รายงานฉบับที่ วว. 51 กองวิเคราะห์และวิจัย
REPORT NO. MR 51 MATERIALS & RESEARCH DIVISION

GEOLOGICAL AND SEISMOLOGICAL ASPECTS OF LANDSLIDES IN NORTHERN THAILAND

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Report No. 51

Materials & Research Division

Department of Highways

June 1980

This paper was presented at the International Symposium on Landslides , New Delhi , India , April 7 - 11 , 1980

PREFACE

Landslide is a common phenomenon of road construction in Northern Thailand. The causes of landslide are many and complex. Sometimes it is hard to justify them correctly. According to the past experience and quite a few local investigation, landslide mostly occurs in the rainy season along some weak planes created. It is the purpose of this paper to hypothesize the effect of geological history, structural complex, as well as the seismic action in inducing landslide in Northern Thailand. Comparison between landslide in the North and the Peninsula of Thailand tends to substantiate that all the local factors are all effective in landslide occurring. It is hoping that this paper will give some significance about seismicity and structural complex in causing landslide in Northern Thailand. Evidence shown will be informative for practicing engineer working various phases of design regarding to earth surface.

(Seree Suebsanguan)
Director - General

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ABSTRACT

During the geologic time Northern Thailand was subjected to many cycles of orogenic event, inducing different structural complexes in the earth crust. Today these events are still effective, especially some forms of earth movement and earthquake which are recorded by the equipment in this particular region. Road cutting in some vicinities encountered the problem of landslide. The primary causes of landslide are geological factor, associated with creep phenomenon, crack formation, and water infiltration, while the trembling effect of microseismic activities is minor in promoting the potential of landslide.

INTRODUCTION

Northern Thailand was subjected to many cycles of orogenic events which resulting from both volcanic and tectonic activities. These activities were accompanied by eruption of andesites and tuffs, and intrusions of relatively large mass of granitic rocks which are widely formed in this region. As a consequence of these complex activities, quite a few fault zones and other structural basement complexes were formed. The belt of the recorded seismic epicenters in Burma and India passing through Andaman Sea and Sumatra tends to substantiate these activities (Gutenburg and Richter, 1965). As Northern Thailand has moderately high annual rainfall of 1500 - 2000 mm with warm temperature, rocks tend to decompose forming a mantle of residual soil and weathered rock

covering the original parent rocks. There exists the boundary or weak transition zone between residual soil and weathered rock in the profile. Road cutting in this area of which the terrain is mountainous encountered the problem of slide or slip in the cut slope. Occurred slides are either along the geologic weak planes, or due to the seismic shock in the region, or both. Field observations reflected the creep phenomenon and progressive failure in some particularly suitable topography, indicating the movement of the mantle of the earth mass along the hillslope through some specific weak planes. These planes might be either the fault zones which were formed in the geologic time, or weak planes created by water infiltration into the residual soil during the rainstorm inducing a saturated zone of low shearing resistance. From the recorded seismic data associated with the field evidence it was found that seismic activities are still active in Northern Thailand. This paper is going to present data pertaing to local seismic events and other structural basement complexes of the area which reduce stability of the cut slope and induce landslide. Examples of local failure are also include. Discussion and conclusion are going to be drawn on rational approach.

STRUCTURAL BASEMENT COMPLEXES OF NORTHERN THAILAND

The present geological condition of Northern Thailand is the result of many orogenic events as described by Campbell and Nutalaya (1975), German Geological Mission (1972) and Piyasin (1978). The map of the structural basement complexes is shown in Figure 1 (Campbell, 1975). The regional major fault zones are Moei-Uthai Thani and Wang Chao, and they could be easily traced from the LANDSAT images. There are some minor fault zones as Yuam, Theon

associated with other basement complexes as anticlines, synclines, joints and folds which extensively formed in this region. Looking through Figure 1 it will be seen how geologic structure of the region is rather complicated. These basement complexes are the seats of geological weak zones inducing landslide in road cutting. However, landslide or slip is accelerated by water percolation during the rainstorm, the seismic shock and other microseismic factors.

SEISMIC ACTIVITIES OF NORTHERN THAILAND

Generally Thailand is not situated in the zone of seismicity as demonstrated by the National Earthquake Information Center Map (Condie, 1978). According to the map of seismicity as compiled by Gutenburg and Richter (1965) Thailand is considered to be a stable mass, and earthquake epicenters are not located in this part of the continent. The seismic region closest to Thailand belongs to the Sumatra - Burma Arc (Condie, 1978; Gutenburg and Richter, 1965). Some recent epicenters in the Sumatra - Andaman Sea - Burma Arc as recorded from the local earthquake recording stations in Changwat Tak and Changwat Lampang and compiled by Yensuang (1978) are shown in Figure 2. It is clearly seen that most epicenters are outside Thailand. The body magnitude M_B of the regional earthquake shown in Figure 2 ranges from 3.0 to 6.5. Even though the epicenter is outside Thailand, for the large earthquake in Burma the trembling effect could be transmitted to Northern Thailand, or even Bangkok which is about 1000 km away.

From the earthquake recording stations in Northern Thailand, quite a few seismic activities with epicenters in Thailand are also recorded, and some are shown in Figure 3 (Yensuang, 1978). The local magnitude M_L of the earthquake hit as in Figure 3 varied from

1.6 to 4.0 with the depth of 0-10 km. which is considered to be shallow. The intensity is not strong enough to destroy the concrete building, but causing some damage as cracking of the brick wall. The local earthquake could be felt by the local people. Hopefully, the earthquake of this type tends to associate with the basement complex and water percolation in accelerating the creep rate, progressive movement and landslide or slip of the earth mantle.

At this stage it may be stated that whether the earthquake hits are from sources outside Thailand or in this region, They do not have the destructive influence. But it is expected that their influence tend to support the weak zones in landslide occurring.

THE CONCEPT OF ZONES AND PLANES OF WEAKNESS IN ROCKS

The concept of "Zones and Planes of Weakness in Rocks" has achieved widespread consideration on engineering geology relating to some degree of investigations on the stability of rock slopes (Komarnitskii, 1968). According to this concept, sliding breaks down along the weak planes in the rock mass. Plane of weakness in the concept included joints, contact surfaces between beds or sequences of rock, fault surfaces, slip surface of ancient and buried slide, interbeds of high plasticity or rock with infiltration instability, lamination, brecciated and other tectonically disturbed zones. Landslides in the cut slopes or hillslope in Northern Thailand tend to satisfy the above concept, whether these weak planes are geologically or environmentally created.

DISCUSSION ON EFFECT OF GEOLOGICAL FACTORS, CLIMATIC CONDITION, AND SEISMIC ACTIVITIES IN LANDSLIDE OCCURRENCE

Geological Factors, Climatic Condition and Creep Phenomenon.

Landslide along the geologically formed weak planes in the hillslope or cut slope was more or less described in the preceding sections. This section is going to explain about mechanism of landslide along the weak plane in residual soil created by water infiltration associated with progressive movement due to creep phenomenon in the hillslope.

Most of the land of Northern Thailand is covered with residual soil derived from the decomposition of both igneous and metamorphic rocks such as granite, gneiss, slate and shale. Road excavation releases the existing overburden pressure and tends to induce some expansion in the cut slope. As a consequence quite a few cracks are shown up in the top of the hill or the face of the cut slope. Crack opening tends to be widened in the rainy season, indicative of the creep phenomenon and progressive failure inducing landslide in residual soil. Creep phenomenon is reflected by some slant trees in the hillslope.

The average annual rainfall in this vicinity is 1500 - 2000 mm, and the rainy season lasts about 4-6 months. Stress relaxation due to road excavation induces expansion and crack in the hillslope, thus reducing the shearing resistance of the residual soil. High rainfall increases the unit weight of the soil, and the percolation water filling in the cracks tends to create the weak plane and destroy the cohesion of the soil. Then the creep rate is increased and the progressive failure is accelerated. Finally, landslide occurs due to the combined effect of stress relaxation, water infiltration, and creep phenomenon.

Seismic Activities. As the magnitude of the earthquake in Northern Thailand is not large and does not have the destructive effect as aformentioned, and as the residual soil and weathered

rock in this region could be assumed to be more or less elastic material, failure of the hillslope or cut slope due to seismic effect alone may not be commonly found. However, according to the report of Yensuang (1978), after investigating the damage of the concrete structure and brick wall due to the earthquake hit in Amphoe Prao, Changwat Chiengmai in May 1978 (local magnitude M_L = 3-4), the maximum width of crack is about 1 cm with its length varying from 3-7 meters. The damage reported is considered to be minor, and no collapse of any concrete structure or brick wall is found. From the evidence as found by Yensuang (1978) it is hoping that the trembling effect of the earthquake hit to the hillslope should be lowered than that to the more rigid structure as concrete building or brick wall. Therefore, the crack or failure due to seismic activities in the hillslope or cut slope is not common.

Combined Geological and Seismological Effects. Even though the magnitude of the earthquake in Northern Thailand is not large enough to create crack in residual soil, or to induce landslide in the hillslope, but as there exists quite a few number of small earthquake hits is this vicinity, it is expected that these microseismic activities could accelerate the creep rate and progressive movement of the hillslope. In other words, seismic activities tend to promote the landslide potential as initiated from ancient fault zones, or water saturated weak planes. There are some reasons for this postulation which is going to be discussed in the following section.

The Peninsula of Thailand also has the mountainous terrain as Northern Thailand, and there are many parts covered by residual soil. Quite a few road cuttings were made through residual soil and weathered rock. The average annual rainfall is 2000-2500 mm,

higher than that of Northern Thailand. The duration of the rainy season is also longer, and temperature is warmer. So higher degree of rock wathering is expected. There are many types of residual soil in this region as the North. But landslide, both in the hillslope and the cut slope, is not common for road excavation in the Peninsula of Thailand. This is presumably due to the lack of the seismic activities in this region. This presumption is consistent to the record of Gutenburg and Richter (1968) which reported that the land of the Peninsula of Thailand and Malaysia is considered to be stable mass. That is, it is not the seat of earthquake hit. Therefore, the number of landslides in Northern Thailand compared to that in this region is conclusively due to the supporting seismic activities regarded.

Figure 4 demonstrates diagrammatically one of a big landslide in a cut slope in Northern Thailand. This slide broke out in 1974 at km 54+415-54+650 along Srisatchanalai - Denchai National Highway. The cause of landslide is due to the combined effects of crack formation, creep phenomenon, water percolation, and probably microseismic activities.

According to the plan - profile of the area as shown in Figure 4a, the quantity of the earth inducing landslide could be divided into two sliding masses. In the top of both sliding masses there one a lot of deep cracks formed as shown in the cross section in Figure 4b, indicative of creep phenomenon before failure. Water flows through these openings, softens the soil down below, and creates the saturated weak zone. When cohesion is destroyed and the shearing resistance is lowered to a critical level, failure occurs. The vertical cliff formed after landslide as shown in Figure 4b indicated that the mass of the earth slipped along some specific weak planes created from water seeping.

As the original structure of residual soil was highly disturbed due to the earth movement, associated with the high water content in both sliding masses, the shearing resistance tends to drop down to the residual value. There exists the progressive movement of the earth mass all the time. As its quantity is very large, especially at the early stage of failure, immediately effective design to prevent the earth flow will be costly. When landslide occurred for the first time, the quantity of the moving earth is so great that the elevation of the adjacent roadway was lifted up for 30 - 50 cm. Even though the slope of the old landslide is about 35 as shown in Figure 4b, there is still unceasing movement of these two sliding masses. The cheapest way being done during the past few years is just taking the flowing earth out of the roadway at the time of slide. However, as the quantity of earth flow is considerably reduced, design to control the drainage of water in the cut slope and the old slide is being proposed for more effective prevention.

CONCLUSION

1. Both geological factors, and seismic activities tend to promote each other for inducing landslide in the cut slope in residual soil and weathered rocks
2. Other factors influencing the sliding potential are creep phenomenon, water percolation and lowering of the shearing resistance in the saturated zone.

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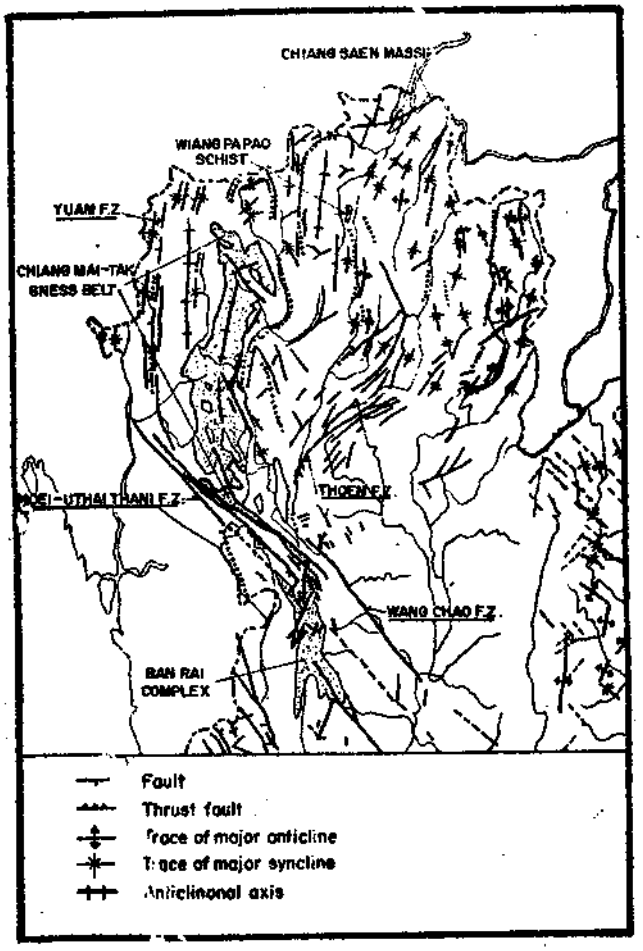

Fig.1 Structural Basement Complexes of Northern Thailand (Compiled by Campbell, K.V. and Nutalaya, P., 1973)

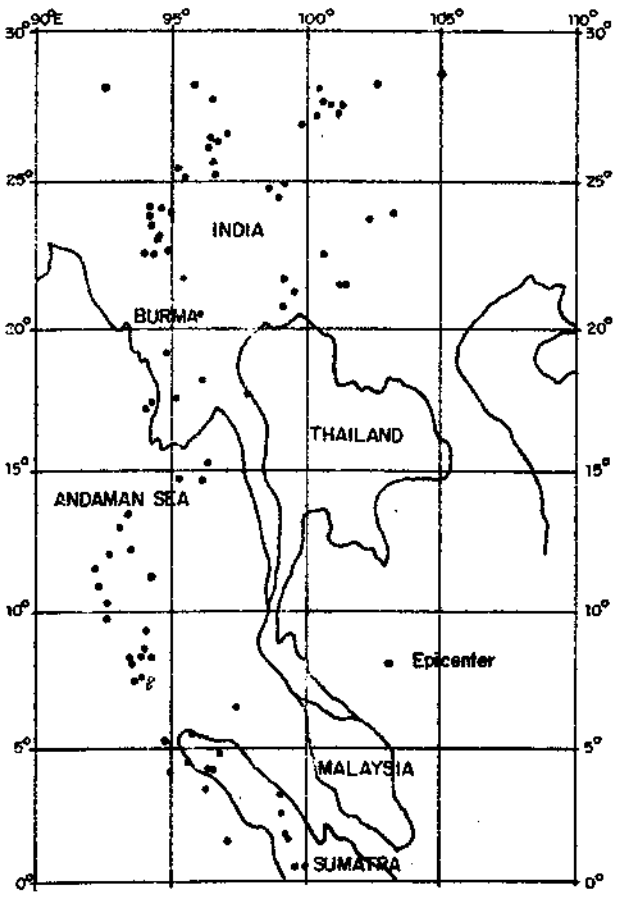

Fig.2 Seismicity Map of Sumatra-Burma Belt
(Yensuang, 1978)

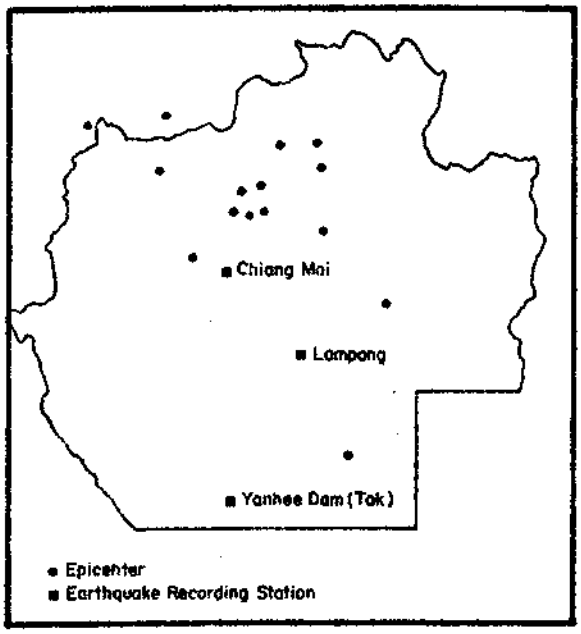

Fig.3 Map of Epicenter in Northern Thailand, Dec. 1977 – July 1978 (Yensuang, 1978)

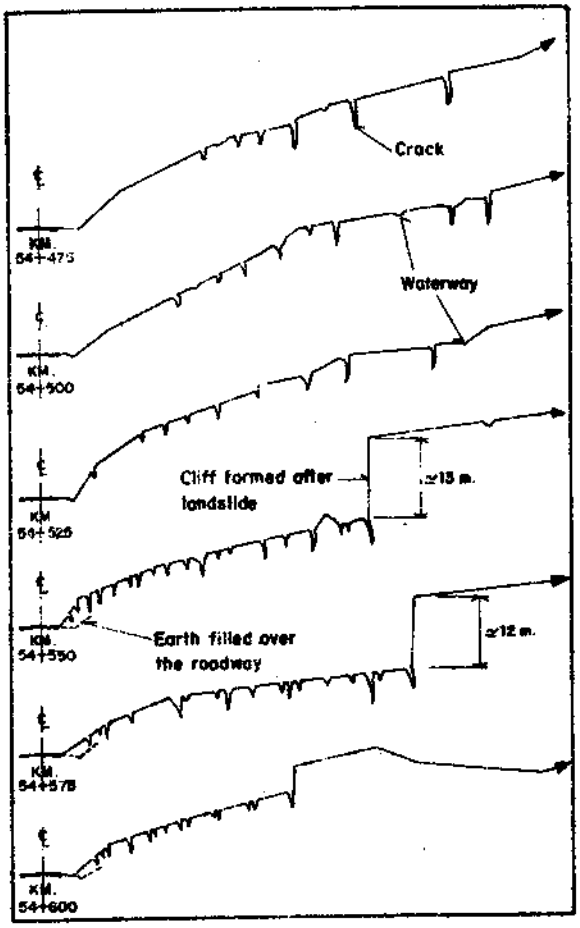

Fig.4b Cross-Section between Km.54+475 - -54 +600 of Srisatchanalai-Denchai National Highway after Landslide

รายงานฉบับที่ วว. 51 กองวิเคราะห์และวิจัย กรมทางหลวง
ผู้เขียน : ดร. ธีระชาติ รื่นไกรฤกษ์ , ภูชงค์ ชินพงสานนท์
ชื่อเรื่อง : ลักษณะทางธรณีวิทยาและการสั่นสะเทือนของผิวพิภพต่อการเคลื่อนตัวของดินในภาคเหนือของประเทศไทย

บทคัดย่อ : ในอดีต ภาคเหนือของประเทศไทยได้ถูกกระทำโดยแรงในลักษณะต่างๆ ทำให้เกิดการขยับตัวบนผิวพิภพ และก่อให้เกิดรอยแตกร้าวทั่วไปในโครงสร้างทางธรณีวิทยา ในปัจจุบัน แรงสั่นไหวต่างๆ ยังคงมีอยู่ โดยจะสังเกตได้จากการเกิดแผ่นดินไหวในภาคเหนือ ผลจากสภาพทางธรณีวิทยาและจากแรงสั่นไหวดังกล่าวนี้ ทำให้เกิดการขยับตัวของดินหรือของภูเขาในภูมิภาคนี้ ทางหลวงที่ตัดผ่านในบริเวณดังกล่าว จึงมักประสบปัญหาดินเคลื่อนตัวเป็นประจำ รายงานฉบับนี้ได้แสดงผลของโครงสร้างทางธรณีวิทยาและผลของการสั่นสะเทือนอันเนื่องจากแผ่นดินไหว ซึ่งเป็นสาเหตุทำให้เกิดดินเคลื่อนตัวในภาคเหนือของประเทศไทย

ทล. วว. / ว. 41 / 2523 / ธ.

Report No. MR 51 , Materials & Research Division, Department of Highways
Authors : Teeracharti Ruenkrairergsa , Puchong Chinpongsanond
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