Consideration of the Different Pile Length Due to Soil Stress and Inner Forces of the Nailed-slab Pavement System under Concentric Load

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Abstract: Concentric loading on the Nailed-slab Pavement System causes stress in the soil and the inner forces in structural elements. The load stress is transferred to the soil by the structural elements tends to concentrate in the centerline area under the system. Since load stress is concentrated in the center line area, the soil stress and inner forces can be higher in the center of the system. To reduce the soil stress and inner forces of structural elements, the longer pile can be put in the center area of the system. This research is aimed to learn the soil stress and inner forces behavior of the Nailed-slab Pavement System in case putting the longer pile in the center area of the system. The maximum double wheel load was taken 50 kN which transfer to the slab surface by contact pressure. Wheel load was loaded in the center of the slab. The Nailed-slab materials properties and soft clay properties were taken from the previous researcher. The piles in the center area of the Nailed-slab were longer 33.3% than others. Results show that the Nailed-slab by longer piles in the center area can reduce the soil stress significantly for maximum shear stress up to 28%. The inner forces were also reduced by about 43% to 46% and caused the reducing in lateral deflection of pile tip about 37%. It can be concluded that the increasing pile length in the central area of the system can reduce soil stress and inner forces of the system.

1 INTRODUCTION

The uniform pile length in bearing the vertical loadings on the Nailed-slab Pavement System was used by the previous researchers. Such as the research by Hardiyatmo (2011), (Puri et al., 2011a; Puri et al., 2011b; Puri et al., 2012; Puri et al., 2013; Puri et al., 2014; Puri et al., 2015; Puri and Mildawati, 2019) and (Puri et al., 2015; Puri, 2016) for Nailed-slab System on the soft clay. The distribution of soil stress will be experienced a maximum settlement due to the load position. A maximum settlement on the center of the Nailed-slab can be occurred due to the concentric load. The soil stress and inner forces analysis can be done by the finite element method of Plaxis software (Puri et al., 2015; Puri, 2016; Puri and Mildawati, 2019; WARUWU, 2018). Inner forces analysis of Nailed-slab can be also done by the finite element method of SAP2000 (Puri et al., 2015; Somantri, 2013) and Abaqus (Syarif et al., 2018; Diana, 2017). This research is aimed to investigate the effect of different pile length due to the soil stress and inner forces behavior of the Nailed-slab Pavement System.

2 METHODOLOGY

This research used the soil and Nailed-slab structural data from Puri (2015). The soft soil geometry was set with thickness 10 m. There was the dense sand layer below the soft clay which neglected in the analysis. The considered load 50 kN was a concentric load on the pavement slab. The boundary condition of the soil is shown in Figure 1. Figure 1a shows the Model 1 which used uniform pile length and Figure 1b for different pile length (piles in the center area longer 33.3% the edge piles). (Somantri, 2013) analyzed full-scale Nailed-slab model by using soil properties from experimental project. (Puri and Mildawati, 2019) simulated the effect of dimensions of Nailed-slab by using soil and structural properties from full-scale test.

The dimension of Nailed-slab model was 6.0 m x 3.6 m and 0.15 m slab thickness. The slab is supported by 5 piles. Pile diameter was 0.30 m. Pile spacing was 1.20 m. The pile-slab connections were monolithically. The pile length for model 1 was 1.50 m and for model 2 was 1.50 m for edge piles and 2.00 m for piles in the center area of the slab. The

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Table 1: Model and parameters of soil.

Parameters	Name/ Notation	Soft clay	Unit
Material model	Model	Mohr-Coulomb	-
Material behavior	Type	*Un-drained*	-
Saturated density	γsat	16.30	kN/m^3
Dry density	γd	10.90	kN/m^3
Young's Modulus	E	1,790.00	kPa
Poisson's ratio	ν	0.45	-
Un-drained cohesion	cu	20.00	kPa
Internal friction angle	ϕ	1.00	o
Dilatancy angle	ψ	0.00	o
Initial void ratio	$e0$	1.19	-
Interface strength ratio	R	0.80	

Table 2: Model and parameters of structural elements in FEM 2D plain strain.

Parameters	Name/Notation	Lean concrete	Structural elements		Unit
			Slab	Pile	
Material Model	Model	Volume element	*Plate*	*Plate*	-
Material behavior	Type	Elastic	Elastic	Elastic	-
Normal stiffness	EA	-	4,554,000	738,528	kN/m
Flexural rigidity	EI	-	8,539	5,649.74	kNm^2/m
Equivalent thickness	d	-	0.15	0.3	m
Weight	w	-	3.60	0.9	kNm/m
Poisson's ratio	v	0.2	0.15	0.20	-
Unit weight	γ	22	24	24	kN/m^3
Young's modulus	E	17,900	25,300	19,600	MN/m^2
Interface strength ratio	R	0.80	0.80	0.80	

models were analyzed by 2D finite element method (FEM). In 2D FEM plain strain analysis, the soft clay was modeled by Mohr-Coulomb in un-drained condition. All structural elements were modeled by plate element in linear-elastic behavior. Lean concrete was modeled by soil with the linear-elastic non-porous material. Soil parameters and idealization of structural elements are presented in Table 1 and 2 respectively.

3 RESULTS AND DISCUSSIONS

Results are shown in Tabel 3, 4 and Figure 2. The loaded Nailed-slab caused soil and structural movements and stresses.

3.1 Soil Stress

Table 3 shows the results of the effects of different pile length due to soil stresses. The soil effective shear stresses are shown in Figure 2. The soil effective shear stresses for Model 2 has a similar shape to Model 1. Maximum shear stress, effective stress, and maximum excess pore pressure tend to decrease (Table 3). That was beneficial for the soil. While the maximum excess pore water pressure under the central pile tip tends to increase about 12%. The distribution of the effective shear stress in the soil is shown in Figure 2. Model 2 can significantly reduce the maximum effective shear stress and maximum excess pore water pressure 37% and 32% respectively. While the maximum excess pore water pressure under the central pile tip a little bit increase about 12% and effective stress of soil insignificantly decrease. Model 2 also has a better stress distribution because it has wider stress distribution.

Table 3: The stresses in the soil

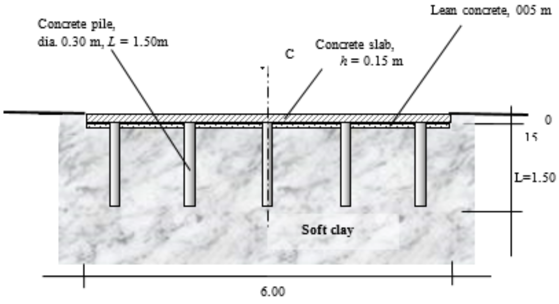
Description	Unit	Model 1	Model 2
Maximum shear stress, τ_{xy-max}	kN/m^2	-15.31	-9.69
Effective stress, σ	kN/m^2	65.33	64.27
Max. excess pore water pressure, U	kN/m2	107,49	72,93
Max. excess pore water pressure under the central pile tip, U	kN/m2	-11.00	-12.31

3.2 Inner Forces of Structural

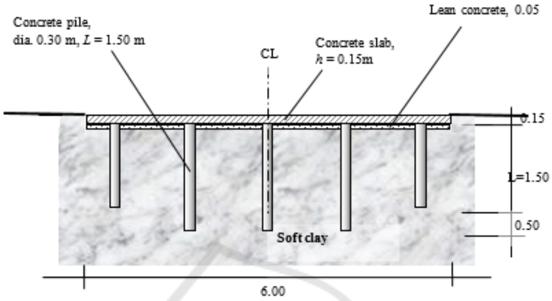
Table 4 shows the inner forces in the structural elements. The slab has a negative bending moment in the area of the slab center similar to other researchers (Puri et al., 2015; Puri, 2016; Diana, 2017; Puri and Mildawati, 2019). Using the longer pile in the center area of the slab were result in the good effects. All inner forces decreased by using the longer pile, except for bending moment on the pile head was relatively constant. Model 2 can significantly decrease the bending moment of slab of about 46%. Otherwise, it can also decrease the bending moment and axial force of pile 46% and 43% respectively. Decreasing the inner forces in the structural elements is very beneficial for this system. In the case of lateral deformation of pile head, Model 2 can significantly reduce it about 37%.

Table 4: The extreme inner forces in the structural elements.

Description	Unit	Model 1	Model 2
Bending moment of slab, M_s	kNm/m	-42.62	-22.78
Bending moment of pile, M_p	kNm/m	2.94	2.95
The axial force of pile, P	kN	12.33	6.61
The shear force of pile, H	kN	15.33	8.72
Lateral deflection of pile tip, U_x	mm	-7.53	-4.73

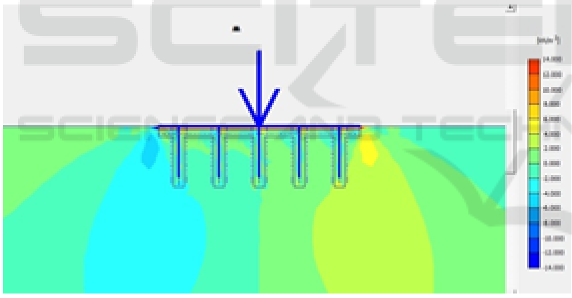


a) Model 1

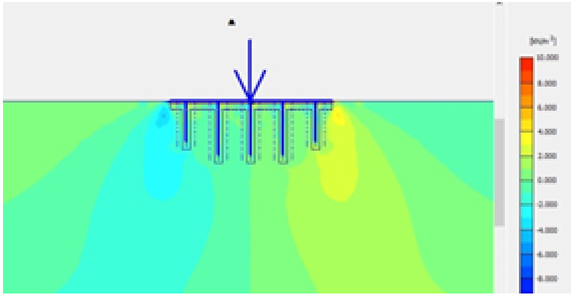


b) Model 2

Figure 1: Variation of the model in the analysis.



Model 1, τ_{xy-max} = 15.31 kN/m^2



Model 2, τ_{xy-max} = 9.69 kN/m^2

Figure 2: Distribution of effective shear stress of soil.

4 CONCLUSIONS

The results of this study prove that although the JCI change pattern follows the changing pattern of macroeconomic variables, but after it has been proven by a series of statistical tests, none of the macroeconomic variables affect JCI in the short run. This might be caused by investors in Indonesia pay more attention to the fundamental factors which are the company's financial performance. In addition, stock indices in a country do have a tendency to increase due to developments in a country's Stock Exchange.

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