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Settlement of nailed slab due to lateral loads

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Settlement of nailed slab due to lateral loads

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Abstracts. The nailed slab is a pavement method that uses a pile as a support plate for pavement. This method can be applied to land that has a lot of soft soil, with a certain depth limit. This method is very efficient when compared to conventional road pavement which is very easy to crack when the soil decreases. with the use of piles it is expected that this pavement can be used for a long time. To test the strength of this pavement structure, a lateral loading test was carried out that had not been carried out by previous researchers, where this loading was applied to 1 kN pavement and 4 kN as a result of braking the vehicle which was considered as lateral loading. The results showed that there was an effect due to lateral loading on the decrease in pavement. where the road pavement decreases when lateral loading is applied. the biggest decrease occurred at the lateral load of 4 kN which is around 39 mm, and deflection slab 32 mm for the lateral load of 1 kN.

Keywords : *lateral loads, soft soil, nailed slab*

1. Introduction

Nailed slab pavement to be one of the alternative of some of the above foundation options that can be used as a pavement solution over soft soil. Pavement with nailed slab system is expected to reduce damage pavement on soft soil with nailed slab pavement using pile as burden distributors down to underground. However, the rigid pavement with a nailed under slab is not functioning to improve soft soil, but one alternative method to improving rigid pavement performance on soft soil [1].

Nailed slab pavement, consisting of thin plates with thickness of 12 - 20 cm supported by a mini pile with length of 150 - 200 cm and diameter 15 – 20 cm [6], in the presence of this pile is expected that the load can be channeled to the base layer of soft soil.

Here is an illustration of the comparison of the use pile under plate or slab pavements with the conventional pavement on soft soil. where, on conventional pavement is not resistant to loading and easily damaged because the soil is essentially soft soil, while the pile under slab pavement or nailed slab system is fixed resistant to loading because there is a pile as a support slab so that it can be increase the strength of the slab, the illustration as shown in Figure 1.

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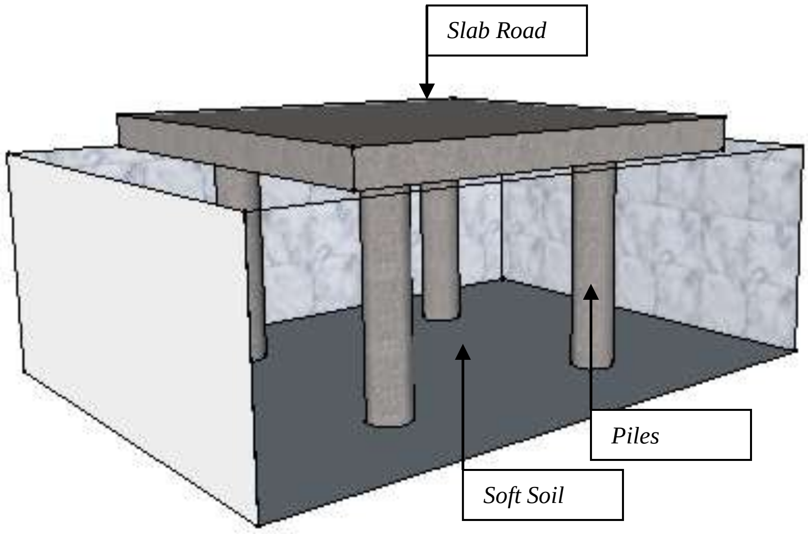

Figure 1. Illustration Nailed Slab.

2. Lateral Loads

From several studies lateral load is a burden that can affect the stability of a structure, especially for rigid pavement with a glued plate system where the pole becomes the main support of the plate structure. To avoid a large plate drop, it is expected that the poles play a role in supporting the plate because the carrying capacity of the pile friction can function properly. But if seen from the research by Cristensen [3], that if the pile receives a lateral load, it will cause a gap called gaps behind pile that occurs between the pile and the ground around the pile.

With the gap between the pile and the ground around the pile, it is likely to reduce friction around the pile which can affect or increase the decrease in rigid pavement plate, because the friction that occurs is no longer thorough along the pile due to the gap.

2.1. Pile as a lateral load support

The pile shall be designed to with stand-in lateral or horizontal loads, since the lateral load of one load may affect the behavior of the pile other than the vertical load. Lateral loads may affect the interaction of soil with piles, where repeated lateral loads can cause gaps between soils and piles that can reduce friction or ground bonds to piles [3], this gap will increase when the lateral load is increased and carried out Over and over again, and when the gap between the pile and the soil is larger then the decline of the slab or pile cap will be larger, the excessive deflection on the pile will also affect the deflection on the plate above.

Here is an illustration of the change of soil or gap between the pile and the surrounding soil by Cristensen [3] Figure 2.

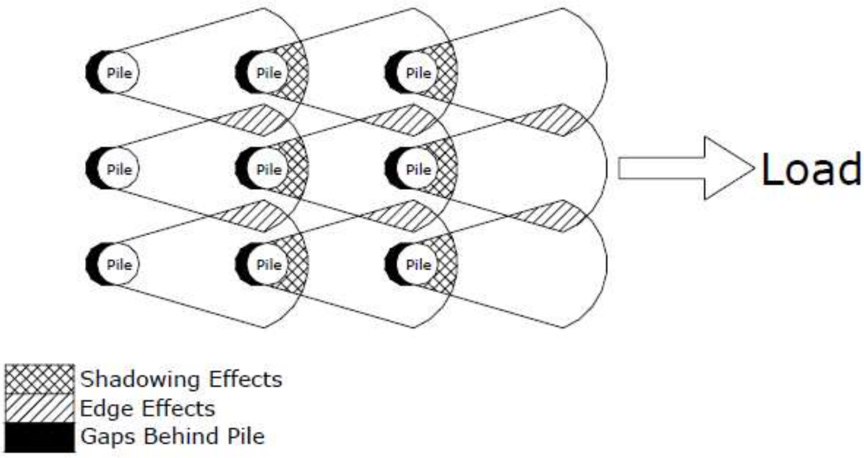

Figure 2. Illustration of lateral effect on soil around pile.

The foundation of long piles and short piles in the design due to lateral loads, must meet several criteria, namely:

1. The pile should be able to withstand bending moments
2. The soil should be able to support the load
3. Factor is safe against ultimit collapse
4. Deflections that occur due to the load must be within tolerable limits

2.2. Analyze of Pile Deflection

Tomlinson [9] in his book Pile Design and Construction Practice, one of which makes the analysis of deflection calculations on the pile, in the book mentions there are two pile conditions in the calculation of deflection that occurs on the pile due to lateral load, namely: free condition, where the tip of the top pile is not monolith with the plate on top and fixed, ie where the top pile of the monolith with pile cap or part plate or slab.

The shape of the pile movement according to Tomlinson [9] is illustrated as in Figure 3 below, and the calculation of the pile deflection analysis due to the lateral load is formulated according to the pile end conditions.

The calculation of deflection at the end of the pile as follows,

a. free head pile

$$y = \frac{H(e + Z_f)^3}{3\,EI} \quad (1)$$

b. fixed head pile

$$y = \frac{H(e + Z_f)^3}{12\,EI} \quad (2)$$

Where :
E = Elastic Modulus of pile material (Mpa)
I = moment of inertia from pile (m^4)
H = Lateral Load (kN)
Zf = Depth of pile of ground elevation
E = Distance of pile end to base ground

While deflection at the base of the pile, Tomlinson [9] describes the following:

a. For Free head pile

$$y_0 = \frac{4H(1 + \frac{1.5e}{L})^3}{k\,BL} \tag{3}$$

b. *Fixed* head pile

$$y_0 = \frac{H}{k\,BL} \tag{4}$$

Where :
k = Basic soil reaction coefficient
B = Diameter of the pole
H = Lateral Load (kN)
L = Depth of pile of ground elevation
e = Distance of pile end to base ground

Pile deflection is a change in pile form due to lateral or axial loading of piles. In general piles with lateral loads are grouped into two parts:

1. Short pile
2. Long pile

The pile deflection analysis is done by the Beam On Elastic Foundation-BoEF theory approach, where the beam is rotated up to 90 degrees [8]. When the soil is non linearly model then the response from the lateral load can be described in 4 orders with differential equations.

$$EI\,\frac{d^4y}{dx^4} + Pz\frac{d^2y}{dz^2} + P - w = 0 \tag{5}$$

Where :
Pz = Axial load pile
y = Pile deflection at depth z
P = Subgrarde reaction at each length
EI = Pile Stiffness
w = Load distribution along pile

$$P = \frac{d^4M(z)}{dz^2} \tag{6}$$

$$y = \frac{1}{EI}\iint M(z)dz \tag{7}$$

M = Bending Momen
P = - Esy
Es = Modulus of subgrade reaction

2.3. Deflection of rigid pavement

Calculating the slab deflection, moment and shear force due to centered load on slab by using beam analysis on elastic foundation (BoEF), this theory will define the soil pressure relation with decrease using subgrade modulus or ground coefficient k. According to the formula used by Hetenyi [7]. Calculation of base coefficient according to the equation below:

$$k_s = \frac{q}{\delta} \quad (8)$$

Where q = pressure
δ = deflection (settlement of slab)

2.4. Deflection of slab due to vertical loads
Hardyatmo [4] has been researching nailed slab pavement monolith with pile and non-monolith. On the slab the monolith decrease can be reduced up to 58%, while for the non-monolith can reduce up to 55%, but the change in the decrease of one of them is caused by the friction resistance of the pile so that the decrease will become smaller.

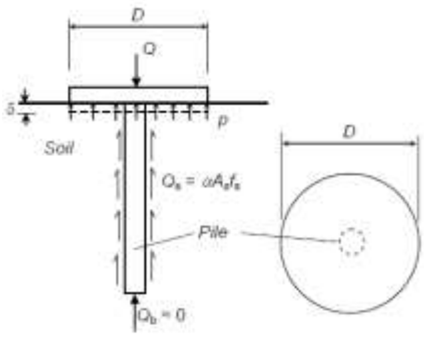

Figure 3. Effect of pile installation under slab [6].

The ultimate bearing capacity used is to use the following equation:

$$Q_u = Q_b + Q_s \quad (9)$$

Where: Q_u = ultimate capacity
Q_b = pile end capacity (assumed Q_b = 0)
Q_s = friction capacity

The carrying capacity of the pile friction is illustrated in the equation :

$$Qs = As \times fs \quad (10)$$

where: fs = friction along the pile (kPa)
As = surface area of the pile shaft (m^2)

Ultimate unit friction resistance on the pile shaft the clasical equation :

$$f_s = a_d c + p_o K_d \tan \varphi_d \quad (11)$$

Where a_d = adhesion factor
c = cohesion (kPa)
p_o = average overburden pressure (*kN/m2)*
K_d = coefficient of lateral soil pressure around the pile-soil
φ_d = angle of internal friction between soil and pile shaft (degrees).

From the above equation, that friction greatly affects the stability of pavement plate, because the addition of soil friction will increase the value of the base soil modulus like the equation below,

$$\Delta k = \frac{\delta_0 A_s}{\delta^2 A} f_s \tag{12}$$

Another research by Anas Puri [1], which does the same research, but modifies it by adding a suitcase to the side edge of the plate used to reduce excessive plate deflection on the outside of the plate. From the results of this study, it was concluded that with the addition of the suitcase can reduce the deflection significantly for the load placed on the end of the plate. But not significantly in the load placed on the central plate, this is seen from the addition of the soil reaction modulus base.

From some of the above studies it is necessary to study the effect of the gap as presented by Cristensen [3], that recurrent lateral load will produce a large gap between the piles and the surrounding soil, with the addition of the gap will affect the stiffness of the base soil due to its reduced friction, Formula presented [5]

3. Method of Research

The equipment used is a thin steel plate formed in the form of a box with dimensions of 2 x 1.5 x 1.5 m, where a rigid pavement prototype is placed inside the box, which is connected to a device that is all connected to the computer. The research will be conducted in the Unissula engineering faculty laboratory. The test procedure suggested by ASTM D [2] was employed.

4. The result of research

These results of the study showed that lateral load is very influential on the deflection of the slab, where the greater lateral load will increase the deflection of the slab. For the lateral load of 1 kN it produces a deflection of 32 mm, but for the load of 4 kN, the deflection increases 39 mm or 22%.

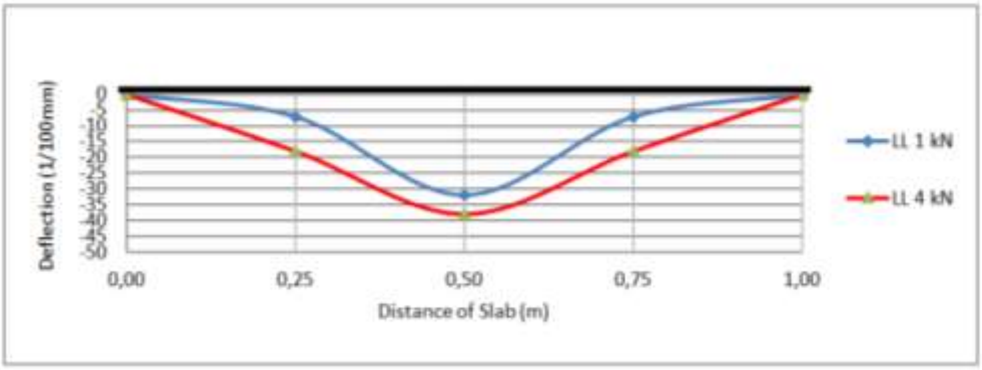

Figure 4. Deflection of Slab.

For pile deformation, the greater of the lateral load, the greater the deformation of the pile, so the deformation will affect the gap between the pile and soil which can affect the capacity of friction. For the lateral load of 1 kN it produces a deformation of 0.16 mm, but for the load of 4 kN, the deformation of pile increases 2.25 mm or 13%.

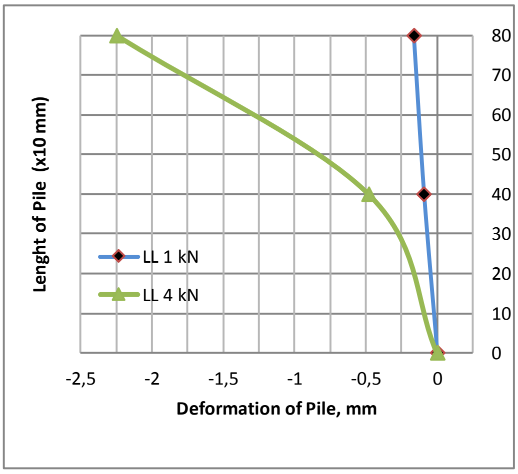

Figure 5. Deformation of Pile.

5. Conclusion and discussions

1. The results of the above research, the addition of lateral loads will result in the addition of settlement of slab the pavement.
2. For the lateral load 4 kN, there is a settlement addition 0.3 mm, this is likely because the friction of pile does not function properly.
3. Proving and analyzing that there is a significant relationship between the decrease in pavement plate and the deflection of the mast due to lateral loads.
4. From the results of the pile deformation analysis concluded that there is a gap between the pile and the ground which can reduce the bearing capacity of pile friction
5. Analyzes the behavior of the Nailed Slab System due to the influence of vertical loads and varying lateral loads.

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