Assessment to the comparison between the initial state and insitu conditions of Bengawan Solo river embankment during the dry and monsoon seasons at Kanor-Village

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ABSTRACT

Water level fluctuation during dry and monsoon seasons might be the cause of river embankment condition changing. The insitu soil properties exhibits different behavior among these seasons, such as soil density, soil shear strength and soil suction. This paper is mainly the comparison between the Bengawan Solo river embankment’s initial state and insitu conditions at Kanor village section, Bojonegoro, East Java, Indonesia. Furthermore, the field investigations at upper and lower embankment were conducted to obtain the insitu soil properties (dry density, shear strength and suction) during dry and monsoon season. In addition, soil sampling was also performed for laboratory investigations. The laboratory investigations were carried out to understand the initial fresh compacted soil (standard Proctor test) condition and to obtain soil properties. The results showed that the upper and lower insitu density condition were affected by the water level fluctuation. The upper and lower sections upon water fluctuation were found to be around 65-85 % and 60-80 % of the optimum Proctor. The soil suction was found to be greatly higher comparing to the soil shear strength during the dry season. Moreover the cracks was developed in upper embankment rather than in lower section embankment.

**Keywords:** Bengawan Solo river embankment, water level fluctuation, standard Proctor test, suction, shear strength, cracks.

1 INTRODUCTION

Bengawan Solo river, is one of the largest natural river in Indonesia, which has 100 m in width and over 500 km in length. The river bed soil is originally weathered from mountain igneous rock and deposit as silty soil material at the downstream region.

In Kanor village, Bojonegoro, the river embankment instability is almost always triggered by the overflowing water during monsoon season. Considering these conditions, the silty soil was removed from riverbed to re-elevate (in dry condition) the embankment along Bengawan Solo river (Mountassir et al, 2010). The difficult problem is the physic and mechanic properties of silty soil that might be decreased rapidly due to water level fluctuation, even though the embankment was initially compacted at nearly optimum Proctor (Soemitro, 2004). Moreover, the developed crack, induced by high negative pore water pressure during low water level, leads to the reduced resistance of soil embankment.

This paper investigates the upper and lower section of river embankment condition in Kanor village section, Bojonegoro, East Java, Indonesia. The field investigations were conducted to obtain the insitu soil properties (dry density, shear strength and suction) during dry and monsoon season. In addition, soil sampling was also performed for laboratory investigation. The laboratory investigations were carried out to understand the initial fresh compacted soil (Proctor) condition and to obtain soil properties. The result showed that during water level fluctuation, the upper and lower sections are found to be below of the optimum Proctor and there was also a probability of crack development on upper section.

2 RESEARCH METHODOLOGY

The research consists of field and laboratory investigation, where the soil were sampled along the river embankment during dry and monsoon season at Kanor village section, Bojonegoro, East Java, Indonesia. The study location is presented in Figure 1.

The insitu surface soil properties test and surface soil sampling were performed in upper and lower section of river embankment during dry and monsoon season (starting from February 25\textsuperscript{th} 2014 until May, 06\textsuperscript{th} 2014), as it is shown in Figure 2.
The observation time started when the end of monsoon season (peak rain intensity) on February 25th 2014 and March 11th 2014, where the water level reached +10.0 m depth measured from riverbed. The following observation was continued on dry season, from March 29th 2014 until May 06th 2014 and the water level fluctuated from +7.8 m until +4.1 m from riverbed.

Li, J.H. et al. (2011) revealed that crack initiation can be assessed by the suction profile and shear strength during drying process. The suction and shear strength at upper and lower section will then be analyzed during dry and monsoon season in order to predict the development of soil cracks.

3 SOIL CHARACTERIZATION

The surface soil was sampled from upper and lower river embankment to obtain the specific gravity, grain size analysis and soil plasticity as shown in Table 1. From the USCS classification, it was pointed out that the upper and lower embankment soil was classified as clayey-silty soil.

Table 1. Surface soil properties at upper and lower river embankment

| Soil Properties | Upper | Lower |
|-----------------|-------|-------|
| Gravel (%)      | 0.09  | 0     |
| Sand (%)        | 19.06 | 10.47 |
| Silt (%)        | 35.62 | 45.35 |
| Clay (%)        | 45.23 | 44.18 |
| LL (%)          | 55.17 | 48.96 |
| PL (%)          | 24.54 | 23.84 |
| PI (%)          | 30.63 | 25.12 |
| USCS Classification | CH (Fat Clay) | CH (Fat Clay) |
| Gradation       | Poor Graded | Poor Graded |
| Specific Gravity, \( G_s \) | 2.678 | 2.634 |

4 SOIL PROPERTIES ANALYSIS

The soil properties analyses were very important to investigate the changes from initial state (fresh compacted soil) into the insitu condition (existing) due to water level fluctuation. The comparison of fresh compacted soil (Proctor) and insitu soil properties at upper section is presented in Figure 3.

![Fig. 1. Study location](image1)

![Fig. 2. Soil sampling location](image2)

![Fig. 3. Comparison of fresh compacted (Proctor) and insitu soil condition at upper section](image3)

As the suction value increased from 20 KN/m² into 3000 KN/m² due to water level decreased (February 25th 2014 to April 15th 2014), the soil dry unit weight...
was increased from 9 KN/m$^3$ into 12 KN/m$^3$, even though these range value is still plotted 65-85% of optimum Proctor. As well as the density, the soil cohesion was also increased from 20 KN/m$^2$ into 100 KN/m$^2$.

To be more specific to understand the phenomenon, grain size analysis (Figure 4) and plasticity test (Figure 5) were carried out into these soils.

![Graph showing soil grain size analysis](image1)

**Fig. 4.** Soil grain size analysis of upper section

![Graph showing soil plasticity index](image2)

**Fig. 5.** Soil plasticity index of upper section

Figure 4 and 5 presents the soil grain size and soil plasticity index induced by water level fluctuation during dry and monsoon season. It can be clearly seen that clay particle reduction occurred (maximum reduction ± 27%) as water level decreased. Considering these particular conditions, the plasticity index reduction (maximum reduction ± 90%) followed to be occurred as clay particle decreased.

The comparison of fresh compacted soil (Proctor) and insitu soil properties at lower section is presented in Figure 6.

Similar with upper section, the slight suction value increased from 10 KN/m$^3$ into 20 KN/m$^3$ due to water level decreased (March 29th 2014 to May 6th 2014), the soil dry unit weight was increased from 9.3 KN/m$^3$ into 11.3 KN/m$^3$, even though these range value is still plotted 60-80% of optimum Proctor. As well as the density, the soil cohesion was also slightly increased from 16 KN/m$^2$ into 18 KN/m$^2$.

![Graph showing soil grain size analysis](image3)

**Fig. 6.** Comparison of fresh compacted (Proctor) and insitu soil condition at lower section

To be more specific to understand the phenomenon, grain size analysis (Figure 7) and plasticity test (Figure 8) were carried out into these soils.

![Graph showing soil plasticity index](image4)

**Fig. 7.** Soil grain size analysis of lower section

![Graph showing soil plasticity index](image5)

**Fig. 8.** Soil plasticity index of lower section
triggered by the water current value at certain water level. Considering these particular conditions, the increased of plasticity index (maximum increased ± 47%) followed to occurs as sand particle decreased.

5 SOIL CRACK INITIATION ANALYSIS

The cracks occurred when the shear strength value is much lower than the suction value (Li, J.H., 2011). Therefore, comparison curve of suction and soil cohesion at upper and lower embankment (Figure 9 and Figure 10) were made to understand the development of crack.

![Soil cohesion, Cu and Suction, Uw](image1)

Fig. 9. Comparison of suction and soil cohesion at upper embankment during dry and monsoon season

![Soil cohesion, Cu and Suction, Uw](image2)

Fig. 10. Comparison of suction and soil cohesion at lower embankment during dry and monsoon season

It can be clearly seen that the suction value was much higher than the soil cohesion at upper embankment along the dry and monsoon season. At lower embankment, the soil cohesions were plotted slight greater than the suction value. Considered these particular condition, the crack was developed in upper embankment rather than in lower embankment. To be more visually described, Figure 11 (a) and (b) present the picture of upper and lower embankment condition.

![Upper section](image3) ![Lower section](image4)

Fig. 11. (a) Upper section; (b) Lower section

6 SUMMARY

The embankment soil at upper and lower was clayey-silty soil. However, the insitu soil properties were different as the upper section had less water content than lower section.

The soil dry density at upper was plotted 65-85 % of optimum Proctor, meanwhile lower condition was plotted 60-80 % of optimum Proctor. In addition to water content influence, the grain size analysis and plasticity index value were considered to be the reason of soil properties changes. The clay particles reduction and decreased of plasticity index occurred at upper section as water level decreased. Whilst, the sand particles reduction and increased of plasticity index occurred at lower section as water level decreased.

Considering the suction and shear strength value, the crack was developed in upper embankment rather than in lower embankment.

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