Behavior of Uplift Resistance of Single Pile Row Nailed-slab Pavement System on Soft Clay Sub Grade

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Abstract

Nailed-slab Pavement System is a new kind of rigid pavement which proposed by Hardiyatmo (2008). This system consists of a thin reinforced concrete slab, and short piles attached underneath. The installed piles under the slab were functioned as slab stiffeners and anchors. Its performance due to compression loadings were conducted by some researchers. Puri, et.al (2015) reported pull out test on 1-pile row Nailed-slab System. In this paper, the finite element analysis will be done by using the test results from Puri, et.al (2015). According to Puri, et.al (2015), the full scale of 1 pile row Nailed-slab System was conducted on soft clay which consisted of 6.00 m x 1.20 m slab area with 0.15 m in slab thickness, 5 short micro piles (0.20 m in diameter, 1.50 m in length, and 1.20 m in pile spacing) as slab stiffeners which installed under slab. Piles and slab were connected monolithically, then in due with vertical concrete wall barrier on the two ends of slab. The system was loaded by pull out loading on the end of slab. The tested model has sufficiency uplift resistance and linear elastic behavior can be reached the load 13.3 kN (Puri, et.al, 2015). Behavior of Nailed-slab Pavement System can be good modeled in linear elastic zone. Contribution of vertical barrier due to pull out loading should be taken in further research. Anchorage resistance of piles was contributed to the uplift resistance. This uplift capacity is very important to resist the uplift loads around the end of slab.

Keywords: soft clay, rigid pavement, nailed-slab system, pull out, uplift resistance

Introduction

Nailed-slab Pavement System was proposed as an alternative solution for solving the problem of rigid pavement on soft soils. This system consists of a thin reinforced concrete slab, and short piles attached underneath. The composite system (consists of piles, slab, and soils surrounding the piles) is expected to be formed to bear the loads ([2]; [3]). This system is recommended to use the thin pile cap (about 0.12 m to 0.25 m in thickness). Utilization of thin pile cap is beneficial for soft soils [4]. The piles are short micro piles with 0.12 m to 0.20 m in diameter, 1.0 m to 1.5 m in length, and 1.0 m to 2.0 m in pile spacing ([3]; [5]). Slab has double functions, as a pile cap and as a pavement slab. Piles were installed form a line in width and length directions. Piles under the slab were connected to the slab monolithically. Vertical concrete wall barrier can be equipped on each end of slab for reducing the deflection of edge slab.

Fig. 1 shows the illustration of effect of installed pile as "nail" on concrete pavement [3]. Fig. 1a shows the installed piles under the slab were functioned as slab stiffeners with the result that the load can be spread widely to soft soils ([3]; [6]). Fig. 1b shows that the piles also function as anchors which can make the slab keeps in contact with the soils ([2]; [3]; [6]).

The uplift load can be occurring on the end of slab by differentiation of slab temperature (lower in the end of slab) or expansive clay. Nailed-slab should be had enough capacity to resist this uplift force [1]. In this paper, the numerical analysis will be done by using finite element method by using the results from Puri, et.al [1].

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The Pull Out Test Results from Puri, et.al [1]

Detail about testing pond and used materials in this full scale test were published in Puri, et.al. ([3]; [1]). The pull out test results were presented in Puri, et.al. [1]. The soft clay properties are presented in Table 1. The slab and piles were reinforced concrete. The concrete strength characteristic of slab and piles were 29.2 MPa and 17.4 MPa respectively. The piles configuration and other nailed-slab detail are shown in Fig. 2. Full scale model represents a one pile row of rigid pavement section.

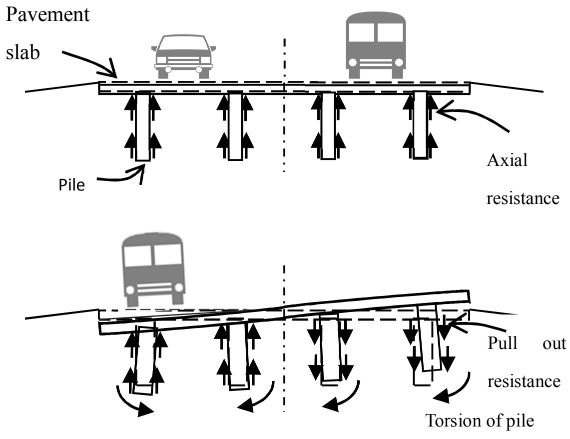

Fig.1. The illustration of effect of installed pile as “nail” on concrete pavement; a) axial resistance of piles, b) anchorage resistance of piles [3].

Table 1 Soft Clay Properties ([1]; [3])

No.	Parameter	Unit	Average
1	Specific gravity, G_s	-	2,55
2	Consistency limits:		
	- Liquid limit, *LL*	%	88,46
	- Plastic limit, *PL*	%	28,48
	- Shrinkage limit, *SL*	%	9,34
	- Plasticity index, *PI*	%	59,98
3	Natural water content, w_n	%	50,49
4	Water content, *w*	%	54,87
5	Clay content	%	92,93
6	Sand content	%	6,89
7	Bulk density, γ	kN/m^3	16,32
8	Dry density, γ_d	kN/m^3	10,90
9	Undrained shear strength, S_u		
	- Undisturbed	kN/m^2	20,14
	- Remolded	kN/m^2	11,74
10	CBR	%	0,83
11	Soil classification:		
	- AASHTO	-	A-7-6
	- USCS	-	CH

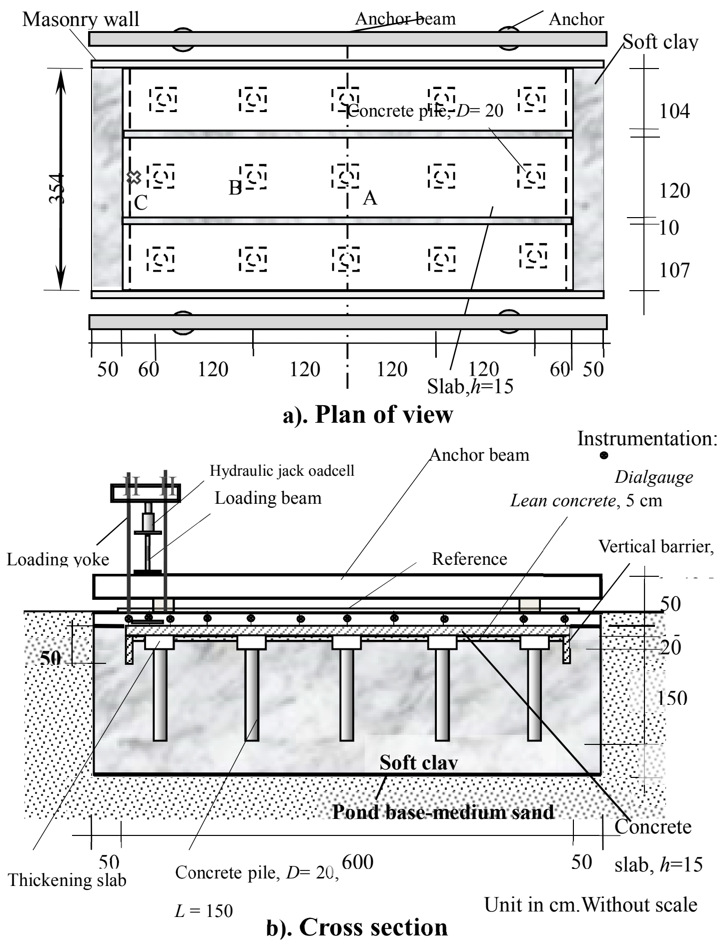

Figure 2 Schematic Diagram of Full Scale Nailed-slab. The tested slab was the middle slab [1].

Slab was cured by wet carpet and after 28 days of concrete age the loading set up was assembled. Pull out load test was conducted on the end of slab. Pull out loads were given stage by stage by load increase twice the previous load. For all loading points, the load intensity was increased gradually from P = 0, then became P = 1.7 kN and continued by twice previous load until reach failure condition. Then all instrumentations were recorded. A photograph in testing is presented in Fig. 3.

Analysis of Deflections

In the 3D finite element analysis (FEM), soft soil model was employed in the study. Likewise, soil parameters and structural elements are presented in Table 2 and 3 respectively. Numerical analysis will be conducted by 3D Plaxis. All structural elements were modeled in linear-elastic behavior. Lean concrete was modeled by soil with linear-elastic non-porous material. The thickening slab was ignored since it could not be modeled by numerical application program. A used mesh in FEM analysis is shown in Fig 4.

Results and Discussion

The P-δ relationship from pull out load test is presented in Fig.5. Failure load was 33.3 kN. Linear behavior is reached until load 13.3 kN. According to Puri, et.al. [1], the failure was occurred on the pile friction resistance and the slab was not having any cracks or damages. Numerical results show that the good agreement occur up to 13.3 kN. The analysis without self weight of structural elements has good agreement with observation, but it is unrealistic to analyze by neglecting self weight.

Fig. 3 Photographs of pull out loading tests on 1 pile row full scale Nailed-slab [1].

Table 2. Soil properties in FEM analysis input

Parameter	Name/ symbol	Soft clay	Sand	Unit
Material model	Model	Soft soil	Mohr-Coulomb	-
Material behavior	Type	Drained	Drained	-
Bulk density	γ	10.9	18	kN/m^3
Soil behavior under phreatic level	γ_{sat}	16.3	20	kN/m^3
Young's modulus	E	1,970	42,750	kN/m^2
Poisson's ratio	v'	0.35	0.35	-
Cohesion	c	20	1	kN/m^2
Friction angle	ϕ	0	47.8	^{o}
Dilatancy angle	ψ	0	2	^{o}
Initial void ratio	e_{init}	1.19	0.5	-
Modified compression index	$\lambda*$	0.12	-	-
Modified swelling index	$\kappa*$	0.024	-	-
Interface strength ratio	R_{inter}	0.8	0.7	-

Table 3. Properties of structural elements

Parameter	Name/ symbol	Lean concrete	Pile	Slab	Vertical wall barrier	Unit
Material model	Model	Soil and interface	Soil and interface	Floor	Walls	-
Material behavior	Tipe	Linier elastik	Linier elastik	Linier elastik	Linier elastik	-
Thickness/ diameter	d	0,05	0,2	0,15	0,15	m
Density	γ	22	24	24	24	kN/m^3
Young's modulus	E	$1{,}79 \times 10^7$	$2{,}03 \times 10^7$	$2{,}53 \times 10^7$	$2{,}53 \times 10^7$	kN/m^2
Shear modulus	G	$5{,}417 \times 10^6$	$8{,}8 \times 10^6$	$1{,}1 \times 10^7$	$1{,}1 \times 10^7$	kN/m^2
Poisson ratio	v	0,2	0,20	0,15	0,15	

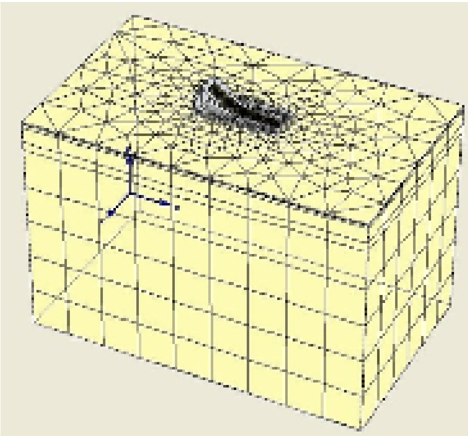

Fig. 4. Used mesh in FEM analysis.

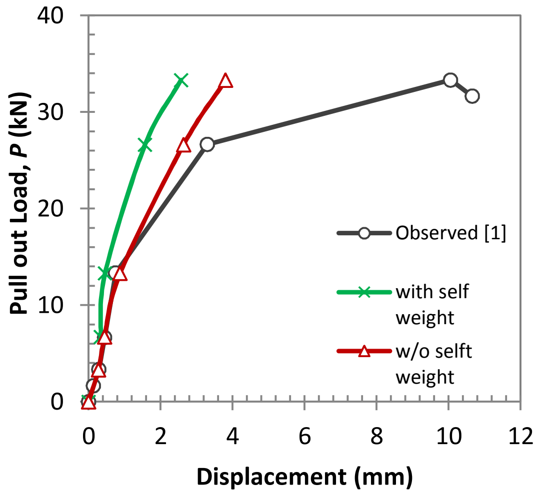

Fig. 5. P-δ relationship of 1 pile row Nailed-slab.

The deflection along the slab is presented in Fig.6. Number of piles that resisted the uplift load was increased by increasing the load intensity. On the load 33.3 kN, 4 piles resisted the uplift load although friction resistance of the first pile from left of slab was failure [1]. Uplift resistance of Nailed-slab system was not only contributed by pile friction resistance (anchorage resistance) likewise the slab stiffness, soil-slab friction, and weight of construction [1]. It is shown that numerical results tend to have over-estimated deflections for load in plastic behaviour (load $P > 13.3$ kN).

For 1 pile row Nailed-slab, the linear behaviour of uplift resistance was 13.3 kN and it will be increased by increasing in pile row number ([1]; [3]). The uplift resistance will resist the uplift load. The uplift load can be occurring by differentiation of slab temperature (lower in the end of slab) or expansive clay.

According to Puri [3], the uplift resistance of single pile of nailed-slab was 20 kN. For 5 piles, the uplift resistance of pile group can be 100 kN for centric load (neglected the slab stiffness). This uplift resistance will be decreased for edge load. In this case, the uplift resistance was 33.3 kN (including the effect of slab stiffness).

Conclusion

The tested model has sufficiency uplift resistance and linear elastic behavior can be reached load 13.3 kN [1]. Behaviour of Nailed-slab Pavement System can be good modelled in linear elastic zone. Contribution of vertical barrier due to pull out loading should be taken in further research.

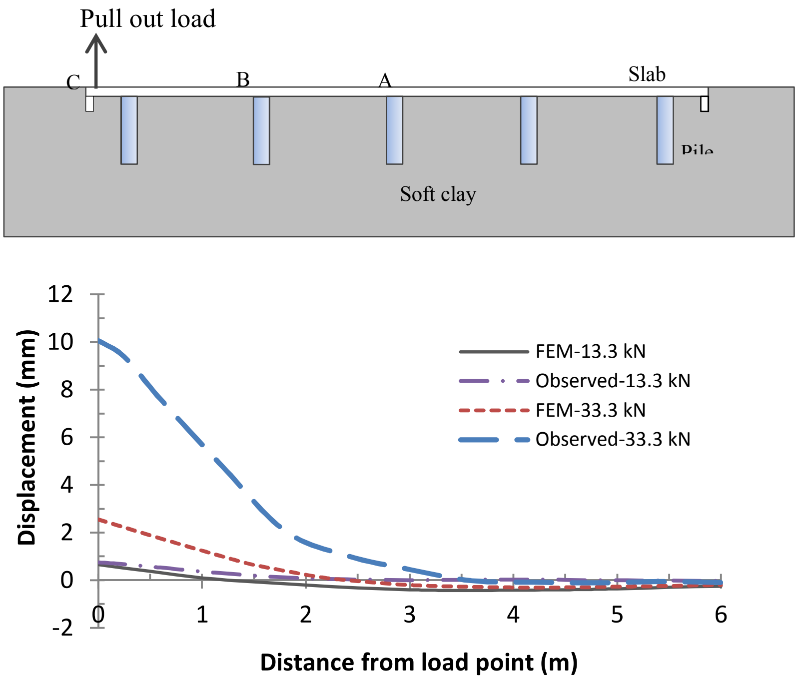

Fig. 6. Deflection along the slab of 1 pile row Nailed-slab.

Reference

1) Puri, A., Hardiyatmo, H.C., Suhendro, B., and Rifa'i, A., 2015, Pull out Test of Single Pile Row Nailed-slab System on Soft Clay, *Proc. of the 14th Intrntl. Conf. on QiR (Quality in Research),* Faculty of Eng. Univeristas Indonesia, Lombok, Indonesia, 10-13 August 2015.

2) Puri, A., Hardiyatmo, C. H., Suhendro, B., and Rifa'i, A., 2011a, Experimental Study on Deflection of Slab which Reinforced by Short Friction Piles in Soft Clay. *Proc. of 14th Annual Scientific Meeting (PIT) HATTI*, HATTI, Yogyakarta, 10-11 Februari, pp. 317-321.

3) Puri, A., 2015, Behavior of Pavement of Nailed-slab System on Soft Clay, *Dissertation*, Gadjah Mada University, Yogyakarta, Indonesia.

4) Hardiyatmo, H.C., and Suhendro, B., 2003, Pile Foundation with Thin Pile Cap as an Alternative to Solve Problems of Building on Soft Soils. *Report of Competitive Grant Research of Higher Education,* Institute for Research and Community Service, Gadjah Mada University, Yogyakarta, Indonesia.

5) Hardiyatmo, H.C., 2008, Nailed-slab System for Reinforced Concrete Slab on Rigid Pavement*, Proc. of National Seminar on Appropriate Technology for Handling Infrastructures*, MPSP JTSL FT UGM., Yogyakarta, Indonesia, pp. M-1—M-7.

6) Puri, A., Hardiyatmo, H.C., Suhendro, B., and Rifa'i, A., 2013c, Application of Method of Nailed-slab Deflection Analysis on Full Scale Model and Comparison to Loading Test, *Proc. the 7th National Conference of Civil Engineering (KoNTekS7)*, Universitas Negeri Sebelas Maret, Surakarta, 24-26 October 2013c, pp. G201-G211.

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