Chapter 3

Data of the Normal Forces from the Model Tests and Data of the Landslides in Northern Thailand

3.1 Introduction

This chapter describes about the experiment of the slope model tests and the results of the normal forces acting on the slip surface. The normal force is one of the important factors which guide to a comparison of various slope stability analysis methods. In addition to, the data of some landslides (4 cases) in Northern Thailand are mentioned. However, all data in this chapter are taken to analyze by various slope stability analysis methods, which are described later in chapter 5.

3.2 Measuring the normal forces from the model tests

The difference of the assumption on each method makes the different values of the normal force and other factors (e.g. inter-slice force, shear force, weight) can be written in the term of the normal force. Thus, the normal force is one of the important factors in the way of analysis. As well as, the normal force can be measured easier than the inter-slice force by the experiment. So the value of the normal force can verify the accuracy of the various slope stability analysis methods.

The experiment was conducted by the author at Laboratory of Soil and Water Conservation, Department of Environmental Science & Technology, Faculty of Bioresources, Mie University, Japan under the supervision of Prof. S.Hayashi and Assoc. Prof. K.Kondo. The research topic is "Measuring the normal forces acting on the slip surface". The objective is measuring the normal forces acting on the failure surface to make the comparison with that by various slope stability analysis methods.

3.2.1 Slope models

A good slope model is a model which has similar condition to the real behavior of earth slope. Hence, the slope model is divided into 3 components. One is the base of model made of the plywood boards. The plywood boards are rigid which represent the high strength soil layer or the bedrock. Another is the slip surface made of the plywood boards cover with sand paper #400. These boards are separate from the model base to represent the failure surface of the slope. The slip plane of each slice is discrete and 4 load cell sensors are set under each board to measure the normal forces for each slice. The other is the sliding mass made of the straw filled with the river sand inside (hereafter called the sand straw). As side view of the slope, the straws filled with the sand have round shape represented the soil particles and made the slope moving. The components of slope model are illustrated in fig. 3.1.

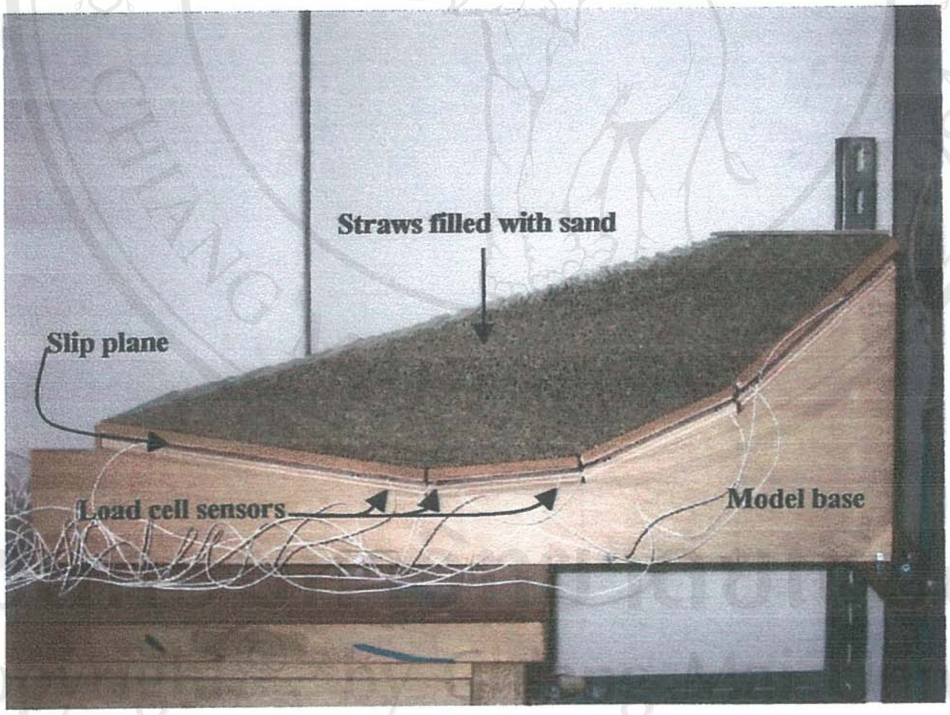


Fig. 3.1 The composition of the slope model

The properties of the straws filled with sand obtained form the experiment are;

The shear strength parameter of the straws filled with sand

$$\varnothing = 29.2^{\circ},\ c = 0.843\ gf/cm^2 = 0.008\ t/m^2 = 0.083\ kN/m^2,$$

The shear strength parameter between the sand paper and the sand straws

$$\varnothing = 28.1^{\circ},\ c = 0.249\ gf/cm^2 = 0.002\ t/m^2 = 0.024\ kN/m^2,$$

and the density of the straws filled with sand

$$\gamma = 1.147\ gf/cm^3 = 1.147\ t/m^3 = 11.24\ kN/m^3.$$

More details of materials, devices and how to obtain the properties are described in appendix A.

At the time of slope failure of real condition, the shear strength on the failure plane is usually smaller than the shear strength of the sliding mass which is in agreement with the properties of materials in the model tests.

It is understand that the cohesionless earth slope can be stable if the inclination angle of slope is smaller than the shear strength of soil. There are 3 slope models varied in the slope inclination angles; 15.0, 17.5 and 20.0 degrees (less than $\varnothing = 29.2^{\circ}$) in the experiment. The shapes of slope models are the optimized shapes, which is done by 4 straight line-shaped of the failure surface. The co-ordinate and the condition of each slope model are demonstrated in table A.1 and fig. A.4 (Appendix A).

3.2.2 Experimentation

After the devices are set up and the straws filled with sand are piled up to form to be a slope model, the forces acting on the sensors are measured by data scanner and data logger. The measured forces are that from the weight of the sand straws (i.e. sliding mass). The summation of loads by 4 sensors on same slice is the net normal forces acting on that slice. Then, the weights are loaded on the top of the slope. The normal forces are measured at every increasing load until the slope fails.

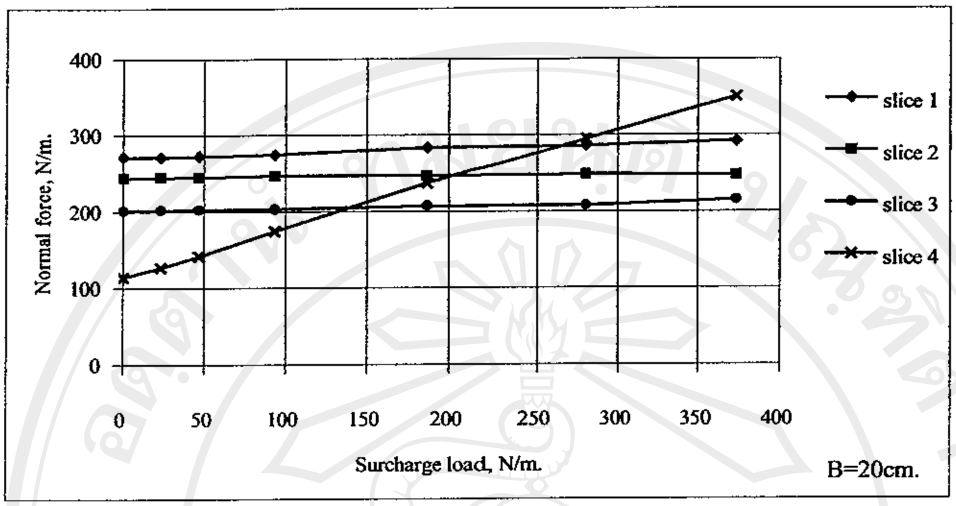
The experiments are done in 2 cases; slope without the anchoring force and slope with anchoring force. In the case of the anchoring slope, the anchoring forces are attached perpendicular to the slope before measuring the forces. The detailed procedures of the experiment are explained in appendix A.

3.2.3 The normal forces acting on the slip surface

The normal forces recorded by data scanner and data logger are shown in table A.3-A.5 (Appendix A). And fig. 3.2-3.4 show the relation graph of the normal forces and surcharge loads in each slice.

According to table A.3-A.5 and fig. 3.2-3.4, it is found that the normal forces acting on the slip surface of almost slice increase in both case (a) and case (b) when the surcharge loads at the top of the slope increase. Especially, the normal force of slice 4 increase in the highest rate because the surcharge loads are almost transferred to slice 4 directly. Although the normal forces acting on slice 1, 2 and 3 rarely increase in the similar rate when gaining the surcharge load, there is an obvious point from the graphs. The increasing rate of the normal forces acting on the slice 3 is higher than slice 2 and slice 1 respectively. The bearing loads effect on the nearer slice than the farther one. Furthermore, the results of the anchoring forces of 3 models do not changed and almost equaled to the first condition of the models (see in fig. A.4; model 1 = 294 N/m, model 2 = 235.2 N/m, model 3 = 196 N/m). The results of the normal forces of slice 3 in case (b) are higher than case, because the anchoring force is directly effect on this slice.

Case (a) : slope without the anchoring force



Case (b) : slope with the anchoring force

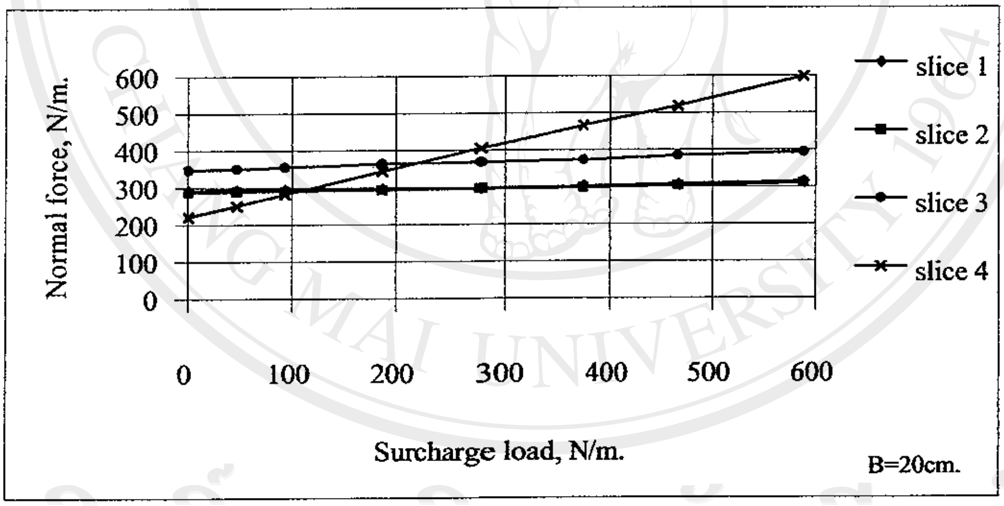
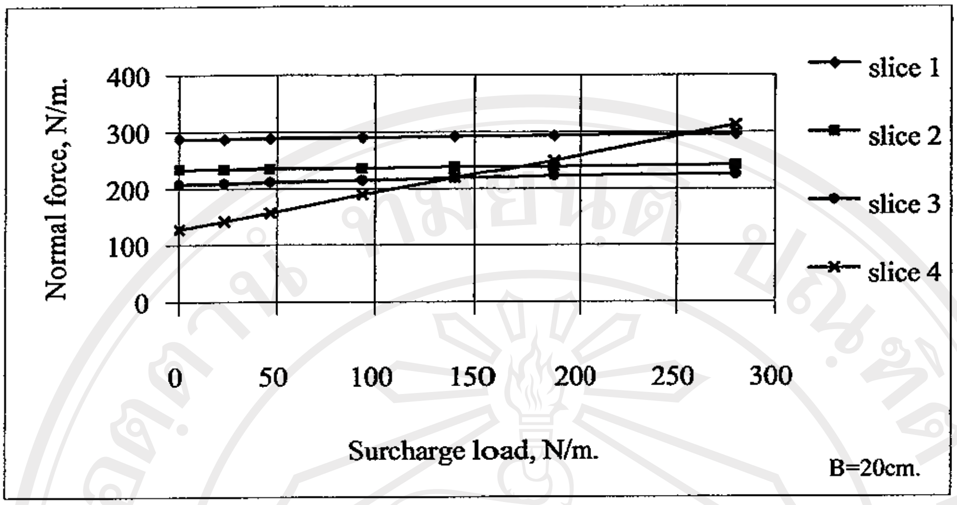


Fig. 3.2 Graph of the normal forces in each slice of the slope model 1 (β=15.0 degrees)

Case (a) : slope without the anchoring force



Case (b) : slope with the anchoring force

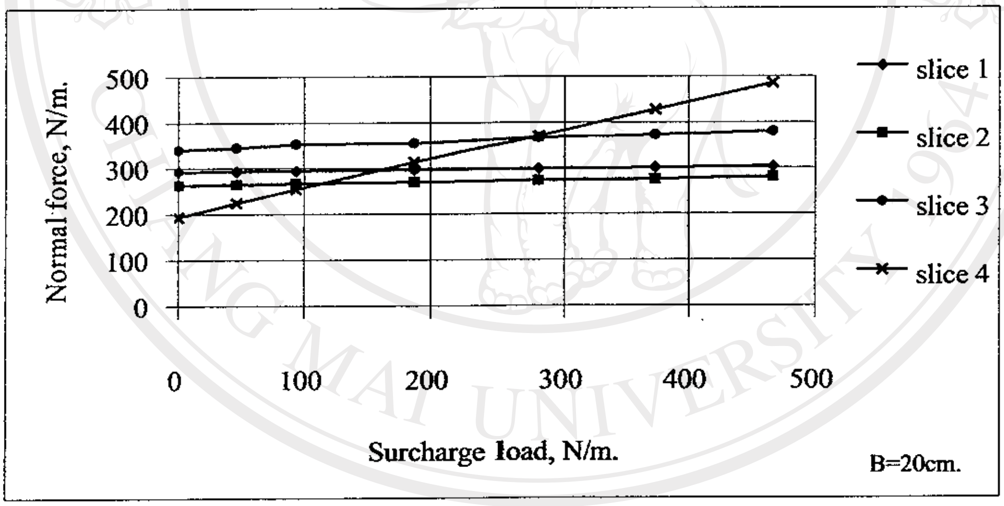
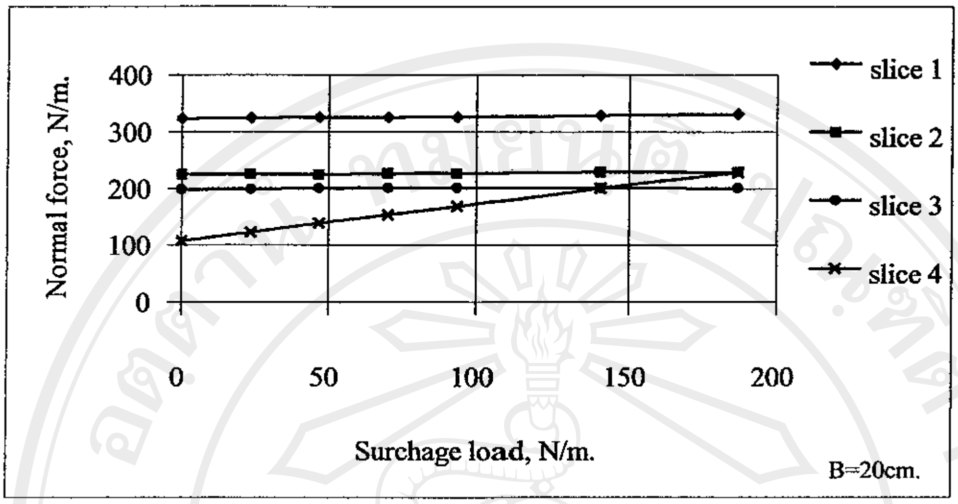


Fig. 3.3 Graph of the normal forces in each slice of the slope model 2 (β=17.5 degrees)

Case (a) : slope without the anchoring force



Case (b) : slope with the anchoring force

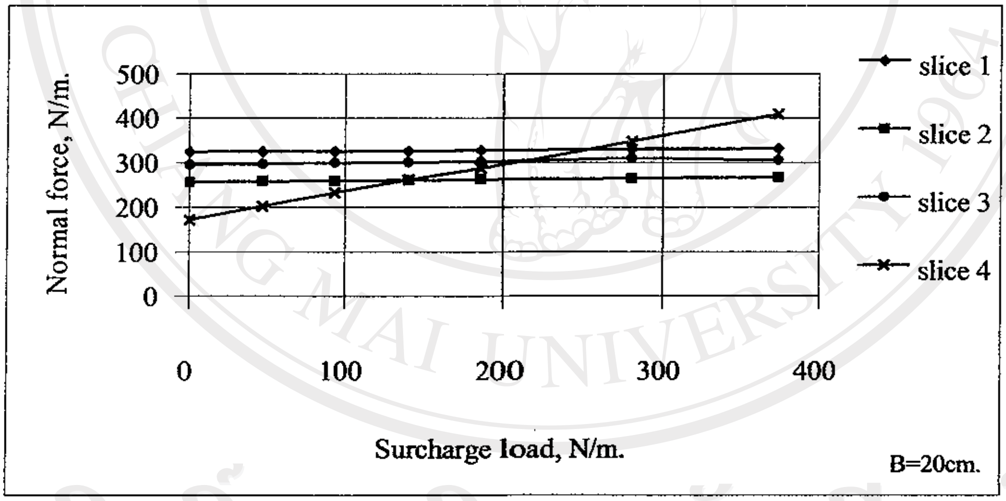


Fig. 3.4 Graph of the normal forces in each slice of the slope model 3 (β=20.0 degrees)

3.3 Landslides in Northern Thailand

From the previously report and site visits by Yamsai and Mairiang (2000), more than half of all landslides in Thailand are occurred in Northern Thailand according to fig 2.22. Almost occurred landslides are in the north and the west region (Chiangrai, Chiangmai and Mae Hong Son province), and some are in the central region (Lampang and Phrae province). The geological formation of landslides in Northern Thailand is mostly residual soil and the weathered rock of granite and quartzite which are in agreement with the distribution area of the decomposed granite in Northern Thailand as shown in fig 2.21 (Ruenkrairergsa, 1978).

The slope failures in Northern Thailand are mostly caused by slope cutting to make the route in the mountain area, natural slope, slope filling and earth dam respectively. The main cause of slope failures in this area is the slope cutting through the granite mountain areas or the low strength of soil areas during the heavy and long duration rainfall. The opening granite still has high strength during the construction. But as the time is gone, the granite is rapidly weathered. The residual soil of the weathered granite has low plasticity and low strength. Then, the slope failure is occurred in the later time.

The problem areas in Northern Thailand; usually occurred slope failure areas; are Doi Tung and Doi Mae Salong in Chiangrai province, Doi Angkhaang and Doi Suthep in Chiangmai province, Public highway no. 1 (Lampang), 108, 109, 1004, 1089, 1093, 1095, 1096, 1097, 1149, 1249, 1268 and earth dam and etc.

Types of the soil movement in Northern Thailand are almost slides and some are flow and fall. In the study, since the slope failure arising from the erosion of water is hardly to analyze, the slides are merely considered in the study. According to the types of mass movements classified by Skempton and Hutchison (1969) in fig 2.1, more than half of landslides in Northern Thailand are in shallow seated rotational slides group (Yamsai and Mairaing, 2000). In the other hand, they are earth slumps and earth slides by Varnes classification system as shown in table 2.6 (Mairaing, 2000). And the failure mode is slope failure type.

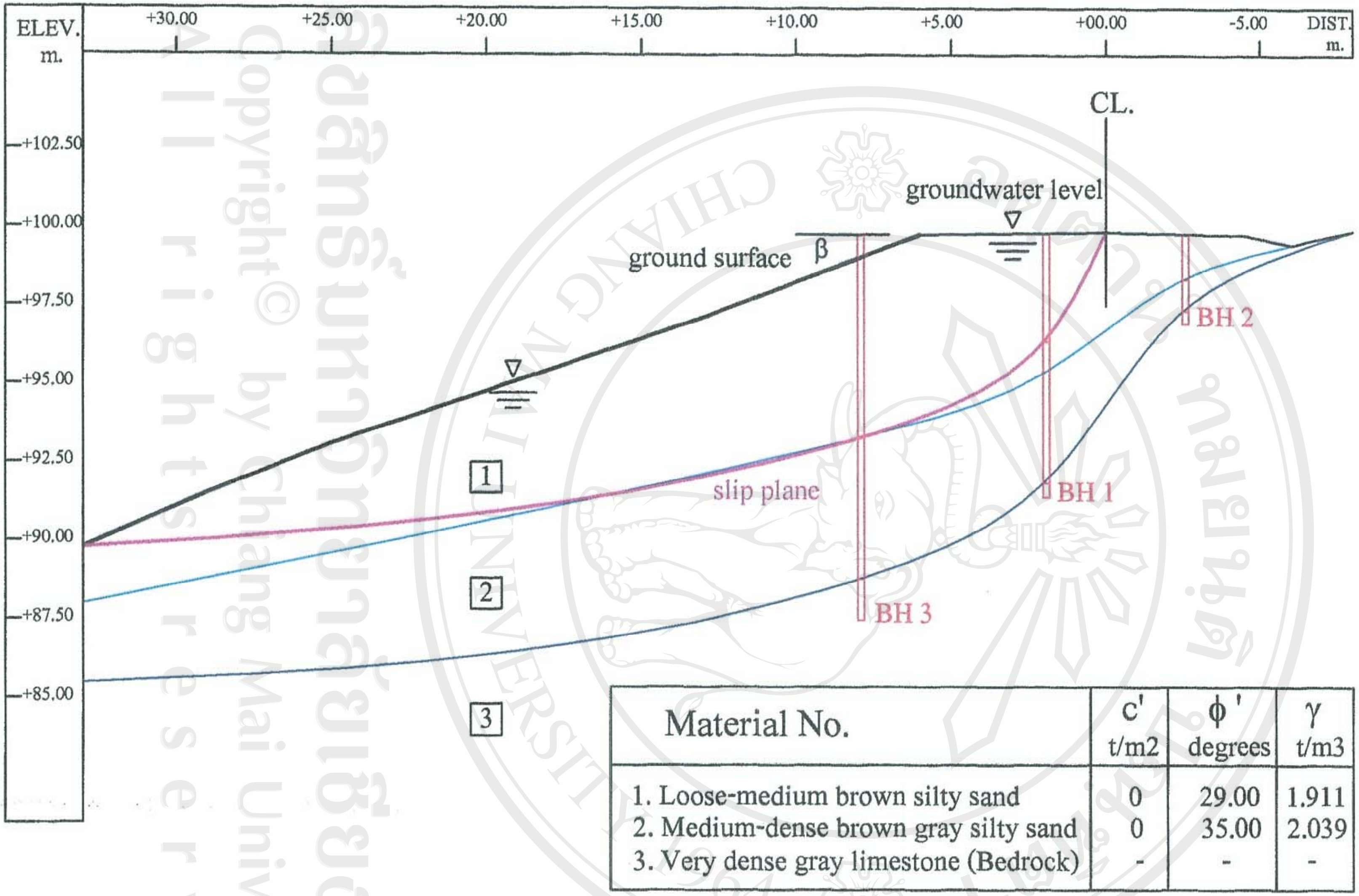
There are 4 landslide cases, which are the representative slope failure cases in Northern Thailand, are studied in the research.

3.3.1 Public highway no. 1093, section Km. 29+000 – Patang village, Chiang Rai

Public highway no. 1093, section Km. 29+000 – Patang village, is under a supervision of Payao2 public highway division, Bureau of 2nd public highway (Phrae), Public highways department, Ministry of Transport. The route is started to construct in 1993 and had 6 meters width. The severe vicinity is between Km 35+380 and Km 35+440 on the left way. The slope movement took place continuously every year after the construction finished in 1993. The failure happened deep inside to the centre of the traffic lane. The route is under damaged 20 meters long. The primary cause of the soil movement is the groundwater from the back slope on the right way flew through under the road. The accumulative groundwater flew under the road along the connection line between the subbase and the bedrock. Under the condition, the pore water pressure in the soil was higher until the critic and, then, the slope failure occurred.

The geological formation is residual soil and weathered rock of limestone. The soil profile has 3 main layers; Loose-medium brown silty sand, Medium-dense brown gray silty sand and very dense gray limestone (bedrock). The example of boring logs, profile of the route, the sketch of the slope failure and picture are demonstrated in fig. B.1-B.5 (Appendix B).

The typical cross-section of the public highway no.1093at Km 35+400 which is the center of the failure slope is shown in fig. 3.5. In addition to, the soil profile and the actual slip plane are illustrated.



Material No.	c' t/m2	φ ' degrees	γ t/m3
1. Loose-medium brown silty sand	0	29.00	1.911
2. Medium-dense brown gray silty sand	0	35.00	2.039
3. Very dense gray limestone (Bedrock)	-	-	-

Fig. 3.5 Cross-section of public highway no.1093 at Km 35+400, Chiang Rai (Source : Bureau of Highway R&D, Department of Public Highways)

3.3.2 Mae Laeng Luang Dam, Chiang Mai

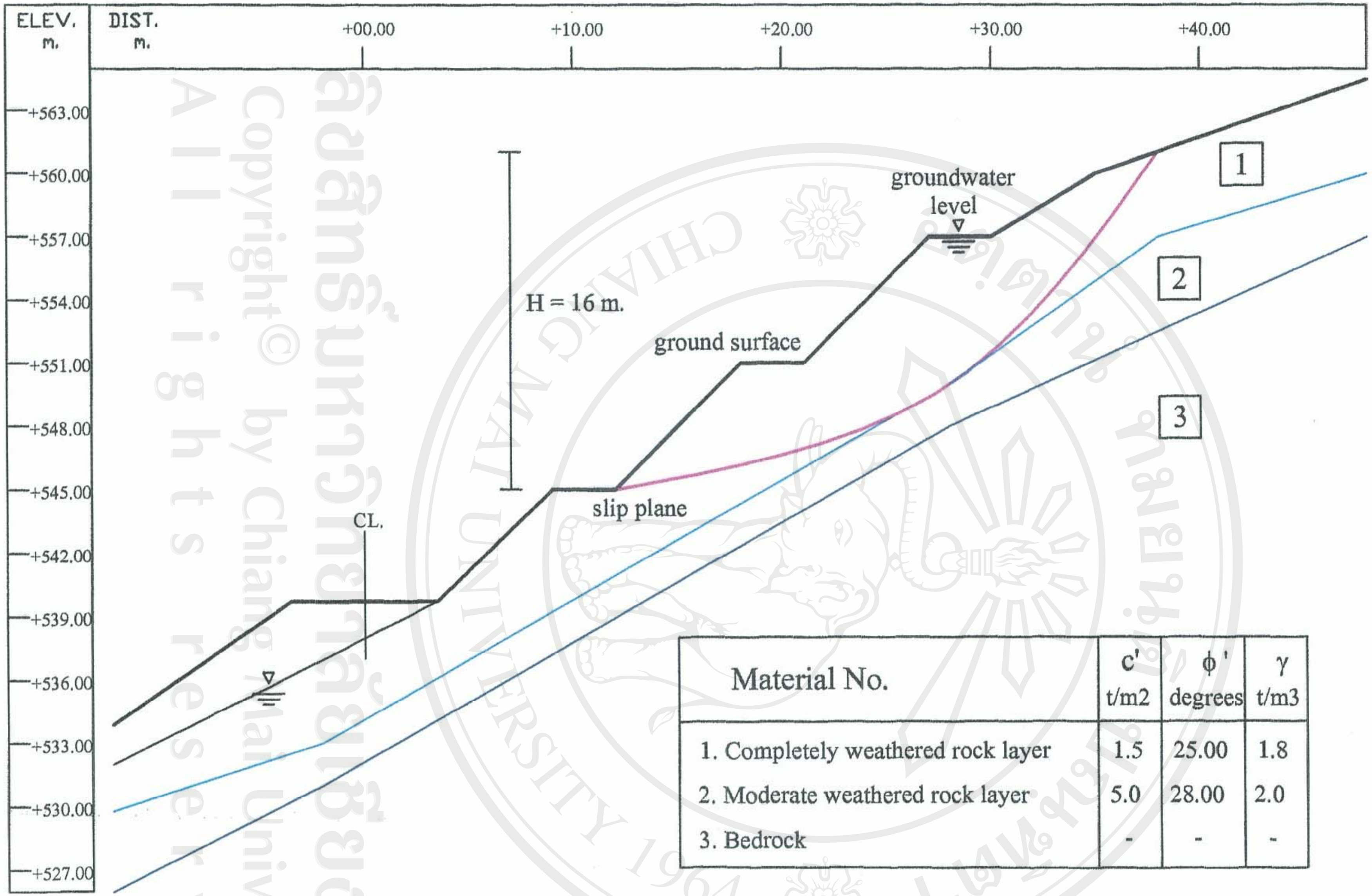
Mae Laeng Luang Dam is rather big, small type earth dam in the project of the agricultural product distribution in Northern Thailand. The geological formation is residual soil and weathered rock of granite and basalt. The slope failure occurred during the construction in the period of cutting the slope upon the spillway on the left embankment. The cause is cutting the slope through the low strength soil area and the effect of the heavy rainfall. Then, the slope failure occurred.

The type of failure is shallow seated rotational slide and the position of failure surface is slope failure surface. The cross-section of failure slope is demonstrated in fig. 3.6. From the failure, the budget of the construction was lost to improve the slope. The improvement method is rock berm and hand dug pile. The re-improvement finished in 1994.

3.3.3 Mountain slope in Bhuping Palace, Chiang Mai

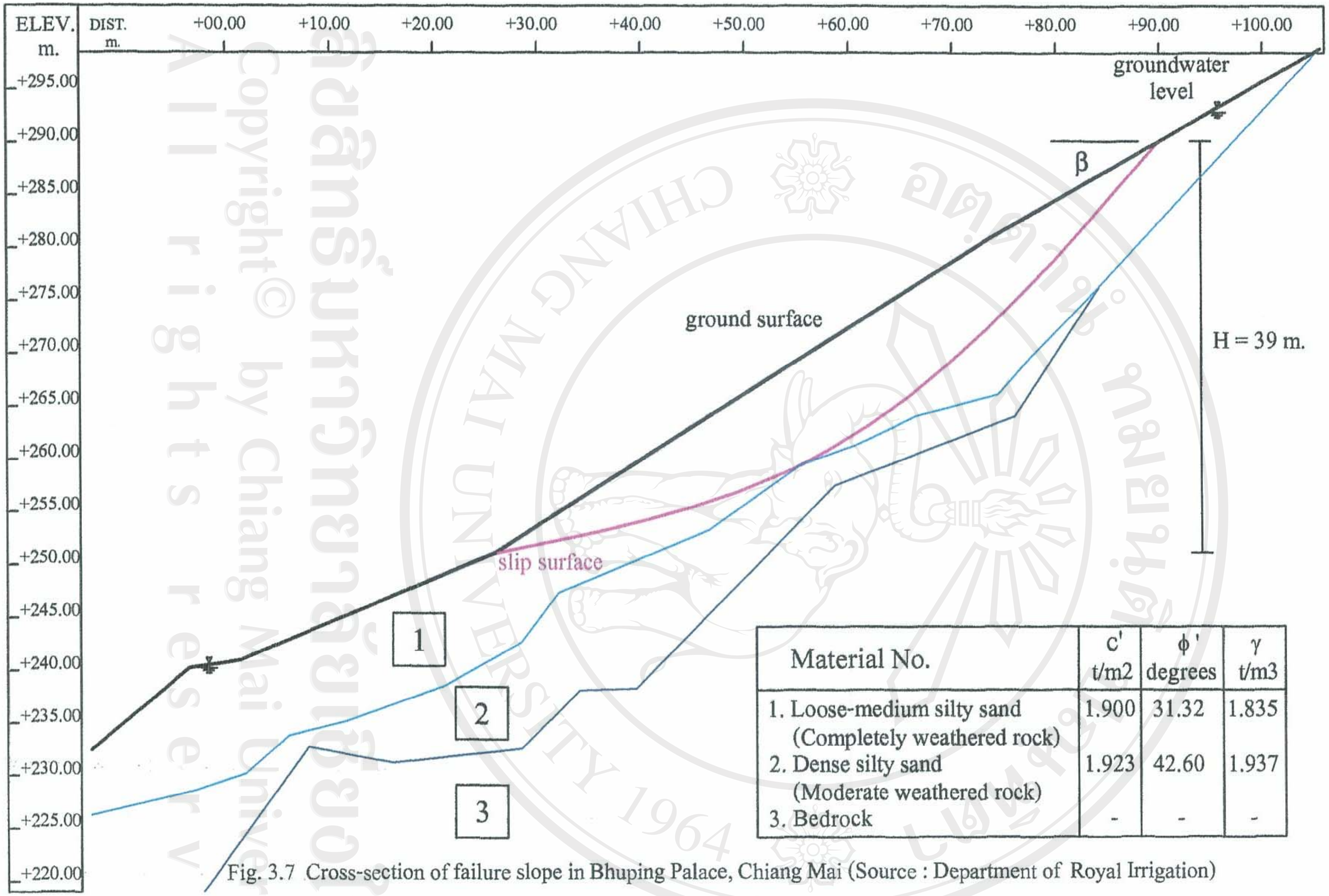
A failure spot is in the area of the mountain slope behind the small reservoir of Bhuping Palace which can enter by taking on the public highway no.1094 and passing Chiang Mai University and Wat Prathat Doi Suthep to the Bhuping Palace. It is far apart from the front gate about 350 meteres. The location and the coordinate of the failure spot are demonstrated in fig. B.7 (Appendix B).

The mountain slope failed because of the water drainage of 15,000 m^3 reservoir flow through the residual soil and weathered rock slope. The geological formation is the residual soil and weathered rock of granite which can classify in SM-SC group (USCS). Type of failure is shallow seated rotational slide. The failure slope has approximately 50 meters wide. But, at the lower slope, there is another drainage channel which made the failure shape bigger and inexactly shape. The plan and the profile of slope are shown in fig. B.8 (Appendix B). Line A-A' is the center line of the failure slope. The cross-section of the failure slope is illustrated in fig. 3.7.



Material No.	c' t/m2	φ ' degrees	γ t/m3
1. Completely weathered rock layer	1.5	25.00	1.8
2. Moderate weathered rock layer	5.0	28.00	2.0
3. Bedrock	-	-	-

Fig 3.6 Cross-section of failure slope on the left embankment of Mae Laeng Luang Dam, Chiang Mai (applied from Mairaing, 2000)



Material No.	c' t/m2	φ' degrees	γ t/m3
1. Loose-medium silty sand (Completely weathered rock)	1.900	31.32	1.835
2. Dense silty sand (Moderate weathered rock)	1.923	42.60	1.937
3. Bedrock	-	-	-

Fig. 3.7 Cross-section of failure slope in Bhuping Palace, Chiang Mai (Source : Department of Royal Irrigation)

3.3.4 Mae Moh Mine, Lampang

Mae Moh Mine is an open-pit of lignite for the materials to make an electric power. The geological formation is the residual soil and weathered rock of yellowish green claystone in the upper soil layer, and the lignite is in the next layer. The final layer of lignite is about 200 meters deep under the ground ("d" in fig. 3.8) with a perimeter of approximately 12 km. Although the efficiency slope stability checking is utilized in Mae Mo Mine, there is the happening of many slope failures. Almost failure slopes are taken place from the mountain slope cutting through the low strength soil area and the fault plane in the upper soil layer. The height of slope is about 15-40 meters and the slope inclination angle is about 20-35 degrees. The types of encountered slope failures are the planar slides along the fault plane and the shallow seated rotational slides. Fig. 3.8 shows the example of failure slope, which has shallow seated rotational slide failure type. The position of failure slope is at the toe of the failure slope. The slope has 13 meters high (H) and 22 degrees of inclination angle (β) according to fig 3.8. The profile plan of the failure slope is illustrated in fig. B.7, section B-B' (Appendix B).

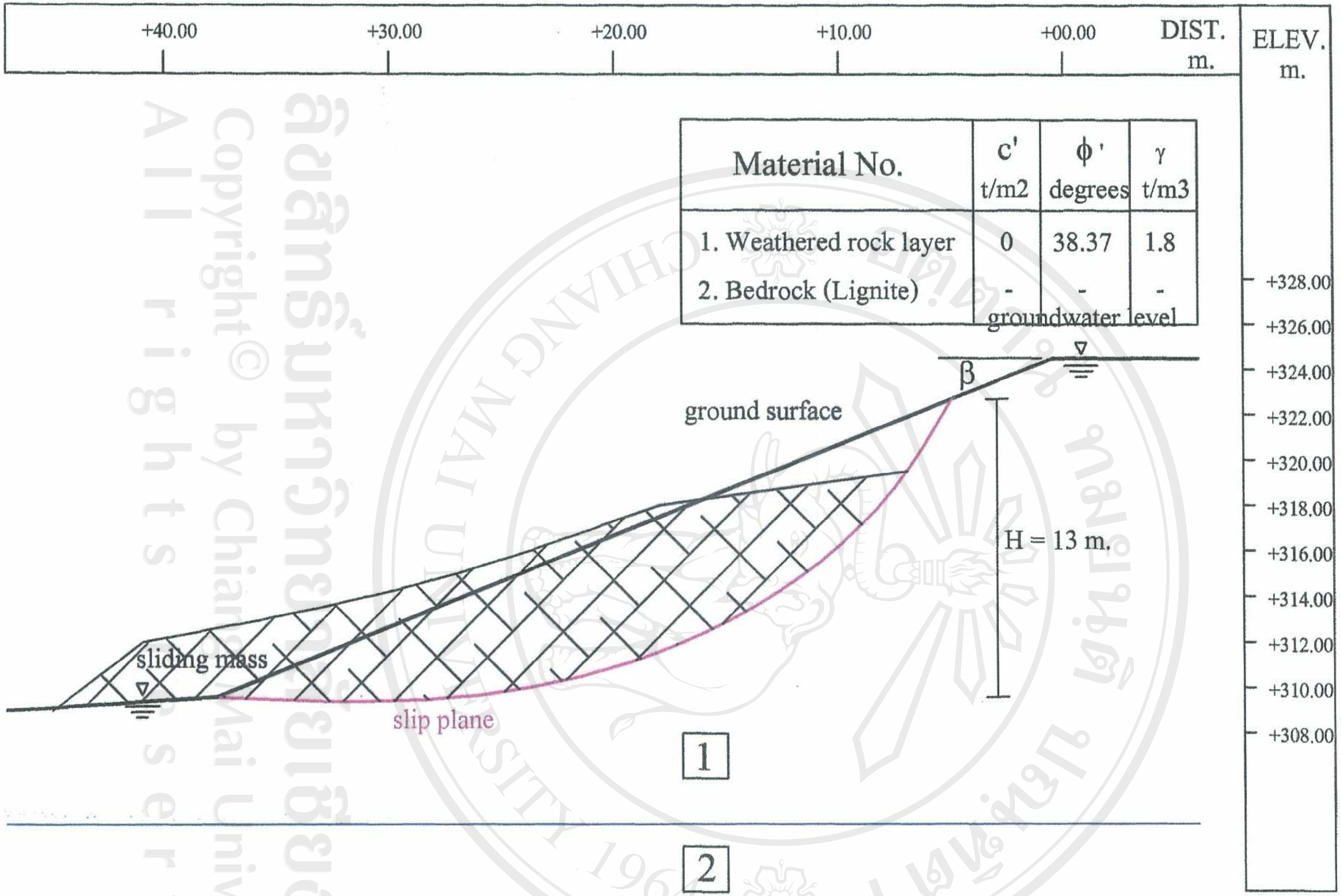


Fig. 3.8 Example of the shallow seated rotational slides failure slope in Mae Moh Mine, Lampang