Chapter 4

Case study: Doi Suthep, Chiang Mai

4.1 Introduction

It is evident on the basic of slope stability analysis that the slope failure plane, the shear strength parameter of soil and the evidence of seepage act as the important factors of the analysis. Thus, how to obtain these factors data are very significant and have to take much precaution.

This chapter mentions geological surveys, field testing and laboratory testing of slide on the public highway no. 1004 (section of Chiang Mai municipal government to Doi Suthep-Palace) between Km. 13+832 and Km. 13+875 which is similar to the general earth slopes in Northern Thailand. Also given in this chapter is a failure surface of the slide which estimates with profile and cross-section of the route and soil profile. More details are shown in section 4.5.

4.2 Soil sampling and field testing

To obtain the important factors for slope stability analysis, soil sampling and field testing are needed to do over the area of the failure slope. Collect disturbed and undisturbed samples to obtain physical and engineering properties of soil, and field test by standard penetration test (SPT) and cone penetration test (CPT) to obtain preliminary data and slip plane of the slide.

The boring tests are drilled in 6 holes (BH1, BH2, BH3, BH4, BH5 and BH6). The locations of all bore holes are demonstrated in fig. 4.2. At the cross line of Km. 13+855 of the highway no. 1004, which is the center line of the slide, BH1, BH2 and BH3 are drilled spread to the toe of the slide to determine the slip plane and the geological condition under the slip plane. The other holes (BH4, BH5 and BH6) are drilled on the left and the right side, out of the sliding area to find the original shear strength parameter of soil and soil condition. The depth of each bore holes should be drilled through the slope failure plane or until the bedrock. Details of boring tests are described in Appendix C.

Because the slide is steep slope (~40 degrees of slope angle) and it is difficult to use big machine. Thus, hand auger, tripod, motor and catch head are utilized in drilling, soil sampling and field testing. Undisturbed samples are collected by thin wall tubes which have inner diameter 7.30 cm, outer diameter 7.62 cm. and 60cm. in length.

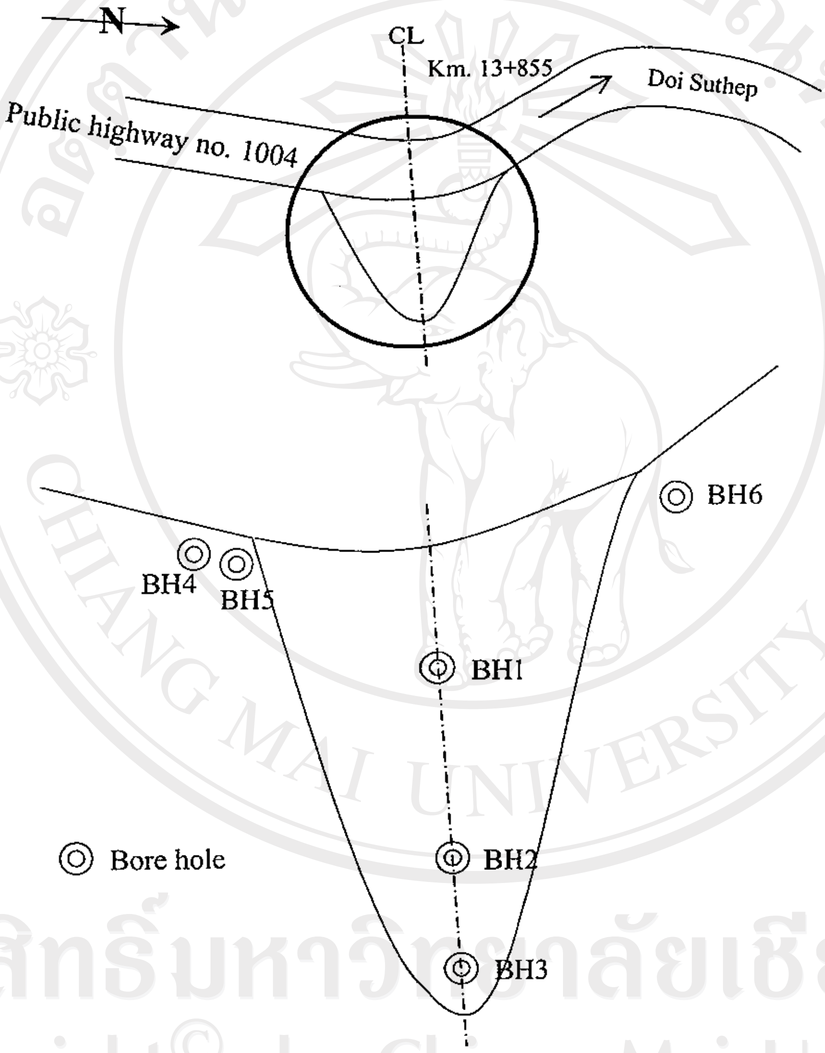

Fig. 4.1 The location of the failure slide in Doi Suthep, Chiang Mai and bore holes to do soil sampling

4.3 Laboratory testing

4.3.1 Laboratory testing for physical properties of soil

Laboratory testing for physical properties of soils follows ASTM which includes:

a) Natural water content

b) Atterberg's limits

c) Grain size analysis

d) Specific gravity

The list of testing is shown in table 4.1. The procedure of each physical properties test is described in Appendix C.

Table 4.1 Lists of testing for physical properties of soil

Depth from Ground surface (m.)	Natural water content	Atterberg's limits	Grain size analysis	Specific gravity
0.70 - 1.60	BH 1,3	BH 1,2	BH 1,2,6	BH 1,2
1.60 - 2.20	BH 1,2,3	BH 1	BH 1,3	BH 1,2
2.20 - 3.00	BH 1,3,4	BH1,3,4	BH 1,4	
3.00 - 3.90	BH 1,3,4	BH 4	BH 1,3,4	
3.90 - 4.50	BH 1,4	BH 4	BH 1,4	
4.50 - 6.00	BH 4			

4.3.2 Triaxial test

The objective of triaxial test is to obtain the effectiveshear strength parameter (c' and ∅') which is one of the significant factors of slope stability analysis. According to the condition of the slide, the type of triaxial test is consolidated undrained triaxial compression test with pore pressure measurement; $\overline{CU}$. Details of tests are shown in table 4.2. The procedure of the triaxial test is described in Appendix C.

Table 4.2 Lists of consolidated undrained triaxial compression test with pore pressure measurement; $\overline{CU}$

Bore hole no.	Depth (m.)	Amount of samples	Sample no.	Consolidated pressure (t/m^2)
BH 2	1.70 – 2.40	3	A10 A20 A30	7.028 14.056 21.084
BH 4	1.80 – 2.70	3	B05 B10 B20	3.514 7.028 14.056
BH 4	3.30 – 4.50	4	C05 C10 C15 C20	3.514 7.028 14.056 21.084

4.4 Results of laboratory testing

4.4.1 Physical properties of soils

The physical properties of soils described former are shown in table C1-C6 (Appendix C), and the details of boring logs and the feature of soil layers are shown in fig. C2-C7 (Appendix C). The feature of soil layers can briefly divide in 3 layers as following;

a) Upper layer : Soft sandy clay with low plasticity

This layer is residual soil which is in CL group. It can easily notice that it has highly composition of fine particle in the soil. The feature of soil is mostly changed because of the weather and climate in this region. Thus, it cannot see the feature and shape of the originai rock. The height of layer is about 0.5-3.5 meters and the soil has low strength (SPT = 0-4 blows/ft.) which can easily lead to the occurrence of slide.

b) Intermediate layer : Medium to hard sandy clay with low plasticity

This layer is still residual soil and classified in CL group, but it has more strength than the upper layer. Although the general feature of soil in this layer is soil more than rock, it can obviously notice the structure of the original rock. The quantity of small stones or core stones is less than 10 percents by volume. The height of layer is about 1.5-4 .0 meters.

c) Moderate to slightly weathered rock

The height of this layer is very wide, because it includes the zone which has the quantity of the stones from 10 to 90 percents by volume. This layer is mainly consists of gravel and sand, and has very low plasticity. It can be classified in SC group.

The soil profile of the failure slide area is shown in fig. 4.1 and table 4.3 shows the average values of the soil properties in each group.

Table 4.3 Average values of soil properties

Soil layers / Soil properties	Upper layer	Intermediate layer	Weathered rock
Soil type (USCS)	CL	CL	SC
Natural water content (%)	27.79	23.06	14.96
Liquid limit, LL. (%)	40.06	39.69	
Plastic limit, PL. (%)	25.19	24.26	
Plasticity index, PI. (%)	14.87	15.43	
Sand + Gravel (%)	30.97	38.88	66.63
Clay + Silt (%)	69.03	61.12	33.37
Specific gravity, Gs	2.61	2.62	
Bulk density (t/m^2)	1.94	1.97	
Dry density (t/m^2)	1.57	1.68	
SPT (blows/ft.)	0-4	5-9	10-50

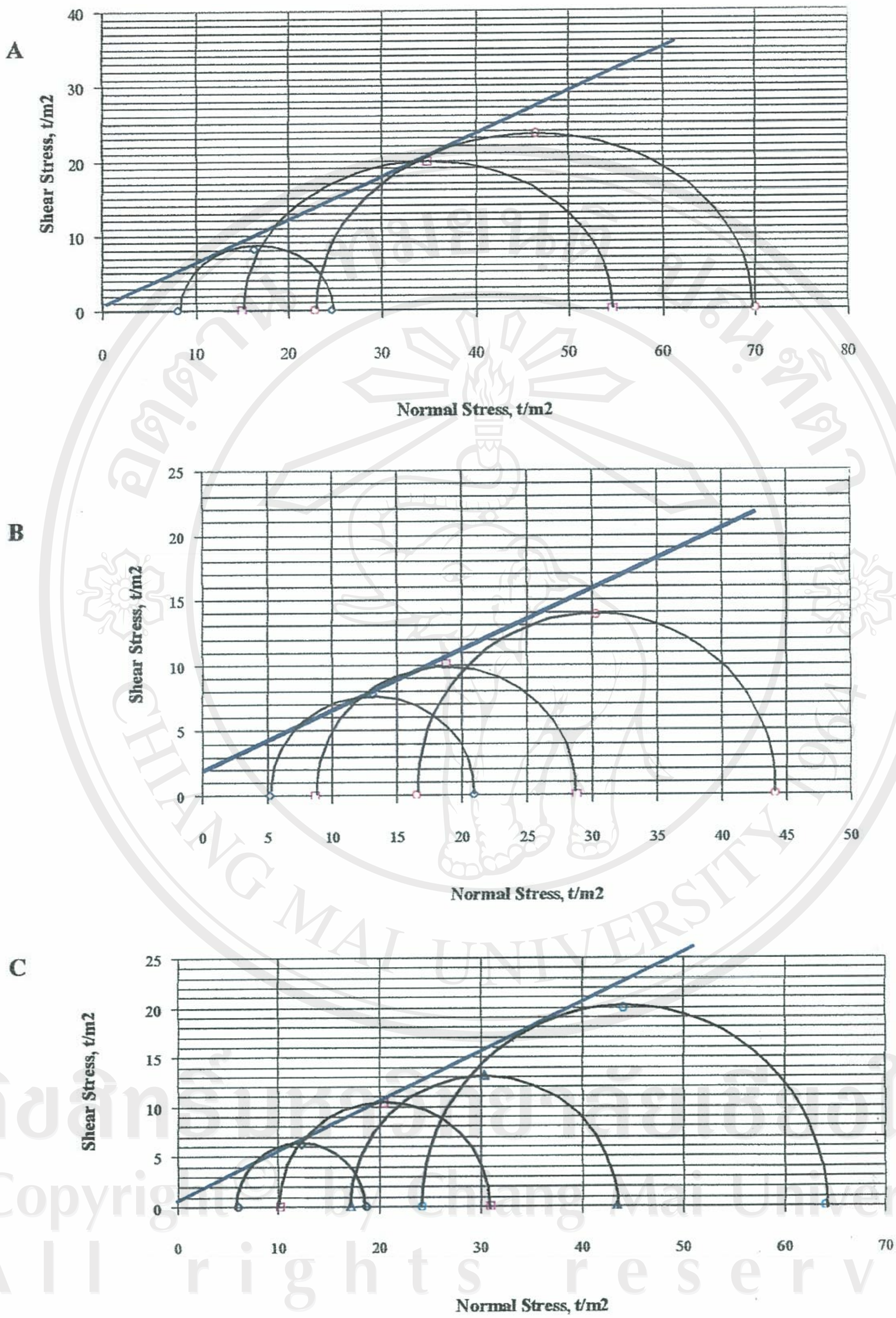

Fig. 4.2 Mohr's circle of sample A, B and C

4.4.2 Triaxial test

The results of the effective shear strength parameter of soil for each layer are shown in table 4.4, which obtained from Mohr's circle of sample no. A, B and C in fig. 4.2.

Table 4.4 Effective shear strength parameter of soil

Soil layers	Effective shear strength parameter of soil	
	c' (t/m^2)	Ø' (degrees)
a) Upper layer	1.1	25.8
b) Intermediate layer	0.5	31.0
c) Moderate to slightly weathered rock	0.0	38.0

4.5 Assume the failure surface

From the field observation and topographic survey (by theodolite T2), the present ground surface of the centerline of failure slope is illustrated as the thin light blue line in fig. 4.3 including location of boring logs and SPT results. The shape of ground surface line indicates the occurrence of slope failure. The soil moved to the toe of the slope, but the sliding mass is still in the failure area as shown in fig. 4.3 and fig. C7-C8 in the appendix C. BH1, BH2 and BH3 are drilled along the centerline down to the toe of the slope to determine the slip plane and the soil conditions under the slip plane. BH1 started to drill from the moving mass area, thus the top of BH1 is the zone of sliding mass, which can be defined by the small value of SPT. BH4 and BH5 are drilled in the outer area of the slide on the left side to find the original ground condition, and to collect undisturbed samples to do the triaxial test. From all data of boring logs, field tests and the results of laboratory tests, the geological condition can divided in 3 soil layers; the upper layer, the intermediate layer and the weathered rock layer, which the details are previously described in the section 4.4. According to fig. 4.3, it can be seen that the failure zone might occur in the upper layer, which the soil is soft sandy clay.

According to the data of the public highway no. 1004 from Chiangmai public highway division, Department of public highway, Ministry of Transportation (Bureau of 1st public highway), the original ground surface at the cross-section of km. 13+855 which is the centerline of the failure slope can estimate by overlapping the adjacent cross-sections (Km. 13+825.00, 13+832.00, 13+ 837.50, 13+850.00, 13+862.50 and 13+875.00) as demonstrated in fig. 4.4. From the shape of cross-section of Km. 13+850.00, it is implied that there is a partly failure at this section. The next higher cross-section, Km. 13+862.50 or the lower cross-section, Km. 13+837.50 might be represents the original ground surface at the centerline of the slope. When compared the original ground surface of both sections and the present ground surface at Km. 13+855.00, it is found that the ground surface of Km.13+862.50 is possible to be the original ground surface, because the ground surface is related to the actual sliding mass.

It is obvious from the soil profile in fig. 4.3 that the upper soil layer has low strength and it is not enough for slope to be stable for a long time under the severe weather and heavy rainfall. The soil layer, therefore, leads to many problems in civil engineering.

From the site investigation, at the upper zone of the slope, the upper ending point and some parts of the slip line can be assumed by the visual because there are no sliding mass in the upper zone. And the lower ending point of the slip line can be assumed by some clues in the field (e.g. the changing of the characteristic of the soil, the color of the soil and the humidity). Since the both ending point and some points of the slip line are assumed by site investigation and the small value of SPT and CPT (1-4 blows/ft) of BH1 indicated the failure mass or the unstable zone of the slope. And the type of slope failures of almost landslides in Northern Thailand is non-circular shallow seated rotational slides (Yamsai and Mairaing, 2000). Therefore, the slip line can be assumed by drawing as the pink line in fig. 4.5. According to the original ground surface in fig. 4.4 and the failure surface in fig. 4.5, the sliding mass is the hatched area in fig. 4.5.

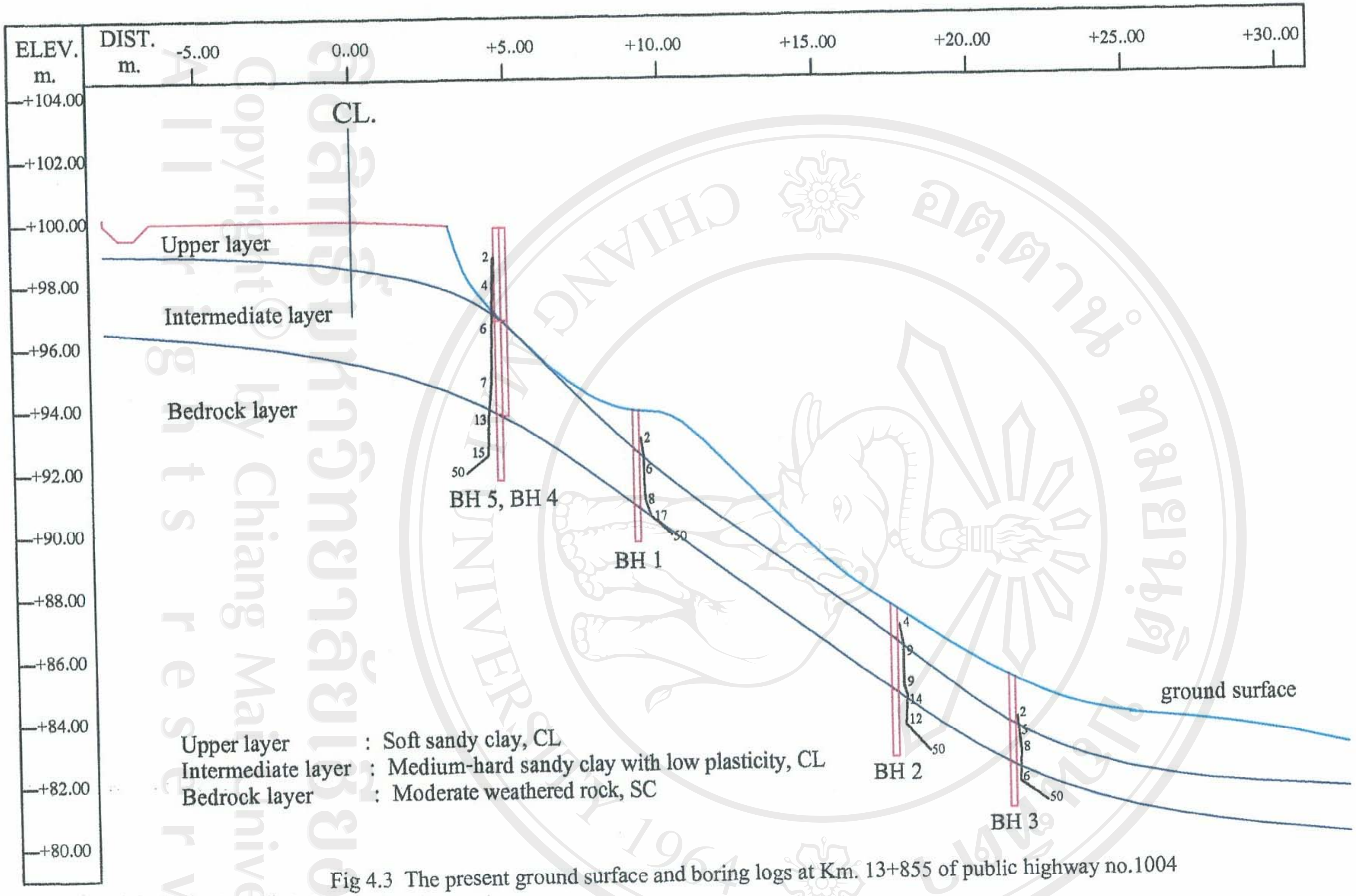

Fig 4.3 The present ground surface and boring logs at Km. 13+855 of public highway no.1004

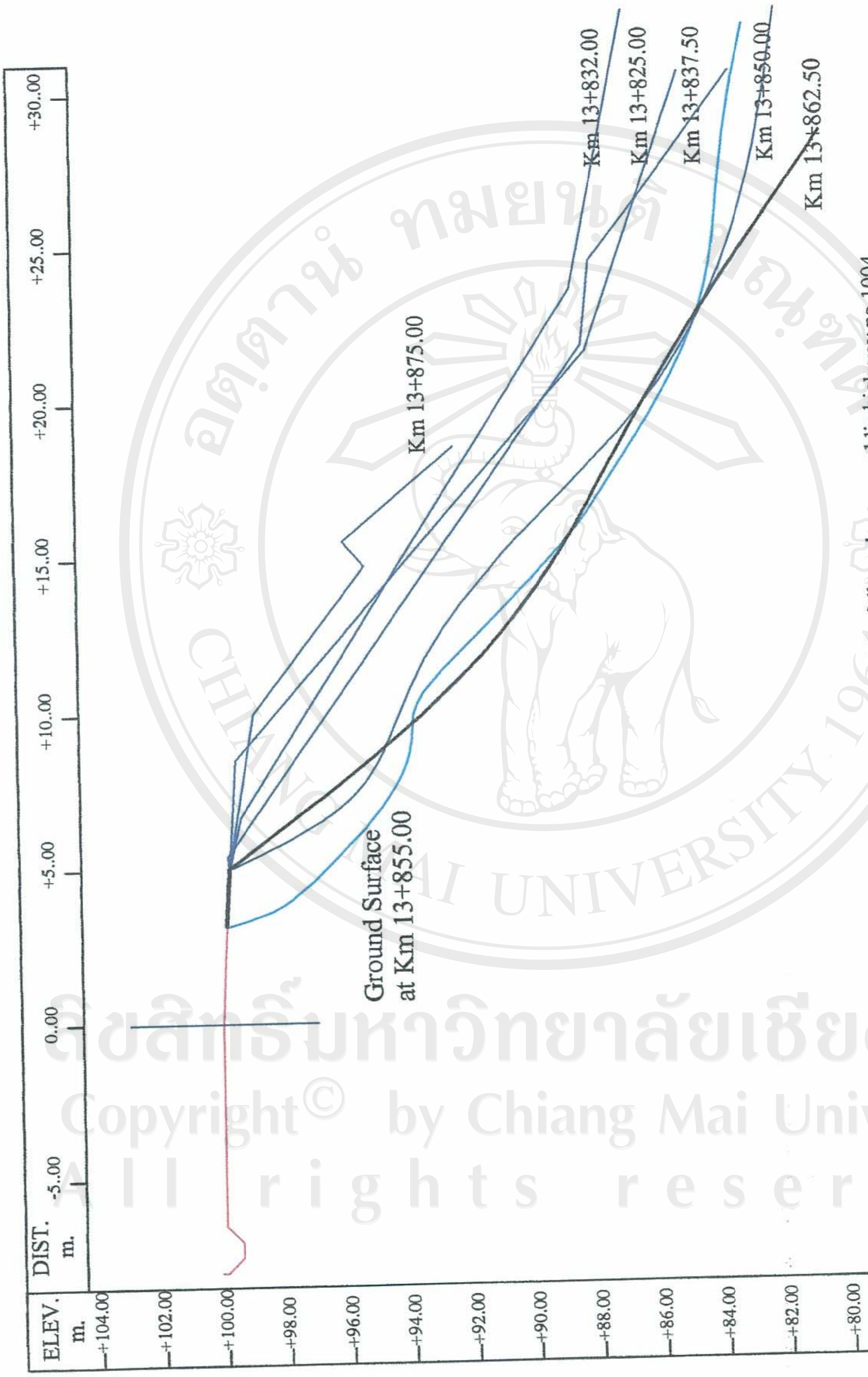

Fig 4.4 The adjacent cross-section of the failure slope on public highway no.1004

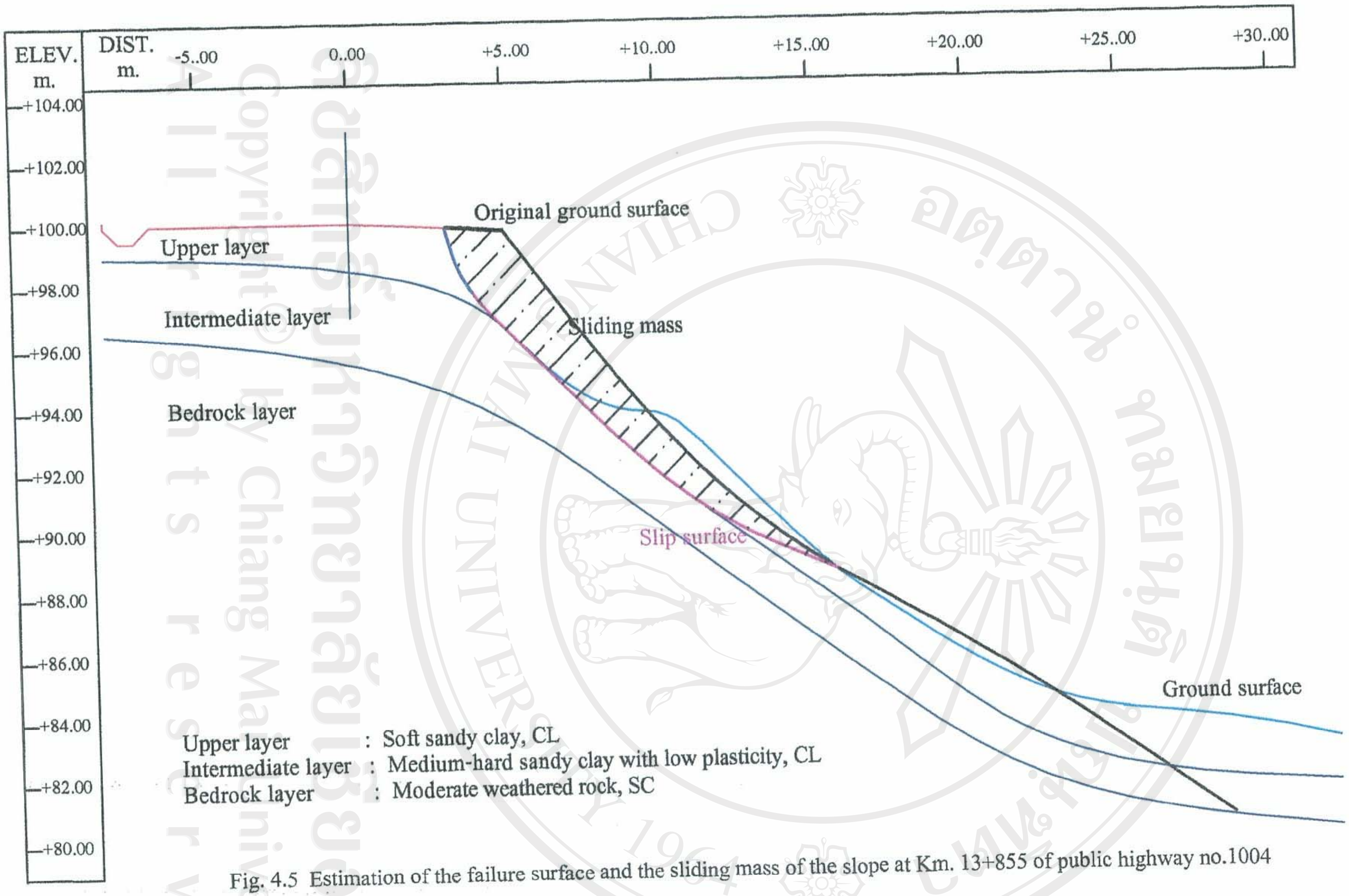

Fig. 4.5 Estimation of the failure surface and the sliding mass of the slope at Km. 13+855 of public highway no.1004