased. The decreasing of slab height can reduce the weight of the structure and will be beneficial for soft soils

(Hardiyatmo dan Suhendro, 2003). Physical modeling of nailed-slab and it's analytical study have been conducted for soft soils (Hardiyatmo dan Suhendro, 2003; Hardiyatmo, 2008, 2009, 2011;

5Nasibu, 2009; Dewi, 2009; Taa, 2010; Puri, et.al, 2011a,

2011b, 2012) and for sand (Somantri, 2013).

2Analysis of deflection of a nailed-slab by using equivalent modulus of subgrade reaction has been done by Hardiyatmo (2009, 2011), Puri, et.al.

(2011b, 2012a, 2012b, 2013), Somantri (2013) and Puri (2015, 2017).

2This modular was also implemented in cakar ayam analysis

(Puri & Ardiansyah, 2017; Afriliyani, et.al. 2017; Agustin, et.al. 2017). The

1equivalent modulus of subgrade reaction is the cumulative of

8modulus of subgrade reaction from plate load test (k) and additional modulus of subgrade reaction due to pile installing (k). Hardiyatmo (2011) used the additional modulus of subgrade reaction

based on

1**the relative displacement between** the **pile and soils.** The developing **of**

formula was based on static theory. Puri, et.al. (2012a) proposed a new approach for practical purpose in designing Nailed-slab System

1**where pile friction resistance is fully mobilized and the tolerable settlement is considered.**

The proposed method of analysis is based on one row of pile. Practically,

1**the Nailed-slab** will **be constructed by multiple** rows of **piles. This system**

will have higher capacity and stiffness. Hence,

1**designing of the Nailed-slab System based on an analysis of the one row pile will produce a safe design**

(Puri, et.al. 2012a; Puri, 2015).

3**This paper is aimed to discuss the** effects **of**

safety factor in

2**the additional modulus of subgrade reaction** due **to the** prediction **of** deflection on **nailed-slab**

under concentric loading. The experimental was conducted

3**by full scale model** test **of one row pile nailed-slab system.**

In designing the Nailed-slab, it is required an equivalent

1**modulus of subgrade reaction due to pile** bearing contribution **(k').** The analytical approach **of** this moduli **is**

determined by accumulating

2**the modulus of subgrade reaction from plate load test (k) and** the **additional modulus of subgrade reaction due to pile installing (k).**

5The equivalent modulus of subgrade reaction (k') is given as follows (Hardiyatmo, 2011; Dewi, 2009; Puri, et.al., 2011b, 2012a): k ' = k + Dk (1) Where k is the modulus of subgrade reaction from plate load test (kN/

m3

7k is the additional modulus of subgrade reaction due to pile installing (kN/m3). The mobilisation of

unit friction resistance of pile shaft is in elastic zone (Puri, et.al. 2012a). Safety factor 2.5 is usually used in practical of determining the pile allowable bearing capacity. Then the the

2additional modulus of subgrade reaction due to pile installing (k) can be

defined as fsAs Dk = 2.5daAps (2) Where a is the tolerable settlement of rigid pavement slab (m), fs is the ultimate unit friction

12resistance of pile shaft (kN/m2), As is the surface area of pile shaft (m2),

Aps is the

2area of plate zone which supported by single pile (m2), and 2.

5 is the safety factor. And the Equation (2) can be written as (Puri, 2015) Dk = SFdaAps fsAs (3) The end bearing resistance of pile can be ignored for nailed-slab which resting

1on soft soils. Ultimate unit friction resistance of the pile shaft in saturated clay is expressed by f s

= ad cu (4) Where ad is the adhesion factor (non-dimensional), and cu is the undrained cohesion of soil (kN/m2). The slab

1deflections due to the load acting on plate-supported piles can be calculated by theory of beams on elastic foundation

(BoEF) (Hardiyatmo,

142009, 2011; Taa, 2010; Puri, et.al., 2011b, 2012a, 2012b;

Somantri, 2013; Puri, 2015, 2017). In this case, BoEF will use Roaks formulas according to Young dan Budynas (2002). The

1k is replaced by k' for analysis of nailed-slab system.

3INVESTIGATED 1-PILE ROW FULL SCALE NAILED-SLAB PAVEMENT SYSTEM Detail of the procedure on 1-pile row full scale Nailed-slab is presented in Puri, et.al. (2013) and briefly described in Puri, et.al.

(2014).

3The 1-pile row full scale nailed-slab was constructed on soft clay.

3The soft clay properties are presented in Table 1. The slab and piles were reinforced concrete. The concrete strength characteristic of the slab and piles was 29.2 MPa and 17.4 MPa respectively. The flexural strength of the slab was 4,397.6 kPa. Table 1 Soft clay properties

(Puri, et.al. 2013) Parameter Unit Average Spesific gravity, Gs

3Consistency limits: - Liquid limit, LL - Plastic limit, PL - Shrinkage limit, SL - Plasticity index, PI - Liquidity index, LI Water content, w Clay content Sand content

d Undrained shear strength, su CBR Soil classification: - AASHTO - USCS - % % % % % % % % kN/m3 kN/m3 kN/m2 % - - 2.55 88.46 28.48 9.34 59.98 0.36 54.87 92.93 6.89 16.32 10.90 20.14 0.83 A-7-6 CH

3The Nailed-slab System Prototype dimension was 6.00 m × 3.54 m, 0.15 m in slab thickness, and the slab was reinforced by micro piles 0.20 m in diameter and 1.50 m in length. The spacing between piles was 1.20 m. This model was obtained by cutting the 600 cm ´ 354 cm ´ 15 cm Nailed-slab to 3 parts where each part consisted of one pile row. The tested 1 pile row Nailed-slab was the middle one with slab dimension 600 cm ´ 120 cm ´ 15 cm.

3All piles were installed under the slab and connected monolithically by using thickening slab connectors (0.40 m × 0.40 m and 0.20 m in thickness). Each end of slab is equipped by the vertical concrete wall barrier. There was a 5 cm lean concrete thickness under the slab. The slab was loaded by compression loadings with different load positions. Loads were transferred to the slab surface by using a circular plate 30 cm in diameter (the plate represents the wheel load contact area). Then the instrumentations were recorded. Details about testing procedure is presented in Puri, et.al.

(2013, 2014). BoEF analysis will use the “BoEF.xls software version 1.4”. According to limitation of BoEF, some simplification have to be done (Puri, 2015). The pile-slab connector and vertical wall barrier were neglected. Lean concrete was also neglected. Comprehensive analysis procedure

3**is presented in Puri, et.al** (2013 **and Puri**

(2015). RESULT AND DISCUSSION

17**Modulus of Subgrade Reaction The** Eq. (3) **was** used **to** calculate **the**

5**additional modulus of subgrade reaction due to** one row **pile installation under** the **slab; the**

results are shown in Table 2 by variation in safety factor.

1**The tolerable settlements (a) were taken** by using maximum **observed deflections.**

Equivalent moduli of subgrade reactions are included k and

13**k’ tend to decrease** by **increasing the**

load because and

13**k’ tend to decrease** also by **increasing** k **the**

safety factor. Load (kN) (mm) Safety factor, SF (kPa/m) k' x 103 (kPa/m) a= s k x 103 Table 2 Modulus of subgrade reaction Load (kN) (mm) Safety factor, SF (kPa/m) k' x 103 (kPa/m) a= s k x 103 5 1 1.5 2 2.5 3 149.32 99.54 74.66 59.73 49.77 152.62 102.84 77.96 63.03 53.07 40 0.93 1 1.5 2 2.5 3 16.06 10.70 8.03 6.42 5.35 19.36 14.00 11.33 9.72 8.65 10 0.27 1 1.5 2 2.5 3 55.30 36.87 27.65 22.12 18.43 58.60 40.17 30.95 25.42 21.73 80 2.06 1 1.5 2 2.5 3 7.25 4.83 3.62 2.90 2.42 10.55 8.13 6.92 6.20 5.72 20 0.41 1 1.5 2 2.5 3 36.42 24.28 18.21 14.57 12.14 39.72 27.58 21.51 17.87 15.44 150 4.52 1.0 1.5 2.0 2.5 3.0 3.30 2.20 1.65 1.32 1.10 6.60 5.50 4.95 4.62 4.40 Results of Deflection Results of defelction analysis are shown in Fig. 1 and 2. Fig. 1 shows the P- relationship on loading point of nailed-slab.

1**Good results are obtained in the sense that the calculated settlement is in good agreement with observation.**

All calculated deflection based on variation of SF tend to over-estimated. For SF = 1.0, the over-estimated about 68% for maximum load 150 kN. SF variation affects the calculated deflections. The over-estimated tends to increase by increasing in SF. It is also shown in Fig. 1 122 | Universitas Islam Riau that P- curves are in elastic zone as defined in the theory . Load, P (kN) 0 50 100 150 0 Observed (Puri, et.al. -2 2013) Deflection, d (mm)

10SF = 1.0 -4 SF = 1.5 -6 SF = 2.0 -8 SF = 2.5 -10 SF = 3.0 -12 Fig. 1.

P- relationship on loading point of nailed-slab. Fig. 2 shows the distribution of calculated occured for other loads. The utilitation

1of deflection along the slab of nailed-slab for the additional modulus of

subgrade reaction load 40 kN.

1Good results are obtained in the sense that the calculated settlement is in

(Dk) can well predict the deflections, despite of the Dk theory based on elastic good agreement with observation. condition (Puri, et.al. 2012, 2013; Puri, Calculated deflections tend to 2015, 2017). The Dk was developed based over-estimated by increasing the SF and on elastic theory; however it can well litle bit uplift on the both ends of slab. predict the deflection in plastic zone These similar behaviour were also .

4Distance from load point (m) -3 -2 -1 0 1 2 3 2

Deflection, d (mm) 0 -2 -4 -6 -8 -10 -12 Observed (Puri, et.al. 2013)

11SF = 1.0 SF = 1.5 SF = 2.0 SF = 2.5 SF = 3.0

Fig. 2.

1Distribution of calculated deflection along the slab of nailed-slab for

load 40 kN. CONCLUSION In this case, the additional subgrade reaction modulus (Dk) can be used for calculating the slab deflection of Nailed-slab Pavement System. SF variation affects the calculated deflections.

1Good results are obtained in the sense that the calculated settlement is in good agreement with observation

especially for SF = 1.0. It can be concluded that the SF = 1.0 is adequate for analysis.

4Since this system will be functioned as pavement in the field, the Nailed-slab will have extensive area and installed pile under the slab will also more and more to all directions. So the performance of this system would be better due to bearing capacity and reduction on the slab deflection

(Puri, et.al. 2014). Further research can be conducted for edge loadings of the Nailed-slab Pavement System. ACTKNOWLEDGEMENT The author would like to express his gratitude to Ms. Dinda Rosita

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