Landslide hazard investigation and evaluation of Doi Tung Palace: Example of soil creep landslide

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ABSTRACT : Landslide Hazard area was analyzed in Doi Tung Development Project. Field and Laboratory investigations were done including hand augers, test pits, soil and rock borings, field permeability tests and shear strength tests. Stability analysis has been done using limit equilibrium concept. The landslide hazard area was assigned based on the slope degree which corresponds to slope factor of safety. As for land cover, considerations were made to include this factor in the analysis. Finally, verification was done and found good correlation between hazard area from the analysis and actual location of slope failure. The obtained landslide hazard areas were assigned the suitable protection based on the risk of each area.

KEYWORDS : Landslide Hazard Map, Landslide, Stability Analysis

1. Introduction

Doi Tung Development project was established by Her Majesty the King's mother where Doi Tung Palace is located. Since starting the project decades ago, the area was damage by the farmer because they burnt the ground after making the harvest. Therefore, landslide and soil erosion has been the problem since then. The royal project has come to develop the area by using various kind of slope protection and erosion control including the research of vetiver grass. The area is safe since then, however recent forest fire has destroyed the soil cover in the area especially near the Doi Tung palace. Therefore, research is needed to ensure the stability of slope around the palace and appropriate slope protection measures need to be done. Department of Mineral Resources is then corporate with Geotechnical Engineering Research and Development center, Kasetsart University in order to evaluate the landslide hazard area and give the possibility of countermeasures methods.

2. Geographic and Geology

The elevation of the project area is 798-1,014 m.msl. The mean value of slope angle is 33.25° with SD =13.155° Fig. 1 shows the slope contour of the area [1].

Based on geological map [2] and geologic data of the project studied by Prinya et al. (1993)[3], the area consist of intrusive rocks in Permo-Triassic era which include Tonalite and Diorite and some Gabbro or Gabbroic Diorite. Fig. 2 presents the geologic section of the study area (Tr_{gr}).

3. Site investigation and Field testing

The objective of field investigation is to evaluate the thickness, homogeneity and engineering properties of residual soil. Theses data will be used to define failure plane and factors safety of slope in stability analysis

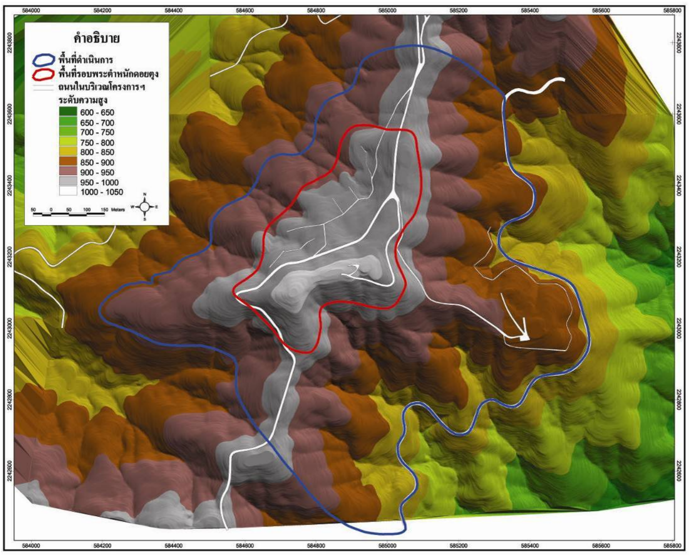


Fig. 1 Geographic map of Doi Tung development project

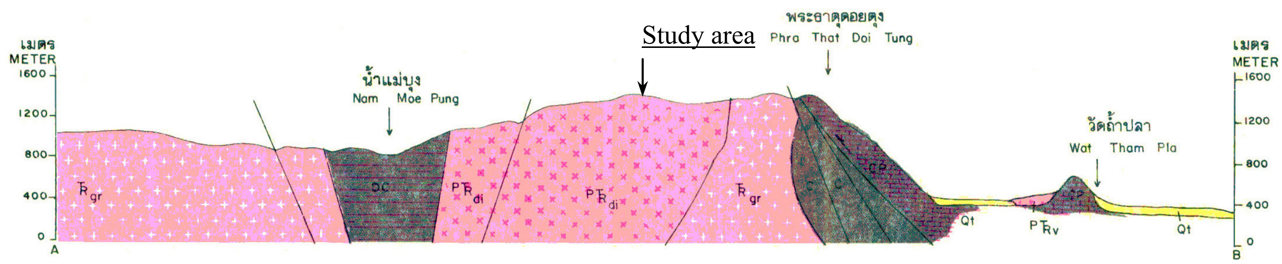


Fig. 2 Geologic section of the study area [2]

3.1 Mineral composition and Geophysics testing

Geological survey was done and found that the area is covered by residual soil which decomposed from Diorite-fine to medium grained. Residual soil consists of silty clay and sandy clay. Based on QAP diagram [4], Diorite consists of Plagioclase Feldspar which its decomposed product could give high percentage of clay mineral. Department of mineral resources [5] has done the resistivity survey and found that the thickness of residual soil is 10-100 meter with some floating rocks.

3.2 Hand Auger Investigation

In order to verify the residual soil thickness as evaluated in 3.1, 4 meter deep hand auger drillings were done along the slope section of stability analysis. 57 bore holes in 22 sections were drilled. Fig. 3 shows the results of Wn, LL, PL and PI from 207 soil samples. Average PI is between 26.45-29.26%. Soil classification is done and found that most of soil type is CL and CH uniformly along auger depth. Fig. 4 shows the test results in plasticity chart, it can be seen that most of soil mineral is Illite.

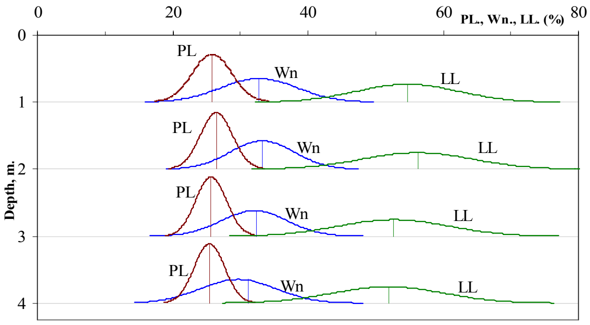


Fig 3 Distribution of consistency from 207 soil samples

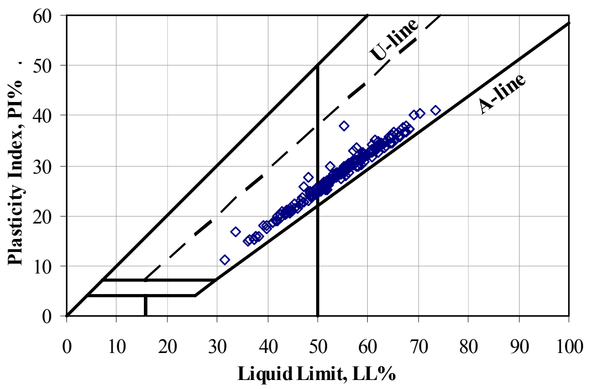
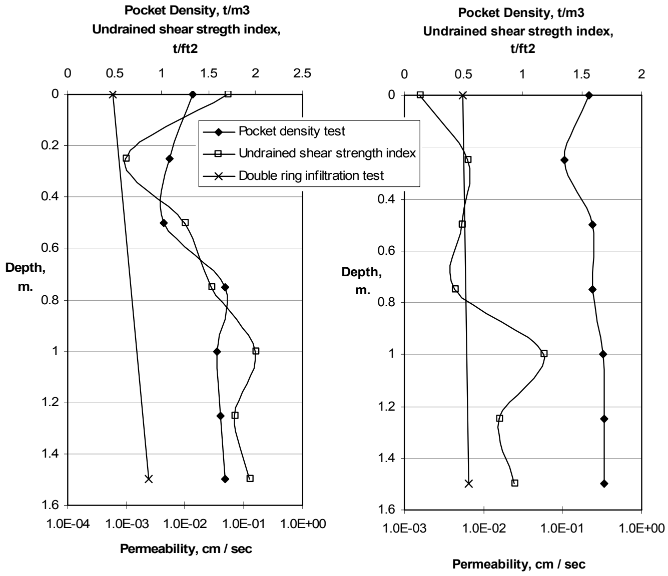


Fig. 4 Test results in plasticity chart

3.3 Test Pits

Undisturbed soil samples were collected from 2 test pit using KU-Miniature sampler [6][7][8]. Soil sample is collected at the interface level between bed rock and residual soil. Furthermore, field permeability is determined by double ring infiltration test (ASTM D 3385).

Fig. 5 shows that the soil permeability is quite high all through the depth of investigation with low total density especially at 0.2-0.5 meter depth.

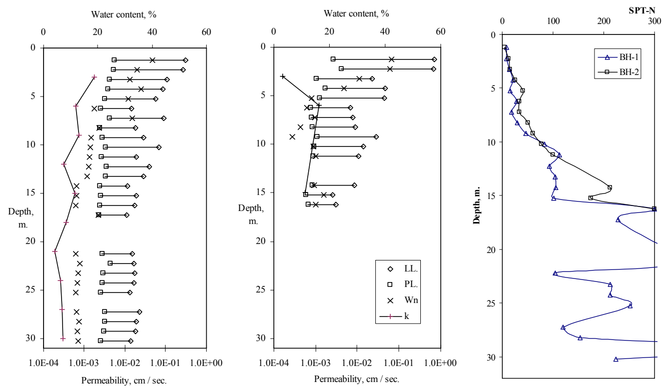


a.) Test Pit 1 b.) Test Pit 2

Fig. 5 Test pit characteristics

3.4 Soil boring

30 meter soil boring was drilled in 2 locations which have high potential of consequences from landslide. Soil samples were collected and SPT were tested together with field permeability test using borehole method. Fig. 6 shows the borehole characteristics which consists of soil layer classified as CH, CL and SC. The bed rock is Diorite. SPT value increases with depth and significantly increase after 8 meter depth. Soil permeability is found to be high along the depth of the bore holes.



a.) BH - 1 b.) BH - 2 c.) SPT

Fig. 6 Soil boring log

4. Failure mode in the study area

Varnes (1978) [9] classified landslide failure mode in to 6 modes. Based on Varnes's classifications, the slope failure in the study area can be classified in to 2 types:

1. Slides: in the slope that steeper than 35 degree, especially in the cut and fill area of road cutting and uncovered

area where erosion can be found. Size of the slide is generally less than 20 cu.m.

2. Soil Creep: mostly over the cut slope of road. Soil moves slowing without showing any surface cracks but can be noticed by the inclining trees.

Fig. 7 is the map showing the location of slope failure and surface erosions.

5. Landslide index identification

Landslide index in the study area is identified:

a. Inclining trees
b. Soil movement
c. Surface crack on the road

The investigation found that there is a direct relationship between soil cover, erosion and soil slide. In the area where there is no soil covered, soil will be eroded and water will infiltrate in to the deeper depth and caused sliding of soil.

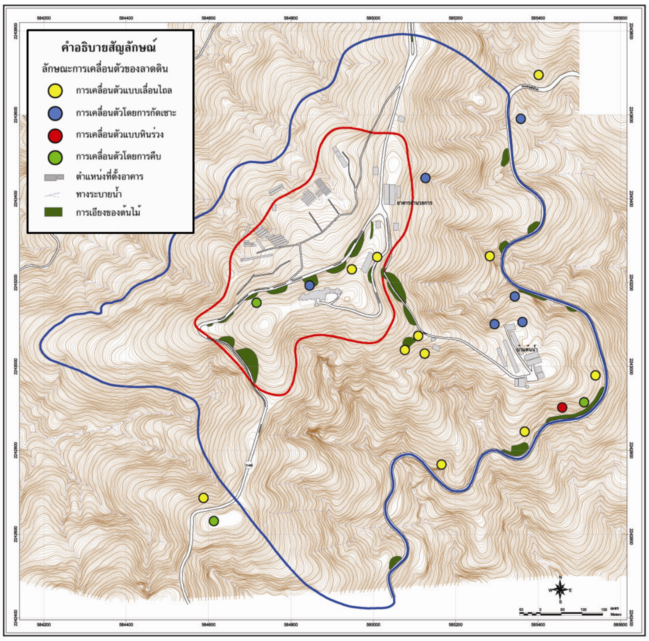


Fig. 7 Landslide index in the study area

6. Evaluation of landslide susceptibility area

Landslide susceptibility area is analyzed based on slope stability analysis by limit equilibrium method [10] and corporate with GIS technique in order to get the landslide susceptibility map in 1:1000 scale.

6.1 Soil properties

Based on site investigation data, subsoil layer is modeled to be thick and homogeneous. Therefore, circular failure mode is valid to be assumed instead of infinite slope model as in other cases of natural slope. Strength properties were done by direct shear test in various conditions as shown in Table 1.

Table 1 Undrained strength parameters in various conditions

Conditions	C, (t/m^2)	ϕ, (deg.)	γ_t ,(t/m^3)
Unsaturated with natural water content	1.00	36.0	1.60
Soaked	1.00	30.0	1.70
Residual strength	0.10	30.0	1.55

6.2 Area based-stability analysis

Stability model is assumed based on actual geography in the area. Homogeneous soil slope with 50 meter high and various slope angles were assumed. Stability analysis is performed and the results are shown in Fig. 8. Model of road cutting is also assumed and the results are shown in Fig. 9.

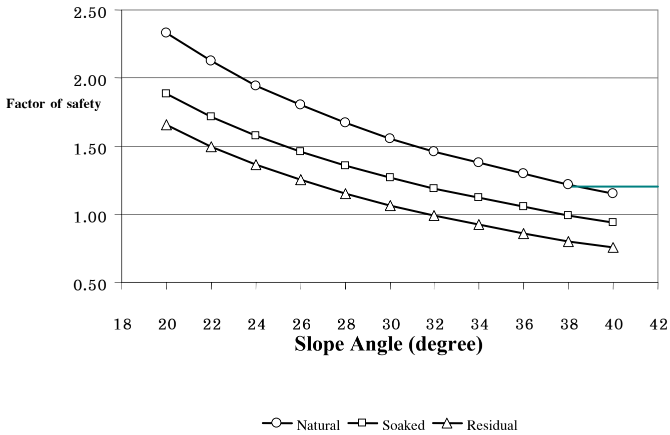


Fig. 8 Factor of safety with various slope angles

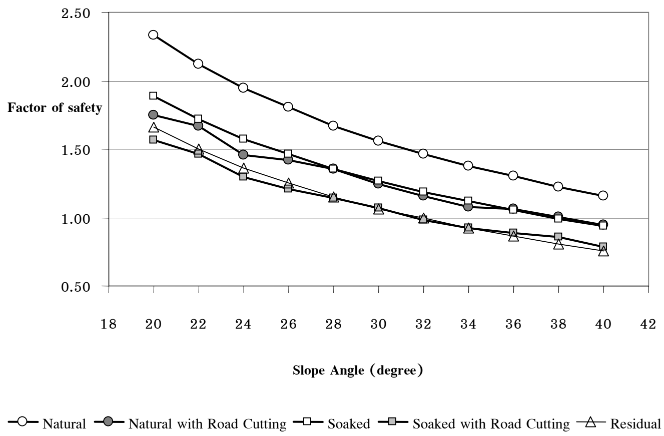


Fig. 9 Factor of safety of slope in case of road cutting

The stability analysis results are used to assign the landslide potential or hazard in the slope map scale 1:1000. Limit factor of safety of 1.2 is used. If the factor of safety is greater than 1.2, the landslide hazard is considered low (Brand 1984 [11] and Trenter 2001 [12]), equal to 1.2 is moderate and lower than 1.2 is high. Fig. 10 shows the result of landslide hazard map.

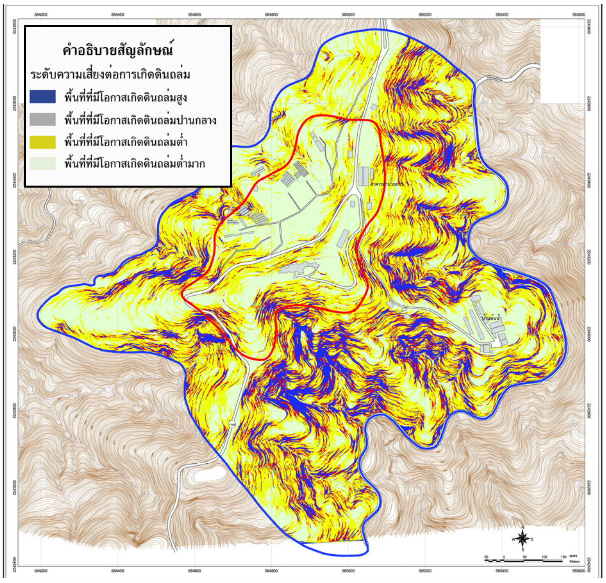


Fig. 10 Landslide hazard map based on factor of safety of natural slope

Since soil cover is important factor for landslide potential in the study area, therefore ground survey was done to indicate various soil cover types and the result is shown in the Fig. 11.

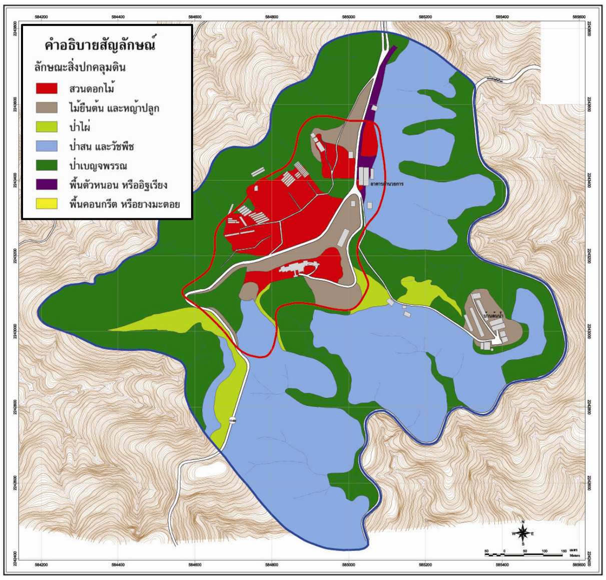


Fig. 11 Soil cover in the study area

The data of soil cover and factor of safety are combined using weighting factor method. Finally, landslide hazard map is produced as shown in Fig. 12.

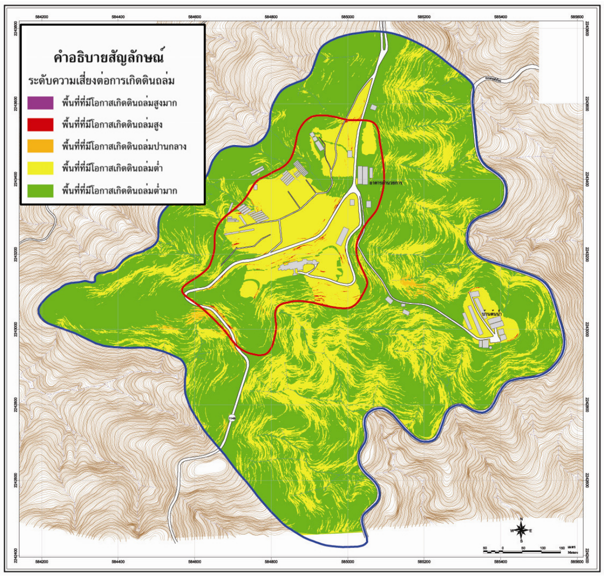


Fig. 12 Landslide hazard map based on soil cover and factor of safety of natural slope

6.3 Verification

Landslide hazard map is verified by landslide data in the area. 21 landslide locations were used and found that some location does not match with the prediction. However, it matches with the cut slope model. This is not surprise since the analysis is based on natural slope.

7. Conclusion

1. From the geotechnical investigation it found that residual soil of diorite gives homogeneous and thick layer of residual soil. Soil type classified as CL, CH and SC.

2. The properties of residual soil were tested and found that it has high permeability ($>10^{-3}$ cm/s) with low density (<1.6 t/m^3) but has high plasticity (PI=26.45-29.26%). The failure mode in the area is classified as creep landslide. Inclinometer was installed in the area and found that the lateral movement is in the rate of creep sliding.

3. Landslide hazard area is analyzed using geotechnical engineering method. Stability model is used and found that the accuracy of the prediction is based on slope changing by road cutting. The overall approach is acceptable.

8. Acknowledgement

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