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The testing of soaked Khon Kaen loess embankment with and without geosynthetics

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ABSTRACT: Loess deposits exist above the water table in abundance in Khon Kaen Province, Thailand. Dry loess is very strong but wet loess is very weak. The use of loess as embankment material is uncertain while transportation of material from distant borrow pit makes some construction projects become costly. This paper presents the results obtained mainly from large scale tests. Plain loess embankment with 53° side slope reached failure state after it was soaked for several days, even if there was not any surcharge load. The material of another vertical side slope embankment was the loess reinforced by 2 types of geosynthetics. Its stability was observed during a long time of heavy rain. After that, 2-meter width strip load of 21 kPa was applied on the top of reinforced loess embankment and then, it was soaked again. Geosynthetics proved useful to loess stabilization in fill work. The embankment showed very good stability under both soaking and soaking combined with surcharge strip load situations. The good stress distribution of reinforced loess was also found. Two problems one should be aware of are: even if reinforced loess has very good stability, it may fail because of erosion. The second problem is that the ground bearing capacity must be checked whether it can bear the load transferred from the embankment.

1 INTRODUCTION

Northeast Thailand comprises an area of about 168,800 square kilometers or about one-third of the total area of the country. Some soils in Northeast Thailand pose problems to engineering works on or with these soils because they are easily erodible, collapsible and dispersible. These soil types are silty sand, clayey sand, sandy silt, clayey silt, sandy clay and silty clay of the Quaternary age, with an overlying bedrock of sandstone and shale of Mesozoic age (Udomchoke, 1991).

Khon Kaen Province is located in Northeast Thailand. The loess deposits exist above the water table in abundance in Khon Kaen. The thickness normally ranges from a few to more than six meters. The soil characteristic is non-plastic red sandy silt or silty sand (ML or SM). Most of the soil particles are 0.005 to 0.042 millimeter in size. Soil grains have a smooth and sub-rounded surface. The microstructure is unconsolidated and loose to medium dense. The pore sizes are usually 200-500 micrometers although some can be as large as 1 millimeter. Small clay content is presented in the form of clay bridge bonds (Phien-wej et al., 1992). Under the 90 percent standard Proctor test condition, it is classified as slightly to moderately dispersive, ND3 (Gasaluck et al., 2000). Figure 1 shows the distribution of loess in Northeast Thailand.

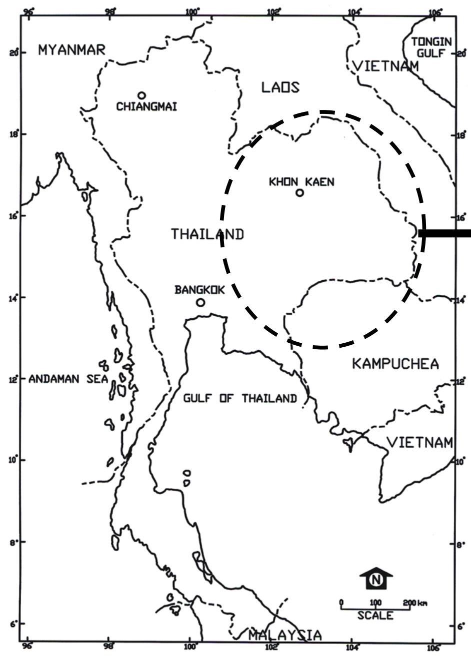

Figure 1. Distribution of loess in Northeast Thailand

Loess usually has a high shearing resistance when natural moisture content is low. However, upon wetting, the clay bond tends to soften and cause collapse of the loess structure and loss of shearing strength (Cleveger 1956). Some researchers reported a soil internal friction angle decrease in accordance with a soil moisture content increase (Horn & Deere, Lee et al. 1967). Especially, Khon Kaen loess internal friction angle was found to be strongly affected by water (Gasaluck & Mobkhuntod 1999). This results in loss of slope stability and then, most of the civil engineers in Thailand hesitate to use loess as construction materials. Some earth structures were costly because soils were transported from borrow pits far from the construction sites. If Khon Kaen loess is used for the proposed fill, its stability behavior effected by the increase of water content should be studied. The instability of soaked loess embankment was expected because the natural loess has already proved to have the poor stability when it is soaked (Gasaluck et al. 2001). Since Haeri et al (2000) reported that reinforced sand has better engineering properties, loess could be stabilized in the same manner, therefore the stabilization by means of geosynthetics should be under consideration as well.

2 OBJECTIVES

The research presented in this paper is to find out the real behavior of compacted loess embankment after soaking. The stability of reinforced loess embankment was also studied. Two types of geosynthetic were used in a Khon Kaen loess embankment with vertical slope under a surcharge strip load and soaking situation. The main tests done in this research were large scale load tests.

3 TEST PROGRAM

3.1 *Laboratory tests*

A lot of basic tests were carried out for obtaining engineering properties of soils such as specific gravity, grain size distribution and Atterberg's limits. Many 90 % standard Proctor soil samples were prepared, water was added and then direct shear tests were done. This was to find the internal friction angle and cohesion of compacted loess with various moisture contents.

3.2 *Field tests*

Loess was used as construction material of the embankment with the dimensions as shown in Figure 2. Field instrumentation details were shown as well. The embankment was placed in roughly 30-cm layers; each layer was placed at about 90% standard Proctor test. Sandbags and plastic plates were placed at the embankment edge, they worked as a reservoir dike and water was added on the top of embankment. The test was stopped when the inclinometer informed a rather rapid horizontal movement.

The second loess embankment had the dimensions as shown in Figure 3. The compaction specification is the same as the first one. The geosynthetics named Geogrid and Geojute were used for slope stabilization. Geogrids are composed of high modulus polyester fibers encased in a protective coating. The fibers are laid to form a grid in a flat orientation that enables maximum load carrying efficiency. The sheet-shape Geojute that is composed of geosynthetic and jute is denser than Geogrid. It is an open-mesh, woven geotextile consisting of alternately interwoven polypropylene yarns and jute yarns to form a continuous mat-liked sheet. While the polypropylene yarns offer the required retention strength, the jute gives the overgrowth potential.

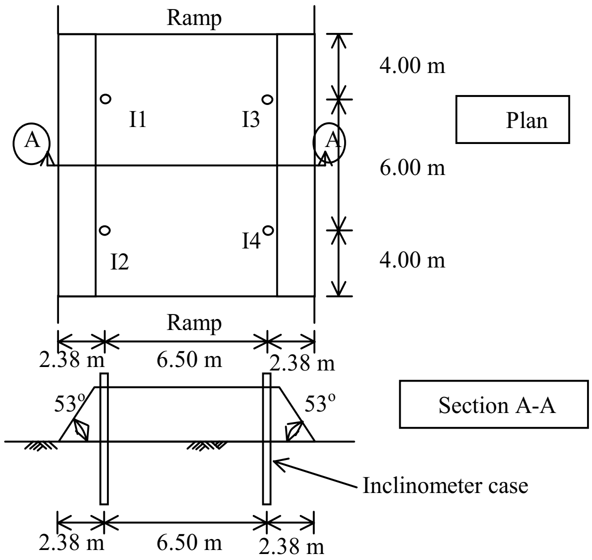

Figure 2. Plain loess embankment model (not to scale).

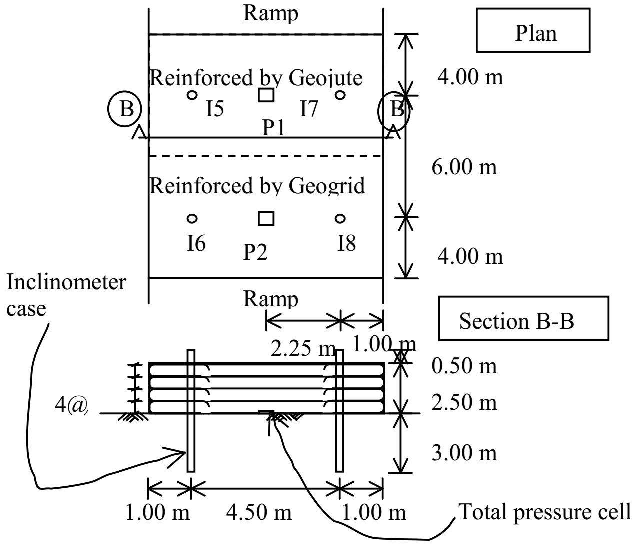

Figure 3. Reinforced loess embankment model (not to scale).

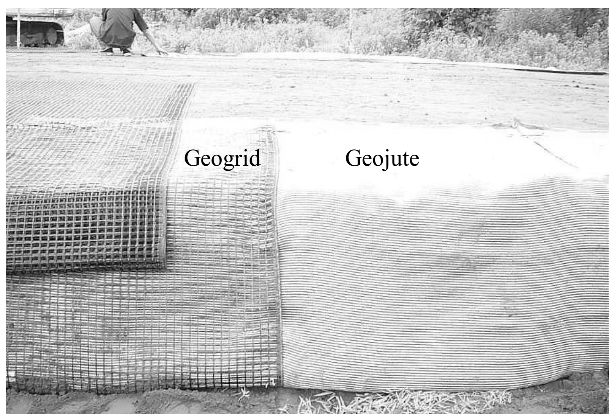

Figure 4. The 2 types of geosynthetics used for stabilization of loess stability.

Figure 4 shows the difference between Geogrid and Geojute. Embankment behavior was observed under a wet situation with the help of heavy rain. After its moisture content decreased, concrete piles were placed as a 2-m-width strip load at the middle along the centerline of embankment and then water was added at the top. The surcharge load was about 21 kPa.

3.3 *Slope analysis*

KUslope, the computer program based on the Bishop method was employed for slope analysis. This program has been developed for the analysis of both plain and reinforced earth structures. The soil parameters obtained from laboratory tests were used and the output was compared to the large scale test results.

4 RESULTS AND DISCUSSIONS

4.1 *Plain loess embankment*

After construction, embankment had an average moisture content of 6 %. The 33° ϕ and 10 kPa c of loess gave a factor of safety of 2.5. The water added at the top of the embankment took about 1 day in order to seep to the bottom, which was observed by means of piezometers. Figure 5 shows that on the first day after soaking, only the upper part horizontally moved. The lower part started moving after the added water arrived and then, tension cracks were found as shown in Figure 6. The average soil moisture content was about 12 % and it had 30° ϕ and 0 kPa c, therefore, the safety factor became 0.92. The embankment reached failure state without any surcharge load.

Even if loess embankment stability became very poor in wet situation, it took many days before failure occured. Therefore, loess may be used as a construction material for fill work if there is a good drainage system.

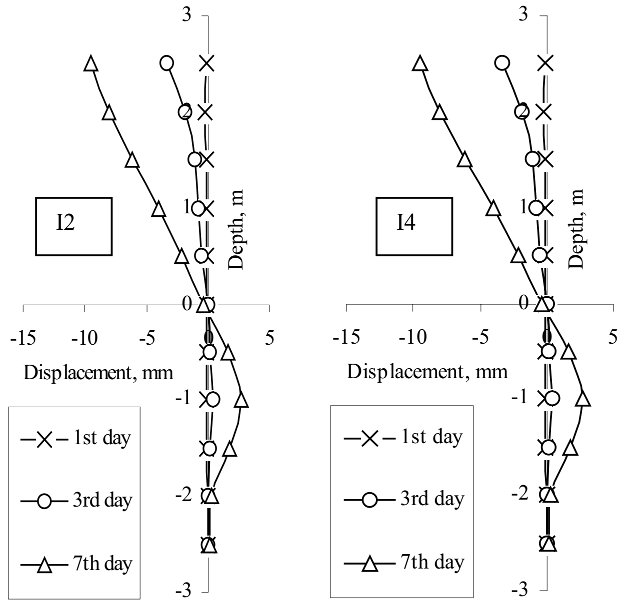

Figure 5. Horizontal displacement of embankment at inclinometers I2 and I4.

4.2 *Reinforced loess embankment*

Since both the embankment parts reinforced by Geogrid and Geojute gave similar results, only the results taken from the Geogrid side are presented herein. The test cycle was different from the plain loess embankment due to the weather. The important evens are as follows:

- The 1st day was the day after construction.

Figure 6. A tension crack was found after soaking.

- During the 8th to 16th days, there was heavy rain almost every day and piezometers recorded the increase in moisture content of the whole loess. The moisture contents were checked from the samples collected by hand auger as well.
- During the 17th to 38th days, there was no rain and the embankment became dry.
- On the 39th day, a 2-meter width strip load of 21 kPa was applied to the embankment and the movement was observed until the 50th day.
- The embankment was soaked again on the 51st day.

Figure 7 shows that the horizontal movements confirm the good stability of the embankment even if it was in the severer situation compared to the plain loess embankment. After about 1 week of heavy rain, the horizontal displacement was lower than 3 mm. On the 50th day, 11 days after 21 kPa strip load was applied, the displacement was still very small but the inclinometer I6 significantly showed the movement of ground soil. Note that the ground soil was the loess without any stabilization.

After the second soaking for 1 week, on the 57th day, the embankment moved back horizontally while the ground soil moved forward. It seemed that if more loads were applied or there was a high water table, failure might occur on the ground.

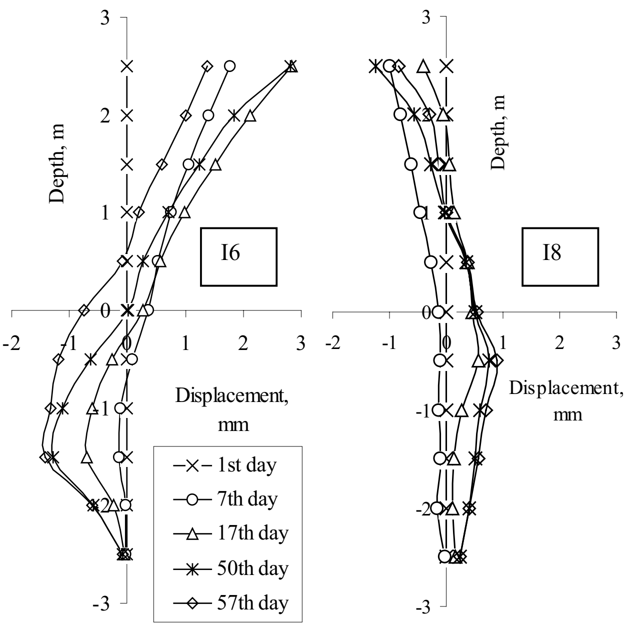

Figure 7. Horizontal displacement of embankment at inclinometers I6 and I8.

With the use of the same parameter values as the plain loess embankment, the safety factors were 2.8 and 2.0 for dry and wet embankment without loading respectively. The factors decreased to be 2.6 and 1.9 if the strip load was applied on the embankment.

The following items should be noticed.

- Even if the reinforced loess embankment has very good stability the bearing capacity of the ground soil should be carefully considered.
- Loess is easily erodible as shown in Figure 8. It happened because water flowed under the sandbags. A reinforced loess embankment must have a good erosion protection system.
- Total pressure cells suggested that at the bottom of embankment, the pressure increased by about 7 kPa (Simons & Menzies 2000) due to the 21 kPa strip surcharge load applied at the top. Based on the pressure bulb assumption, plain soil was expected to have about 11 kPa pressure increase. It could be concluded that reinforced loess has good behavior in stress distribution. Note that the denser geosynthetics, Geojute, showed a slightly better stress distribution behavior.

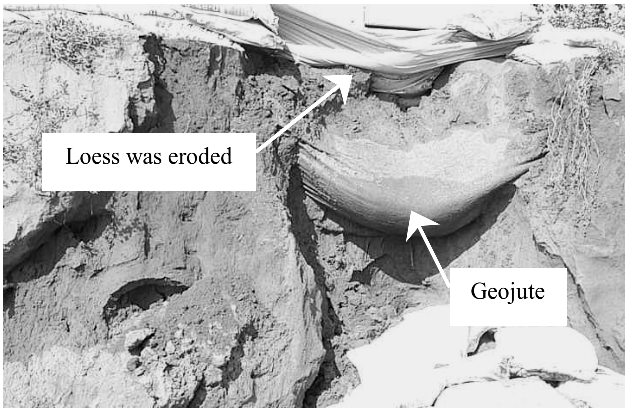

Figure 8. Water seeped through the gap between embankment and sandbags, then loess was eroded till sandbags fail to the ground.

5 CONCLUSION

Plain loess could be used as embankment material but a good drainage system is virtually necessary because it can reach failure even though there isn't any surcharge load but its moisture content increases.

The loess reinforced by geosynthetics makes the embankment with vertical side slope very stable under a surcharge load and high moisture content situation. Reinforced loess can be used as construction material for earth structures carrying heavy loads such as highways and airports. Erosion and ground soil bearing capacity are suggested for concern because they may be the causes of failure.

6 ACKNOWLEDGEMENT

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