Current and Future Trends of Geotechnical Engineering in Malaysia – A Consultant's Perspective (2009)

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Abstract. In Malaysia, the construction of industrial structures, commercial and residential buildings on soft ground and hill-sites has increased tremendously over the last 15 years due to depleting competent land near cities like Kuala Lumpur, Penang and Johor Bahru. In addition, highrise development in the city often entails the need for a deep basement to maximise use of space despite the implementation of a mass transit system to reduce car use into and out of the cities. Often these developments require geotechnical engineering input during planning, design and implementation. This is to ensure designs are safe, economical and construction friendly. This paper presents a brief summary of the current status of geotechnical engineering practice in Malaysia and the likely trend of its future development. Some of the interesting projects involved by the Authors that have significant geotechnical engineering input are also presented.

Keywords: Geotechnical Engineering, Consultant, Malaysia.

Introduction

In Malaysia, public awareness on the importance of geotechnical engineering in development and the role of geotechnical engineers, especially in engineering consulting service, has increased since the catastrophic collapse of Block 1 of the Highland Towers Condominium in Hulu Klang, Selangor in December 1993 which killed 48 people. Figure 1 shows the picture of Block 1 of the Highland Towers Condominium when it started to topple.

Figure 1. Block 1 Starts to Topple (from MPAJ, 1994)

Recently, another landslide occurred not far from the Highland Towers Condominium collapse site and had resulted in 5 casualties and extensive damage to infrastructures. Figure 2 shows the damaged houses after the landslide.

The occurrence of such failures demonstrated the need of proper geotechnical engineering input to ensure public safety and has created increased public awareness on the importance of geotechnical engineering in Malaysia.

This paper presents a brief summary of current status of geotechnical engineering practice in Malaysia from a consultant's perspective, and its likely future development trend. Some interesting projects that the Authors are involved with significant geotechnical engineering input are also presented.

Figure 2. Landslide at Bukit Antarabangsa, 2008

(from www.thestar.com.my)

Geotechnical Consultants in Malaysia

In Malaysia, there are only a few independent geotechnical engineering consulting firms and normally they are only engaged as specialist consultants to assist the main consultant of a project. Many geotechnical engineers either practice as sole proprietors or work in a multidiscipline organization (e.g. Civil and Structural Consultants). In view of this, not all projects engage geotechnical consultants unless the project involves difficult ground conditions (e.g. soft ground, hill-sites, limestone formations, etc), complicated foundations or retaining structures (e.g. deep basements, rafts or combined foundations, etc.) or ground treatment selection and design.

However, with more awareness in the construction industry of the importance of geotechnical engineering input in ensuring the success of a project in terms of safety, value engineering and construction duration, the role of geotechnical engineers has become more significant.

Since geotechnical consultants are only engaged in a supporting role and to give specialist input, the main consultant (Civil and Structural consultant) is commonly the submitting engineer to local authorities for various compliances.

Current and Future Trend

The Prospects for Geotechnical Engineers

As the population of a country such as Malaysia continues to grow, coupled with scarcity of suitable development land, future development will undoubtedly have to be built on difficult and complex ground conditions such as hilly terrain, soft ground, former mining land, limestone formations, congested urban landscapes, etc. These together against a backdrop of increasing specialisation of the engineering profession, the awareness and the demand for geotechnical engineers will be more prominent. Many civil engineering graduates are choosing the field of geotechnical engineering either in consultancy or contractors after graduating from university. Further details can be referred to Gue & Tan (2003).

Hill-Site Developments

With scarcity of flat land and the change in the Malaysian lifestyle towards country style living, hill-site development within Malaysia is increasing over time especially near cities like Kuala Lumpur and Penang Island. With recent awareness of the difficulties and risks involved in building on hill-sites, a more systematic control of hill-site development is taking shape in the public and private sectors. An example of this is the position paper titled "Mitigating the Risk of Landslide on Hill-Site Development" (IEM, 2000) prepared by The Institution of Engineers, Malaysia.

In the IEM position paper, the slopes for hill-site development are proposed to be classified into three classes and the necessary requirements are as follows:

(a) Class 1 Development (Low Risk): Existing Legislation Procedures can still be applied.

(b) Class 2 Development (Medium Risk): Submission of geotechnical report prepared by professional engineers to the authorities is mandatory. The taskforce for the position paper committee viewed professional engineers for hill-site development as those who have the relevant expertise and experience in analysis, design and supervision of construction of the slopes, retaining structures and foundations on hill-sites.

(c) Class 3 Development (Higher Risk): Other than submission of a geotechnical report, developers should also engage an "Accredited Checker" (AC) in the consulting team. The AC shall have at least 10 years relevant experience on hill-sites and should have published at least five (5) technical papers on geotechnical works in local or international conferences, seminars or journals.

Table 1. Classification of Risk of Landslide on Hill-Site Development (after IEM, 2000).

Class	Description
1 (Low Risk)	For slopes either natural or man made, in the site or adjacent to the site not belonging to Class 2 or Class 3.
2 (Medium Risk)	For slopes either natural or man made, in the site or adjacent to the site where : o $6m \leq H_T \leq 15m$ and $\alpha_G \geq 27°$ or o $6m \leq H_T \leq 15m$ and $\alpha_L \geq 30°$ with $H_L \geq 3m$ or o $H_T \leq 6m$ and $\alpha_L \geq 34°$ with $H_L \geq 3m$ or o $H_T \geq 15m$ and $19° \leq \alpha_G \leq 27°$ or $27° \leq \alpha_L \leq 30°$ with $H_L \geq 3m$
3 (Higher Risk)	Excluding bungalow (detached unit) not higher than 2-storey. For slopes either natural or man made, in the site or adjacent to the site where : o $H_T \geq 15m$ and $\alpha_G \geq 27°$ or o $H_T \geq 15m$ and $\alpha_L \geq 30°$ o with $H_L \geq 3m$

H_T	=	Total height of slopes
	=	Total height of natural slopes & man made slopes at site and immediately adjacent to the site which has potential influence on the site. It is the difference between the Lowest Level and the Highest Level at the site including adjacent site.
H_L	=	Height of Localised Slope which Angle of Slope, α_L is measured.
α_G	=	Global Angle of Slopes (Slopes contributing to H_T).
α_L	=	Localised Angle of Slopes either single or multiple height intervals.

The classification is based on the geometry of the slopes such as height and angle for simplicity of implementation by non-specialist personnel in the local authorities. Although in reality there are many other factors affecting the stability of the slopes such as geological features, engineering properties of the soil/rock, groundwater regime, etc, in order to make the implementation of the classification easier, simple geometry has been selected as the basis for risk classification. Table 1 and Figure 3 summarise the details of the classification (Gue & Tan, 2002).

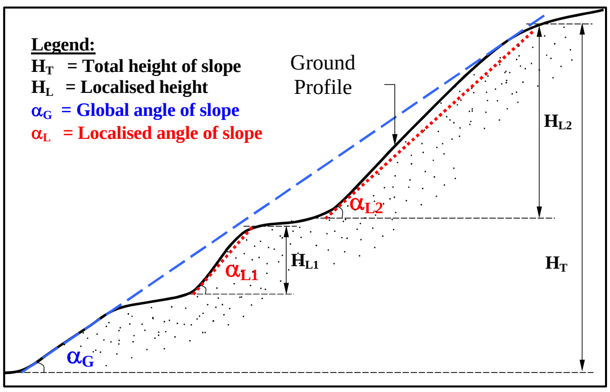

Figure 3. Slope Geometries (after IEM, 2000)

The IEM position paper also proposes that a new federal department called the "Hill-Site Engineering Agency" should be formed to assist Local Governments in respect to hill-site developments. The Agency would assist local authorities to regulate and approve all hill-site developments. The Agency could engage or out-source, whenever necessary, a panel of consultants to assist and expedite implementation. For existing hill-site developments, the Agency should advise local governments to issue "Dangerous Hill-Side Orders" to owners of doubtful and unstable slopes so that proper remedial and maintenance works can be carried out to stabilize unstable slopes and prevent loss of life and property.

In 2004, the Slope Engineering Branch is formed under the Public Works Department to manage, control and monitor all slopes in Malaysia.

Slope Engineering in Practice

The Geotechnical Manual for Slopes published by the Geotechnical Engineering Office (formerly known as the Geotechnical Control Office) of Hong Kong has been widely used with some modifications to suit local conditions by geotechnical engineers in Malaysia (Gue & Tan, 2002). Presently it is not advisable to include soil suction (negative pore pressure) in the design of long-term slopes in view of many factors that can cause the loss of suction during prolonged and high intensity rainfall, especially during monsoons that occur at least twice a year in Malaysia.

During construction of high cut slopes either in sedimentary formations or residual soils, it is important to carry out confirmatory geological slope mapping of the exposed slopes by experienced engineering geologists or geotechnical engineers to detect any geological discontinuities that may contribute to the following potential failure mechanisms, namely planar sliding, anticline sliding, active-passive wedges, toppling and also 3-D wedges. All these discontinuities cannot be fully addressed during the design and analysis stage as they are still not yet exposed and field tests such as boreholes or trial pits are not able to detect these discontinuities adequately for incorporation into designs. Therefore during the design stage, the design engineer should make moderately conservative assumptions for the soil/rock parameters and also the groundwater profile to ensure adequacy in design and only carry out adjustments on site if necessary based on the results of the geological slope mapping and re-analyses of the slopes.

In addition, formation of high cut slopes in residual soil or sedimentary formation usually involves soil and rock with varying degrees of weathering. Proper sampling and testing of such materials, especially weathered rock is very difficult and the design of such slopes is usually critical to the project in terms of public safety and also cost. Extensive experience on geotechnical aspects of construction in residual soils was acquired during the construction of the North-South Expressway in the 1980s and is summarised in various seminars (e.g. PLUS, 1990).

The Authors recommend that in the absence of reliable test data and past experience on similar structures and materials, the estimation of the equivalent Mohr-Coulomb parameters for slope design should be guided by the method proposed by Hoek et al. (2002). The equivalent Mohr-Coulomb parameters obtained are based on the Hoek-Brown failure criterion for rock mass and are derived based on strength parameters (uniaxial compressive strength) and site observations (e.g. rock surface conditions and structure). The equivalent Mohr-Coulomb can now be easily computed with the availability of free software, "RocLab", which is available on the internet (www.rocscience.com).

The use of soil nails has also gained popularity in Malaysia in tandem with growing developments on hill-sites. The design and construction of soil nails in Malaysia has also evolved from the early methods summarised by FHWA (Elias & Juran), 1991 to the more comprehensive and systematic method proposed by FHWA (Byrne et al.), 1996. Extensive reference is also made to works by Hong Kong GEO and British publications (e.g. UK Highways Agency HA 68/94 and BS 8006: 1995, Code of practice for strengthened/reinforced soils and other fills). Comparison of the various design methods has been made by Chow & Tan (2006) and Love (1995).

For a mixed commercial development project in residual soils overlying metasedimentary formation, the Authors have adopted permanent soil nail slope in place of diaphragm walls or contiguous bored pile walls. The project posed significant challenges as existing residential houses are situated very close to the soil nail slope (≈ 3m from a brick wall boundary fencing and ≈ 6m from the building). The total depth of the excavation is 30m and the soil nail slope has since been completed and the monitoring results showed that the deflection is less than 10mm. Figures 4 and 5 show the completed 30m high soil nailed slope and completed basement works respectively.

Figure 4. 30m high soil nail slope.

Figure 5. Superstructure works in progress after completion of soil nailing works.

The design of such high soil nail slope requires proper consideration of all possible failure modes from external to internal stability. One potential failure mode which is often overlooked by designers is face failure. This situation arises where previously, soil nail has been used mainly for slope stabilization with heights ranging from 5m to 15m and rarely for high cut slopes.

For slopes with gradients ranging from 45° to 30° and with only moderate heights, the active pressure acting on the shotcrete surface is insignificant. However, for soil nail slope with gradients of up to 76° and great heights, the active pressure acting on the shotcrete surface is significant and cannot be ignored. Figure 6 shows an example of face failure with clear evidence of face failure as the shotcrete surface has "sheared off" from the slope whereas the nail can be seen protruding from the failed slope, indicating that the structural strength of the nail and bond strength of the nail-ground is adequate.

In addition to face failure, proper design of the soil nail facing is also important as it affect the development of bond resistance along the nails. Therefore, an inadequately designed facing will also result in reduced Factor of Safety (FOS) in addition to potential face failure (Tan & Chow, 2004). Similar findings have also been reported elsewhere (e.g. Wong & Ko, 2006).

Figure 6. Example of face failure.

The nature of residual soils in Malaysia also poses another unique challenge to geotechnical engineers in Malaysia. Due to geological features/discontinuities, e.g. bedding planes, faults, etc. inherited from the parent rock, geological surveys should be carried out for works involving large areas (e.g. highway projects). Liew & Liong (2006) reported a case history involving soil nail slope failure (Figure 7) where the daylighting geological features (Figure 8) contributed to the slope failure. Therefore, desk study involving review of geological maps, aerial photographs and initial geological mapping during the design stage is recommended followed by geological mapping progressively during construction works. Routine QA/QC works are also important to ensure construction works are carried out in accordance with design and good engineering practice. Guidance on construction checklists for soil nailing works have been summarised by Neoh (2006) and Tan & Chow (2004).

Future advancements in the design of soil nails in Malaysia will include refinements in the estimation of nail-ground resistance, the influence of nail spacing (arching) on active pressure acting on the shotcrete surface, etc. Based on the Authors' experience, a preliminary estimation of ultimate nail-ground resistance based on SPT-N correlations of 3*N (kPa) is reasonable for residual soils commonly encountered in Malaysia but extra care is needed for nails in the upper part of the slope due to inadequate overburden stress. The active pressure acting on the shotcrete surface can be assumed as 50% of the active pressure calculated using conventional active pressure theory based on the recommendations of FHWA, 1996 for typical nail spacing of 1.0m to 1.5m. Efforts to compile more data using instrumentation are ongoing in order to validate and refine these recommendations for a safer and more economical design.

In addition, the Malaysian government has also embarked on a National Slope Master Plan Study in response to the rising problems and difficulties of managing landslide hazards in Malaysia. The study's scope will cover various aspects ranging from public awareness and education to R&D and is expected to provide encouragement for the improvement of slope engineering practice in Malaysia.

Figure 7. Front view of failed soil nail slope.

Figure 8. Daylighting joint sets observed on slope.

Development on Soft Ground Areas

The development of national road networks, residential and commercial properties has encroached into areas underlain with very soft soils (e.g. alluvial soils, marine clays, etc.). In this formation, usually the competent layer (stiff or dense soils) and bedrock are very deep (sometimes more than 60m deep) and result in higher costs of foundation.

Geotechnical works in deep deposit of highly compressible soft clay are often associated with problems such as excessive differential settlement, negative skin friction and bearing capacity failure. Traditionally, piles are introduced to address the issue of bearing capacity and excessive differential settlement. Piles are often installed into competent strata or 'set' in order to limit the differential settlement by reducing the overall settlement of a structure.

However, this solution only addresses short-term problems associated with soft clay, as pile capacity will be significantly reduced with time due to negative skin friction (down drag). This option often reduces the cost-effectiveness of such 'conventional solutions'. In view of this, geotechnical engineers in Malaysia have started using settlement reduction piles coupled with strip-raft foundations for housing developments (2-storey to 5-storey residential and commercial buildings) on soft ground. When designing the foundation system, short piles (the length of piles is 1/4 to 1/2 of the depth to the hard layer with SPT'N' >30, depending on the load of the structures).

In a housing development project of 1200 acres at Bukit Tinggi, Klang which is on very soft ground termed as Klang Clay (Tan, et al., 2004(a)), the Authors have used the 'floating' piled raft foundation system. The 'floating' piled raft foundation is designed to limit differential settlement and it consists of short piles strategically located in areas of concentrated loadings and interconnected with a rigid system of strip-rafts to control differential settlement (Tan, et al., 2004(b)). This system is a hybrid of the piled raft design combining 'creep piling' and differential settlement control piling defined by Randolph (1994). This foundation system, coupled with a properly planned temporary surcharging of the earth platform has shown to be very effective, as demonstrated by monitoring results on the completed structures. Figure 9 shows the completed 2-storey link houses and schematics of the foundation depth relative to the thickness of the soft compressible subsoil. Figures 10 and 11 show the typical layout of the foundation system for 2-storey link houses and a cross section of the strip raft foundation system respectively.

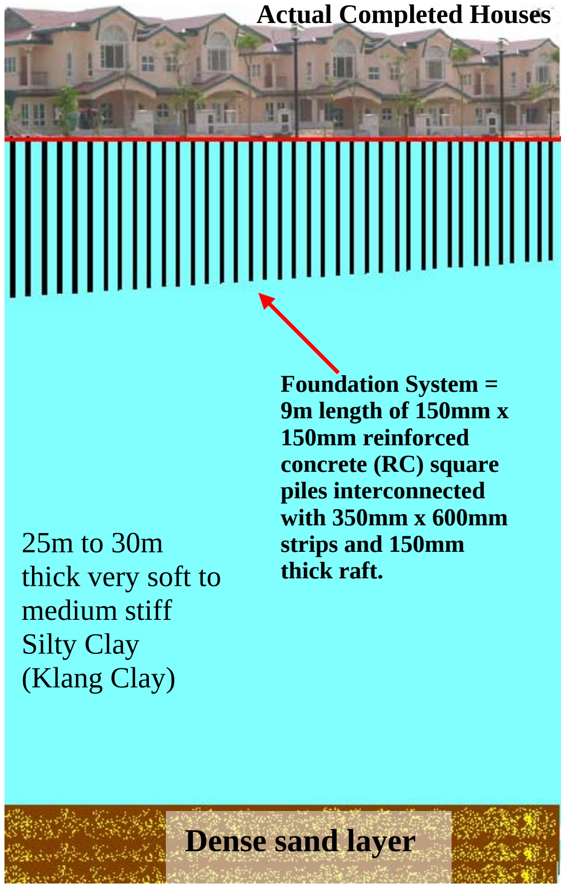

Figure 9. 2-storey link houses on floating piles.

Piled rafts with different pile lengths have also been used as a cost effective foundation replacing conventional piled to set systems as the support for 5-storey apartments on very soft alluvial clayey soil of about 25m to 30m thick as shown in Figure 12. The foundation system adopted for the low cost apartments consists of 200mm x 200mm reinforced concrete (RC) square piles with pile lengths varying from 18m to 24m interconnected with 350mm x 700mm strips and 300mm thick rafts. Figure 13 shows a typical section of the strip-raft foundation system. Tan, et al. (2005) have described the design approach for the foundation system where the primary objective is to limit differential settlement and distortion within acceptable limits together with results of monitoring demonstrating the satisfactory performance of the foundation system.

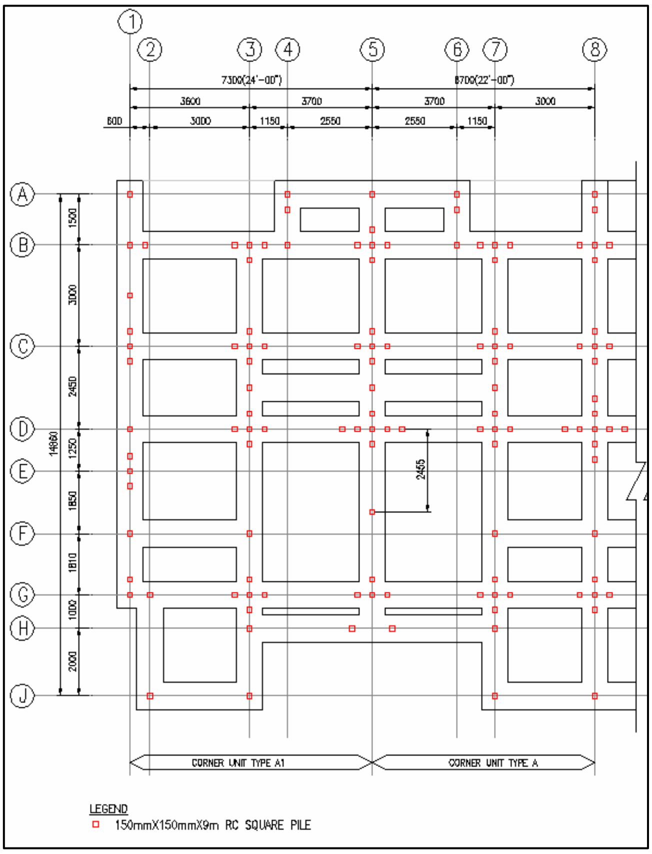

Figure 10. Typical layout of foundation system for link houses (Tan, et al., 2004(b)).

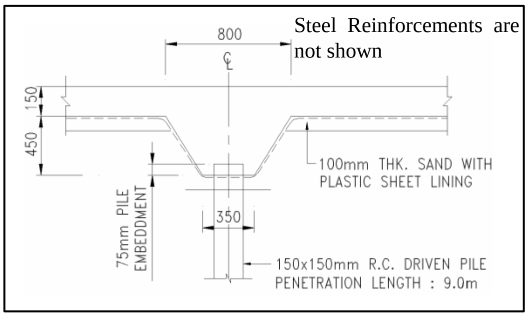

Figure 11. Cross-section of strip raft foundation system for link houses (Tan, et al., 2004 (b)).

A similar system has also been used for industrial buildings such as the support for 2500 Ton oil storage tanks on very soft alluvial clayey soil of about 40m thick as shown in Figure 14. The storage tanks sit on a 20m diameter and 500mm thick reinforced concrete (RC) circular raft. The pile points have been strategically located beneath the RC raft. Varying pile penetration lengths have been designed to minimize the angular distortion of the thin RC raft and the out-of-plane deflection at the tank edge. (Liew, et al., 2002).

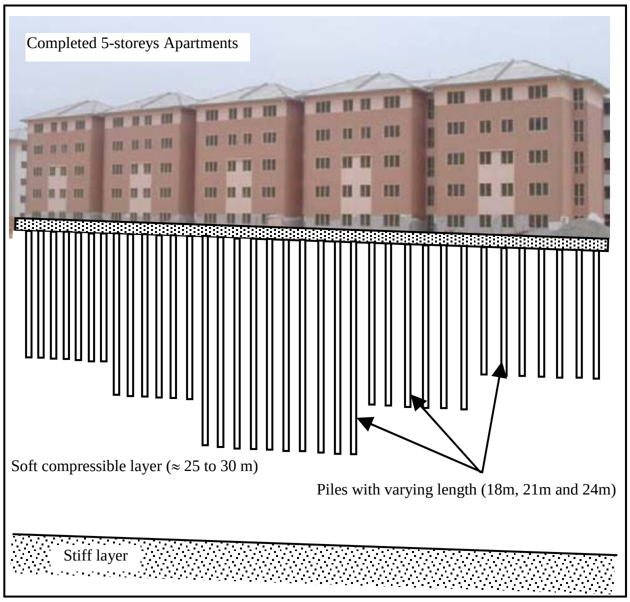

Figure 12. Schematic of piled raft system with varying pile lengths superimposed on completed low cost apartments.

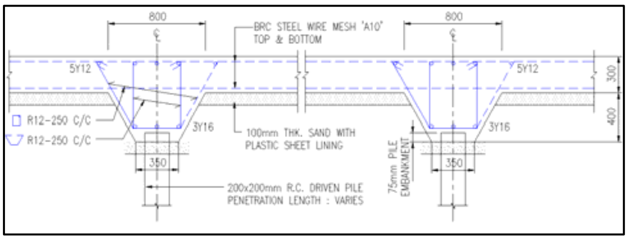

Figure 13. Typical cross-section of strip raft foundation system for low cost apartments (Tan, et al. 2005).

The current trend in the design of expressway or rail embankments over soft ground has placed emphasis on value engineering and long term serviceability of the ground treatment options. The conventional ground treatment methods such as surcharging, partial soft soil replacement, prefabricated vertical drains with surcharge, stone columns, dynamic replacement, piled embankment with reinforced concrete slabs, or combinations of these techniques are widely used in Malaysia. Experience of various ground treatment techniques has been accumulated over the years through projects such as the KL International Airport where extensive peat deposits are encountered and also from findings such as the Trial Embankments on Malaysian Marine Clays carried out by the Malaysian Highway Authority (1989). Emphasis is also placed on controlling differential settlement between piled structures (viaducts and bridges) and approach embankments (usually unpiled). The techniques commonly used in Malaysia are transition piled embankments, expanded polystyrene (EPS), oversized culverts, etc. (Gue, et al., 2002). Lately, foam (light weight) concrete has been introduced to Malaysia as one of the options to replace EPS in view of its inertness to fire.

With the availability of three-dimensional (3-D) finite element programs, the design of structures such as piled embankments which are essentially 3-dimensional in nature can also be carried out with greater confidence and accuracy. In one of the Authors' projects (Gue & Tan, 2005), 3-D finite element analysis was carried out to investigate the effectiveness of soil arching in the design of a piled embankment using isolated piles as shown in Figures 15, 16 and 17.

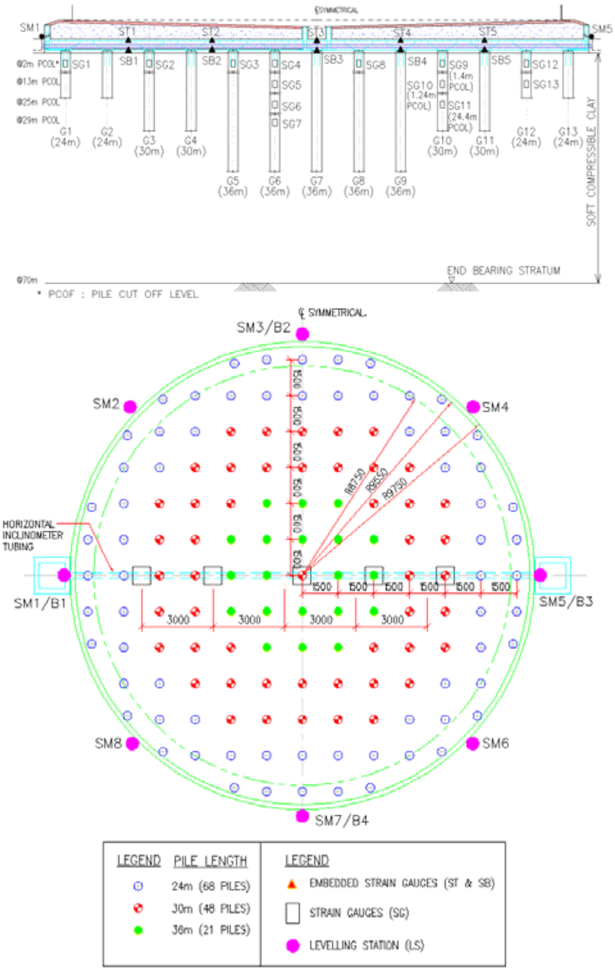

Figure 14. Details of Piled Raft with Varying Pile Lengths (from Liew, et al., 2002)

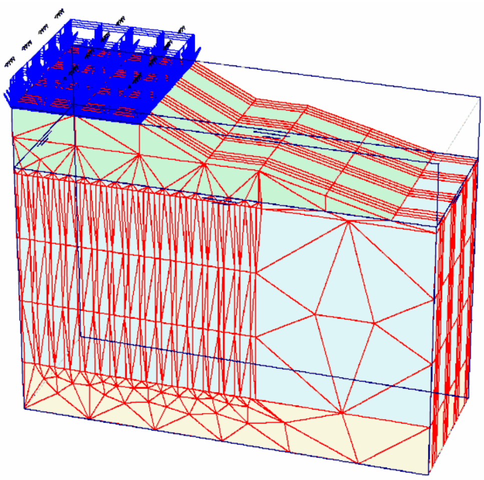

Figure 15. 3-D Model of Embankment.

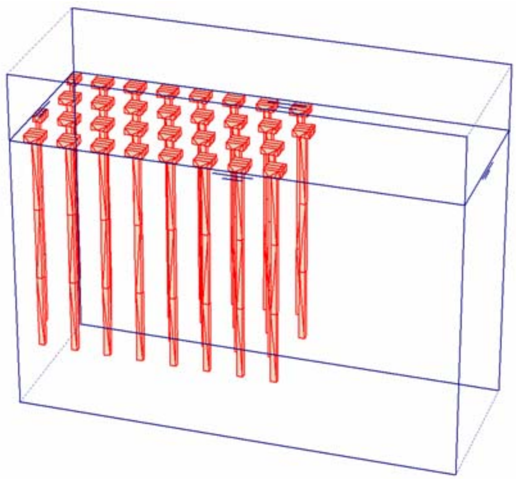

Figure 16. 3-D Model of Isolated Piles and Pilecaps.

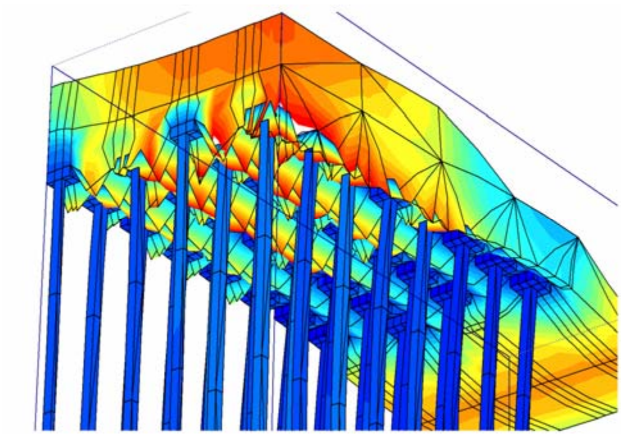

Figure 17. Results of 3-D Finite Element Analysis Showing Ineffective Arching Mechanism due to Unsuitable Fill Materials and Large Pile Spacing.

Developments in Congested Urban Areas

In expensive and congested urban areas like Kuala Lumpur, Penang and Johor Bahru, basements have been constructed to effectively utilise underground spaces for car parks and other usage. Other than basements, construction of tunnels in the city has been extensively carried out for light rail transit.

Many deep basements have been constructed in Kuala Lumpur. One of the deepest excavations for a basement is 28.5m for Berjaya Times Square, Jalan Imbi (Tan, et al., 2001). Figure 18 shows the excavation reaching its final depth before construction of the basement. The commonly used retaining wall systems are diaphragm walls, contiguous bored piles, secant piles, sheet piles and soldier piles. The support systems commonly used include temporary pre-stressed ground anchors, internal strutting, top-down or semi top-down, etc. The finite element method (FEM) is widely used in the design of deep excavations in view of its versatility in modelling soil-structure interaction and its capacity to predict more representative ground deformations of the retained soil, which is very important to ensure the safety of adjacent properties in congested urban areas.

Figure 18. Berjaya Times Square, Kuala Lumpur during Construction.

For deep excavation in urban areas, Gue & Tan (2004) presented two case histories showing the lowering of groundwater in the retained ground due to basement excavation had cause cracks and settlements to the surrounding buildings. The effect of lowering of the groundwater can extend the influence zone up to 30 times the maximum depth of excavation depending on the subsoil conditions and the amount of water lost through hydraulic failure or water pumping. The influence zone of settlement due to lowering of groundwater is six times more than other contributing factors causing the settlement of the retained ground during basement excavation. Therefore, careful assessment of the effect of settlements of retained ground and structures is vital to ensure safety of the excavation works and adjacent properties. Extra care should be given to various checks on ground heave and hydraulic failure due to excavation works.

Tunnelling, especially with tunnel boring machines (TBM) in urban areas of Kuala Lumpur, has been a challenge, especially tunnelling through different geological formations with different complexity. Three major geological formations are found in Kuala Lumpur namely; metasedimentary, granite and cavernous limestone or marble. Many surprises are expected even with comprehensive ground investigations especially in the limestone formations. This is due to the complex and difficult geological features of limestone such as pinnacles, sinkholes, cavities and slump zones, etc.

Gue (1999) describes the difficulties of foundation works in limestone formations. Additional features such as the presence of a very strong rock, Skarn, which has an unconfined compressive strength of about 300MPa, posed additional difficulties in tunnelling (Gue & Muhinder, 2000). Working in a limestone formation and its surrounding area requires frequent change of equipment and as well as increases in the construction time when some of the features mentioned above are encountered. In view of the difficulty of the tunnelling projects, input from experienced geotechnical engineers and engineering geologists is very important.

Malaysia has also made significant advancement in the innovative use of the TBM technique in the SMART tunnel construction in the highly erratic limestone formations. The Stormwater Management and Road Tunnel (SMART) project is unique as it combines stormwater and road traffic congestion relief in one dual-purpose tunnel. Experience gained in the design and construction of the tunnel has since been summarised in various conferences (e.g. IEM, 2006).

Since the development of the Finite Element Method in three-dimensional (3-D) analysis, it is a trend in Malaysia to take advantage of this technique instead of the conventional two-dimensional plane strain analysis for the design of tunnels.

Developments on former mining lands are also common in Malaysia. The mining process leaves behind ponds, loose sandy soils, and slime deposits in the ponds or on land. The slime is a waste material from mining and consists of very soft silty clay usually containing some fine sand (Ting, 1992). In these areas, proper geotechnical engineering input is very important to prevent failures during construction and long term serviceability problems such as continuing settlement of the fill with time, etc.

Foundations in Limestone Area

Geotechnical engineers in Malaysia have also gained significant experience in the design and construction of foundations in limestone areas given the rapid development of its capital Kuala Lumpur, where limestone is one of the major geological formations.

Various foundation systems can be adopted ranging from bored piles and barrettes, generally used for high-rise buildings, while driven/jacked-in piles are adopted for low-rise buildings. However, with the introduction of higher capacity jacked-in piling systems, jacked-in piles can also be adopted for high-rise buildings. Tan & Chow (2006) summarises some of the foundation design and construction aspects in limestone areas in Malaysia.

Malaysian geotechnical engineers have also made contributions to the development of micropiles, especially for applications in limestone formations. Chan & Ting (1996), Neoh (1996) and Gue & Liew (1998) have also extensively discussed on the applications of micropiles in Malaysia, especially in limestone formations.

Foundation Design for Highrise

In Malaysia, geotechnical analyses and designs of foundations still generally rely on conventional design methods. However, the trend is moving towards limit state design with emphasis on the serviceability limit state which requires proper prediction of deformations (e.g. settlement and lateral movements).

Piles are generally used to support highrise structures. The selection of the types of piles depends on factors such as loadings, ground conditions, geological formation, noise etc. The piling systems used in Malaysia include bored piles, driven pre-cast piles, micropiles, jacked-in piles, barrette piles, etc. The design of bored piles in residual soils generally follows simple empirical correlations to SPT'N' values as presented by Toh et al. (1989) and Tan et al. (1998). In the design of long bored piles, the base resistance should be ignored unless it is a dry hole and the base can be properly cleaned and inspected. This is due to the impracticality of properly cleaning the base of bored piles drilled through unstable bored holes. The prediction of pile movements under different loads is also gaining popularity in Malaysia. (Gue, et al., 2003).

In areas where driven piles are prohibited by local authorities due to noise and pollution, jacked-in piles using square piles (size 150mm to 400mm) and spun piles (diameter of 300mm to 600mm) have gained popularity in view of their speed of installation and lower construction cost compared to bored piles.

In Malaysia, experience with highrise projects has shown that the termination criterion for a jacked-in spun pile is to jack the pile to 2.0 to 2.5 times the design load for a minimum of two cycles depending on the ground condition. The corresponding pressure has to be held for a minimum of 30 seconds with settlement not exceeding 2mm. Nevertheless, the termination criteria should be validated by maintained load test results to ensure satisfactory performance of the piles, especially with regards to serviceability. Future developments in the application of jacked-in piles will include the study of the effects of different termination criteria in different geotechnical conditions with respect to both geotechnical capacities and settlement considerations.

Geotechnical Engineering for Flood Mitigation

Due to extreme weather phenomenon such as El Niño, La Niña and the rapid industrialization of cities in Malaysia which is traditionally located in river confluences or coastal areas, there is great need to carry out flood mitigation measures to protect the public and existing infrastructures.

The need for proper geotechnical input is highlighted by the catastrophic failure of flood protection structures in New Orleans, USA in 2005 due to Hurricane Katrina. The failure of the levees and flood walls in New Orleans had resulted in devastating loss of lives and damages to properties and this presents different challenges to geotechnical engineers.

In Malaysia, several major floods had also occurred in cities such as Kuala Lumpur (Figure 19), Shah Alam, Kota Bahru and Penang and this has prompted the government to put in place various long-term flood mitigation measures.

Traditional flood protection structures include levees, flood walls and other hydraulic structures such as barrages, inlet/outlet structures, etc. The design of such structures requires inter-disciplinary cooperation between hydrology & hydraulics engineer, structural engineer, mechanical & electrical engineer, geotechnical engineer, etc. In the design of such hydraulic structures, various loading conditions should be considered such as:

a) Immediate / End-of-construction

b) Long-term / Steady-seepage

c) Rapid drawdown

The assessment of the loading conditions also depends on the load condition probabilities or return period and typical load condition categories include (EM 1110-2-2100):

a) Usual (Return period less than or equal to 10 years)

b) Unusual (Return period greater than 10 years but less than or equal to 300 years)

c) Extreme (Return period greater than 300 years)

Figure 19. Flooding in Kuala Lumpur.

Stability of hydraulic structures shall also take into consideration various failure modes such as:

a) Sliding

b) Bearing capacity

c) Overturning

d) Flotation

e) Internal erosion/piping

For the design of levees and flood walls, references can be made to publications by US Army Corps of Engineers (USACE) such as EM1110-2-1913: Design and Construction of Levees and EM1110-2-2502: Retaining and Flood Walls. Figure 20 shows an inlet structure nearing completion for a flood mitigation project in Kuala Lumpur.

Figure 20. Inlet Structure under Construction.

Proper detailing of the levees and flood wall is also important to ensure its long-term effectiveness as progressive failure due to scouring/erosion will affect the stability of the structure. Figure 21 shows typical components of a levee. As such, proper design of revetment, toe protection and seepage control measures is also essential for levees and flood walls.

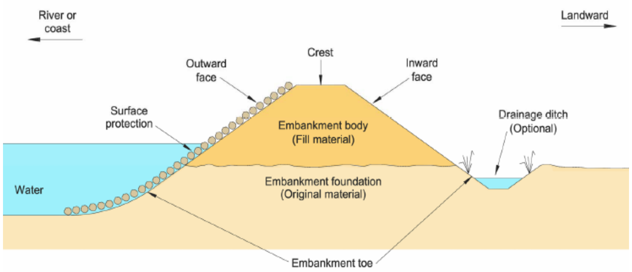

Figure 21. Typical Features of Levee

(Courtesy: Prof. Mark Dyer).

The construction of flood mitigation works in urban areas also poses challenges due to the close proximity of existing houses/structures to the existing river. As such, new technologies have to be adopted for the construction works. For example, proprietary press-in sheet piling technique from Japan is adopted for river widening works beneath existing bridges due to headroom constriction as shown in Figures 22 and 23.

Figure 22. Press-in Sheet Piling Works underneath the Bridge.

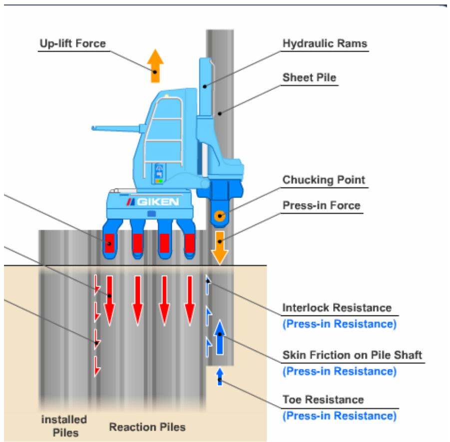

Figure 23. Principle of Press-in Technique.

Even though the use of press-in piling technology has facilitated installation of sheet piles beneath the existing bridge with low headroom, various improvements to the system is necessary so that it is suitable for works in Malaysian rivers with rapid rise in water level after heavy rain (water rises a few metres within 15 to 30 minutes). As such, future improvement such as durability in the event of submergence in water or fast retrieval and subsequent setting-up will greatly aid the use of the technique for river improvement works.

Future Trends

With a borderless world, geotechnical engineers in Malaysia also face challenges and opportunities in a new global economy. Geotechnical engineers should not only focus on geotechnical aspects which are relevant only to their local conditions but should also expose themselves to other geotechnical aspects which are not common in their country. For example, traditionally Malaysia is blessed in such a way that we are not subjected to large magnitude earthquakes as compared to our neighbours such as Indonesia, the Philippines, etc. However, within the current global economy, it is important that geotechnical engineers in Malaysia also equip themselves with the relevant knowledge to cater for a wider range of problems. Through international projects, Malaysian geotechnical engineers are given the opportunity to gain experience in soil conditions which are not common in tropical countries such as Malaysia. Some typical problematic soils which are associated with other regions of the world are as follows (FHWA (Sabatini et al.), 2002):

a) Loess and Collapsible Soils

   These soils are typically wind-blown sand, silt, and clay with weak binder (loess); silty clays exhibiting loose structure and weak interparticle bonds (collapsible soils).

b) Expansive Soils

   Clay-rich soils in arid and semi-arid regions that are subject to wet/dry and freeze/thaw cycles resulting in deep dessication cracking.

c) Colluvium and Talus

Weathered materials that migrate and accumulate on the sides and at the toe of slopes; fine grained material with rock fragments (colluvium); coarse grained material with boulders (talus).

d) Cemented Sands

Sandy soil with salt or calcareous bonding at the points of grain-to-grain contact; cementing agents may be soluble or insoluble.

e) Wind-blown Sand or Eolian Sand

Poorly graded sand with predominantly quartz and with a potential of contamination with precipitated salts and chlorides (Bell, 2000).

Malaysian geotechnical engineers should also be open-minded to different geotechnical practice around the world which may differ significantly to British/American practice which they have grown accustomed to. For example, in one of the project involved by the Author in Turkmenistan, preliminary SI is carried out using a drill on a make-shift army truck and collection of undisturbed samples is not possible (Figures 24 and 25). Some geological and geotechnical aspects of the deposits encountered in Turkmenistan has been reported by Chow (2005). As such, it has become more important for geotechnical engineers to exercise judgement in such situation and to “get their hands dirty”. A sound understanding of soil mechanics/geotechnical engineering principles is important for international projects and universities should emphasise teaching of fundamentals rather than codes of practice. This is because while codes of practice can be different for each country/region, the principles behind the code are still the same.

Figure 24. SI Drill Rig in Turkmenistan.

Figure 25. Tools for Collection of Soil Samples.

Malaysian geotechnical engineers also need to embrace other aspects of geotechnical design such as liquefaction analysis (Youd et al., 1997 and Seed et al., 2001) and geotechnical earthquake engineering (Towhata, 2005 and FHWA (Kavazanjian, et al.), 1997). Sufficient experience has been accumulated over the years for liquefaction evaluation using in-situ tests such as the Standard Penetration Test (SPT), the Cone Penetration Test (CPT) and the Measurement of Shear Wave Velocity (Vs). However, other aspects such as the effect of soil aging on liquefaction resistance and the assessment of post-liquefaction strength and stability still merits further research and development.

The new frontiers in offshore geotechnical engineering (Randolph, 2005) and geo-environmental engineering (Shackelford, 2005) also offers exciting opportunities and challenges to geotechnical engineers from Malaysia and also the rest of the world. For example, the offshore industry offers geotechnical engineers challenges in designing structures in a harsh environment with difficult construction conditions. Some of the latest innovations in geotechnical engineering such as the developments of penetrometer testing, such as the T-bar penetrometer (Stewart & Randolph, 1994), developments of bearing capacity theories for complex vertical, horizontal and moment (VHM) loadings (Randolph et al., 2004), skirted foundations and design methods for pile foundations in carbonate sediments have been successfully applied in the offshore industry. With increasing deepwater projects in Malaysia and around the world such as Kikeh, Gumusut/Kakap, etc. with water depths exceeding 1000m, geotechnical engineering for deepwater applications such as design of offshore anchors, skirted foundations and piles for SPAR platform, floating production system (Figure 26), etc. will provide an exciting opportunity for geotechnical engineers in Malaysia and around the world.

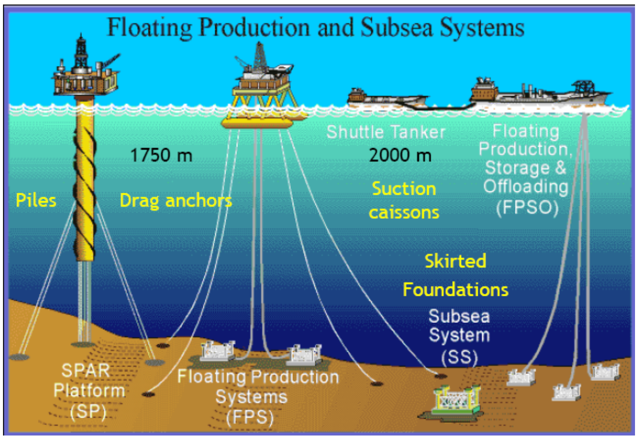

Figure 26. Floating and Subsea Facilities (Randolph, 2005)

Quality Management Systems

In the Authors' opinion, the quality management principles (MS ISO 9000:2000) are very important and should be practised by the consultancy service. With the implementation of Quality Management Systems (QMS), the performance of a company will surely improve. A brief interpretation of the principles is as follows:-

Customer focus:-It is important to understand the current and future clients' needs, and to meet and exceed their expectations by providing high quality service. For geotechnical engineering consultancies, this means providing services with an emphasis on safety, innovativeness, economy and construction friendliness.

Leadership:-The management of the company must believe that by providing quality service, the growth and stability of the company will be achieved and sustained. The management should create and maintain a conducive working environment in which all personnel in a company can become fully involved in achieving the targeted objectives. A conducive environment includes, but is not limited to, providing sufficient guidance from experience engineers to junior staff, training programmes (internal colloquia, forums and external courses, workshops, seminars and conferences), rewards for quality work, etc.

Involvement of people:- Personnel at all levels are the "assets" of a company and their full involvement as a team will enable their abilities to be used to the fullest for their own and also the company's benefits. One good example is the sharing of knowledge and experiences through networked group learning which increases the efficiency of learning for all personnel.

Systematic and factual approach to decision making:- Identifying, understanding and managing interrelated processes as an overall system contributes to the company's effectiveness and efficiency in achieving its objectives. Effective decisions should be based on analysis of data and information instead of using gut feelings. This approach is very important when carrying out planning, analysis and design, and also for policy decision making for the company.

Continual improvement:- Continual improvement of the company's overall performance should be a permanent objective. For consultancy services, this includes technical competency and overall management of the company. It also involves carrying out in-house research and development (R&D) such as development of engineering computer programs to assist in analysis and design, specifications, checklists for design or supervision of various geotechnical works, geotechnical risk management, technical manuals, technical papers, etc. Many of the products stated above are available at the webpage of G&P Geotechnics Sdn Bhd at www.gnpgeo.com.my.

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