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A case study of reinforced slope in Thailand: Lumpang - Lamphun highway

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ABSTRACT: The reinforced structure has been used since 1970. It is prevailing among foreign countries because of its advantage that are less time consuming and reducing costs of construction. This structure is known to be flexible. It can tolerate both horizontal and vertical movement. Besides, it also appropriately increases splendor of the external structure to be blended with the environment. However, this type of construction is still a new technology in many countries therefore an accurate analysis will be beneficial to engineering field. In this research, the analysis of using the finite element to study and develop the relationship of the time dependent behavior by concentrating on the creep and the stress relaxation of the reinforcing materials. Lumpang – Lamphun national highway is chosen as a sample in the study. The outcome is very likely to be a model for a standard design and an improvement of the earth reinforcement analysis. The new design of the earth reinforcement will be more appropriate with local material and environment. It is designed by emphasizing on engineering concern of internal and external stability, which ultimately turns out to be cost effective design.

1 INTRODUCTION

Road is the heart of transportation. There is a record shown that more than 80% of road usage is for people traveling. And over 90% is for products transportation. It means that road improvement is extremely essential for economic and social development of our country, which is a developing country. Although, government has spent over ten billions baht on road construction and renovation each year, there are still many of them face the economic and engineering problem in road expanding construction for example ones in the mountain areas in Northern and Southern parts of Thailand. The construction in the area needs to be cut section and fill section. In order to maintain stable slope or prevent landslide from hillside slope, (see Fig. 1) fixing an appropriate rate of the cut slope and the fill slope is very important. It sometimes not only increases the sectioning and filling tasks, but also the toe slope of the roadside may be over the right of way. Particularly, environment is playing an important role at the moment. If there are any routes pass the national reserved forest area or the water source forest, a proper plan and design is needed preserve the geographical surrounding. Therefore, the way to solve these problems is to limit the road construction area not to be over the R.O.W. or using the least construction area as much as possible. It means that the side slope must be the steepest rate as possible. As a result, the reinforcing materials are selected to increase the slope stability for the steeped slope.

Figure 1. Type of side slope failure at Doi-Tung, Chiang Rai Province, Thailand.

The highway route no. 11, Lamphun – Lumpang STA. 30+000 – 40+100 KM., had applied the mentioned technique. The construction area was in the national forest land and the water Zone A which its natural aspect must be preserved so advance technique was applied to reduce the construction area. The engineer who designed the route's specification had created this part of the road to disturb the natural aspect as less as possible. This part's structure designing was more special than the other parts because the side slope of the route was very high due to many layers of reinforcing materials. A special drainage system was created to prevent a collapsing of the side slope. Besides, the road was also installed with many geological technique instrumentations such as settlement plate, inclinometer, piezometer etc. to examine its behavior after officially opening to the traffic.

2 THE IDEA OF THE EARTH REINFORCEMENT STRUCTURE

Soil is one of constructional materials, which are plentiful and its quality is like concrete in the way of having high stress but low strain. In order to correct this weakness, it is necessary to add other materials into the soil's layer so it will be like concrete with steel reinforcement. There has been the idea of using the reinforcing materials for over three thousand years. Including, Babilonian utilized this technique in constructing Ziggurats. Chinese used bamboos and plastic tubes as the reinforcing materials in building the Great Wall. Besides, Dutch has also applied the technique in irrigating canal construction for more than seven hundred years. All of these constructions can still be found elegantly standing in the place until present time. These can prove that using reinforcing materials is practically working in constructions. There always had been the new inventions on the earth reinforced structure. Until 1997, Holtz and FHWA had compiled and developed the new way of reinforcement, which were classified into groups according to their functions. Both of Holtz's and FHWA's ideas emphasized on the limit equilibrium. Supposing, if the level of collapse had a safety factor at 1.0, which mean the structure was still able to remain the same but it could collapse at anytime. Whenever the safety factor was less than 1.0: 0.999 or even 0.99999, the structure would lose stability and then would suddenly collapse. Dechasakulsom (2001) reported a study on the relationship between the creep and the stress relaxation of the reinforcing materials in 2001. He found that the relationship between those two things were the Polymeric materials' general characteristics, which lowered the reduction factor rate when calculating the safety force of the reinforcing materials as shown in the following equation (1).

$$T_{all} = \frac{T_{ult}}{\text{Reduction factor (Creep} \times \text{degradation} \times \text{installation)}} \quad (1)$$

When
T_{all} = An allowable tensile strength of the reinforcing materials
T_{ult} = An ultimate tensile strength of the reinforcing materials
Reduction factor by creep = 1.8 – 2.4 depends on kinds of polymer in used
Reduction factor by degradation = 1.1
Reduction factor by installation = 1.1

The result was that the reduction factor by creep is the highest, which will affect the overall safety factor of the reinforcing materials. Unlike, a typical design that was done by using too much material or over conservative, considering the relationship of those two behaviors in design could effectively make the better structure because the safety factor of the reinforcing materials would be higher than the one with no considering the relationship between the creep and the stress relaxation.

3 CREEP AND STRESS RELAXATION

The creep is a material's behavior which its strain will be increasing under the constant applied load. This phenomenon can be called time-dependent. In the laboratory, the sample's weight will determine the force level in the creep testing with measured elongation. In contrary, stress relaxation is a material's behavior which its rate of strain will be constant under the decreasing of load. There have been many attempts to do the stress relaxation of geosynthetics. The testing uses the controlling force up to the desired level and then maintains the rate of strain. During this period, the stress will be changed into the performed direction, or rendering with time.

4 THE TIME DEPENDENT MODELS FOR GEOSYNTHETICS

Dechasakulsom (2001) has proposed model used to capture the behavior of creep and stress relaxation response in the following;

$$T = C_1 \varepsilon^{C_2} \frac{1}{1 + \alpha t^{\beta}} \quad (2)$$

When T is the tensile force of the geogrids per a unit width. α and β are the model's parameter, $0.10 \leq \beta \leq 0.20$ and α, C_1 and C_2 are material parameters. And t is the time that passed by. From the above equation, T will be decreased by time. From the observation, if the strain ε is in stable state, the aspect is as same as the imitation of the relaxation testing. The reversion of the equation (2) would be as stated below.

$$\varepsilon = \left[\frac{T}{C_1} (1 + \alpha t^{\beta}) \right]^{\frac{1}{C_2}} \quad (3)$$

5 THE FINITE ELEMENT PROGRAM

The models' designing that are explained by using the equation (3) will then be gathered and put on to a computer program called APES (Analysis Program for Earth Structures) (Kaliakin, 2000). The APES program was written by using a computer language called Fortran 90. It has the ability to analyze in 2 and 3 dimensions. In the 2 dimensions analysis, the internal and external limits can be corrected to be more complete by setting the conditions of the plane strain and the plane stress to be able to analyze the saturated filling soil. The unnecessary factors in calculation are all avoided putting into the program and this makes the analysis shorter.

6 THE PROJECT HISTORY

The Highway Project no. 11 - Lumpang – Chiang Mai route is the main highway that starts at the highway no. 1 intersection (Muang, Lumpang) and ends at the highway no. 1004 intersection (Muang, Chiang Mai). It is about 99.650 kilometers long. The construction, which is a P1 (7/12) standard highway, had begun in 1966 and finished in 1969. It has 7.0 meter carriageway wide with 2.5 meter shoulder on each side. Since the number of vehicles has been increasing, approximately 20,000 vehicles per day that causes the inconvenience and safety problems. Therefore, The Department of Highways ordered that the route should be reconstructed to reach the special standard - The Divided Highway, which is needed to have at least four lanes. The four lanes were divided the directions by utilizing of the Concrete Barrier Type II. The construction in the area needs to pass through the national reserved and the water source forest which its natural aspects must be preserved so advance technique was developed and applied in the construction as shown in Fig. 2. The examples of the technique that were using were the soil reinforcing in the earth filling task.

Figure 2. The picture of reinforced slope Lamphun – Lumpang highway with its height over fourteen meters.

7 THE FINITE ELEMENT MODELS

The finite element regulations that are used in the APES program have been applied in this analysis. Other materials then are adding between the soil and the geosynthetics layers. However, building the soil and the geosynthetics layers model needs to consider the soil interface. The soil needs to be separated by using rectangular shape with four connection points. The geosynthetics also are separated by using one with two connection points. Besides, the soil interface is separated as well by one with four connection points but its thickness is equal to zero. The roadside has a slope of 70 degree, the angle at which the roadside slopes in relation to the horizontal surface. It is unable to expand the road area as the second part of the Lamphun – Lumpang route is constructed through the national forest. However; it is necessary to add up to four lane road as shown in the Fig. 3 below.

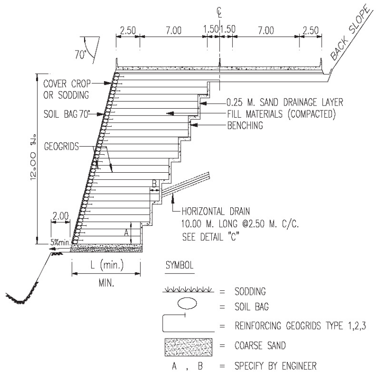

Figure 3. The cross-section model of the Lamphun – Lumpang route with its twelve meter height of reinforced slope.

In order to divide the mesh element, the cross-section model of the route with its twelve meters of the reinforced slope is needed. The height of soil has been divided into layers at which each one is 0.25 meters. There are 50 layers that are filled with the reinforcing materials as shown in the Fig. 4. The information for analysis will be input by following the materials type such as rock, sand, soil, the reinforcing materials and the roadside surface.

8 THE RESULT OF FINITE ELEMENT ANALYSIS

In our study, we have studied the displacement analysis in two dimension aspect and the reinforced roadside structure. The study period is at four years after opening traffic. From the study of the reinforced slope with twelve meter height of reinforced slope at four years after construction, the displacement analysis of the frontal area of reinforced slope and the top of roadside at four years after construction found that the most vertical and lateral displacement is equal to 0.0305 meters, respectively and the most displacement

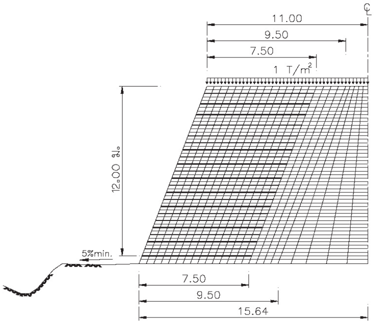

Figure 4. Showing the division of the mesh element that is used in the finite element analysis of the Lamphun – Lumpang route with its twelve meter height of slope.

in y axis is equal to 0.2267 meters. However; the displacement in other rear parts and at the top of the reinforced roadside at twelve meter height of reinforced slope at four years after construction are put into graphs, which are shown in Fig. 5.

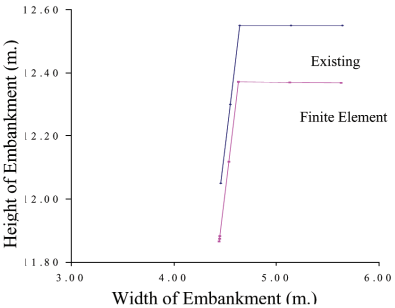

Figure 5. Showing the displacement in the different parts of the four year reinforced slope with twelve meter height of the filling soil.

Over all, the displacement in both horizontal and vertical are increased according to the height of the roadside. Besides, the more working period is, the more the displacement occurs. The most displacement rate will be occurred at the edge of shoulder. For the top part of the reinforced roadside, the most settlement area is also on the edge of shoulder, but the displacement will be decreasing at the point nearing the center of the road.

9 CONCLUSION

The displacement analysis of the reinforced slope shows that the amount of settlement will be depended on the height of embankment. The higher embankment, the bigger amount of the displacements is. The biggest amount of displacement in both of x-axis and y-axis would happen on the edge of shoulder, which is turned out to be a rehabilitated area or widened zone. There are small amount of displacements in x-axis due to the reinforcing materials while the displacement in the y-axis is higher because the quality of selected fills and compacting during the construction process. However, if considering the displacement on the top of the side slope from the center of the road to the edge of shoulder, it shows that the movement is hardly find at the center of the road but the displacement will be increasing where it is near the edge of side slope. Undoubtedly, the higher rate is at the edge of side slope.

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