

Numerical Simulation by using Soldiers Pile of the Embankment on Semarang-Solo Highway

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Abstract. Semarang-Solo highway works section II Gedawang-Penggaron constitutes a labile area. It is thought to be effect of the existence of coat clay shale which have moulded. For the purpose of anticipating the embankment mass movement it is placed line bored pile and stringed up (soldiers pile). The objective of this research is to know the efficient use of soldier's pile of the embankment on Semarang-Solo highway section II Gedawang-Penggaron pursuant based upon numerical simulation. The result of analysis depicts that original slope in a stabil state with horizontal displacement which equal to 0.06 m and safety factor (SF) which equal to 1.31. The strengthened embankment with bored pile is not effective to give am SF improvement at slope so that, at this phase, the slope cannot be slid to be safe enough from landslide namely with horizontal displacement which equal to 0.20 m and SF which equal to 1.09. The effect of traffic load horizontal displacement is which equal to 0.21 m with SF which equal to 1.00. The earthquake simulation results horizontal displacement which equal to 0.75 m with SF which equal to 1.00. Long variation of bored pile of phase II by neglecting bored pile phase III at the depth 35 m yields horizontal displacement which equal to 0.03 m and SF optimum which equal to 2.17. The variation of pile location by placing bored pile under embankment slope foot with distance from the location of bored pile of phase II which equal to 20 m without changing the profile of the existing bored pile creates the horizontal displacement which equals to 0.02 m with SF which equal to 2.29. The result of the horizontal displacement and SF of the two alternative is safer compared to the existing condition (SF>1.5).

1. Introduction

Semarang-Solo highway is a main regional road connecting East-West area and North-South area and contributing to economic growth in the Central Java and surrounding areas. Semarang-Solo highway with Section II Semarang-Bawen Space of Gedawang-Penggaron was constructed [1], starting from Sta.3+525-Sta.8+475 (4950 m). In general, this work of construction consisted of excavation, heap, overpass, box culvert and two bridges, Susukan and Penggaron [2].

Performance of highway construction in area Sta.5+600 – Sta.6+200 is labile area and frequently experiencing creep landslide. It is supposed as result soft clay and weathered clay shale layers. The area is location of embankment construction as high as 20-25 m with embankment soil characteristics such as clay silt put on sub grade layer in 9° – 10° slope. This embankment is worried to experience mass landslide if there are changes in soil characteristics in rainy season [3]. The mass heap landslide is coped with soldiers pile. Dimensions of soldiers pile used are 1 m pile diameter, minimally 10 m and maximally 18 m length of pile; 2 m pile distance and 500 m length of soldiers pile (Sta.5+600-Sta.6+100).



The objective of this research was to find efficiency of soldiers pile application to embankment of Semarang-Solo highway of Section II Gedawang-Penggaron with Numerical simulation. To analyze slope stability of embankment and effectiveness of placement of soldiers pile, software of version 8.2 Plaxis would be used [4].

2. Methods

2.1 Location

Location which was used for this research object was Sta.5+739 of Semarang – Solo High way of phase I of Semarang – Bawen space of Section II Gedawang – Penggaron in Semarang, Central Java. Map of research object location of Sta.5+739 can be seen in **Figure 1**.



Figure 1. Map of research object location of Sta.5+739 (Cipta Strada, 2009).

2.2 Materials

The object in Sta.5+739 can represent from Sta.5+600 to Sta.5+800 and the location is vulnerable to mass movement. Mass movement landslide can be coped with placement of soldiers pile. To analyze efficiency of soldiers pile placement, secondary data were used.

2.3 Tools and collection of data

Tools used in this research were a set of hardware unit, namely, Pentium IV based-computer with 1 Gb memory and software of version 8.2 [4]. Plaxis data which were needed in this research were primary and secondary data. Primary data of this research consisted of data of interview and field observation, and secondary data used in this research were:

- Map of topography, bestek picture, and research sketch;
- In situ data (SPT, CPT, Bore Log, Geoelectric);
- Laboratory data.

2.4 Traffic load and earthquake load

In simulation of traffic load, 16 kPa was used based on design parameters in of Semarang - Solo Wighway [1]. Based on earthquake zoning map issued by Public Work Ministry published in 2010, research location existing on Semarang City, Central Java Province, is included in Zone 5 with rock peak speed (PGA) 0.2g – 0.20g. Earthquake data used were earthquake spectrum files of SMC format which were downloaded from USGS, with peak speed (PGA) 0.2399g or 239.9 Club of Multimillionaires/s² on February 28 of 1990 in Upland, California [5].

3. Results and Discussion

3.1 Numeric simulation using Plaxis software

Analysis of slope in Sta.5+739 was simulated in some conditions according to field condition with various water surface depths, -4m depth and -8m depth based on machine bore test data and assumed representing land condition in rainy and summer seasons. The analysis was conducted to find

displacement tendency behavior [6], examine bored pile placement efficiency, potential fall mechanism, and safe rate in Sta.5+739.

Numerical analysis of stability was classified into three models:

- 1) Model 1, analysis of existing slope condition before there was highway construction;
- 2) Model II, analysis of existing condition in site. Model II has three analytic reviews, namely:
 - a. Slope condition with only embankment and it had been conducted by sub grade replacement under embankment;
 - b. Embankment slope condition with reinforcement system application of *bore pile* installed parallel to embankment foot; and
 - c. Condition with loading simulation.
- 3) Model III, analysis of bored pile reinforcement system use efficiency. This model based on variation of length and location of bored pile to improve or increase rate of slope safety factor to be > 1.5.

3.2 Validation based on measurement data

Considering the results of field test and instrumentation data, changes in parameter data inputs were made, also geometry of model according to inclinometer 3 data as shown in **Table 1**. Based on consistence of land parameter data, modeling of validation geometry is classified into five land layer clusters: first, embankment layer (clay silt); second, silt clay layer which is outset layer; third, weathered clay shale; fourth, clay shale; and fifth, fresh clay shale. Geometry of Sta.5+739 can be seen in **Figure 2** [4].

Based on the results of simulation in validation phase, value of horizontal displacement was 0.14 m and data of horizontal displacement in field in inclinometer 3 data is 0.14 m, so the simulation could be continued to modeling phase. Graphic of horizontal displacement of validation results in point inclinometer 3 is shown in **Figure 3**.

Table 1. Land parameter data after making trial and error.

No	Parameter	Type of Land				
		Fresh Clayshale	Clayshale	Weathered Clayshale	Silt clay	Heap
1	Model	MC	MC	MC	MC	MC
2	Type	<i>Undrained</i>	<i>Undrained</i>	<i>Undrained</i>	<i>UnDrained</i>	<i>UnDrained</i>
3	γ_{unsat} (kN/m ³)	19.0	17.0	15.5	16.0	17.5
4	γ_{sat} (kN/m ³)	20.0	19.0	17.5	18.0	18.0
5	k_x (m/day)	0.00315	0.00315	0.0315	0.00315	0.00315
6	k_y (m/day)	0.00315	0.00315	0.00315	0.00315	0.00315
7	E_{ref} (kN/m ²)	370000	9000	560	8500	20000
8	V	0.35	0.35	0.35	0.35	0.35
9	C_{ref} (kN/m ²)	320.00	80.00	15.00	70.00	65.0
10	Φ	26	10	9	10	23
11	Ψ	0	0	0	0	0
12	R_{inter}	0.7	0.7	0.7	0.7	0.7

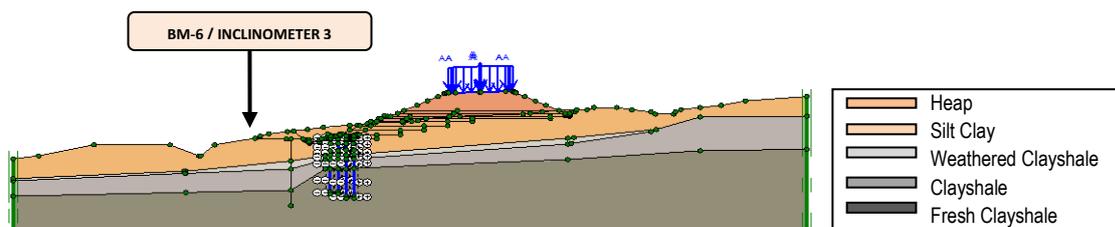


Figure 2. Geometry of Sta.5+739.

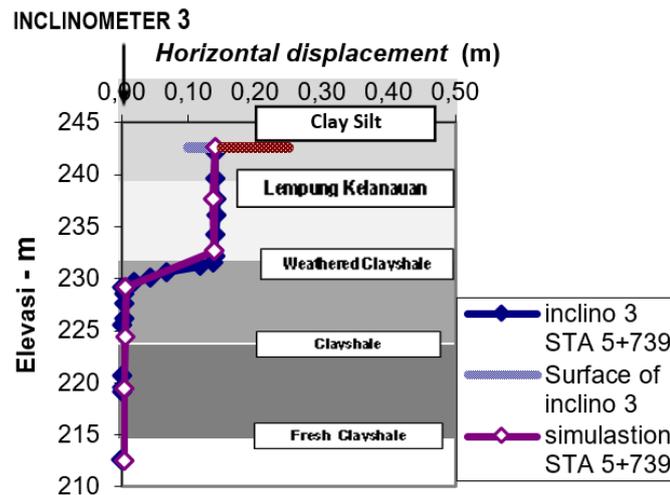


Figure 3. Graphic of horizontal displacement of validation results in point inclinometer 3.

Table 2. Data of recapitulations of horizontal displacement (cross section in location of inclinometer 3) and safety factor in Plaxis software.

No.	Simulation of Plaxis	Horizontal Displacement (m)	SF
1	Existing condition of slope	0.06	1.31
2	Condition of Stripping/Digging, Heap of Phase I, and Installation of Phase II <i>Bore Pile</i> (Validation Phase)	0.14	1.09
3	Condition of Phase II Heap	0.20	1.08
4	Condition of Phase III <i>Bore Pile</i> Installation	0.20	1.09
5	Condition of Traffic Load	0.21	1.00
6	Condition of Earthquake Load	0.75	1.00
7	Alternative 1 (Length variation of <i>Bore Pile</i>)	0.03	2.17
8	Alternative 2 (Position/Distance Variation of <i>Bore Pile</i>)	0.02	2.29

3.3 Analysis of horizontal displacement and safety factor (SF)

From the results of simulation for various conditions, data of horizontal displacement and safety factor deformations were obtained as shown in **Table 2**. Recapitulation of horizontal displacement can be seen in **Figure 4** and recapitulation safety factor can be seen in **Figure 5** [7].

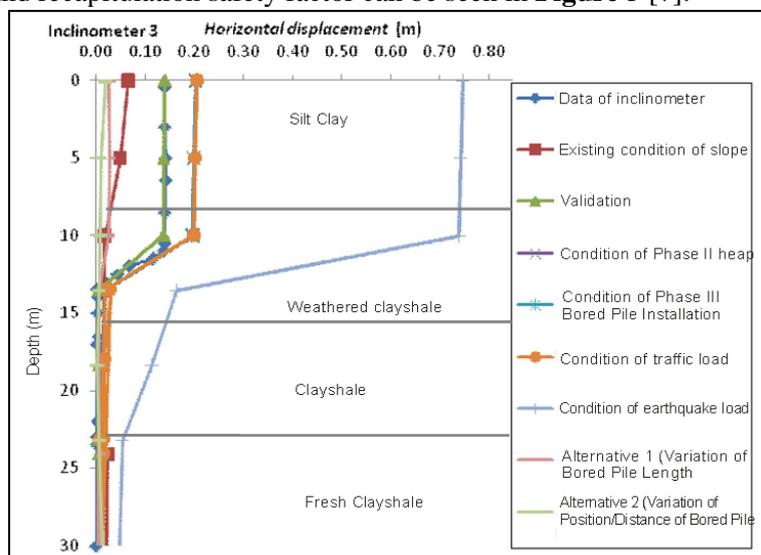


Figure 4. Recapitulation of horizontal displacement.

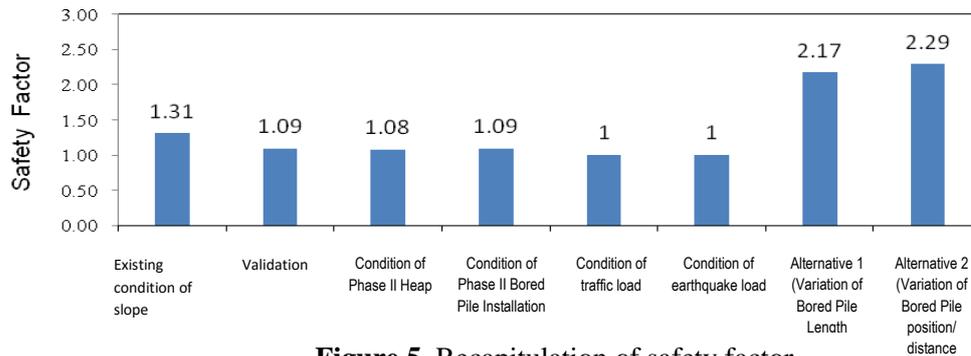


Figure 5. Recapitulation of safety factor.

4. Conclusions

Based on results of analysis conducted in this research, it can be concluded that: analysis of Model I (simulation of sub grade slope condition) generated horizontal displacement = 0.06 m with safety factor = 1.31. the safety factor indicates that the embankment slope condition of Sta.5+739 was stable ($SF > 1.25$); analysis of Model II (simulation of existing condition) indicates that road heap which had been reinforced by bore pile was ineffective to increase safety factor in slope, so that, in this phase, slope had not been found sufficiently safe for slide, namely, horizontal displacement = 0.20 m and safety factor = 1.09, as result of traffic load, the horizontal displacement = 0.21 with safety factor = 1.00. Simulation of earthquake generated horizontal displacement = 0.75 m with safety factor = 1.00. Based on the results of depth analysis, bore pile was not flanked perfectly by layer of fresh clay shale; mass movement in embankment was affected by land layer of weathered clay shale, so that it reduced landslide strength parameters resulting in cracking on road body. It caused less stability of embankment slope resulting in mass movement embankment; pattern of mass movement in slope was slide where slip plane tended to curve with rotational motion; analysis of Model III (analysis of embankment reinforcement by bored pile showing variations of Phase II bored pile length in depth 35 m by ignoring Phase III bored pile generated horizontal displacement = 0.03 m and optimum safety factor = 2.17. Variations of Phase III bored pile location in condition under body embankment slope foot with distance from Phase II bored pile location = 20 m without changing profiles of bored pile and Phase II bored pile remained as in existing condition generating horizontal displacement = 0.02 m, with safety factor = 2.29. The results of horizontal displacement and safety factor of both alternatives were safer than existing condition; proposal of embankment reinforcement alternatives to improve or increase safety factor was to increase Phase II bored pile length to be 35 m without changing profiles by ignoring Phase III bored pile. This alternative was more efficient and economic because it ignored installation of Phase III bored pile construction; and effect of pile location and distance between piles, gave great effect to safety factor increase.

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