Deflection Of Rigid Pavement Nailed Slab System With Lateral Loads

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Abstracts- Indonesia is a country with a soft land area of about 60 million ha or about 30% of the total land area of about 198.6 million ha. Soft soils include peat soils, clay soils and other soft soils scattered throughout the province in Indonesia. If a rigid pavement or flexible pavement rigid pavement layer is built on soft soil without prior repair on the ground, it will be damaged as cracks in the concrete or wavy in the asphalt layer, this is due to soft soils, Which is not uniform which can cause damage to the pavement layer.

Rigid pavement with nailed slab system is one solution to overcome the frequent breakdowns of soft soils, and it is hoped that using pavement models will increase the pavement strength when placed on soft soil. This pavement consists of 15 cm plates and 1-2 m long poles, 15-20cm in diameter, which are monolithically coupled with plates.

From the results of several previous studies that pavement is more resistant seen from small plate deflection when compared with without using a pile or anchor. But due to repeated lateral load will cause a gap between the pile and the subgrade around the pile that can reduce the friction value along the pile so as to reduce the modulus of subgrade reactions.

Keywords *: modulus of subgrade reactions, lateral loads, soft soil*

1. Introduction

Rigid Pavement with nailed slab system is one of the best solution of pavement on soft soil, besides some other pavement that has been done and built in Indonesia, such as Konstruksi Sarang Laba Laba (KSLL) which is widely used on airport runway And highways, Suryabumi (2008) has developed KSLL at Juwata airport Tarakan, and Djajaputra et.al. (2009) has conducted several studies on the use of KSLL for soft base soils. In addition to KSLL, there are also Pondasi Cakar Ayam that have undergone many modifications called Cakar Ayam Modifikasi (CAM), as developed by Suhendro (2005) on CAM on soft soils, Hardyatmo (2010) conducted a study of calculation methods on CAM system for the design of concrete pavement, and still a lot of research and development has been done in Indonesia about the two types of foundation is placed on soft soil. From some of the above foundations the research concludes that the use of KSLL and CAM can increase the strength of the pavement as seen from the increase in the modulus of subgrade reaction.

Rigid pavement with nailed slab system to be one of the alternatives 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 system using pile as burden distributors down to underground, so it is very different from KSLL or CAM foundation. However, the rigid pavement with nailed slab system is not functioning to improve soft soil, but one alternative method in improving rigid pavement performance on soft soil (Anas Puri, et al, 2013).

Rigid pavement with a nailed slab system, consisting of thin plates with thickness of 15 cm supported by a small pile of 1-1.5 meters of long and 15-20 cm in diameter, 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 of fixed plate pavements with conventional pavement on soft soil.

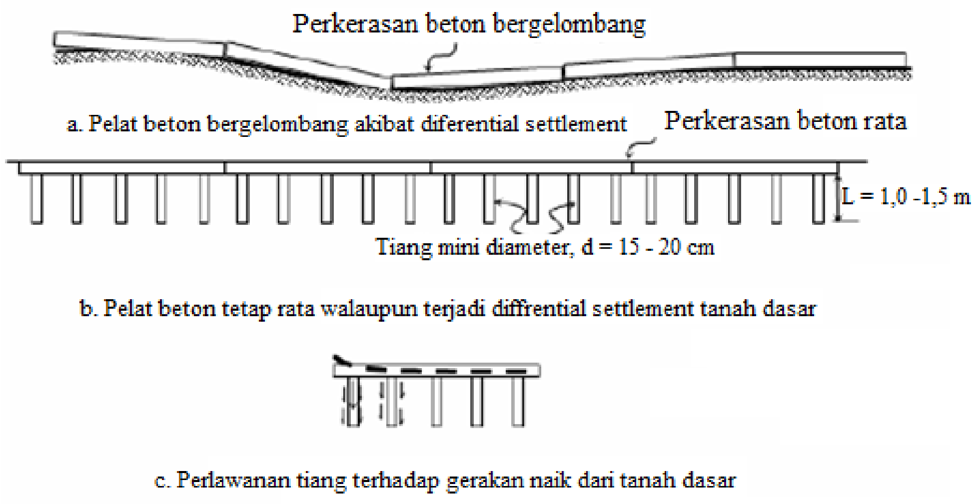


Figure 1. Illustration Effect of Pile Mounting on Plates With Conventional Pavement (Hardyatmo, 2008)

Purpose and objectives

1. The purpose of this research is to know the description of the behavior of pavement plate on rigid pavement with nailed slab system on soft soil and pile movement pattern which can influence plate deformation that serves as pavement when receiving lateral load.
2. Know the deformation pattern (decrease) of rigid pavement nailed slab system fixed when receiving lateral load.
3. To determine the effect of pile deflection on the decline of pavement after rigid pavement receives lateral load.

2. Lateral Loads

Lateral loads are horizontal loads that work on building structures, on road pavement or bridge load can be caused due to vehicle braking, due to wind, due to changes in temperature, due to soil pressure, or due to earthquakes, and others. Each building, either in the ground or on the ground, must be taken into account of its strength to the lateral load effect, this is done to determine the capacity and ability of a structure to withstand lateral loads.

For the piles on the deep foundation, lateral loading effects may cause excessive deflection which may result in damage to the foundation or pole of both short poles and long poles. A study conducted by Abhijit Deka (2016) on the influence of lateral loads on poles, concludes that lateral loading results may cause significant changes in pole behavior in addition to vertical loading, so the study of structures due to lateral loads is essential. Melting Omid Taheri et.al (2015), with increasing lateral loads will decrease the soil base reaction, thus reducing the strength of the ground soil which may lead to the reduction of rigid pavement plates above it.

3. Pile In Supporting Lateral Loads

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 poles that can reduce friction or ground bonds to piles (Cristensen, 2006), 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 plate 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, (2006).

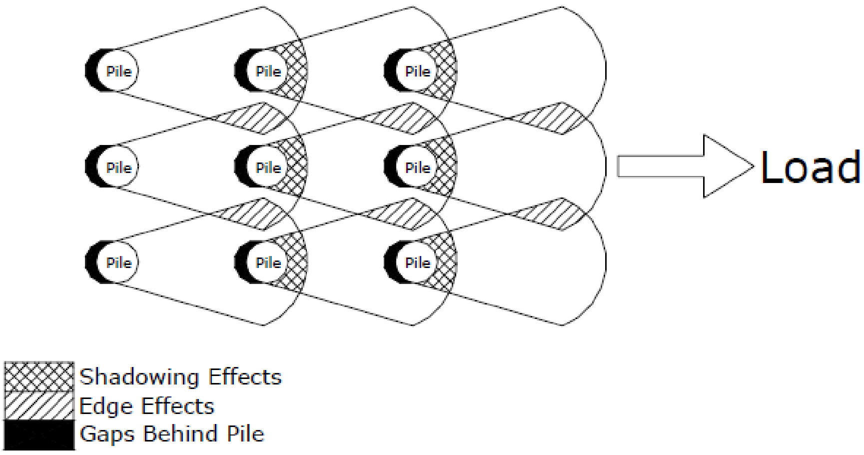


Figure 2. Illustration of lateral effect on land around pillars (Cristensen, 2006)

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

4. Analyze of Pile Deflection

Tomlinson 1977 in his book Pile Design and Constroction Practice, one of which makes the analysis of deflection calculations on the pole, 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. The shape of the pole movement according to Tomlinson (1977) 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.

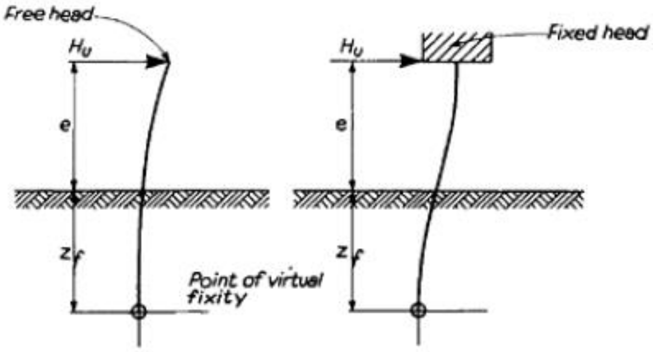


Figure 3. Piles in holding lateral load (Tomlinson, 1977)

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

a. free head pile

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

b. fixed head pile

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

Where :
E = Elastic Modulus of pole material (Mpa)
I = moment of inertia from pole (m4)
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 (1977) describes the following:

a. For Free head pile

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

b. *Fixed* head pile

$$y_0 = \frac{H}{k\ BL} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \ (4)$$

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 degree (Mukherjee, (2016). When the soil is non linearly model then the response from the lateral load can be described in 4 orders with differential equations (Brown and Reese, 1985).

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

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

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

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

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

5. Deflection of rigid pavement

Calculating plate deflection, moment and shear force due to centered load on plate 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 (1974). Calculation of base coefficient according to the equation below:

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

Where q = pressure
= deformasi (settlement of beam)

In the deflection analysis using the Roark (Young and Budynas, 2002) formula used by Anas Puri (2014), the calculation of deflection due to centralized load is as follows:

$$y = y_A\,F_1 + \frac{\theta_A}{2\beta}F_2 + \frac{M_A}{2EI\beta^2}F_3 + \frac{R_A}{4EI\beta^2}F_4 - \frac{W}{4EI\beta^3}F_{a4} \quad \cdots\cdots (9)$$

For both free ends *RA* = 0 and *MA* = 0, while θ_A and y_A are

$$\theta_A = \frac{W}{2EI\beta^2}\frac{C_2C_{a2} - 2C_3C_{a1}}{C_{11}} \quad \text{.......................} (10)$$

$$y_A = \frac{W}{2EI\beta^3}\frac{C_4C_{a1} - C_3C_{a2}}{C_{11}} \quad \text{.......................} (11)$$

$F_1 = \cosh\beta x\ cosh\beta x$
$F_2 = \cosh\beta x\ sinh\beta x + sinh\beta x cosh\beta x$
$F_3 = \sinh\beta x\ cosh\beta x$
$F_{a4} = \cosh\beta(x-a)sinh\beta(x-a) + sinh\beta(x-a)cosh\beta(x-a)$
$C_2 = \cos h\beta l\ sin\ \beta l + sinh\beta l\ cos\beta l$
$C_3 = \sin h\beta l\ cos\beta l$
$C_4 = \cos h\beta l\ sin\ \beta l - sinh\beta l\ cos\beta l$
$C_{a1} = \cos h\beta(l-a)cos\beta(l-a)$
$C_{a2} = \cosh\beta(l-a)sin\beta(l-a) + sinh\beta(l-a)cos\ \beta(l-a)$
$C_{11} = \sinh^2\beta l - \sin^2\beta l$

Where
W = central load (kN),
β = flow flexibility
k = base soil reaction modulus (kN / m2 / m)
B = beam width (m)
E = modulus of elasticity of the beam (kN / m2)
I = moment of inertia of beam (m4)
a = the load distance to the left edge of the block (m)
x = the distance of the point being reviewed against the beam edge
L = beam length (m)

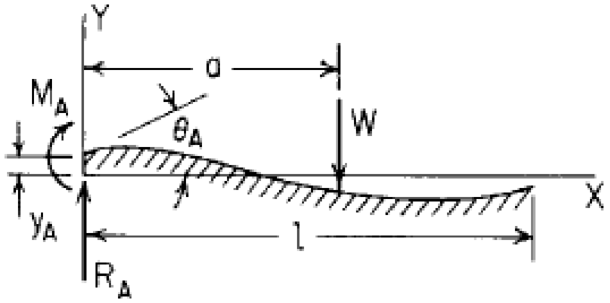


Figure 4. Beams above elastic foundation with limited length due to centralized load

6. Deflection of plate due to vertical loads

Hardyatmo (2008) has been researching nailed slab system monolith with pile and non-monolith. On the plate 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 decrease will become smaller.

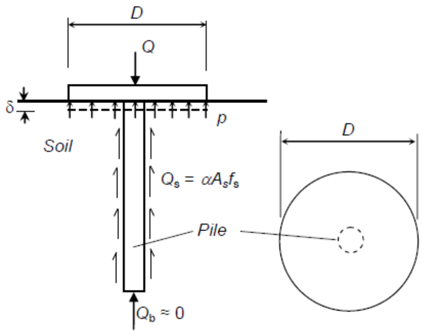


Figure 5. Effect of using pile in soil under plate (Hardyatmo, 2011)

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

$$Q_u = Q_b + Q_s \cdots\cdots\cdots\cdots\cdots\cdots\cdots (11)$$

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

The carrying capacity of the pile friction is illustrated in the equation :
Qs = As x fs

where: fs = friction along the pile (kPa)
As = broad pole circumference (m2)

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

$$f_s = a_d c + p_o K_d \tan \varphi_d \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots (12)$$

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,

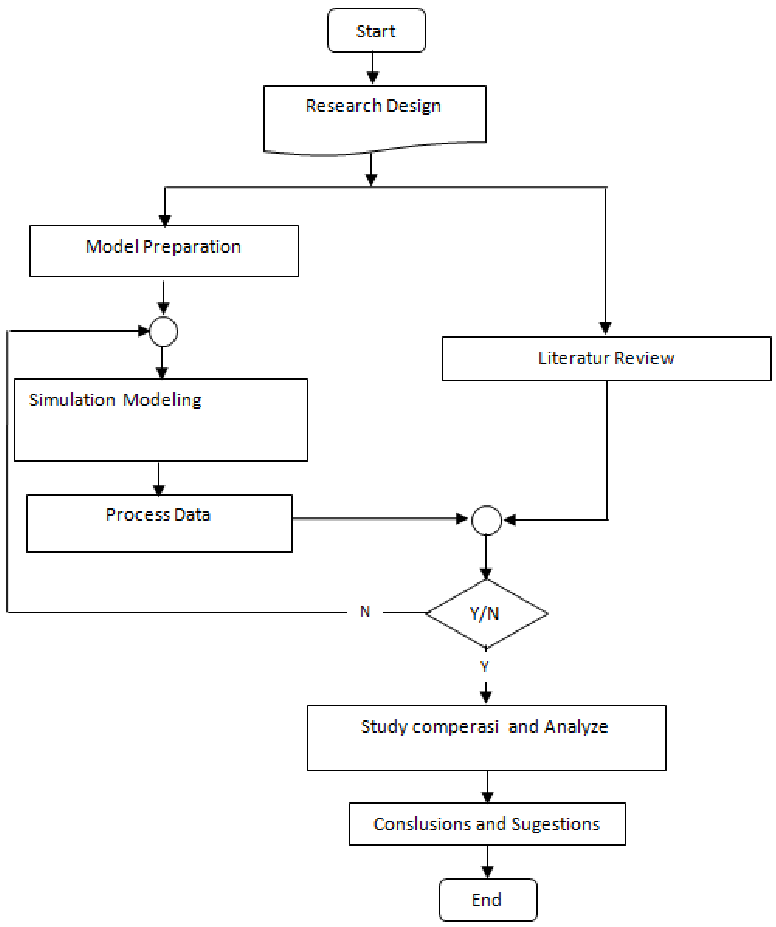
$$\Delta k = \frac{\delta_0 A_s}{\delta^2 A} f_s \cdots\cdots\cdots\cdots\cdots\cdots\cdots (13)$$

Another research is Anas castle (2013), 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, 2006, 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 Hardyatmo (2009).

7. 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.



Gambar 6. Flowcart of Research

8. Conclusion

1. From the previous researchs concludes that the addition of pile can increase the modulus of the soil reaction basis, and increasing the stiffness of the rigid pavement.
2. The lateral loads will greatly affect the change of plate reduction due to deflection on the pile.
3. Deflection occurring on the pile due to lateral load will affect the decrease of pavement plate due to the decrease of friction which happened due to the gap between pile and ground.
4. The larger the pile deflection due to the lateral load will be the greater the decrease of the pavement plate.

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