Analysis Of Soil Improvement Using Bamboo Net-System On Railway

Aditya Wahyu Erlangga, Jamaludin, Handoko, Sapto Priyanto, Devi Cosmalinda Laynardo, Akademi Perkeretaapian Indonesia Madiun
E-mail : aditya@api.ac.id

Abstract. Soft soil conditions and shallow groundwater positions are found in the project process of the Railway Double Track, so it may reduce the carrying capacity of the soil and cause a decrease in soil if the soil is given a load. Based on the sondir test for soil with a value of qc > 10 kg/cm² at a depth of below 20 m, bamboo net may use as soil improvement as a more environmentally friendly alternative. Bamboo net-system has a diameter of 10 cm and a length of 5 meters, and the distance between the poles is 60 cm = 6 x 10 (6D). The total of bamboo was 8 stems. Soil improvement using bamboo net of 10 cm in diameter and 5 meters length, with a distance between bamboo 60 cm, then it obtained analysis results of the carrying capacity of 738.8 kN/m². The train voltage and landfill are 249,295 kN/m² < carrying capacity of the group pole is 738.8 kN/m². Based on the results of the density test of Sand Cone obtained a degree of density of 96.5%.

Keywords: BambooNet, Soil Soft Layer, Soil Bearing Capacity
1. INTRODUCTION

1.1 Background
Soft soil conditions and shallow groundwater positions are found in the project process of the Railway Double Track on Gombong – Karanganyar KM 435 + 300, so it may reduce the carrying capacity of the soil and cause a decrease in soil if the soil is given a load. Soil improvement is a way to increase the carrying capacity of the soil, such as bamboo net may use as soil improvement as a more environmentally friendly alternative.

Graph 1. Result of Sondir Test

After soil test using Sondir on every 100 m, it concluded that the soft soil conditions are relatively thick, which is more than 1m. Therefore, an effort is needed for soil improvement. Based on the analysis, for soils with qc values > 10 kg / cm² at depths below 20 m, then the soil improvement may use the bamboo nets.

1.2 Railway Load
If G is the average load of 2 axles and borders each other, (d) is the distance of the locomotive axle. (a) is the bearing distance (m) = d/a, then the bearing pressure for both axles gives the maximum price. This price still has to be multiplied by speed coefficient.

For lok CC 202, the adjacent axle (d) = 1.75 meters and the axle pressure is 18 tons. For 18 ton of axle pressure, the concrete bearing distance is 0.60 m, speed coefficient:

$$1 + \frac{V^2}{30000}$$

(Source: Konstruksi Jalan Rel, H.Surakim, Nuansa Cendekia, 2014)

If the two axles are an unfavorable combination, then for a speed of 100 km/ h, the highest bearing pressure becomes

$$D_{max} = 6.2 \left(1 + \frac{V^2}{30000}\right)$$

But, for speeds above 110 km/h has a formula for bearing pressure.
When used with concrete bearings of size
- 20 cm top width
- 23 cm of bottom width
- 22 cm height

1.3 Soil Carrying Capacity
Aiming to determine the carrying capacity of a single pole with a vertical load can be calculated based on data from the land test. The carrying capacity of a single pile foundation can be calculated based on field data and laboratory data of the land test report. Calculation of carrying capacity of foundation based on field data, namely data sondir (CPT/cone penetration test).

\[ Q_v = Q_s + Q_b \]

\[ q_{ult} = C_u N_c \]

\[ Q_s = \sum F_c K_c R_c C_p L_i \]

\[ Q_b = N_c c_u A_b \]

Where
- \( Q_v \): Planning vertical carrying capacity
- \( Q_s \): Carrying capacity by resistance around the pole
- \( Q_b \): Carrying capacity by pole end resistance
- \( K_c^R \): Factor of power reduction
- \( c_u \): Un-drained shear strength of soil
- \( C_p \): Effective perimeter of the pole
- \( L_i \): Pole length
- \( N_c \): Carrying capacity factor
- \( c_u \): Un-drained shear strength of soil
- \( A_b \): Cross section area of the pole

1.4 Safety Factor
Ultimate carrying capacity (qult) is defined as the maximum load per unit area where the ground can still support the load without experiencing collapse. Converted into the equation, then:

\[ N_c = \text{the carrying capacity factor obtained in the Terzaghi table} \]

\[ C_u = \text{Cohesion of un-drained clay saturated water (kg/cm2)} \]

\[ C_u = \frac{q_c}{F} \]

\( C_u \): Cohesion of un-drained clay saturated water (kg/cm2)
\( q_c \): Cone resistance value
\( F \): Soil cohesion score between 10 - 20
\( SF \): Safety Factor
2. RESEARCH METHOD

2.1 Chart Flow

- Start
- Preparation: Field Survey, stripping, and utility checking under the ground
- Install the Bamboo net
- Pile up the previous layer
- Pile up the ground for the Baan Body
- Finish

2.2 Analysis of Technical Problem

The work of hoarding or piling up is carried out along the railway line from KM 431 + 800 - 438 + 600. Based on the Detail Engineering Design, soil improvement is only found in KM 436 + 250 - 437 + 000. However, after field test and soil test, there are several technical problems, including:

- By reviewing the results of the field test and soil test, there are differences between the DED and the existing in the field. Based on DED, soft soil is not deep and does not need soil improvement. However, after a soil test, the depth of the soft soil layer is depth to 1-7 m, so it may endanger the stability of the hoarding.
- The depth of soft soil may cause an over lowering of the soil, which may endanger the safety of the train if the lowering is not immediately fixed.
- The condition of the existing field is also runny and it makes the soil to be soft.
2.3 Scope of the Work
The scopes of the work are:

- Soil test using sondir and borlog to know the depth of soft soil and soil properties.
- Soil improvement based on the stability analysis and soil lowering aiming to obtain the safety and hoarding stability.

2.4 Load of Train
Defined; Dimension of bearing
Length = 23 cm
Width = 200 cm
Height = 20 cm
G (load of axle) = 18 ton
\( V_{\text{max KA}} = 110 \text{ km/jam} \)
\( x_1 = (2 \times 30 \text{ cm}) + 200 \text{ cm} = 320 \text{ cm} \)
\( x_2 = (2 \times 75 \text{ cm}) + 200 \text{ cm} = 350 \text{ cm} \)

Coefficient of velocity (m)
\[ m = \frac{d}{a} = \frac{\text{distance between axle}}{\text{distance between bearing}} = \frac{175 \text{ cm}}{60 \text{ cm}} = 2.91 \]
\[ G = \frac{18 + 18}{2} = 18 \text{ ton} \]

Bearing Pressure (Dmax)
\[ D_{\text{max}} = \frac{G}{m} \times \varnothing \]
\[ = \frac{18}{2.9} \left( 1 + \left( \frac{4.5 \times V^2}{10^5} - \frac{1.5 \times V^2}{7} \right) \right) \]
\[ = \frac{18}{2.9} \left( 1 + \left( \frac{4.5 \times 110^2}{10^5} - \frac{1.5 \times 110^2}{10^7} \right) \right) \]
\[ = 5,881 \text{ ton} \]

Base Bearing Area = \( p \times l \)
\[ = (23 \times 200) \text{ cm} \]
\[ = 4600 \text{ cm}^2 \]

Bottom Bearing Tension
\[ (\sigma_1) = \frac{D_{\text{max}}}{A} = \frac{5,881 \text{ ton}}{4600 \text{ cm}^2} \]
\[ = 1.2783 \text{ kg/cm}^2 \]

2.5 Carrying Capacity of Single Pole
\[ Q_s = Q_s + Q_b \]
\[ Q_s = \sum F_c K_s^c c_u C_p L_i \]
\[ Q_b = N_c c_u A_b \]
Where:
\( K_c^R = 0.8 \)
\( C_u = 0.71 \text{ kg/cm}^2 = 71 \text{kN/m}^2 \)
\( C_p = 3.14 \times 0.1 \text{ m} = 0.314 \text{ m} \)
\( L_i = 5 \text{ m} \)
\( A_b = 3.14 \times 5^2 = 78.5 \text{ cm}^2 = 0.0078 \text{ m}^2 \)

\[
Q_s = \sum F_c K_c^R c_u C_p L_i
\]

\[
 Q_s = \sum 1 \times 0.8 \times 71 \times 0.314 \times 5
\]

\[
 Q_s = 89,176 \text{kN/m}^2
\]

\[
 Q_b = N_c \cdot c_u \cdot A_b
\]

\[
 Q_b = 5.7 \times 71 \times 0.00785
\]

\[
 Q_b = 3,1176 \text{kN/m}^2
\]

\[
 Q_v = Q_s + Q_b
\]

\[
 Q_v = 89,176 + 3,1176
\]

\[
 Q_v = 92,352 \text{kN/m}^2
\]

2.6 Carrying Capacity of Group Pole

It used Bamboo with 10 cm in diameter and 5 meters in length. The distance between poles is 60 cm = 6 x 10 (6D). The total of bamboo is 8 steams. Then, it uses the formula:

\[ Q_v \cdot k = Q_v \cdot n \cdot \mu \]

\[
 Q_v \cdot k = 92,35 \times 8 \times 1
\]

\[
 Q_v \cdot k = 738,8 \text{kN/m}^2
\]

Based on the results of the Cone Penetration Test (CPT) at KM 435 + 300, the vertical carrying capacity is \( Q_v \cdot k = 92,35 \text{kN/m}^2 \) and the single bearing capacity per 1 m is \( Q_v \cdot k = 738,8 \text{kN/m}^2 \) uses Terzaghi's calculation theory.

- The load of a train is 49.659 kN/m\(^2\) less than carrying capacity of single pole is 92.35 kN/m\(^2\) (safe).

Group

- 49.659 x 5 m (width of track) = 248,295 kN/m\(^2\)
- 92.35 x 8 steams of bamboos = 738,8 kN/m\(^2\)
- The load of group train is 249,295 kN/m\(^2\) carrying capacity of group pole is 738,8 kN/m\(^2\) (safe).

2.7 Planning Value of Safety Factor

This type method of soil improvement is recommended for soil with less than 2 to 6 m of sub-grade conditions with a height more than 2.50 m. Calculation of the value of \( c_u \) is approximated by \( q_c/20 \) with the height of embankment considered 4.0 m.

Used as soil data for planning analysis with the bamboo net.

Aiming to find out the Safety Factor, it must know the load of the train and construction. Calculation of load is explained as follows
Calculation of planning is for poor soil at KM 435+300.
Defined:
\[ Q_c = 14,290 \text{ kg/cm}^2 \] (cone resistance value obtained from soil test data)
\[ F = 20 \]
\[ q_{KA} = 43,129 \text{ kN/m}^2 \]
\[ H_{hoarding} = 4 \text{ m} \]
\[ q_{hoarding} = 72 \text{ kN/m}^2 \]

1. \[ C_u = \frac{q_c}{F} = \frac{14,290 \text{ kg/cm}^2}{20} = 0.71 \text{ kg/cm}^2 \]

2. \[ q_{ult} = C_u N_c = 0.71 \text{ kg/cm}^2 \times 5.7 = 4.071 \text{ kg/cm}^2 = 407.1 \text{ kN/m}^2 \]

3. \[ S_F = \frac{q_{ult}}{q_{tot}} = \frac{407.1 \text{ kN/m}^2}{(49,659+72) \text{kN/m}^2} = \frac{407.1 \text{ kN/m}^2}{121,659 \text{kN/m}^2} = 3.34 \]

\[ S_F > S_F \text{ Allowed (3)} \]
\[ 3.34 > 3 \text{ (safe)} \]
So, with the planned SF score of 3.34, the soil improvement using the bamboo net-system; the train is safe to pass.

The Result of Sand Cone Test.
Table 1. Result of Soil Density Test

The result of sand cone test obtained the degree of density of 96.5%.

3. CONCLUSION
Soil improvement using a bamboo net with 10 cm in diameter and 5 meters in length, with a distance between the poles is 60 cm, obtained the carrying capacity analysis of 738.8 kN/m². The train tension and hoarding are 249.295 kN/m²<carrying capacity of the pole group is 738.8 kN/m². Based on the results of the Sand Cone density test, obtained the degree of density of 96.5%.

4. SUGGESTION
Compaction of soil hoarding should be done in each layer aiming the degree of density is evenly distributed for the layers.

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