International Journal of GEOMATE, April, 2017, Vol. 12, Issue 32, pp. 25-29
Geotec., Const. Mat. & Env., ISSN:2186-2990, Japan, DOI: http://dx.doi.org/10.21660/2017.32.6577

EFFECTS OF VERTICAL WALL BARRIER ON THE RIGID PAVEMENT DEFLECTION OF FULL SCALE 1-PILE ROW NAILED-SLAB SYSTEM ON SOFT SUB GRADE

*Anas Puri[1], Bambang Suhendro[2], Ahmad Rifa'i[3]

[1]Faculty of Engineering, Islamic University of Riau, Indonesia
[2, 3] Faculty of Engineering, Gadjah Mada University, Indonesia

*Corresponding Author, Received: 12 July 2016, Revised: 26 July 2016, Accepted: 29 Nov. 2016

ABSTRACT: The weaker part of rigid pavement when it is loaded is the edge of slab. Vehicle wheels that are often running in/out from/to pavement can cause void in the sub base-pavement interface for a long time loading period. Flexural moment caused by temperatures also precipitate the damages of pavement edge. To avoid the damage of pavement edge, the vertical wall barrier is added. This research is aimed to learn the contribution of vertical wall barrier on the pavement of Nailed-slab System to reduce the slab deflection. Full scale observation was done over models in soft clay soil. 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 as slab stiffeners which were installed under the 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 compression loadings on the slab. Deflection of model without vertical wall barrier was analyzed by finite element method. Results show that the vertical wall barrier cannot significantly reduce the deflection for edge loading. It is opposite to the model test result from Puri, et.al. (2011) where the vertical wall barrier can reduce 74% deflection for edge loadings. It is to be expected that numerical application program could not model the vertical wall barrier which lower position than slab level.

Keywords: rigid pavement, soft clay, Nailed-slab System, vertical wall barrier, deflection

1. INTRODUCTION

The edge of a rigid pavement is the weaker part in bearing the traffic load. This part tends to get maximum deflection and to damage the pavement such as broken pavement, developed voids between sub grade and pavement, and can be followed by pumping. The edge of rigid pavement is also the weaker part in the Nailed-slab System [1]. Hence, in this research the edge of the pavement is reinforced by a vertical wall barrier. Furthermore, the behavior of Nailed-slab System and the contributions of vertical wall barrier will be studied.

A vertical wall barrier is usually reinforced concrete that is 10 cm – 20 cm in thickness and it is conducted in a vertical position that is 40 cm – 50 cm in height. Figure 1 shows an example of a vertical wall barrier. Another shape was used by The Indonesian Research and Development Center for Highway and Bridge [2]. Some benefits of a vertical wall barrier are [3]: (1) it acts as a slab stiffener for edge of pavement because this part will be a weaker part of pavement, (2) to avoid the void between sub grade and pavement due to the effect of the tires which often exit/ enter to/ from pavement, (3) to reduce the disturbing on berm, and (4) as a vertical wall barrier to isolate the negative effects of water changing in sub grade. It prevents the water infiltration to the soil under the pavement slab.

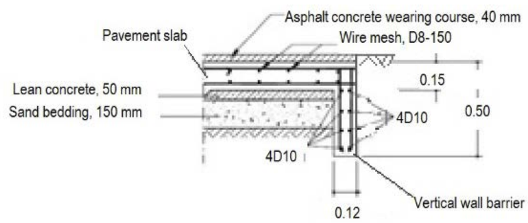


Fig. 1 An example of vertical wall barrier

Puri, et.al. [1] conducted the 1-pile row Nailed-slab model tests on the soft clay to learn the effects of vertical wall barrier. The vertical wall barrier can reduce deflection 34% and 74% for concentric and edge loadings respectively.

This paper is aimed to discuss the comparison of the slab deflection behavior between the Nailed-slab with a vertical wall barrier and without a vertical wall barrier. The Nailed-slab models consider the vertical wall barrier on each end of the slab. The experimental study was conducted by full scale model tests of one row pile Nailed-slab system and analyzed by finite element method.

2. INVESTIGATED 1-PILE ROW FULL SCALE NAILED-SLAB SYSTEM

Detail of the procedure on 1-pile row full scale Nailed-slab is presented in Puri, et.al. [4] and briefly described in Puri, et.al. [5]. In this paper, it will be presented again comprehensively.

2.1 Soil Pond and Materials

A full scale model of Nailed-slab was conducted on soft clay. A 6 m x 3.6 m soil pond was conducted by digging the existing soil until the depth of 2.5 m. On the two longer sides it was retained by masonry walls and supported by some temporarily bamboo girder. The anchorage system was built near the pond. Separator sheets were set on the pond walls and base to avoid the effects of surrounding existing soils. A 2.15 m of pond depth was filled by soft clay which was taken from District Ngawi, East Java, Indonesia. The 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.

2.2 Dimension of Nailed-slab Prototype

The 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 as shown in Figure 2. All 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 transfered 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. ([4], [5]).

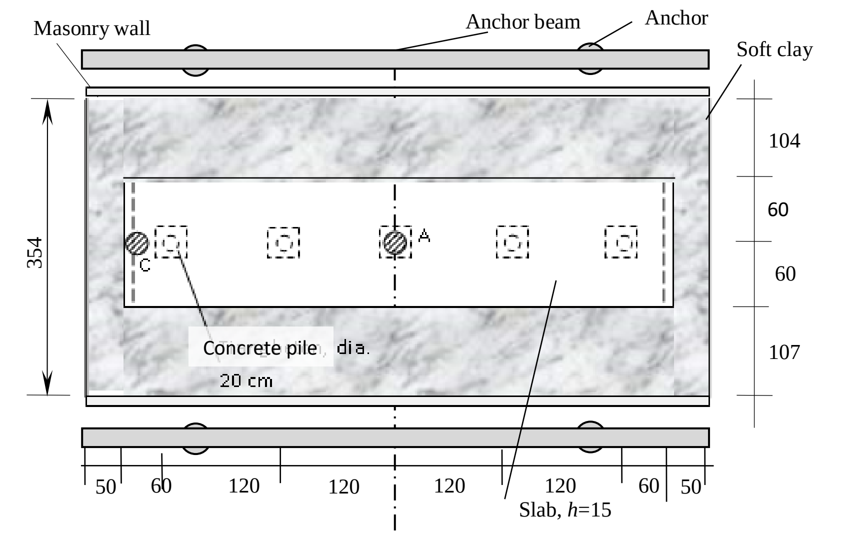
Table 1 Soft clay properties [4]

Parameter	Unit	Average
Spesific gravity, G_s	-	2.55
Consistency limits:		
- Liquid limit, *LL*	%	88.46
- Plastic limit, *PL*	%	28.48
- Shrinkage limit, *SL*	%	9.34
- Plasticity index, *PI*	%	59.98
- Liquidity index, *LI*	%	0.36
Water content, *w*	%	54.87
Clay content	%	92.93
Sand content	%	6.89
Bulk density, γ	kN/m^3	16.32
Dry density, γ_d	kN/m^3	10.90
Undrained shear strength, s_u		
- Undisturbed	kN/m^2	20.14
- Remolded	kN/m^2	11.74
CBR	%	0.83
Soil classification:		
- AASHTO	-	A-7-6
- USCS	-	CH

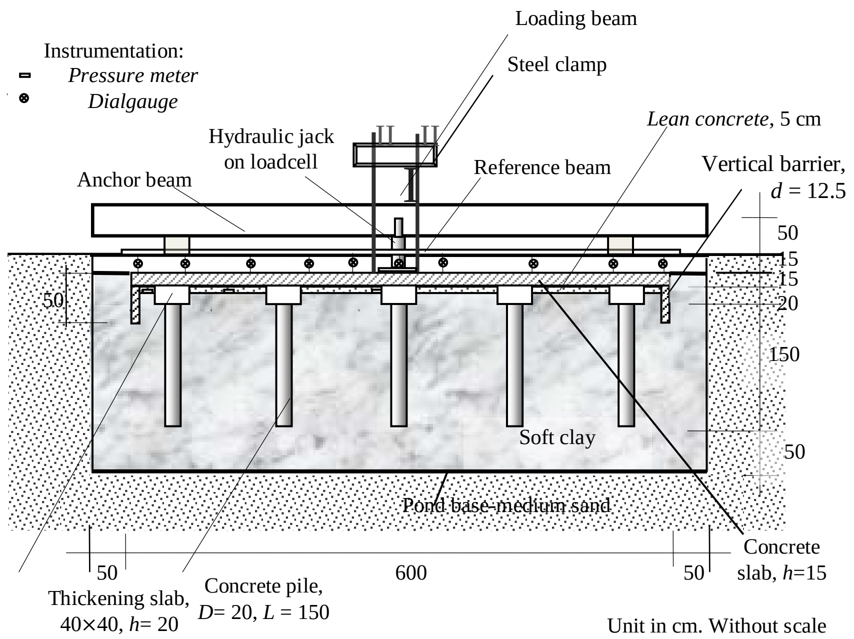
2.3 Analysis of Deflections

In the 2D finite element analysis (FEM), Mohr-Coulomb soil model was employed in the study. Likewise, soil parameters and idealization of structural elements are presented in Table 2 and 3, respectively. The material properties were adjusted due to the plain strain case [6]. The slab width is 120 cm and the length of considered section is 20 cm (perpendicular to cross section). Numerical analysis was conducted by 2D Plaxis version 8.6. The soft clay was modeled by Mohr-Coulomb in undrained condition. All structural elements were modeled by plate element 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.

The used mesh in plain strain FEM analysis is shown in Fig. 3. Fig. 4 shows one of deformed shape outputs.



a). Plan of view



b). Cross section

Fig. 2 Schematic diagram of full scale Nailed-slab with 1 pile row

Table 2 Model and parameters of soil

Parameters	Name/ Notation	Soft clay	Sand	Unit
Material model	Model	Mohr-Coulomb	Mohr-Coulomb	-
Material behavior	Type	*Undrained*	*Drained*	-
Saturated density	γ_{sat}	16.30	18.00	kN/m^3
Dry density	γ_d	10.90	20.00	kN/m^3
Young's Modulus	E	1,790.00	42,750.00	kPa
Poisson's ratio	v	0.45	0.35	-
Undrained cohesion	c_u	20.00	1.00	kPa
Internal friction angle	ϕ	1.00	47.80	o
Dilatancy angle	ψ	0.00	2.00	o
Initial void ratio	e_0	1.19	0.50	-
Interface strength ratio	R	0.80	0.70	

Table 3 Model and parameters of structural elements in FEM 2D plain strain

Parameters	Name/ Notation	Lean concrete (LC)	Structural elements			Unit
			Slab	Vertical wall barrier	Pile	
Material model	Model	Volume element	*Plate*	*Plate*	*Plate*	-
Material behavior	Type	Elastic	Elastic	Elastic	Elastic	-
Normal stiffness	*EA*	-	4,554,000	3,795,000	616,696	kN/m
Flexural rigidity	*EI*	-	8,539	4.941	75,655	kNm^2/m
Equivalent thickness	*d*	-	0.15	0.125	0,027	m
Weight	*w*	-	3.60	3.00	29.12	kNm/m
Poisson's ratio	v	0.2	0.15	0.15	0.20	-
Density	γ	22	24	24	24	kN/m^3
Young's Modulus	*E*	17,900	25,300	25,300	19,600	MN/m^2
Interface strength ratio	*R*	0.80	0.80	0.80	0.80	-

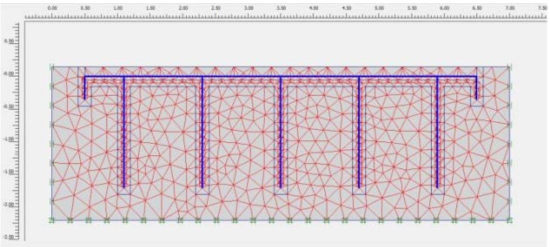


Fig. 3 A used mesh in plain strain FEM analysis.

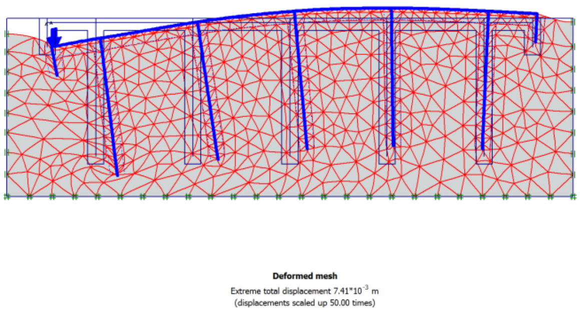


Fig. 4 A deformed shape output of numerical analysis for edge loading

3. RESULTS AND DISCUSSION

3.1 *P-δ* Relationship for Nailed-Slab with Vertical Wall Barrier

Fig.5 shows deflection shape along the slab (cross section in field condition). It is seen that the deflection shape is a bowl shape. Analysis results show that maximum displacement occured under the loading point and decreased as you move further away from the loading point. This phenomenon fulfilled the expectation. The maximum deflections were appropriate with the observations. But the end of slab was uplifted. Both ends of the slab were uplifted for concentric loading (Fig. 5a). However, the opposite end of the slab was uplifted caused by edge loading (Fig. 5b).

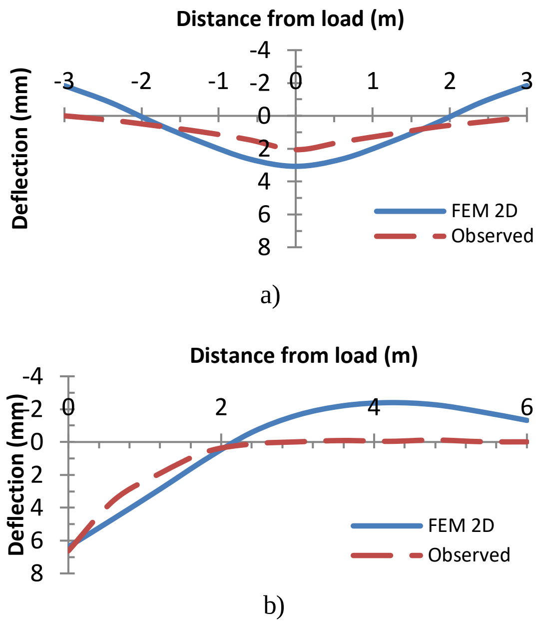


Fig. 5 Deflection shape along the slab for load *P* = 80 kN; a) concentric load, b) edge load

According to Figure 6, the maximum shear between soil and pile occured around the pile tip of the middle piles (Fig. 6a) and the left pile for edge loading (Fig. 6b). The extreme shear stresses on pile were 12.63 kN/m^2 and 10.46 kN/m^2 for concentric loading and edge loading, respectively. Both shear stresses did not reach the ultimate value of 16.00 kN/m^2 (=$R_{inter}c_u$).

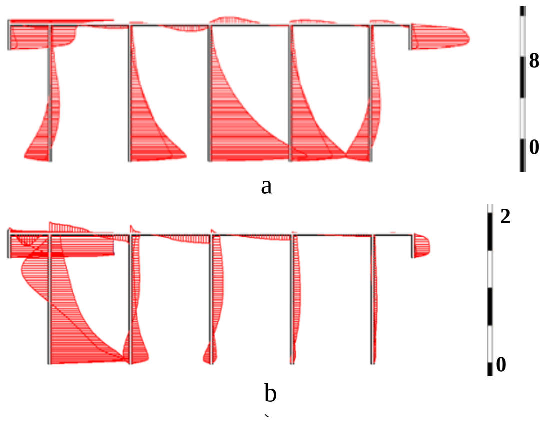


Fig. 6 Shear stress on the interface of structural elements; a) concentric load, P = 150 kN, b) edge load, P = 80 kN

3.2 Effects of Vertical Wall Barrier

Figure 7 shows the P-δ relationship for edge loading. It seems that the vertical wall barrier can reduce deflection 5.25% only. It is an insignificant reduction if it is compared to the model test. The vertical wall barrier can reduce 74% deflection for edge loadings in the model test [1].

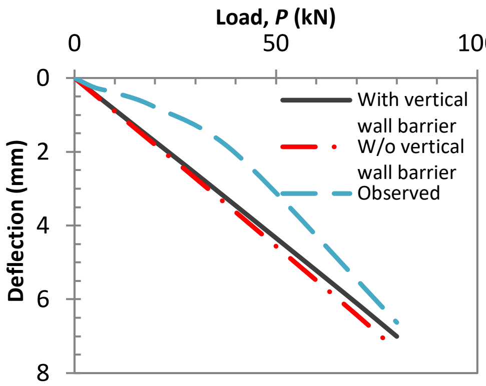


Fig. 7 P-δ relationships for load on C (edge load)

4. CONCLUSION

In this paper, observations for pavement of Nailed-slab System which are equiped by vertical wall barrier on the end of slab were conducted and numerical analysis for both systems with and without vertical wall barrier has been done. Numerical results show that the vertical wall barrier gave insignificant reduction to the slab deflection. It is opposite to the model test result from Puri, et.al. [1] where the vertical wall barrier can reduce 74% deflection for edge loadings. Soil shear stresses did not reach the ultimate value for both load positions.

5. ACKNOWLEDGEMENTS

The authors acknowledge the financial support from the Directorate General of Research and Technology and Higher Education Republic of Indonesia number SP DIPA-042.06.401516/2016.

6. REFERENCES

[1] Puri, A., Hardiyatmo, H.C., Suhendro, B., and Rifa'i, A., 2011, Contribution of Wall Barrier to Reduce the Deflection of Nailed-Slab System in Soft Clay, *Proc. of 9^th^ Indonesian Geotech. Conf. and 15^th^ Annual Scientific Meeting (KOGEI IX & PIT XV) HATTI*, HATTI, Jakarta, 7-8 December 2011, pp. 299-306 (in Bahasa Indonesia).

[2] The Indonesian Research and Development Center for Highway and Bridge, 2007, *Uji Coba Skala Penuh Teknologi Cakar Ayam Modifikasi, Bab-7 Gambar Rencana*, Satuan Kerja Pusat Litbang Jalan dan Jembatan, Departemen Pekerjaan Umum Republik Indonesia.

[3] Suhendro, B., dan Hardiyatmo, H.C., 2010, Modified Chicken Foot Pavement System as an Alternative Solution for Road Construction on Soft Soils, Expansive, and Embankment, *Proc. of One Day Seminar and Exhibition 2010 New Innovative Technology on Highway and Bridge*, DPD HPJI Jatim, Surabaya, 31 March 2010 (in Bahasa Indonesia).

[4] Puri, A., Hardiyatmo, H.C., Suhendro, B., and Rifa'i, A., 2013, Behaviour of Full scale Nailed-slab System with Variation on Load Positions, *Proc. 1^st^ Intl. Conf. on Infrastructures Development (ICID)*, Surakarta, 1-3 November 2013, pp. 26-36.

[5] Puri, A., Hardiyatmo, H.C., Suhendro, B., and Rifa'i, A., 2014, Behavior of Nailed-slab System on Soft Clay Due to Repetitive Loadings by Conducting Full Scale Test, *IJCEE-IJENS*, Vol. 14 No. 06, pp. 24-30.

[6] Plaxis 3D Foundation, *Material Models Manual version 1.5.*