Investigation of Slope Instability of a Concrete-Faced Slope in Chiangrai

Phantachang, T.
Department of Civil Engineering, Faculty of Engineering, Rajamangala University of Technology Lanna Chiangrai

Jotisankasa, A.
Geotechnical Engineering Research and Development Center, Department of Civil Engineering, Faculty of Engineering, Kasetsart University, Bangkok

Reference :
Phantachang. T. & Jotisankasa, A., 2010. Investigation of Slope Instability of a Concrete-Faced Slope in Chiangrai. International Conference on Slope 2010 : Geotechnique and Geosynthetics for Slopes, 27-30 July, 2010 Chiangmai, Thailand. organized by the Department of Highways, Thailand (DOH)

Keywords: slope stability, fill, concrete face, piezometer, pore water pressure

ABSTRACT: Signs of distress and movement have been observed on the concrete-faced slope in Rajamangala University of Technology Lanna Chiangrai. The slope was constructed as fills in 2002 on the siltstone/sandstone hill, with multi-storey buildings situated nearby. As a precaution measure, various instrumentations have been installed on the slope, including piezometer, tensiometer, in-place inclinometer as well as rain gauge. A wide range of materials involved in the fill slope vary from clayey sand, low-to-high plasticity silt as well as low-to-high plasticity clay. The monitoring results of pore water pressure indicate a high groundwater table within the slope, due to the hydro-geological feature of the slope, the presence of concrete face and only limited length of the horizontal drains. The inclinometer reading show some steady movement of the slope during the monitoring period which is not clearly related to the rainfall pattern. Sensitivity analysis performed based on the observed pore water pressure profile indicate that the factor of safety would be increased by about 16% by lowering the ground water. A slope stabilization based on dewatering principle has thus been considered as a future remedial measure.

1 BACKGROUND

Slope instability is a common problem in Chiangrai province, which is situated in Northern part of Thailand as shown in Figure 1. Natural slopes as well as fill/cut slopes along highway and buildings suffered from landslide problems affecting infrastructure development of the province.

Rajamangala University of Technology Lanna Chiangrai campus in Umpur Phan was established in 1999, of which many campus buildings were constructed on hillsides slopes, with shallow footings. Many of these footings are seated partly on fills and natural soils. At the time of construction, compaction quality control was not fully practiced throughout the campus, the fill materials used as foundation soils in some locations were considered to be poorly compacted and randomly selected. Their properties thus vary greatly and heterogeneity is to be expected.

In particular, signs of distress and movement have been observed on the concrete-faced slope where the laboratory building of civil engineering department was located (Figure 2). The fill slope was constructed in 2002 and faced with concrete slab (5 cm thick) on beam (25cm thick). The concrete face was seated on the slope without internal drainage. Only short weep holes (5cm in length) were provided on the concrete slab at about 2 metre spacing. Nevertheless, majority of these holes appear to be clogged only a few years after their construction.

Figure 1: Location of the studied site.

These observations led to serious concern on the overall safety of the building. Therefore, a program of instrumentation, site investigation and stability analysis was initiated in order to understand the cause of the instability, to assess any likely continuation of movement and finally to find the most effective stabilization method.

Figure 2: Studied slope and crack observed on concrete face.

2 MATERIALS

2.1 *Geology and Soil Investigation*

The geology in Chiangrai province consists of rocks in the Upper Paleozoic Era, including siltstone interbeddend with limestone, volcanic rock andesite tuff and rhyolite tuff (Department of mineral resources, 2007). The studied slope was constructed as cut and fills in 2002 on the siltstone and sandstone hill with a uniform slope angle of 30^{o} and a 4 m wide berm at the middle part of the slope (Figure 2). The material on the slope was investigated by ways of hand auger borehole, and light weight dynamic cone test (or the so—called kunzelstab penetration test). The ground profile is shown in Figure 3 consisting of low plasticity clay, high plasticity silt, high plasticity clay and low plasticity silt. The basic properties of the materials are summarized in Table 1.

As shown in Figure 4, the soil under the concrete slab on the upper slope, especially near the ground surface, appeared loose with a high water content. The material near upper slope (Figure 4a) is classified as poorly graded gavel with low plasticity clay (CL) while those near the lower slope (Figure 4b) is classified as low plasticity clay (CL) with high moisture contents.

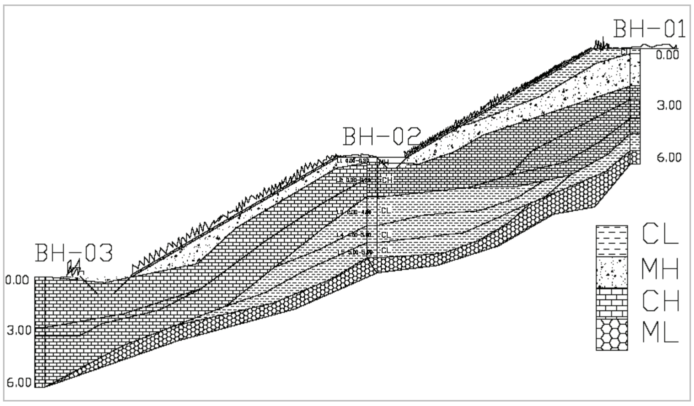

Figure 3: Typical ground profile of the study area.

Table 1: Summary of material properties.

Depth	Atterberg's limits, %			G_S	USCS
(meter)	LL	PL	PI		
0.00-0.30	48.19	28.18	28.72	2.688	CL
0.30-5.00	65.01	32.50	32.51	2.800	CH
5.00-6.00	50.80	48.61	2.19	2.850	MH
6.0 0-8.00	41.10	28.03	13.07	2.500	ML

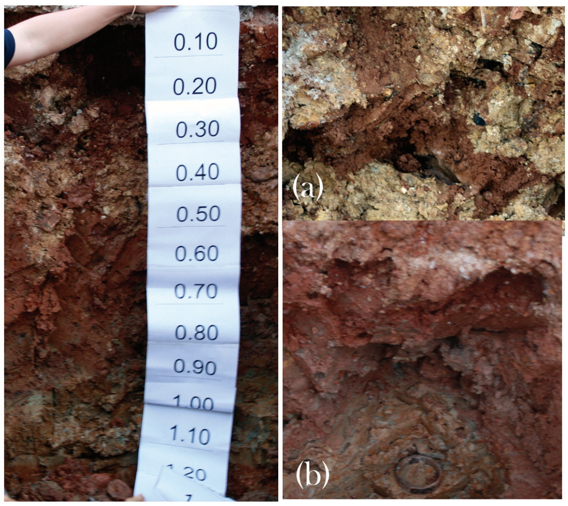

Figure 4: Soil profile under concrete slab.

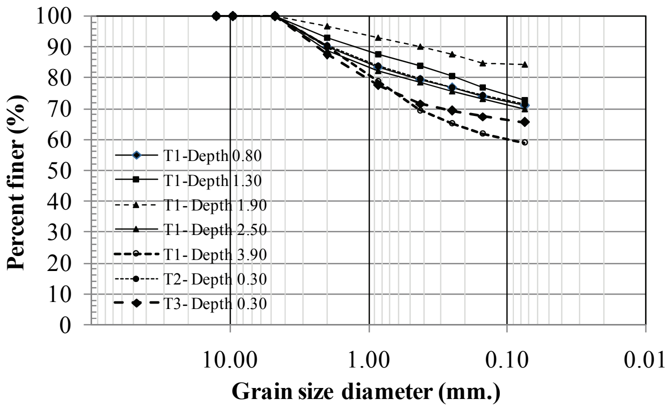

Figure 5: Grain size distribution curves.

2.2 *Soil Strength Parameter Test*

In order to investigate the strength characteristic of the soil, a series of slow direct shear test (with a shearing rate of 0.01 mm/min) were conducted at normal stress range of 64 to 252 kPa on undisturbed samples. These samples were collected near the first bench of the slope about 1m into the slope. Undisturbed samples at greater depths were not taken due to limited sampling equipments and budget. The behaviour of the material at the surface is however thought to be approximately representative for the whole slope in this first stage of study. The stress-strain behavior observed in the shearing tests appear to be mainly strain hardening, which is typical of loosely compacted soils, as show in Figure 6 and Figure 7. Some trial tests were conducted in order to investigate the influence of shearing rate. The shearing rate variation (between 0.001 and 0.05 mm/min) was found to be insignificant for the values of strength determined.

The failure envelope of unsoaked sample is only slightly above that of soaked sample. This is because the unsoaked samples were nearly saturated (degree of saturation, Sr = 86%) and the samples' suction could have been small.

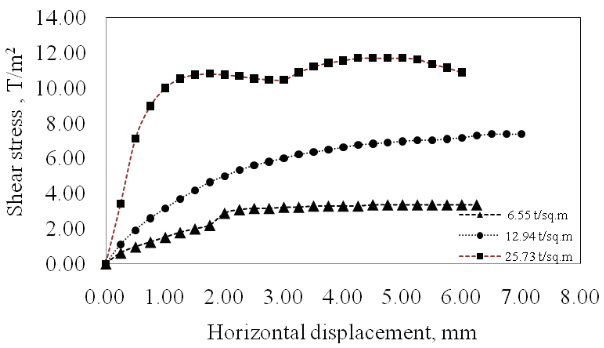

Figure 6: Typical results of slow direct shear.

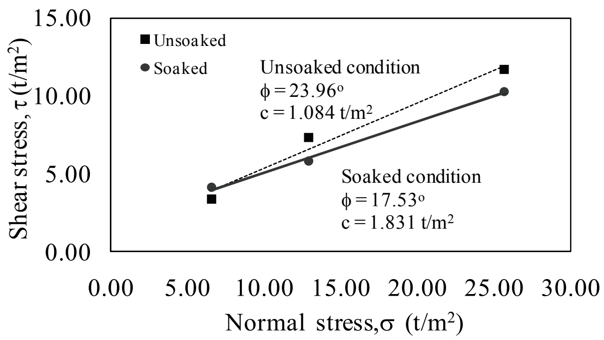

Figure 7: Failure envelopes from the slow direct shear tests on samples in soaked and unsoaked conditions.

3 INSTRUMENTATION

3.1 *Instrument Locations*

Extensive instrumentation has been installed on the slope as indicated in Figure 8 and Figure 9. Six stations of piezometers, nine stations of tensiometers, four observation wells and rain gauge were installed as well as inclinometers at four elevations. The tensiometers have been developed by Jotisankasa et al. (2007) and manufactured at Kasetsart University using commercial miniature MEMs pressure sensors and standard 1bar AEV porous stone. The devices, capable of measuring pore water pressure ranging from -80 to 600kPa, were installed at depths of 0.5m and 1m. One manual bucket rain gauge was also installed near the slope. Inclinometers installed were based on MEMs accelerometer attached to a PVC tube buried to a depth of firm ground about 1.5 – 7.5m below ground surface. The readings from the sensors were recorded with a manual readout system as shown in Figure 10.

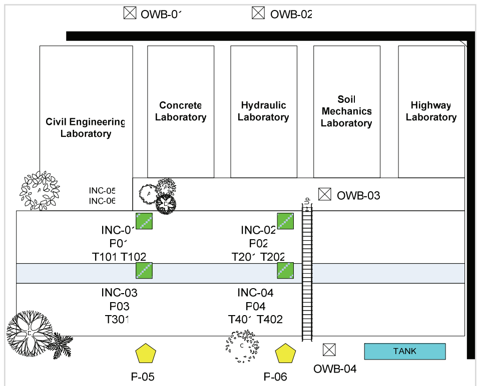

Figure 8: Plan of the studied site and instrumentation layout.

Figure 9: Cross sections and instruments location.
(x,y,z) = (position number, sensor number, 1=left side 2=right side)

Figure 10: Instrument installation and monitoring.

3.2 *Monitoring Results*

Typical results of pore water pressure and rainfall during the monitoring period from 10th April to 30th December are shown in Figure 11. During the rainy season, pore water pressure from P05 sensor increased gradually ranging from 0 to 15 kPa and then began to decrease slightly after the peak of rainfalls in the rainy season (around August). The inclinometer reading show some steady movement of the slope during the monitoring period as shown in Figure 12. The slope movement seems to be at a creeping rate, corresponding to the high ground water table. This observation is similar to the pattern of creeping slopes in Doi-Tung development project as described by Jotisankasa & Soralump (2008).

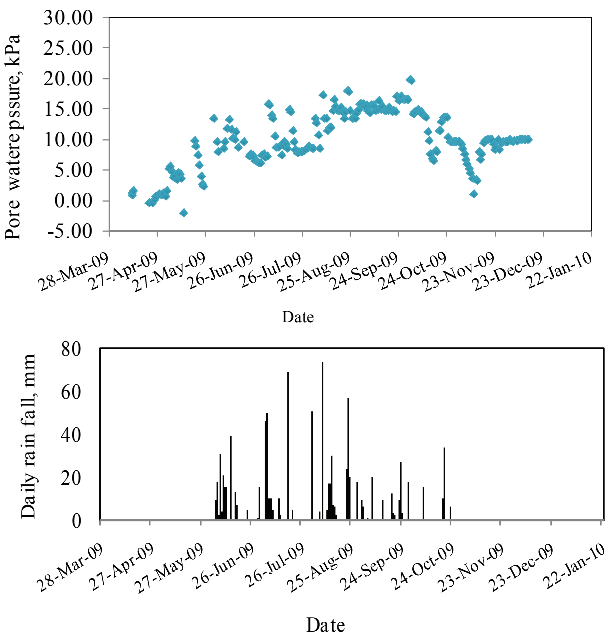

Figure 11: Pore water pressure and daily rainfall.

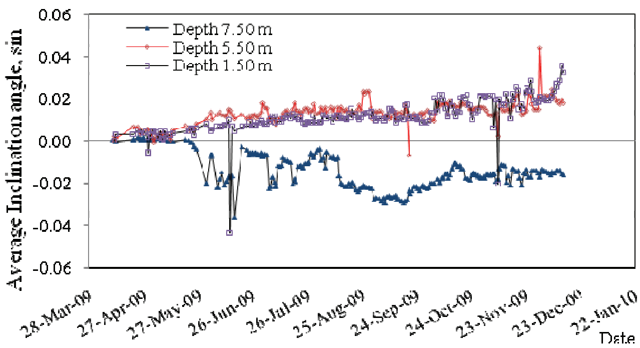

Figure 12: Inclination at various depths and time.

Based on the readings of piezometers and tensiomenter at section 2 during rainy season (8th August 2009) and before dry season (8th December 2009), the total head contours were plotted in order to indicate the approximate flow line or the seepage directions (which is normal to equipotential line) as shown in Figure 13 and 14. It is clearly shown that the total head contours and seepage direction did not differ much between 8th August and 8th December 2009, suggesting the steady ground water level in the slope under the cover of concrete slab.

4 SLOPE STABILITY ANALYSES

In order to put the soil investigation data, and field monitoring results in the context of slope stabilization, some Limit-Equilibrium slope analyses were performed using simplified Bishop Method. The analyses were performed for two scenarios; including (*i*) slope with current ground water level and (*ii*) slope stabilized by perforated pipes (5 cm in diameter, 12 m in length for upper slope and 10 m in length for lower slope) as shown in Figure 15.

The analysis results for case (*i*) shows that the global factor of safety is 1.362 (Figure 16). With the ground water level lowered as in case (*ii*) the factor of safety is increased to 1.582 (Figure 17). The results show that the drainage system proposed could increase the factor of safety by about 16% as a result of increase in effective stress and shear strength. Whether this increase in Factor of safety could lead to cessation of the bulging and cracking of the slope is yet to be confirmed. Nevertheless, the dispersivity of the fill materials (Sherard et al., 1976) should also further investigated in order to ensure that the drainage principle will stabilize the slope and not causing further dislodging of fine particle or internal erosion from the slope.

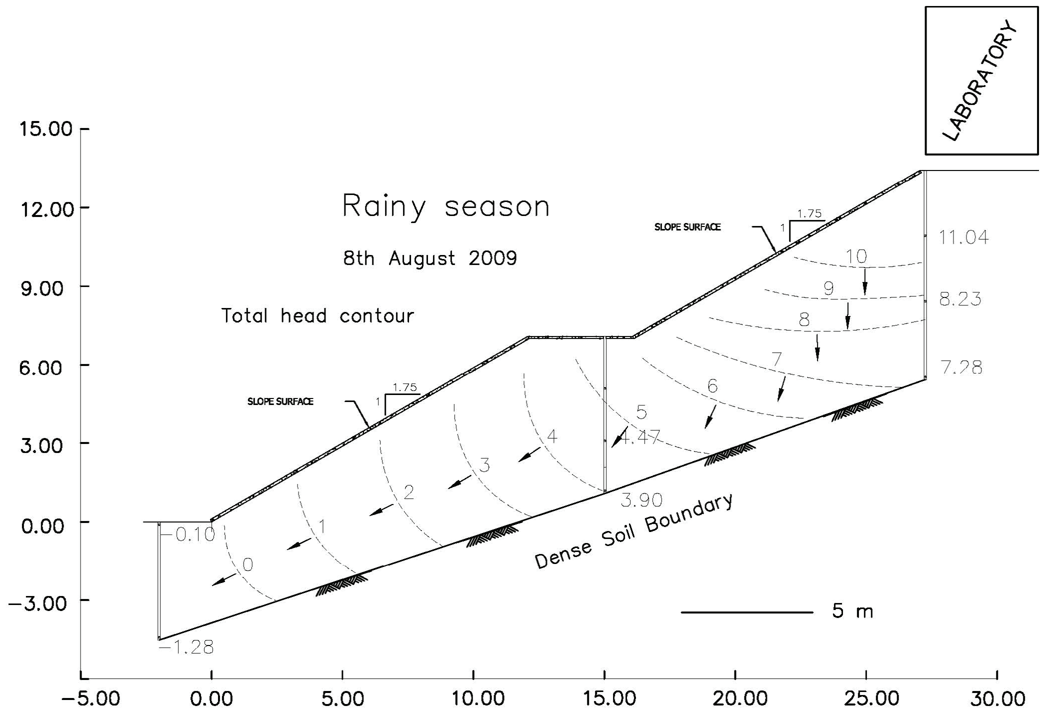

Figure 13: Total head contour (metre) and seepage direction during rainy season.

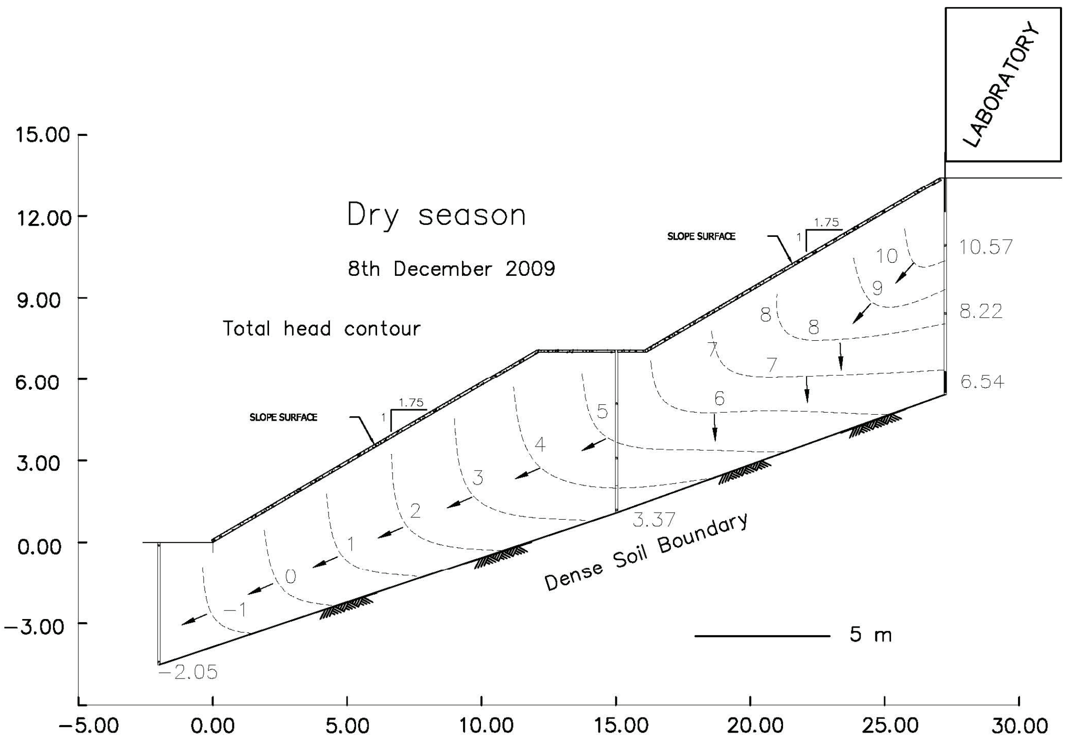

Figure 14: Total head contour (metre) and seepage direction before dry season.

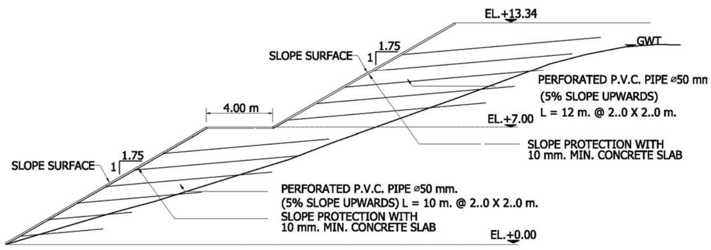

Figure 15: Slope stabilization using drainage.

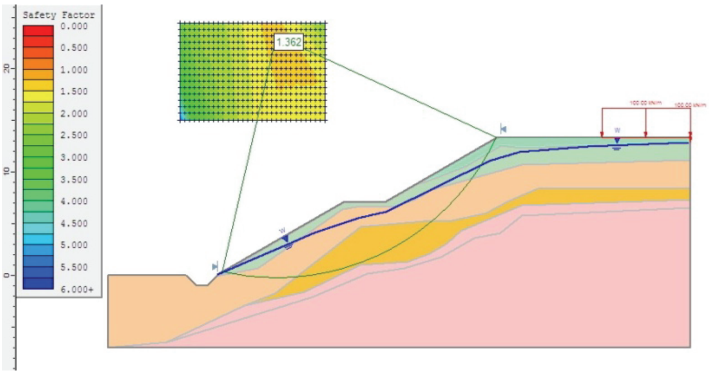

Figure 16: Slope stability analysis – slope without stabilization.

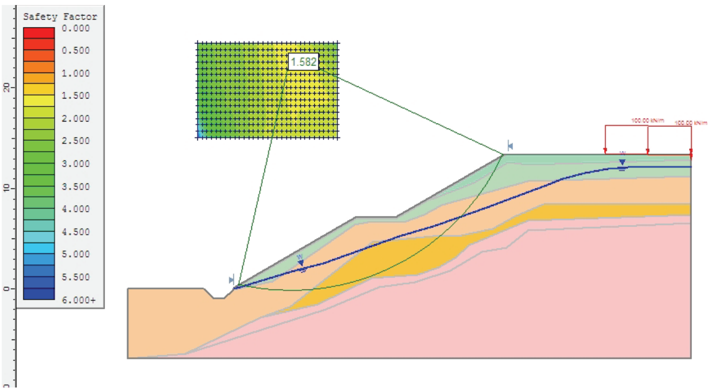

Figure 17: Slope stability analysis – slope with stabilization.

5 SUMMARY AND CONCLUSIONS

The investigation of slope instability of a concrete-faced slope in Chiangrai RMUL Chiangrai campus has been reported including the 8 month monitoring results using piezometers, tensiometers and inclinometers as well as stability analysis. The monitoring results show a relatively high ground water table and side-flow seepage under the concrete faced slope due to lack of drainage in the slope. This high pore water pressure leads to lowered effective stress and lowered shear strength of the fill material and foundation as well as soil movement and cracks on slope surface. The inclinometer reading similarly show some steady movement of the slope during the monitoring period corresponding to high ground water table.

The proposed stabilization technique of the slope is the installation of perforated pipe as drainage which could increase the factor of safety by about 16%. Further investigation is required on the effectiveness of this method as well as the possibility of the dispersivity of the material involved.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the research grant by the office of National Research Council of Thailand and to RMUTL Chiangrai campus for allowing the use of this study area.

Also gratefully acknowledged are the guidance of Dr. Warakorn Mairaing, and Mr.Rattatam Isaroranit as well as RMUTL students who have helped and worked for this research.

REFERENCES

Department of mineral resources (2007). *Geology of Thailand* (in Thai), Bureau of geology, Bangkok.

Jotisankasa, A. and Soralump, S (2008). Monitoring Slope Deformation near Doi Toong Palace. *Proceeding of the 13th National Convention of Civil Engineering. Thailand.* (in Thai)

Jotisankasa, A.,Hunsachainan, N., Kwankeo, N., Chunrod, P. and Mancharoen, J. (2010). Development of a wireless landslide monitoring system. *International conference on slope Thailand 2010. Geotechnique and geosynthetic for slopes.* 27-29 July 2010, Chaingmai

Jotisankasa, A., Porlila, W., Soralump, S., and Mairiang W. (2007). Development of a low cost miniature tensiometer and its applications. *Proc. 3rd Asian Conference on Unsaturated Soils (Unsat-Asia 2007),* Nanjing, China, 21-23 April 1007, 475-480

Jotisankasa, A. and Tapparnich, J. (2010). Shear and soil-water retention behaviour of a variably saturated residual soil and its implication on slope stability, *5th International conference on unsaturated soils,* Barcelona, 6-8 September 2010

Sherard, J.L., Dunnigan, L.P., Decker, R.S. 1976. Identification and Nature of Dispersive Soils. *Journal of the Geotechnical Engineering Division.* pp. 287-301.