Development of Geotechnical Engineering in Malaysia – A Consultant's Perspective.

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Abstract. In Malaysia, the construction of industrial structures, commercial and residential buildings on soft ground and hill-site has increased tremendously for 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 current status of geotechnical engineering practice in Malaysia based on a consultant's perspective and the likely trend of its future development. Some of the interesting projects involved by the Author 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 have 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 the Block 1 when it started to topple.

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

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

Geotechnical Consultants in Malaysia

In Malaysia, there are only a few independent geotechnical engineering consulting firms and normally they are only engaged as specialist consultant to assist the main consultant of a project. Many geotechnical engineers either practice as sole proprietor or work in a multidiscipline consultants (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-site, Limestone formation, etc), complicated foundation or retaining structures (e.g. deep basement, raft or combine foundation, etc.) or ground treatment selection and design. However, with more awareness in the construction industry on the importance of geotechnical engineering input to ensure success of a project in terms of safety, value engineering and construction duration, the role of geotechnical engineer will be more significant.

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

Current and Future Trend

Prospect of Geotechnical Engineers

As the population of a country such as Malaysia continues to grow coupled with scarcity of suitable development land, future development would undoubtedly have to be built on difficult and complex ground conditions such as hilly terrain, soft ground, former mining land, limestone formation, congested urban landscape, etc. These together with 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 contractor as their career after graduate from universities. Further details can be referred to Gue & Tan (2003).

Hill-Site Development

With scarcity of flat land and the change in Malaysian lifestyle towards country style living, hill-site development within Malaysia is increasing with time especially near a city like Kuala Lumpur and Penang island. With the recent awareness of the difficulties and risks involve in building on hill-sites, a more systematic control of hill-site development is taking shape in the public and private sectors. One of them 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 engineer to the authority is mandatory. The taskforce for the position paper committee viewed the 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, developer shall also engage an "Accredited Checker" (AC) in the consulting team. The AC shall have at least 10 years relevant experience on hill-site and have published at least five (5) technical papers on geotechnical works in local or international conferences, seminars or journals.

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 $\alpha_G \geq 27^o$ or o 6m $\leq H_T \leq$ 15m and $\alpha_L \geq 30^o$ with $H_L \geq$ 3m or o $H_T \leq$ 6m and $\alpha_L \geq 34^o$ with $H_L \geq$ 3m or o $H_T \geq$ 15m and $19^o \leq \alpha_G \leq 27^o$ or $27^o \leq \alpha_L \leq 30^o$ 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 $\alpha_G \geq 27^o$ or o $H_T \geq$ 15m and $\alpha_L \geq 30^o$ 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 to 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 =	Localise Angle of Slopes either single and multiple height intervals.

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

The classification is based on the geometry of the slopes such as height and angle for simplicity of implementation by less technical personnel in our local authorities. Although in reality there are many other factors affecting the stability of the slopes like geological features, engineering properties of the soil/rock, groundwater regime, etc, but in order to make the implementation of the classification easier, simple geometry has been selected as the basis for risk classification. Table 1 together with Figure 2 summarise the details of the classification (Gue & Tan, 2002).

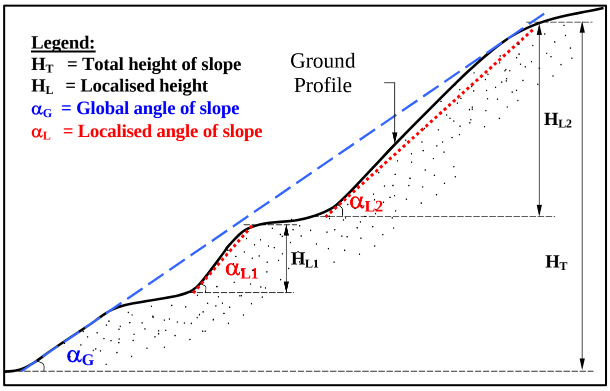

Figure 2 : Geometries of Slope (after IEM, 2000)

The IEM position paper also proposes that a new federal department called "Hill-Site Engineering Agency" be formed to assist Local Governments in respect to hill-site developments. The Agency is to 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 Order" to owners of doubtful and unstable slopes so that proper remedial and maintenance works could be carried out to stabilize unstable slopes and prevent loss of lives and properties.

Slope Engineering in Practice

Geotechnical Manual for Slopes published by Geotechnical Engineering Office (formerly known as Geotechical 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 the long term slopes in view of many factors that can cause the loss of the suction during prolong and high intensity rainfall, especially during the monsoons that occur at least twice a year.

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 geologist or geotechnical engineer to detect any geological discontinuities that may contribute to the following potential failure mechanisms, namely planar sliding, anticline sliding, active-passive wedge, toppling and also 3-D wedges. All these discontinuities cannot be fully addressed during 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 design stage, the design engineer shall 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.

Development on Soft Ground Area

The development of national road networks, residential and commercial properties have 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 resulting in higher cost of foundation.

Geotechnical works in deep deposit of highly compressible soft clay is 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 stratum or 'set' in order to limit the differential settlement by reducing the overall settlement of a structure. However, this solution only addresses short-term problem 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 solution'. In view of this, geotechnical engineers of Malaysia have started using settlement reduction piles coupled with strip-raft foundation for housing development (2-storey to 6-storey residential and commercial buildings) on soft ground. When designing the foundation system, short piles (length of pile is 1/4 to 1/2 of the depth to hard layer with SPT>50, 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)), Author and his colleagues 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 at areas of concentrated loadings and interconnected with a rigid system of strip-raft to control differential settlement (Tan, et al. 2004(b)). This system is the hybrid of piled rafts 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 3 shows the completed 2-storey link houses and schematic of the foundation depth relative to the thickness of the soft compressible subsoil. Figures 4 and 5 show the typical layout of the foundation system for 2-storey link houses and cross section of the strip raft foundation system respectively.

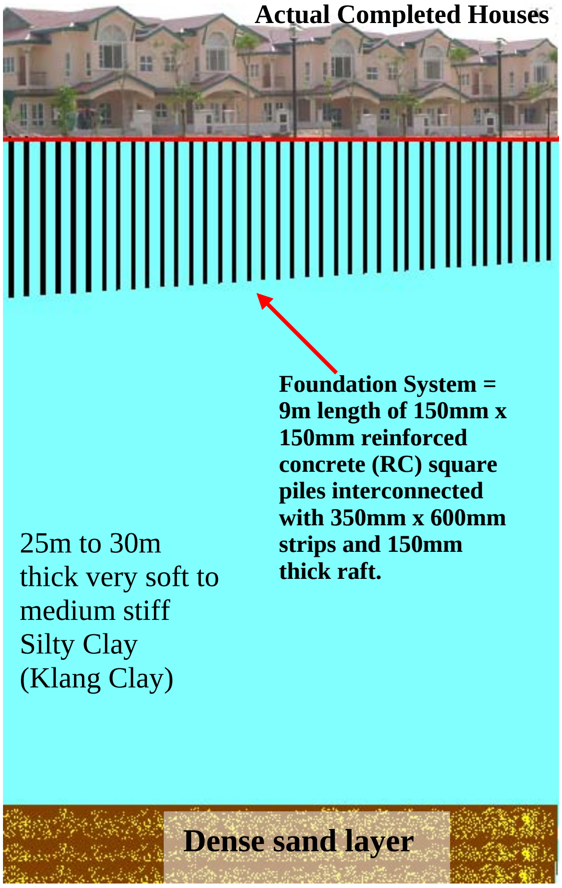

Figure 3. 2-storey link houses on floating piles.

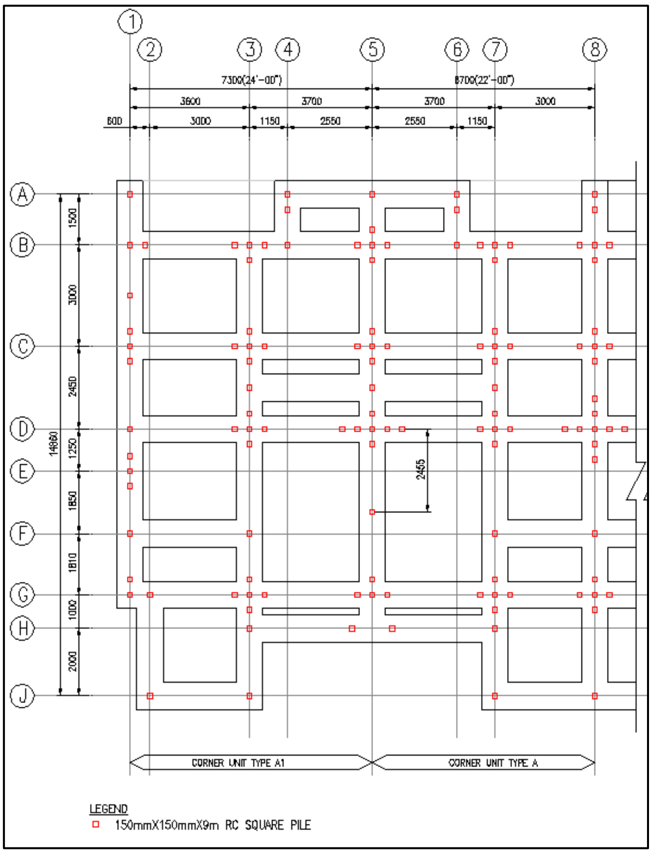

Figure 4. Typical layout of foundation system for terrace houses. (Tan, et al. 2004(b))

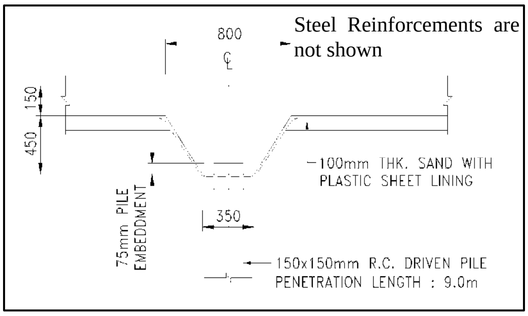

Figure 5. Cross-section of strip raft foundation system. (Tan, et al. 2004 (b))

Piled rafts with different pile lengths have also been used as more cost effective foundation replacing conventional piled to set system as the support for 2500Ton oil storage tanks on very soft alluvial clayey soil of about 40m thick as shown in Figure 6. 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).

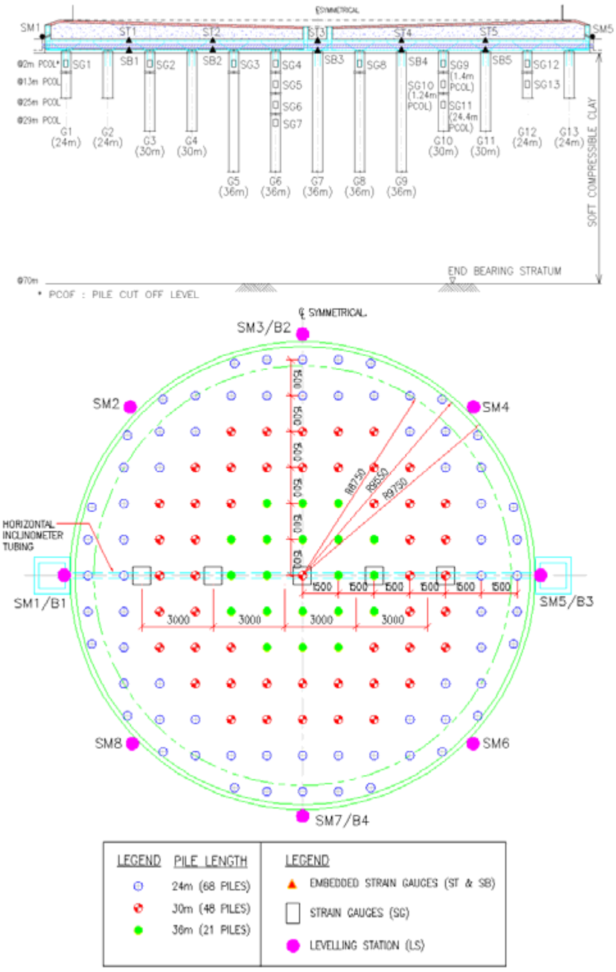

Figure 6. Details of Piled Raft with varying Pile Lengths (from Liew, et al., 2002)

The current trend in the design of expressway or rail embankment over soft ground has placed emphasize 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 slab, or combination of the techniques are widely used in Malaysia. Emphasis is also put on controlling differential settlement between piled structures (viaducts and bridges) and approach embankment (usually unpiled). The techniques commonly used in Malaysia are transition piled embankment, expanded polystyrene (EPS), oversized culvert, etc. (Gue, et al. 2002). Lately foam (light weight) concrete has been introduced to Malaysia as one of the option to replace EPS in view of its inertness to fire.

Developments in Congested Urban Areas

In the expensive and congested urban area like Kuala Lumpur, Penang and Johor Bahru, basements have been constructed to effectively utilise the underground for car parks and other usage. Other than basements, construction of tunnel 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 excavation depth used for basement is 28.5m for Berjaya Times Square, Jalan Imbi (Tan, et al., 2001). Figure 7 shows the excavation 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 system commonly used includes temporary pre-stressed ground anchors, internal strutting, top-down or semi top-down and etc. Finite element method (FEM) is widely used in the design of deep excavation in view of its versatility in modelling soil-structure interaction and capacity to predict more representative ground deformations of the retained soil which is very important to ensure safety of adjacent properties in congested urban areas.

Figure 7. Berjaya Times Square, Kuala Lumpur during construction.

For deep excavation in urban areas, Gue & Tan (2004) presents 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 condition 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 on 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 area 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 formation. This is due to the complex and difficult geological features of limestone such as pinnacles, sinkholes, cavities and slump zones and etc. Gue (1999) describes the difficulties of foundation works in limestone formation. Additional feature such as the presence of a very strong rock; Skarn, which has an unconfined compressive strength of about 300mPa posed additional difficulties to the tunnelling (Gue & Muhinder, 2000). Working in limestone formation and its surrounding area, requires frequent change of equipment and as well as increase in the time of construction when some of the features mentioned above are encountered. In view of the difficulty of the tunnelling projects, input from experience geotechnical engineers and engineering geologists are very important.

Since the tremendous 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.

Developments on former mining lands are also common in Malaysia. The mining process leaves behind ponds, loose sandy soils, and slime deposits in the pond or on land. The slime is a waste materials from mining and is a 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.

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 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 the factors such as loadings, ground conditions, geological formation, noise etc. The piling systems used in Malaysia include bored piles, driven pre-cast piles, micropiles, jack-in piles, barrette piles, etc. The design of bored piles in residual soils generally follow simple empirical correlations to SPT'N' values as presented by Toh et al. (1989) and Tan et al. (1998). In the design of bored piles, the base resistance shall be ignored unless it is dry hole and the base can be properly cleaned and inspected. This is due to the impracticality to properly clean 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 the areas where driven piles are prohibited by local authorities due to noise and pollution, jack-in piles using square piles (size 150mm to 400mm) and spun piles (diameter of 300mm to 600mm) have gained popularity in view of its speed of installation and lower construction cost compared to bored piles.

Quality Management Systems

In Author's opinion, the quality management principles (MS ISO 9000:2000) are very important and should be practised for 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 are 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 consultancy, this means providing services with emphasis on safety, innovativeness, economical and construction friendly.

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. Conducive environment includes but not limited to providing sufficient guidance from experience engineers to junior staffs, training programmes (internal colloquium, forums and external courses, workshops, seminars and conferences), rewards on quality works and 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 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 shall be based on analysis of data and information instead of using gut feeling. This approach is very important when carrying out planning, analysis and design, and also for decision making of policy for the company.

Continual improvement:- Continual improvement of the company overall performance should be a permanent objective of the company. For consultancy service, this includes technical competency and overall management of the company. Carrying out in house research and development (R&D) such as development of engineering computer programmes to assist in the analysis and design, specifications, checklists for either design or supervision of various geotechnical works, geotechnical risk management, technical manual, technical papers and etc. Many of the products stated above are available at the webpage of Gue & Partners Sdn Bhd (2004) at www.gueandpartners.com.my.

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