SIMSG ISSMGE

ISSMGE Bulletin

Volume 5, Issue 6
December 2011

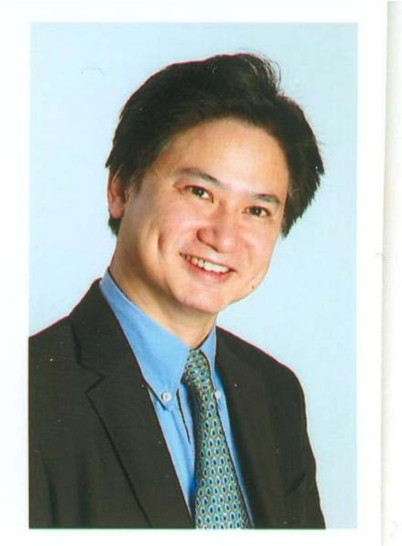
International Society for Soil Mechanics and Geotechnical Engineering

If the quality of the distributed file is not satisfactory for you, please access ISSMGE website and down load a better one.

www.issmge.org

Message to ISSMGE Members
Charles W.W. Ng, Appointed Board Member of ISSMGE

INSIDE THIS ISSUE



It is my great honour and pleasure to be appointed by the President – Professor JL Briaud as one of 12 Board Members to serve the community of ISSMGE. In this bulletin, I would like to share with you some of my recent experience about promoting and improving the standard of soil mechanics and geotechnical engineering in three developing countries in the Far East of Asia and a case history about one of the largest civil, geotechnical and hydraulic engineering projects in the world – the South-to-North Water Diversion Project (SNWDP), which is being planned, designed and constructed in China. This report is therefore divided into two parts, which are composed of Part A - International seminar and Part B - the SNWDP in China (geotechnical aspects).

PART A - INTERNATIONAL SEMINAR IN THE FAR EAST OF ASIA

Under the leadership of the immediate Past President of ISSMGE, Professor Pedro Pinto and the President of the Southeast Asian Geotechnical Society (SEAGS), Dr Ooi Teil Aun from Malaysia, a series of international seminars were organized and held in three developing countries including Cambodia, Laos and Myanmar, which are not yet member societies of ISSMGE. Prior to the international seminars, three days of lectures were delivered by Professors Dennes Bergado (together with Ir Dr Lai Yip Poon), Pedro Pinto and myself in Kuala Lumpur from 31 July to 2 August 2011. The contents of the lectures

Plate 1 – Five speakers in Phnom Penh seminar (with courtesy of Dr Ooi)

Message to ISSMGE Members (Continued)
Charles W.W. Ng, Appointed Board Member of ISSMGE

INSIDE THIS ISSUE (CONTINUED)

covered far field seismic design, soil improvements and design case histories, and advanced unsaturated soil slope engineering. After the three-day lectures, the series of international seminars began in Phnom Penh of Cambodia on 4 August 2011. Plate 1 shows the five speakers at the Phnom Penh seminar. About 200 participants attended the seminar. Subsequently, three more one-day seminars were held in Vientiane of Laos, Yangon and Mandalay of Myanmar from 8 to 11 August 2011. Approximately 120 participants attended the one-day seminar. What I learnt from travelling and giving the seminars in these countries are (i) they are hungry for knowledge (not necessary the most advanced one but practical enough for their local conditions); (ii) they need our help and assistance to meet their rapid economic growth; (iii) ISSMGE can certainly play a major role and make an impact.

PART B - THE SOUTH-TO-NRTH WATER DIVERSION PROEJCT IN CHINA (GEOTECHNICAL ASPECTS)

B1. Introduction

In addition to the world largest hydropower project – the Three Gorges Dam in China, another mega infrastructure project being undertaken is the South-to-North Water Diversion Project (SNWDP) as shown in Figure 1. This project is intended to tackle the uneven distribution of water resources in China since the north accounts for 37% of the country's total population and 45% of cultivated land, but it only shares 12% of the total water resources. Over 80% direct water runoff in China takes place in the south. The total annual discharge of the Yangtze River in the south, is 1,000 billion m^3, about 20 times that of the Yellow River in the north. The SNWDP has therefore been proposed to carry potable water from the Yangtze River region in the south to many arid and semi-arid areas in the northern regions of China. As shown in Figure 1, three water transfer projects have been proposed, i.e., the Eastern Route, the Middle Route (or Central Route) and the Western Route. The Eastern Route starts from the lower reach of Yangtze River to supply water for the eastern Huang-Huai-Hai Plain and terminates in Tianjin and Weihai. The construction of the Eastern Route is almost completed. The Middle Route runs from Danjiangkou Reservoir in Xichuan County, Henan province and Danjiangkou City, Hubei province along the Hanjiang River, which is a tributary of the Yangtze

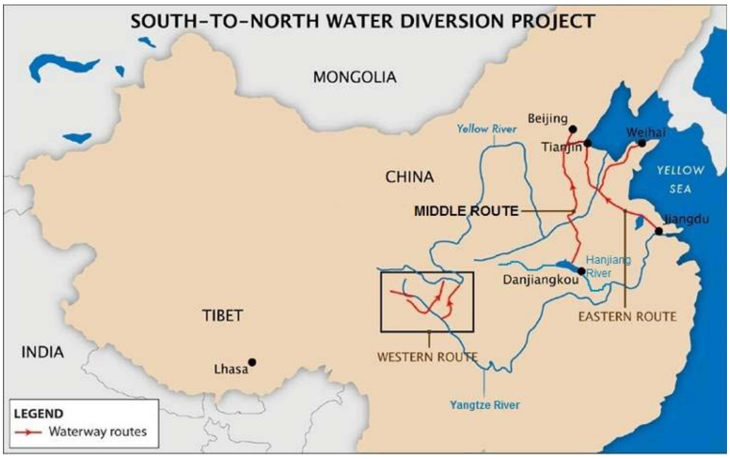


Figure 1 General layout of the South-to-North Water Diversion Project (Modified from http://www.meltdownintibet.com/images/map_diversion2_lg.gif)

Message to ISSMGE Members (Continued)
Charles W.W. Ng, Appointed Board Member of ISSMGE

River, to Beijing and Tianjin. This route is being designed and is partly under construction. The Western Route is planned to divert water from the upper reach of the Yangtze River into the upper and middle reaches of the Yellow River. At present, this SNWDP is believed to be the largest infrastructure project in the world and the planned construction period for the entire project is about 50 years. Due to page limit, only some geotechnical challenges and research work carried out relevant to the Middle Route (MR) of SNWDP are introduced and discussed in this bulletin.

The MR is composed of two major parts: engineering structures in the water source region and the water transfer systems. The former includes Danjiangkou Dam extension on the Hanjiang River in Danjiangkou City, Hubei province, whereas the latter consists of the main trunk canal for diverting water from the Hanjiang River to Beijing and Tianjin. The total length of the MR is about 1,432km. The design water level at the start of the main trunk canal is about 147m and that at the termination is about 49m (http://www.nsbd.gov.cn/zx/english/mrp.htm). In other words, the difference in elevation along the canal is about 100m, which permits water flowing mostly under the gravity along the entire canal. Figure 2 shows the existing 60m wide intake of the main trunk canal in Nanyang, Henan. Along the MR, the shape of the open-channel canal is being finalized. It is most likely to be a trapezoidal cross section formed by cut slopes and fills.

Figure 2 Intake canal of the Middle Route in Nanyang, Henan

Figure 3 A typical failure of an expansive soil slope at Dagangpo

B2. Geotechnical challenges of the Middle Route (MR)

The MR of SNWDP passes through different geological conditions and encounters various geotechnical challenges including how to ensure the long-term slope stability of the trapezoidal shaped canal in unsaturated expansive soils and rocks, and the design and construction of the canal to cross the Yellow River. In order to connect the canal at both banks of the Yellow River, two parallel tunnels with internal diameter of about 7m were constructed across the riverbed by the shielding tunnel method. The total length of each tunnel is 4,250m. More details about the Yellow River crossing project can be found in the website: http://www.nsbd.gov.cn/nsbdgc/zxgc/ch/. Due to page limit, this report only focuses on the investigation and design of the slope stability for the trapezoidal shaped canal.

About 386.8km of the proposed main trunk canal of the MR passes through areas of unsaturated expansive soil (217.1km) and soft rock (169.7km) (Liu et al., 2011). It is well-known that expansive soil and weak rock have a potential for swelling when there is an increase in water content (Bao & Ng, 2000). The swelling in expansive soil/soft rock is mainly due to the presence of active clay minerals such as montmorillonite. Swelling-induced slope failures are often observed. Figures 3 and 4 show typical shallow retrogressive slope failures of expansive soil slopes at Dagangpo in Zaoyang, Hubei.

Message to ISSMGE Members (Continued)
Charles W.W. Ng, Appointed Board Member of ISSMGE

Figure 4 Typical shallow retrogressive failures at Dagangpo

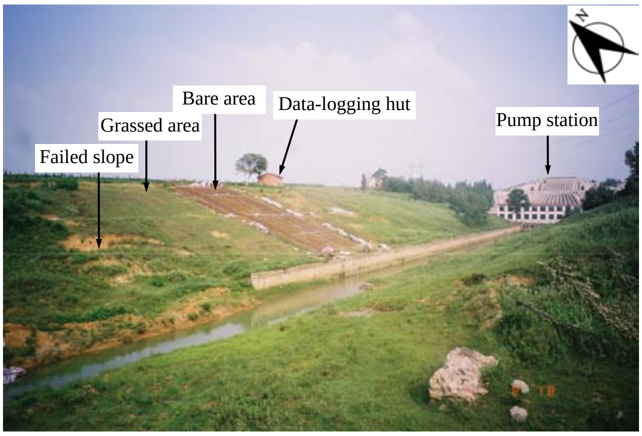


Figure 5 General layout of the test site in Zaoyang for preliminary field study

B3. Preliminary field study for the schematic design of MR

It is generally recognized that a number of landslides in unsaturated soils are triggered by rainfall infiltration during wet seasons (Bao & Ng, 2000). To assist the schematic design of canal for the MR of SNWDP in unsaturated expansive soil, a research collaboration was developed between the Hong Kong University of Science and Technology (HKUST) and the Yangtze River Scientific Research Institute (YRSRI), under the leadership of Professor C.G. Bao (the former director of YRSRI), to carry out a comprehensive field monitoring programme to investigate the fundamental mechanisms of rainfall-induced landslides in unsaturated expansive soil (Ng et al., 2003). An 11m high cut slope in a typical medium-plastic expansive clay in Zaoyang, close to the MR in Hubei, China, was selected for the well-instrumented field study. Some key monitored responses of the unsaturated expansive soil slope due to changes in both suction and net stress (i.e., two stress state variables governing unsaturated soil behaviour) are described and summarized in this bulletin.

Test site

The test site was located at the intake canal of the Dagangpo second-level pumping station in Zaoyang, Hubei. It was about 230km northwest of Wuhan and about 70km south of the intake canal for the SNWDP in Nanyang, Henan. The site is located in a semi-arid area with an average annual rainfall of about 800mm with 70% of the annual rainfall occurring between May and September.

The test site was selected on a cut slope on the northern side of the canal, as shown in Figure 5. The test site consisted of two neighbouring monitoring areas (both 16m wide by 31m long): namely a bare area and a grassed area. The bare and grassed areas may represent surface cover conditions of the real slope under different climatic conditions, such as winter and summer. The slope had an inclination angle of 22° and a height of 11m. There was a 1m wide berm at the mid-height of the slope, dividing the slope into upper and lower parts. The selected test areas had a significant depth of typical unsaturated expansive soil. The slope surface was originally grassed but no trees were present. The depths of roots observed on an excavated face ranged from 100 to 300mm. The bare area was obtained by removing the top soil to a depth of about 100mm.

Message to ISSMGE Members (Continued)

Charles W.W. Ng, Appointed Board Member of ISSMGE

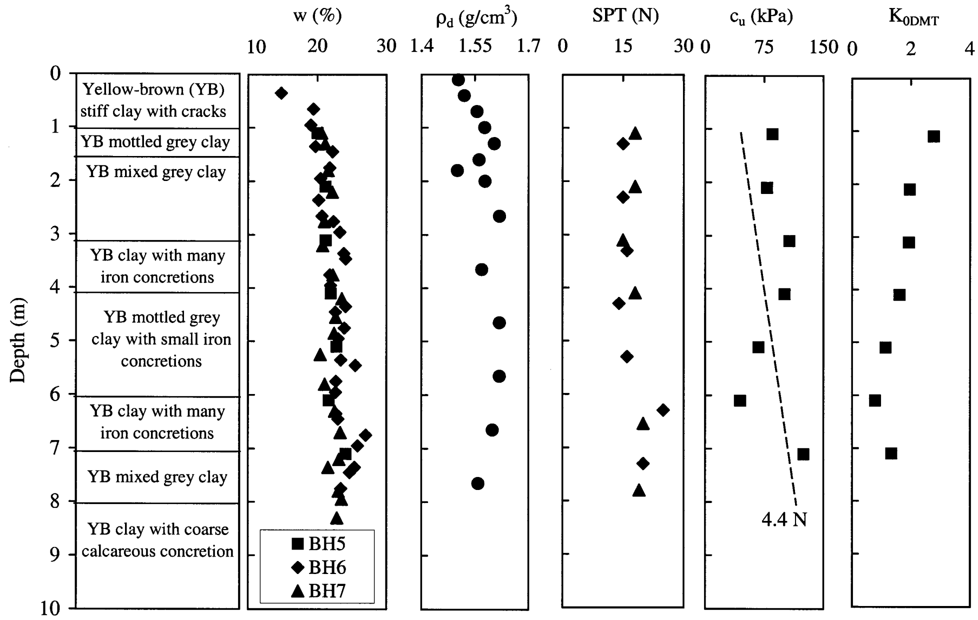


Figure 6 Soil profiles and geotechnical parameters (Ng et al., 2003)

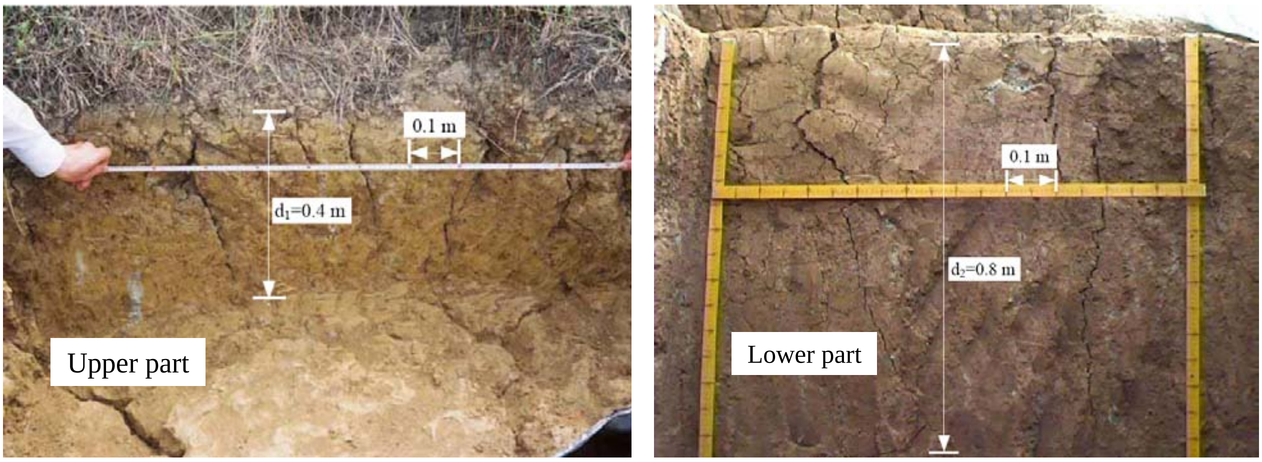


Figure 7 Cracks and fissures observed in a trial pit (Zhan et al., 2007)

Soil profile and properties

Prior to instrumentation, site investigation was carried out on the selected slope to investigate the ground conditions and soil properties. The obtained soil profile and geotechnical parameters are shown in Figure 6. The geotechnical parameters include water content (w), dry density (ρ_d), SPT N value, undrained shear strength (c_u) and K_0 value from dilatometer tests (K_{0DMT}). The predominant stratum below the slope surface is a brown-yellow mottled gray clay. The clay layer is sometimes interlayered with thin layers of gray clay or iron concretions. X-ray diffraction analyses indicated that the predominant clay minerals are illite (31%-35%) and montmorillonite (16-22%), with a small percentage of kaolinite (8%). The expansive clay is silty clay with an intermediate plasticity and a medium expansive potential.

Message to ISSMGE Members (Continued)

Charles W.W. Ng, Appointed Board Member of ISSMGE

Figure 7 shows cracks and fissures observed on the wall of a trial pit near the monitoring areas. The maximum depth and width of the open cracks observed were estimated to be approximately 1.2m and about 10mm, respectively.

Instrumentation and rainfall simulation

The layout of instrumentation in both the bare and grassed areas and the cross section of the instrumented slope are shown in Figures 8 and 9, respectively. It can be seen that the instrumentation includes jet-filled tensiometers and thermal conductivity sensors for measuring soil suction, Theta-probes for determining water content, vibrating-wire earth pressure cells, inclinometers, movement points, tipping bucket rain gauges, vee-notch flow meters and evaporimeters. The instruments were installed in three rows in both the bare and grassed areas, i.e., R1 in the upper part, R2 in the middle part and R3 in the lower part of the slope.

Artificial rainfall was produced to accelerate the field test program. Rainfall was produced artificially using a purpose-designed sprinkler system. Two rainfall events were simulated in the bare area. The first one lasted for seven days, from the morning of 18 August 2001 to the morning of 25 August 2001, with an average daily rainfall of 62mm. The second simulated rainfall was begun from the morning of 8 September 2001 to the afternoon of 10 September 2001 with an average rainfall intensity of 45mm per day. Due to the limited length of this bulletin, only some key monitored results obtained from the bare area are reported, including soil suctions or pore-water pressures, horizontal stresses and horizontal displacements.

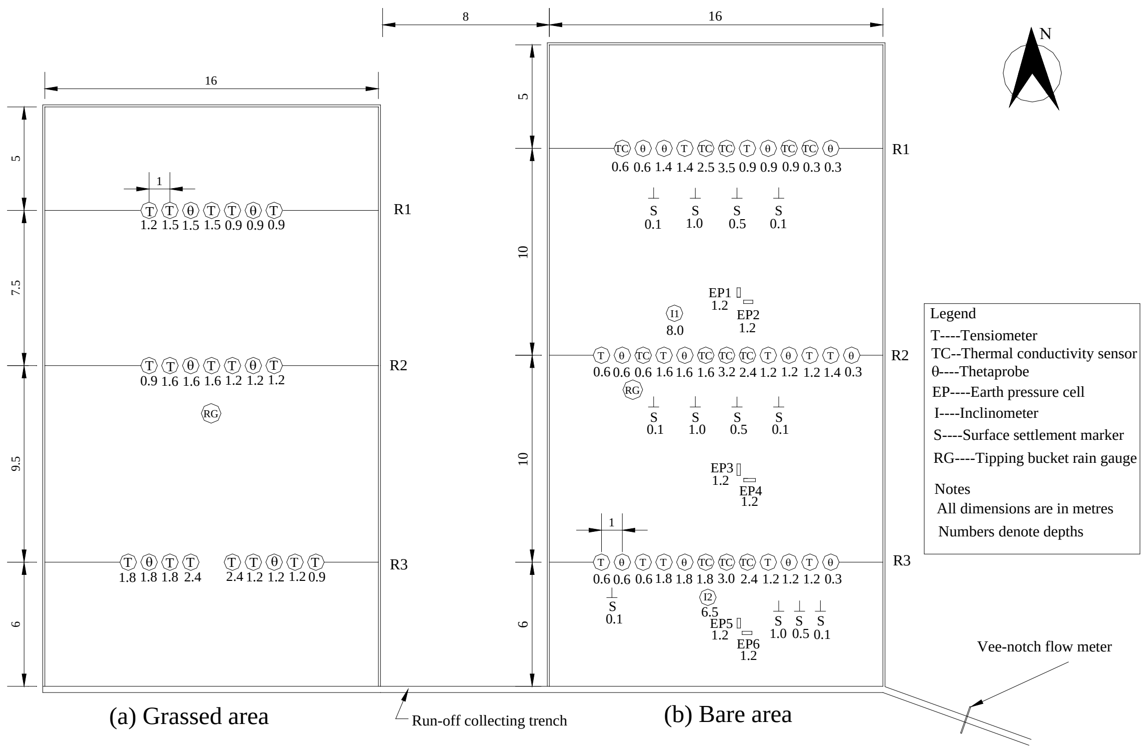


Figure 8 Layout of instruments on the expansive soil slope in: (a) Grassed area and (b) Bare area (Ng et al., 2003 and 2009)

Message to ISSMGE Members (Continued)

Charles W.W. Ng, Appointed Board Member of ISSMGE

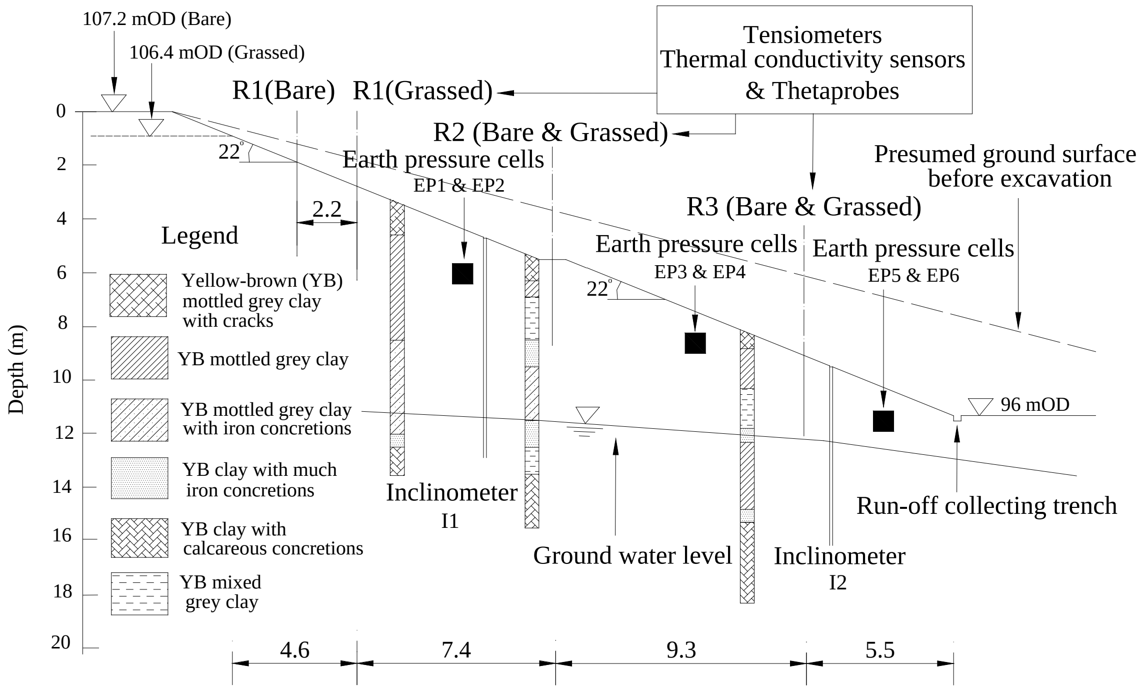


Figure 9 Cross-section of the instrumented slope (Ng et al., 2003 and 2009)

Soil suction or pore water pressure

Figure 10a shows measured negative pore-water pressures (PWPs) increased with time before the first rainfall event. This indicates that the soil was under drying conditions. As expected, the higher the elevation of the tensiometer, the higher the negative PWP. During the first two days of the first artificial rainfall event, the negative PWPs at different depths all continued to increase slightly. But they began to decrease after about two days of rainfall. In other words, there was a delay in the PWP response to rainfall infiltration.

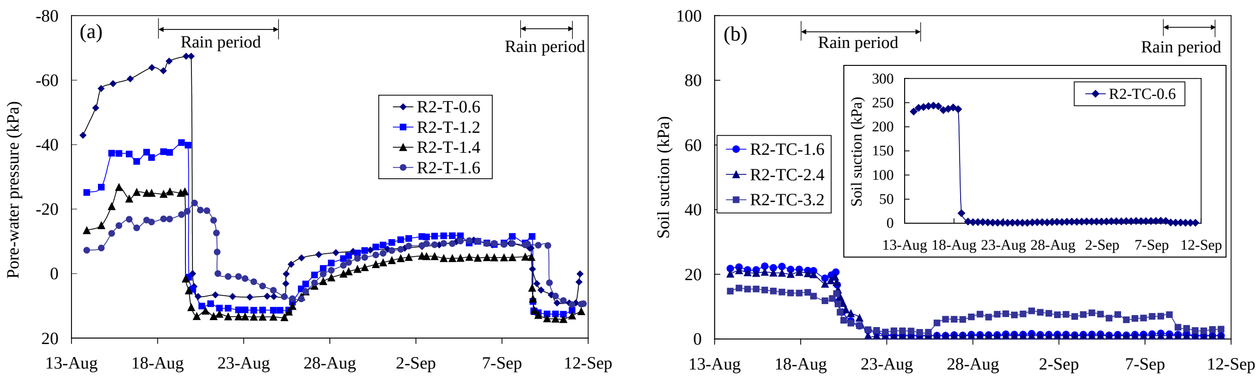


Figure 10 Variations of pore-water pressure or suction with time (Ng et al., 2003)

Message to ISSMGE Members (Continued)

Charles W.W. Ng, Appointed Board Member of ISSMGE

After the first rainfall was completed, the four tensiometers all showed an increase (or recovery) in negative PWP and appeared to reach a steady state condition after 2 September. Unlike the responses of tensiometers in the first rainfall, the lower three tensiometers showed almost no delay in response to the second rainfall. On the other hand, the top tensiometer showed a one-day delay. However, the "final equilibrium" PWPs recorded during the second rainfall was similar to those during the first one.

Figure 10b shows the soil suction responses to the two artificial rainfalls measured by thermal conductivity sensors. The responses were similar to those recorded by the tensiometers, but the former showed a slower rate of response than the latter. The magnitudes of PWPs or suctions measured by the two different types of sensors were generally consistent, particularly at the depth of 1.6m below ground. However, the thermal conductivity sensor at 0.6m below ground showed a very high soil suction of about 250kPa before the first rainfall, which was much larger than the negative PWP of about 62kPa measured by a tensiometer. This inconsistency between the results of the two sensors may be due to the inherent limitation of tensiometers caused by cavitation at high suction.

Horizontal total stress

The horizontal total stresses (σ_h) were measured by six vibrating-wire earth pressure cells (see Figures 8 and 9) installed at a depth of 1.2m, giving rise to an estimated total vertical stress (σ_v) of 23.4kPa. Figure 11 shows the variations of the monitored total stress ratio (σ_h/σ_v) with respect to time. Pressure cells EP1, EP3 and EP5 measured the stress changes acting in the East-West (EW) direction (i.e., perpendicular to the inclination of the slope), whereas EP2, EP4 and EP6 recorded pressures acting in the North-South (NS) direction (i.e., parallel to the inclination of the slope).

Prior to the first rainfall, the total stress ratios recorded by all the pressure cells were lower than 0.3. An initial equilibrium stress ratio appeared to have been established for each pressure cell shortly before the start of the rainfall. Two out of the six pressure cells registered a small tensile stress, probably induced as a result of soil drying. After the start of the first rainfall, no earth pressure cells registered any significant change of stress for about one and a half days. The delayed response of the earth pressure cells was consistent with the PWP responses (see Figure 10a). Once the earth pressure cells started to respond, the stress ratios increased rapidly and significantly within one day and then approached a steady value during the first rainfall event. For a given pair of pressure cells located at the same elevation, the measured stress ratio in the EW direction was always larger than that in the NS direction. This was likely caused by a higher constraint imposed in the EW direction as opposed to that in the NS direction. After the end of the first rainfall, a further increase in σ_h/σ_v was observed at EP1 and EP2 during the two-week no-rain period. On the other hand, the EP3 and EP4 pressure cells showed a slight decrease in σ_h/σ_v throughout the no-rain period, and EP5 and EP6 recorded a larger reduction in σ_h/σ_v.

After the start of the second rainfall event, the responses of the three pairs of earth pressure cells were distinctly different. At EP1 and EP2, the observed σ_h/σ_v decreased. This may be attributed to the softening of the soil after prolonged swelling during the no-rain period. In the earth pressure cells near the toe of the slope (EP5 and EP6), an increase in σ_h/σ_v was recorded due to the positive PWP during the second rainfall. The performance of EP3 and EP4 fell between the former two cases. The high in-situ stress ratio due to the swelling of expansive soil upon wetting might be one of the main reasons for the retrogressive shallow failures found near the monitored slope (see Figures 3 and 4).

Slope deformations

Figure 12 shows measured horizontal displacement profiles of the slope in response to the simulated rainfalls. The measured downslope (North-to-South, NS) and lateral displacements (West-to-East, WE) are defined as negative and positive, respectively.

Message to ISSMGE Members (Continued)

Charles W.W. Ng, Appointed Board Member of ISSMGE

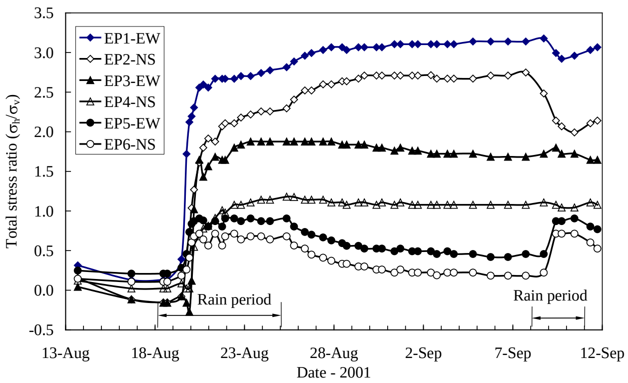


Figure 11 Variations of in-situ total stress ratio with time (Ng et al., 2003)

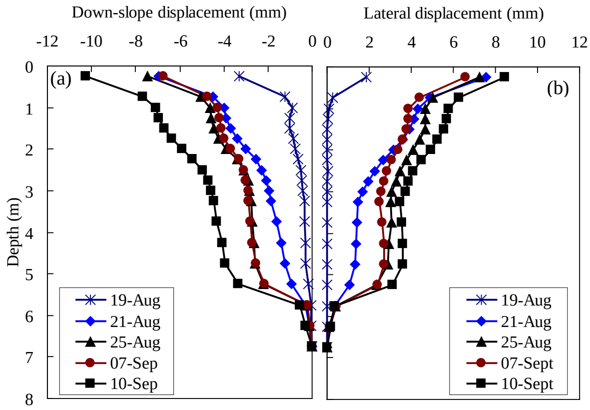


Figure 12 Observed horizontal displacement in response to rainfalls (Ng et al., 2003)

Figures 12a and b show the monitored horizontal displacements from inclinometer I2 located near the toe of the slope in the NS and EW directions, respectively. It can be seen that the magnitudes of displacement and deformed shapes observed in both directions were fairly consistent. The horizontal displacements measured on 19 August (after one day of rainfall) were small in both directions, probably because of the delayed response similar to PWP. After three days of rainfall (i.e., 21 August), there was a significant increase in horizontal displacements in both directions. After the first rainfall event, a small recovery of horizontal displacement (i.e., a shrinkage response) was observed with respect to both directions during the two-week no-rainfall period, due to the increase in soil suction. The horizontal displacements increased again after the second rainfall. A “deep-seated” mode of ground deformation was observed in both directions. The depth of influence zone was about 6m.

The results indicate that the ground moves toward the down-slope direction and towards the East direction. The observed eastern movements of the ground due to rainfall infiltration might be attributed to the direction of the sub-surface water flow from the West to the East.

B4. Field trials for the detailed design of the MR

After the success of the research collaboration between HKUST and YRSRI for the investigation of the unsaturated expansive slope in Zaoyang, the YRSRI was subsequently appointed to be the main designer of the MR of the mega SNWDP. Under the leaderships of Professors Cheng Zhan-lin, Li Qing-yun, Guo Xi-ling and Gong Bi-wei of YRSRI, a very comprehensive field trial programme was planned and carried out (Cheng et al., 2011) to investigate possible failure mechanisms of expansive soil and soft rock slopes with and without treatments and to verify design assumptions by using different protective and stabilizing schemes. Due to page constraints, theoretical design calculations are not included in this bulletin.

Two trial test sections, one for expansive soil slopes and the other one for expansive soft rock slopes, along the main trunk canal of the MR were selected for field trials. For the soft rock section, a length of 1.5km of soft rock slope of the canal in Luwangfen, Xinxiang, Henan, was instrumented and tested. The Luwangfen trial section consisted of eight test areas with different protective and stabilizing treatment schedules. Figure 13 shows a part of the Luwangfen test section for expansive rock. The bottom width of the canal is 9.5m and the heights of the trial slopes range from 15 to 42m. Depending on local geological conditions and expansibility of soft rocks, various slope angles (ratios), 1:1.5, 1:2.0, 1:2.5 and 1:3.0 were tested. More details of the field investigation on expansive rock slopes in the Luwangfen test section are given by Liu et al. (2011).

Message to ISSMGE Members (Continued)
Charles W.W. Ng, Appointed Board Member of ISSMGE

Figure 13 Part of Luwangfen test section in expansive soft rock (with courtesy of Professor Gong Bi-wei)

Figure 14 Part of Nanyang test section in expansive soil (Cheng et al. 2011)

For expansive soil slopes, a 2.05km long trial section was designed and built in Nanyang, Henan. The Nanyang test section consisted of totally 13 test areas. Figure 14 shows a part of the Nanyang test section in expansive soil. In the medium expansive soil region in Nanyang, seven trial areas were designed to evaluate different surface protective treatment measures. The surface layer of the original expansive soil slope in Area I was replaced by non-expansive clay. The surface layer of soil slopes in Areas II and V was replaced by cemented soil. Slopes in areas III and IV were protected by using soil bags and geogrids (see Figure 15), respectively. Slope in Area VI was stabilized and protected by composite geomembrane, while that in Area VII was untreated bare slope used as a control section. The bottom width of the canal is about 22m. The heights of slope range from 5 to 17m and the trial slope angle (ratio) is 1:2. A berm with a width of about 5m was constructed to separate the lower and upper slopes in the trial section.

Under two years of natural rainfalls, large horizontal deformations were observed in Areas I to V. Figures 16a and b show horizontal displacements measured by inclinometers at the upper and lower slopes treated with soil bags (Area III), respectively. The measured horizontal displacements at the upper and lower slopes treated with geogrids (Area IV) are also shown in Figures 17a and b, respectively. Failures of the slope (landslides) occurred in the first year in the treated Area III, while landslides happened in the second year of the treated Area IV.

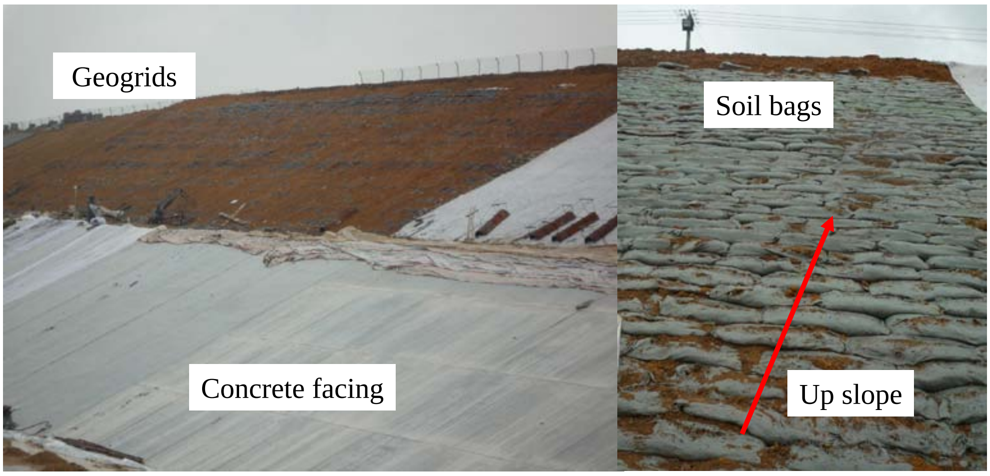


Figure 15 Use of geogrids and soil bags for surface protection and stabilization

Message to ISSMGE Members (Continued)

Charles W.W. Ng, Appointed Board Member of ISSMGE

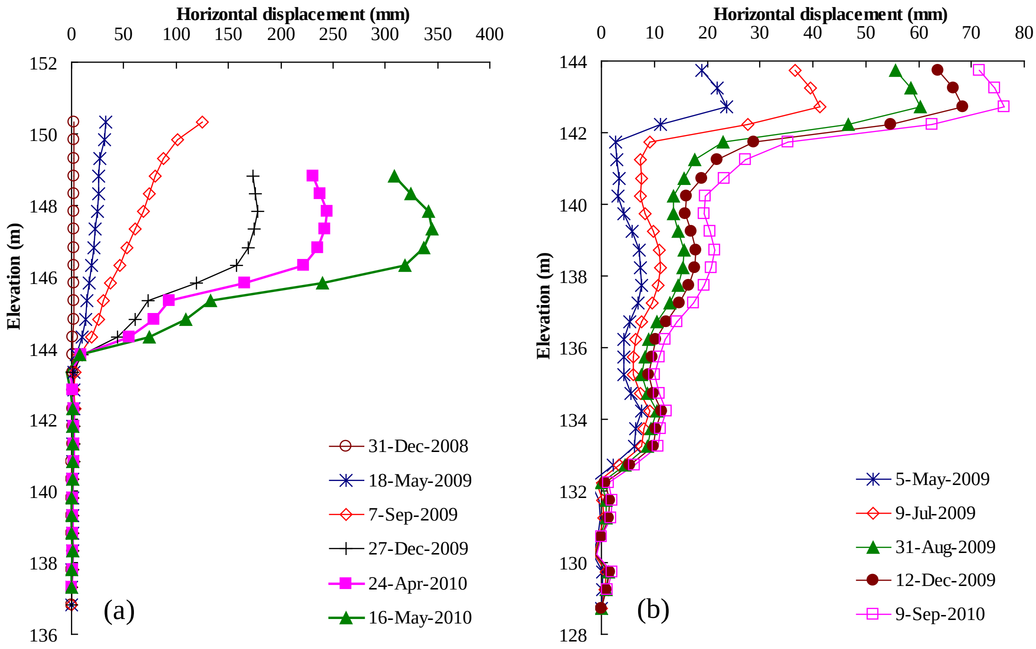


Figure 16 Measured horizontal displacements at (a) crest and (b) berm of the slope in Area III (treated with soil bags) (data from Cheng et al., 2011)

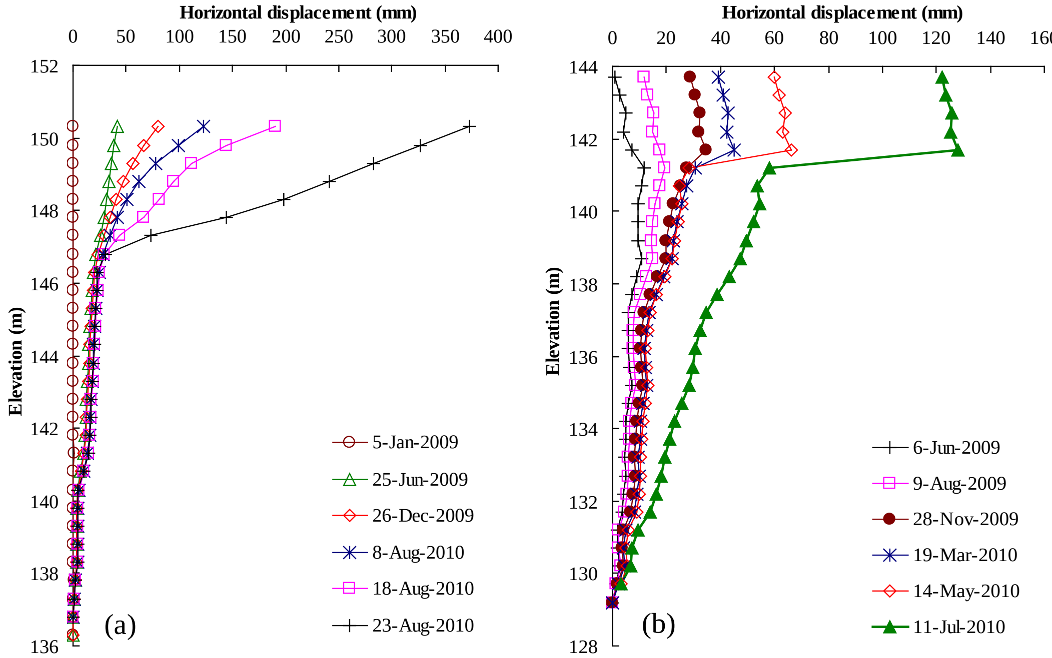


Figure 17 Measured horizontal displacements at (a) crest and (b) berm of the slope in Area IV (treated with geogrids) (data from Cheng et al., 2011)

Message to ISSMGE Members (Continued)
Charles W.W. Ng, Appointed Board Member of ISSMGE

B5. Physical model tests for the detailed design of the MR

In addition to field trials, controlled physical model tests were carried out under one gravity (1g) at YRSRI and at elevated gravity in the geotechnical centrifuge facility at HKUST.

1g model test for the detailed design of the MR

In order to further investigate failure mechanisms of expansive soil slopes subjected to various rainfall conditions, 1g physical model tests were planned and carried out by YRSRI (Cheng et al., 2011). Figure 18 shows the setup of an expansive soil model slope together with artificial rainfall control system. The 1g model dimensions are 6.0m × 2.0m × 2.0m and the slope ratio is 1: 1.5. The model slope was prepared by moist tamping method using highly expansive soil at water content of 20% and dry density of 1,600kg/m^3. Artificial rainfall was produced using a purpose-designed sprinkler system. Sprinkler heads were arranged to simulate continuous rainfall events. Local failures were observed in shallow depths of the model slope initially and then developed to deeper depths, leading to a global slope failure eventually. The failure mechanism of the 1g model test is consistent with that observed from an untreated (bare) expansive soil slope in Area VII when it was subjected to similar artificial rainfall event in the field trial, where shallow retrogressive failures (within 2m depth) were observed after rainfall.

Figure 18 Prof. Z.L. Cheng explains an expansive soil model slope tested at 1g (with courtesy of Prof. B.W. Gong)

Centrifuge model tests for the detailed design of the MR

After the success of the research collaboration between HKUST and YRSRI for the preliminary investigation of an unsaturated expansive slope in Zaoyang (Ng et al, 2003), HKUST was commissioned by YRSRI to carry out a number of centrifuge model tests to investigate possible failure mechanisms of expansive soil slopes subjected to varying water levels in the canal and to evaluate the effectiveness of different treatment measures (Ng & Zhou, 2009). The geotechnical centrifuge facility (GCF) at HKUST was adopted. The GCF has a beam centrifuge with a rotating arm of 8.4m in diameter. The design maximum g-level is 150g and the designed maximum payload is 400g-ton. The centrifuge is the world first centrifuge equipped with two dimensional hydraulic in-flight shaking table (Ng et al., 2004) and an advanced four-axis robotic manipulator (Ng et al., 2002). Real-time monitoring and viewing test results via internet are available in this facility.

Centrifuge model test plan and instrumentation

Figure 19 shows the cross section of a centrifuge model package for an expansive soil slope. A two-dimensional model container with dimensions of 1.25m × 0.35m × 0.85m was used for four model tests at 70g. The height of each model slope was 430mm (i.e., 30.1m in prototype) and the bottom width of model canal was 115.1mm (i.e., 8.1m in prototype). A berm with a width of 71.4mm (5m) separating the upper and lower slopes was also simulated. The heights of the upper and the lower slope of each model were 295.7mm (20.7m) and 134.3mm (9.4m), respectively. The slope angle of each model was about 27°. Each model slope was compacted by moist tamping to its initial field density. The soil used was taken from a medium expansive soil taken near the main trunk canal of MR (Ng & Zhou, 2009).

Message to ISSMGE Members (Continued)

Charles W.W. Ng, Appointed Board Member of ISSMGE

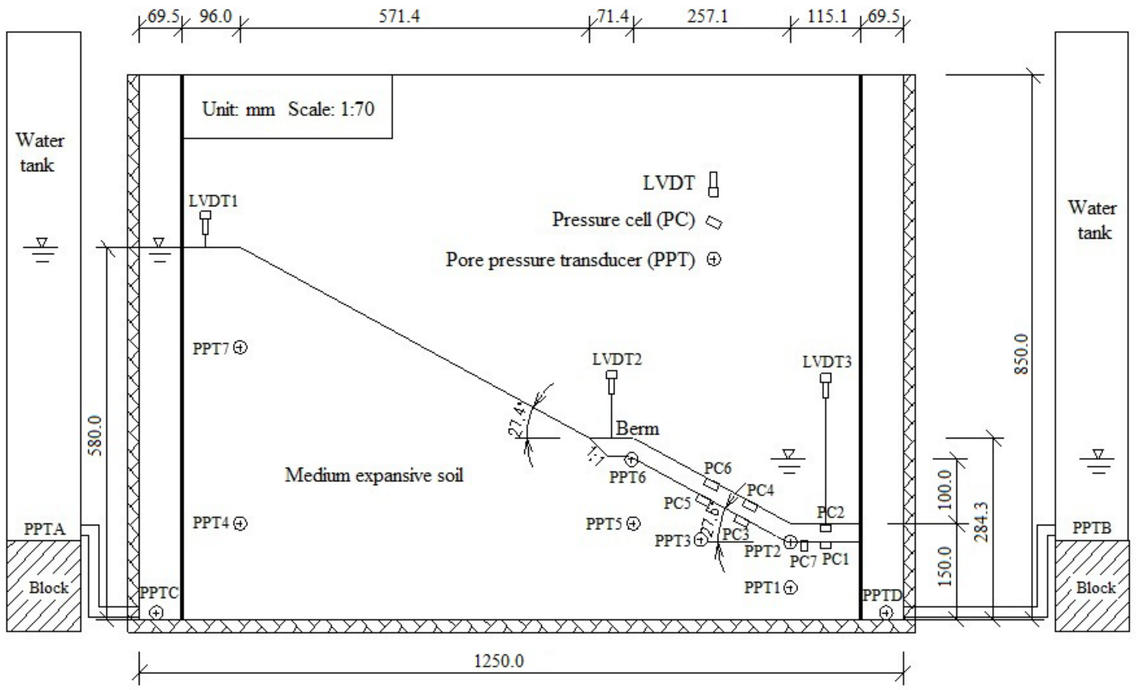


Figure 19 Cross section of a typical centrifuge model package (Ng & Zhou, 2009)

Four model tests were designed to verify design assumptions and to compare findings with field observations. These four tests included (i) one control model slope covered with a properly scaled concrete facing, (ii) a model slope that replaced top 2m (prototype scale) expansive clay with a non-expansive clay covered with a scaled concrete facing; (iii) a model slope that replaced top 3m (prototype scale) expansive clay with a non-expansive clay covered with a scaled concrete facing; (iv) a model slope that replaced top 2m expansive clay with a non-expansive clay covered with scaled concrete facing. Scaled miniature geo-grids were also installed for slope stabilization. As shown in the figure, three Linear Variable Differential Transformers (LVDTs) were installed on the surface of each model slope to measure surface settlements at the crest, the berm and the toe of each model slope. Seven earth pressure cells (PCs) were installed at the lower slope of each model to monitor changes of total stress resulting from variations of water level in the canal. Various pore pressure transducers (PPTs) were also embedded in each model slope to measure pore water pressure changes at different locations of the slope. Slope deformations were captured by using the particle image velocimetry (PIV) technique and close-range photogrammetry developed by White et al. (2003) originally. In addition, strain gauges were used for measuring tensile stresses developed in the geogrids. To control water levels in the canal properly, two water tanks were connected to the model package.

Centrifuge model test procedures and results

After each model preparation, the g-level in the centrifuge was accelerated to 70g for soil consolidation. Then, the water level at lower reach of the canal was raised up by 100mm (7m in prototype). After that, the water level at upper reach was raised up to the crest of the slope. The water levels were maintained for about 22-58 hours (model scale) to simulate the water storage condition of the canal of the MR. Subsequently, the water in the canal was drained away rapidly in 60 seconds (model scale) and the soil was allowed to consolidate again for another 15 hours (model scale). Finally, the g-level in the centrifuge was decelerated to 1g and the test was finished.

Message to ISSMGE Members (Continued)

Charles W.W. Ng, Appointed Board Member of ISSMGE

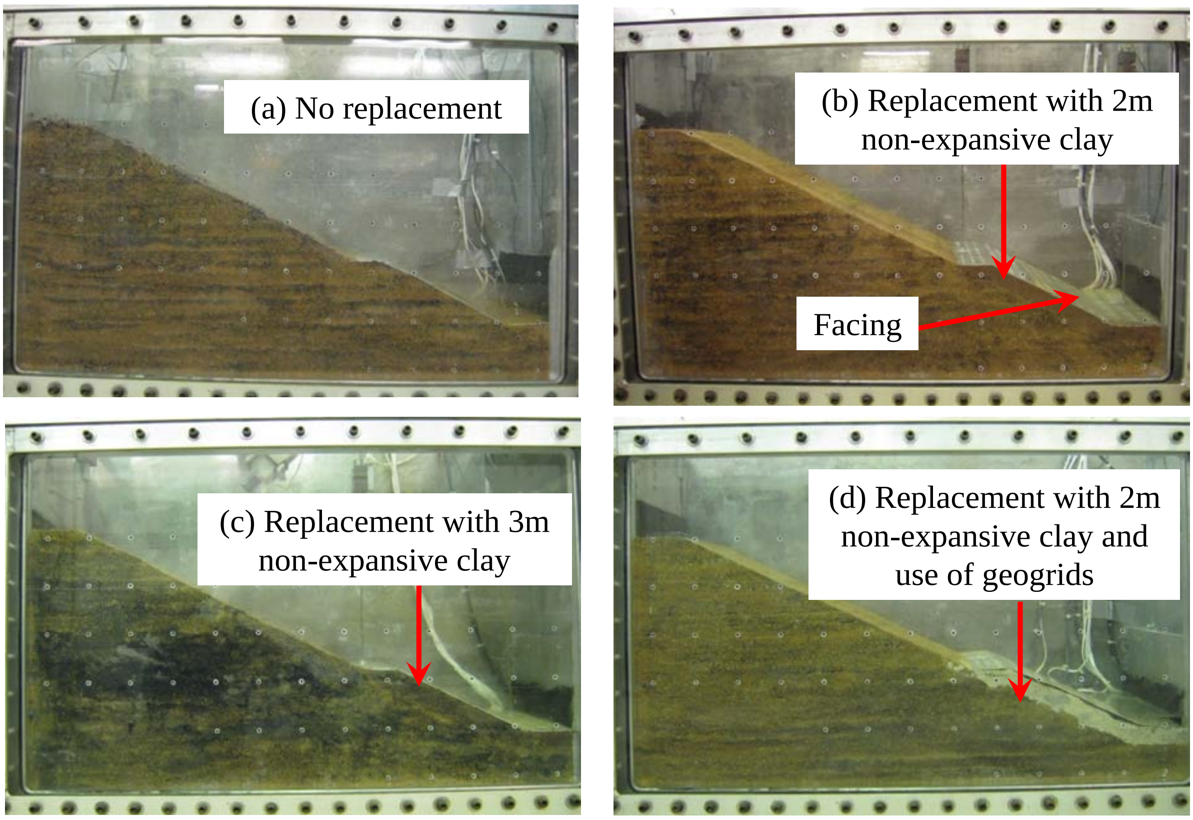


Figure 20 Four different model slopes after centrifuge tests (Ng & Zhou, 2009)

Figures 20 and 21 show the four model slopes and measured soil displacements captured by PIV after tests, respectively. No slope failure was observed for all four tests. It can be seen that the measured maximum displacements at the crest of the model expansive soil slope without replacement are larger than those of the other three treated slopes (see Figure 21). Besides, the measured increase of soil stress due to wetting in the two model slopes replaced by non-expansive compacted clay are smaller than that in the slope without clay replacement. Therefore, a replacement of expansive clay by non-expansive compacted clay is beneficial to slope stability. However, an increased thickness of replacement does not provide significant further beneficial effects. Although the deformation of the slope reinforced with geogrids is the smallest among the four tests, measured pore water pressures and soil stresses revealed that presence of geogrids may have created a preferential flow path for water seepage into the slope. This may be detrimental to the stability of an expansive soil slope.

Message to ISSMGE Members (Continued)

Charles W.W. Ng, Appointed Board Member of ISSMGE

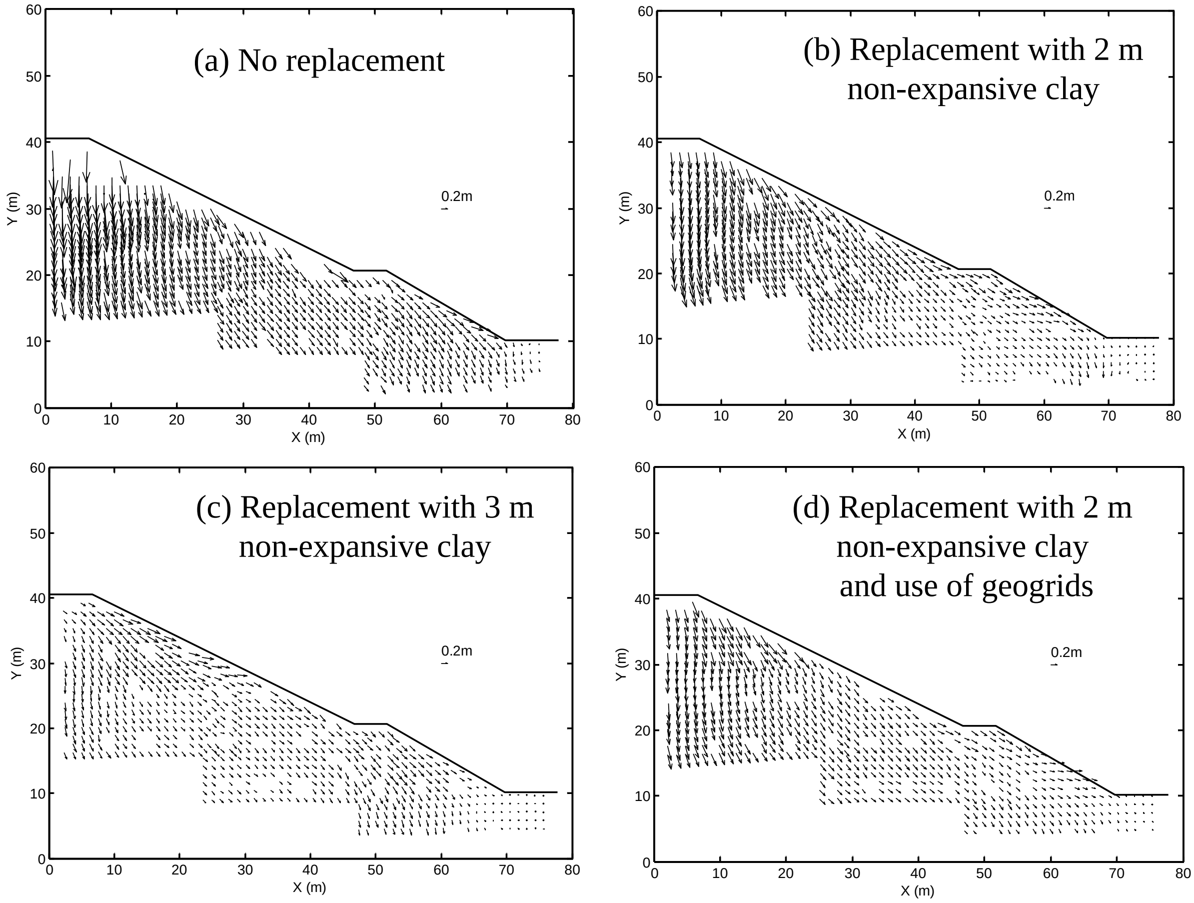


Figure 21 Measured displacement vectors in four different model slopes in centrifuge (Ng & Zhou, 2009)

B6. Conclusions

Based on theoretical design calculations (not discussed in this bulletin due to page limits), results of physical model tests at 1g and in centrifuge, and comprehensive field trials in expansive soil and soft rock slopes, it was decided to use a concrete facing together with 1 to 3m soil replacement with compacted non-expansive clay (if it is available locally). The thickness of soil replacement adopted depends on the expansibility (or swelling index) of natural expansive soil and soft rock along the MR. The designed soil slope angles (ratios) are typically 1:2.0 and 1:2.5. Geogrids are not adopted mainly because of their relatively high costs and complex construction procedures but they do not appear to offer distinctively improved stability. If non-expansive soil is not available locally for replacement, local weakly expansive soil is mixed with 3 to 4% of cement by mass for replacement. It is expected that the entire MR will be completed in 2014.

References

Bao, C.G. & Ng, C.W.W. (2000). Keynote Lecture: Some Thoughts and Studies on the Prediction of Slope Stability in Expansive Soils. 1st Asian Conf. on Unsaturated Soils, Singapore: 15-31.

Cheng, Z.L., Li, Q.Y. Guo, X.L. & Gong, B.W. (2011). Study on the Stability of Expansive Soil Slope. Journal of Yangtze River Scientific Research Institute, 28(10):102-111.

Message to ISSMGE Members (Continued)
Charles W.W. Ng, Appointed Board Member of ISSMGE

Liu, M., Liu, J., Tan, F.Y. & Zou, R.H. (2011). In-situ Monitoring of Canal Slope Treatment at the Expansive Rock Test Section in Xinxiang. Journal of Yangtze River Scientific Research Institute, 28(10):148-161.

Ng, C.W.W. & Zhou, Z.B. (2009). Report on “Centrifuge Modelling of Slope Protection Schemes for the South-to-North Water Diversion Project – Middle Route”. Yangtze River Scientific Research Institute, China.

Ng, C.W.W., Van Laak, P.A., Zhang, L.M., Tang, W.H., Zong, G.H., Wang, Z.L., Xu, G.M. & Liu, S.H. (2002). Development of a Four-axis Robotic Manipulator for Centrifuge Modelling at HKUST. Proc. Int. Conf. on Physical Modelling in Geotechnics, St. John’s Newfoundland, Canada, 71-76.

Ng, C.W.W., Zhan, L.T., Bao, C.G., Fredlund, D.G. & Gong, B.W. (2003). Performance of an Unsaturated Expansive Soil Slope Subjected to Artificial Rainfall Infiltration. Géotechnique, 53(2): 143-157.

Ng, C.W.W., Li, X.S., Van Laak, P.A. & Hou, D.Y.J. (2004). Centrifuge Modeling of Loose Fill Embankment Subjected to Uni-axial and Bi-axial Earthquakes. Soil Dynamics and Earthquake Engineering, 24(4): 305-318.

Ng, C.W.W., Xu, J. & Zhan, L.T. (2009). Keynote Paper: The Mega South-to-North Water Transfer Project in China - Unsaturated Soil Mechanics Aspects., Proc. of 4th Asian-Pacific Conference on Unsaturated Soils, 23-25 November, Newcastle, Australia, Vol. 2, 545-564.

White, D.J., Take, W.A. & Bolton, M.D. (2003). Soil Deformation Measurement Using Particle Image Velocimetry (PIV) and Photogrammetry. Géotechnique, 53(7): 619-631.

Zhan, L.T., Ng, C.W.W. & Fredlund, D.G. (2007). Field Study of Rainfall Infiltration into a Grassed Unsaturated Expansive Soil Slope. Canadian Geotechnical Journal, 44(4):392-408.

MESSAGES FROM ISSMGE PRESIDENT
Professor J-L. Briaud

ISSMGE President 760 days progress report

Distinguished Colleagues, Dear Friends,

This is my twenty fifth progress report after 760 days as your President. Note that previous reports are on the ISSMGE web site (http://www.issmge.org/) under "From the President" if you need them. In this report, I would like to talk to you about our upcoming webinar, a thank you on music feedback, and the results of our Council meeting in Toronto.

Webinars: We continue our successful series of webinars. The October webinar on Intelligent Compaction by Antonio Correia and George Chang was another resounding success with 56 computers connected worldwide. The next webinar will be on the geotechnical engineering code Eurocode 7 entitled "Eurocode 7 – past, present, and future" by Andrew Bond, current Chair of the Geotechnical Engineering Eurocode Committee. The webinar is scheduled for 19 Dec 2011. Please contact Hanna Prichard, my assistant, at hprichard@civil.tamu.edu if you wish to receive more information as we get closer to the date. The webinar will be $200 per computer connected (if we can solve the on line payment problem!), so find a big screen computer and get many people in the room to decrease the cost per person. We are in negotiations with 3 more speakers for the Feb, April, and June 2012 webinars. More news on this later.

Music progress report: I have received many heartwarming emails in response to my last progress reports about my love for music. Thank you so much for sharing with me your favorites, I added all of them to my collection.

Council meeting results: We had a very successful meeting of the ISSMGE Council in Toronto on 2 Oct 2011. 26 member societies were present and came with an additional 37 proxy votes. I want to thank Neil Taylor and Paloma Peers for an excellent preparation of the agenda and the detailed process, a daunting task indeed. Our Canadian hosts were impeccable as usual. Among the important issues covered, we heard regional reports from our Vice Presidents (Samuel Ejezie-Africa, Askar Zhussupbekov-Asia, Michael Davies-Australasia, Ivan Vanicek-Europe, Gabriel Auvinet-North America, and Roberto Terzariol-South America), then we heard progress reports from the Chairs of the Board Level Committees (Suzanne Lacasse-Technical Oversight, Dimitris Zekkos-Innovations and Development, Jean-Louis Briaud-member of the Students and Young Member Presidential Group, Jean-Louis Briaud-Vice Chair of the Corporate Associates Presidential Group, Charles Ng-Board liaison of the Awards Committee) as well as Ikuo Towhata on publication of Bulletin. We also heard reports on FedIGS and the ISSMGE Foundation.

Votes were taken on 4 proposals. For Israel moving to the Europe region, the vote was 52 yes, 5 no, 6 abstain. For the amendment to bylaws regarding audited financial statements, the vote was 60 yes, 1 no, 2 abstain. For changing the name of our quadrennial conference to World Conference on Soil Mechanics and Geotechnical Engineering, the vote was 25 yes, 35 no, 3 abstain. For changing the name of our society to International Society for Geotechnical Engineering, the vote was 23 yes, 39 no, 1 abstain. We had a wonderful and professional discussion on this topic which brought out the passion all of us have for our profession. One of my goals during my presidency has been to engage the membership, I believe this topic definitely contributed to that. Thank you all for a meaningful debate.

After that the budget was presented by Neil Taylor and Michael Davies (ISSMGE Treasurer) and approved by Council. Roger Frank gave us an update on our 2013 quadrennial conference in Paris 1-6 Sept 2013; the French organizing committee is doing a remarkable job and this is going to be one of the best conferences in years; I hope that all of you plan to attend. If you have cash flow problems to come to the conference in Paris in 2013, do not forget that you can ask for some help from the ISSMGE Foundation. At the end of the Council meeting, Jana Frankovska (our friendly President of the Czech and Slovak Society) and I sang the new ISSMGE song and the Council members joined in. Jana promised me that she would sing again in