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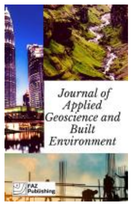

Investigating Malaysian Tropical Ground: JKR Experiences

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Abstract: The problematic tropical ground conditions encountered by Geotechnical Engineering Branch, Public Work Department of Malaysia (PWD) are presented. These problems cover on all aspects including technical and contractual issues. The geotechnical failures during and after construction mostly occur when some considerations are neglected due to lack of data, information and knowledge on the geological and soil conditions. Therefore, particular case studies are focused and discussed which experienced by PWD. Some cases are very common and uncommon depend on the location of the site. The author's experiences with government projects hopefully become lessons learned for all players in construction industries especially in design, construction procedures, construction quality as well cost of project. Finally, this sharing experiences will open for discussion within the geotechnical expertise on how to improve the construction practice when dealing with these problematic soils.

Keywords: Tropical soil, Geotechnical forensic, soft soil, earthwork, soil settlement.

1. Introduction

Infrastructure has become one of the focal points in developing a country. Apparently, our nation has experienced a rapid and vast development since decades ago. Public Work Department of Malaysia (PWD) is known as the main technical agency for Malaysian government that involves in highway and building projects throughout the country. PWD has solved many problems related to construction industry and become the technical expert especially when dealing with problematic tropical ground. In fact, these problematic tropical ground covers residual soil involving boulders and sedimentary rock, ex-mining ground and soft ground (i.e: marine clay, peat etc). These grounds have their own distinctive condition that need to be dealt properly to avoid any circumstances that may affect the integrity of the building and the whole project development. However, this paper discusses a case study of problematic tropical ground conditions which related on soft soil.

One of the problems faced by PWD is when dealing with residual soil which formed directly by the physical and chemical weathering of the rock underlying them. In the meantime, difficulties in identification of complex geological setting are the challenges of construction in residual soil. Adverse geological settings are more prominent in sedimentary and meta-sedimentary formations due to inherent beddings [1-3]. These geological features such as discontinuities are not usually detectable during the design stage even with proper subsurface investigation. Most of these geological features can only be detected after exposing the slopes during excavation. With such uncertainty, the common problem that usually arise is about stability of the slope/excavation and contract disputes during the excavation due to confusion in agreeing the identification of excavation material [1] which requires different method of excavation and subsequently lead to cost variation.

In view of the stability problem, design engineers will make conservative assumptions about the soil/rock parameters and also the groundwater profile due to lack of data and uncertainty [4]. Hence, it will lead to over design or otherwise. On the contrary, when optimistic assumptions are made and the results obtained during construction on sites that are less favorable then expensive options such as retaining walls or slope strengthening using soil nails are required. Thus, the safety of slopes is often compromised due to

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economic factor and additional protection works that needed to be done [5].

Another issue of the tropical ground conditions is soft soil. In general, the soft soil in Malaysia is considered as quaternary sediments consist of alluvial deposits and organic or peat soils. In this country, soft ground usually found in the coastal plains of the country covers large area of west coast and east coast of Peninsular and East Malaysia [6]. Soft soil is usually related to low shear strength, highly compressible and low permeability [7]. The condition of soft alluvial soils is influenced by the source of the parent material, depositional processes, consolidation and fluctuations in groundwater levels. According to Mohamad et. al [8], the shear strength of the soil is reported to be less than 40 kPa and it can be physically mould by light finger pressure. Therefore, the main geotechnical problem in this deposit is usually related to poor bearing capacity, settlement and stability. The settlement problem can be defined as a deformation in the soil due to the applied stresses [9-13]. When the settlement occurs, the geometry of load carrying system will change and result to the instability of soil embankment itself [14-15].

PWD had involved in many construction projects nationwide to construct new government buildings, infrastructures, state and federal highways, monitoring and maintenance of soil slopes as well as forensic investigations [16]. Since 2010, statistics of government projects on tropical ground conditions nationwide carried out by PWD is summarized in Table 1. There are 191 out of 531 projects (new building and highway projects) from 2013 to 2017 are related to the construction over soft soil which is approximately 36% of the projects, whereas the remaining 64% of the projects are constructed over residual soil. Therefore, it is clearly shown that PWD has experienced and encountered many problems in construction on topical ground condition.

Table 1 - New building and highway projects carried out by PWD on Malaysian tropical soil from 2013 to 2017

Areas	Building Projects		Highway project		Total
	Soft Soil	Residual Soil	Soft Soil	Residual Soil	
Northern part of Peninsular Malaysia	48	67	17	19	151
Central part of Peninsular Malaysia	19	54	10	11	94
Eastern part of Peninsular Malaysia	39	44	17	33	133
Southern part of Peninsular Malaysia	14	54	3	24	95
Sabah & Labuan (West Malaysia)	10	22	2	4	38
Sarawak (West Malaysia)	6	5	6	3	20
Total	136	246	55	94	531

2. Construction of 4-lanes highway for Infrastructure and Public Facilities for Construction of Pengerang Integrated Petroleum Project

2.1 Project Background

The government of Malaysia through it implementation agency, PWD is constructing new road transportation infrastructure, Phase 1 (P1) for Pengerang Integrated Petroleum Project, Kota Tinggi, Johor. This project was executed in four phases. The project was implemented through conventional consultant concept, where Geotechnical Engineering Branch was involved in reviewing design proposal from the appointed consultant.

The construction of the new road was commenced in 2016. It is consisted of dual lane carriageway with 3 m road shoulder with proposed length of 6.3 km. Fig. 1 shows the proposed route alignment of the road. The route alignment is underlain by a layer of very soft to soft clay with the thickness ranges from 1.5 m to 7.5 m. This layer followed by a layer of stiff clay, whereas hard stratum is subsequently found at depth of 6 m to 20 m. However, peat was encountered at CH 850 to CH 1450.

2.2 Geology of the area

The findings of the geotechnical investigation confirm the geology of the area as indicated in the geological map published by the Geological Survey of Malaysia. The summary of the geology and superficial deposit along the route is shown in Fig. 2 and summarized as follow;

i) Pengerang Tuff and Mersing Formation
ii) Pengerang Volcanic show pyroclastic flows, forming thick bed succession. The clasts composed of lapilithic and re-sedimented of pyroclastic rocks.
iii) Mersing Formation distributed in Eastern Johor and Southern Pahang.
iv) The oldest rock in Eastern Johor, overlain unconformably by all other sedimentary rocks formation.
v) Composed by metamorphic rocks such as schist, phyllite and quartzite, some interbedding of slate and metaquarzite
vi) Folded, faulted and intruded by granite; quartz vein is common as crack filling.

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Fig. 1 - Proposed Phase 1 (P1) road alignment

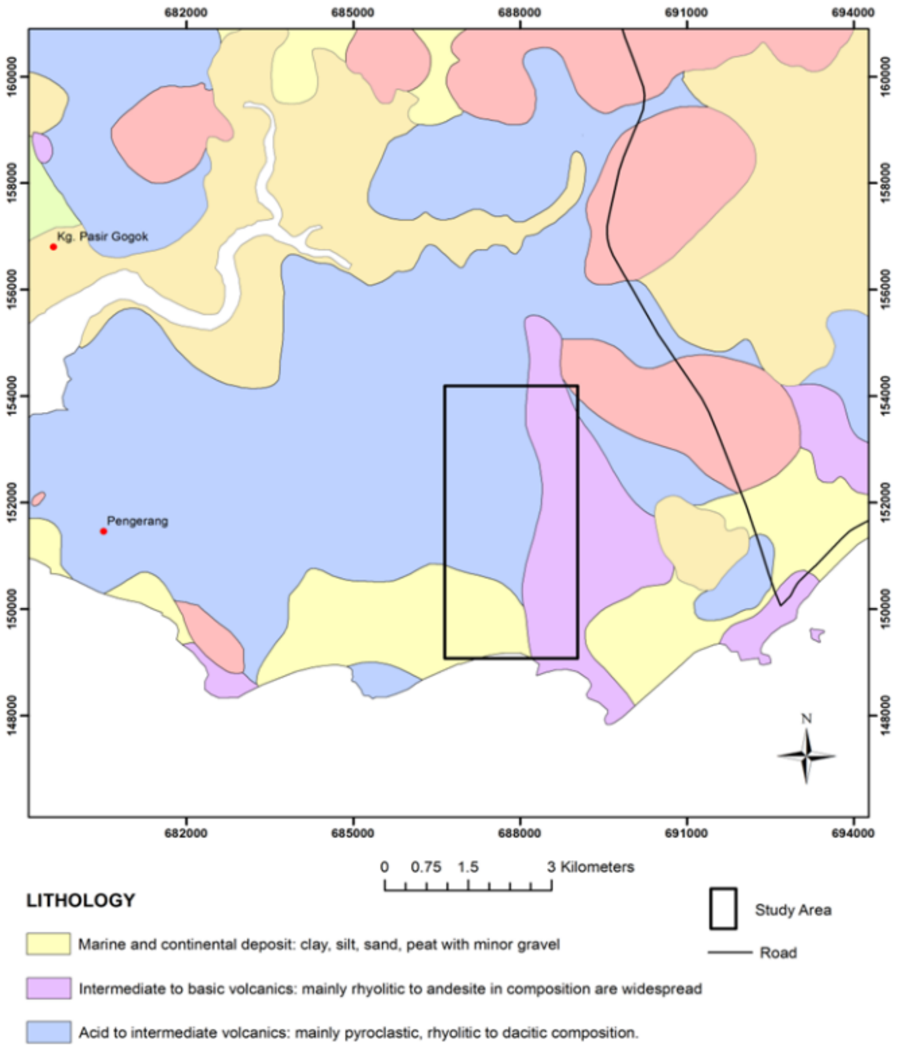

Fig. 2 - Geology area

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2.3 Geotechnical Investigation

The subsoil conditions along the stretch as interpreted from the desk study evaluation and the findings of the geotechnical investigation results. From CH 0 to CH 3400 and CH 4500 to CH 6300, the thickness of the alluvial deposit of very soft clay are between and 1.5 m to 7.5 m with SPT value of 0 and followed by stiff clay up to 6 m to 20 m. These layers are underlain by very dense sand with SPT value of 50. However, peat is encountered at CH 850 to CH 1450. From CH 3400 to CH 4500, the soil is mainly stiff silt which can be considered as hilly terrain. Overall, the consistency of cohesive materials (clay and silt) is found to be very soft at the surface up 30 m deep and gradually increase from stiff to eventually hard.

2.4 Issues on Soft ground

In this project, the engineering problem was encountered during construction stage. A portion of the road embankment from CH 5600 to CH 5900 had experienced failure. Tension crack starts to appear along the chainage when the embankment has reach 6 m high. The proposed total embankment height for that chainage is 10 m. Therefore, any further construction has been stopped to investigate the cause of failure. It was found that confirmatory soil investigation using Mackintosh Probe was carried out at the centre line of the proposed road and based on those results, the remove and replace was proposed. However, the presence of the soft clay at the toe of the embankment was not removed assuming that the depth of soft lay at the centre of the road and toe of embankment are similar. This wrong assumption of the designer has caused the tension crack due to stability issue. The undrained shear strength was assumed to be 20 kN/m^2 in the design. However, in real situation, the undrained shear strength at the toe of the embankment might be less. Furthermore, the instrumentation monitoring was not installed at this chainage. Thus, it was very difficult to investigate the cause of failure for that particular case.

Based on the results of the slope analysis, the factor of safety for chainage 850-1450, 1450-2150 and 4975-6300 based on the original design are 1.448, 1.223 and 1.208, respectively. Therefore, the slopes are safe based on the design criteria as follows;

- FOS > 1.2 (embankment on soft ground) and FOS> 1.25 (embankment not on soft ground).
- FOS > 1.25 (unreinforced cut slope) and FOS > 1.5 (reinforced embankment and cut slope).

With the proposed ground treatments, the embankment, retaining wall and cut slope shall achieve certain factor of safety against slope stability failure. However, the soil parameters obtained from soil investigation work have been in the analysis with the assumption that Cu= 20 kPa and Cu = 48 kPa for Foundation Soil 1 and Foundation Soil 2, respectively. The results of the analysis are summarized in Table 2 below. The proposed improvement method for this chainage was using remove and replace method with recommended 2 – 3 m depth of soft material removal. This proposal was based on soil data obtained from the soil investigation works that has been done during design stage. However, it was found out later that the soil investigation was done only at the centre of the alignment.

Table 2 - Summary for slope stability analysis (original design) with the estimated soil parameters.

Chainage	Foundation Soil 1	Foundation Soil 2	Embankment Height (m)	Depth of Remove and Replace (m)	Factor of safety
850-1450			5	3	1.448
1450-2150	Cu = 20 kPa	Cu = 48 kPa	8	2	1.233
4975-6300			10	2	1.208

2.4 Slope Stability Analysis

Slope stability analysis was carried out by the consultant in order to check the factor of safety of the embankment for remedial work. Boundary condition of external stability check using Slope-W as shown in Fig. 3, Fig. 4 and Fig. 5. Boundary condition of external stability check using Slope-W software. There are three cases of analysis using different soil parameters at foundation soil 2 whereas the soil paramater for foundation soil 1 is remained constant. It was proposed to be 6.0 m Exposed Height Embankment + 1.5 m Exposed Height Surcharge with 6.0 m depth of remove and replace (R&R) for Phase 1 of CH 1450 – 2150: CH 4500 – 6300.

The stability check is based on back analysis and the C_u for foundation soil 1 (very soft soil) is 6 kPa but in the analysis 5 kPa is adopted on a conservative basis. The C_u for foundation soil 2 (soft soil) is 40 kPa. Sensitivity analysis is done for foundation soil 2 (soft soil) in which the C_u will be as low as 20 kPa and 15 kPa. With the stability analyses check, it is still recommended that further soil investigation need to be done including CPT/vane shear to further confirm the soil parameters used. The results of the analysis for remedial work are summarized in Table 3 as below.

Table 3 - Summary for slope stability analysis (remedial work) with the estimated soil parameters.

Case	Foundation Soil 1	Foundation Soil 2	No. of Reinforcement	Factor of safety
1		Cu = 40 kPa	2 layers of Mirafi PET1000	1.773
2	Cu = 5 kPa	Cu = 20 kPa	2 layers of Mirafi PET1000	1.276
3		Cu = 15 kPa	2 layers of Mirafi PET1000	1.145

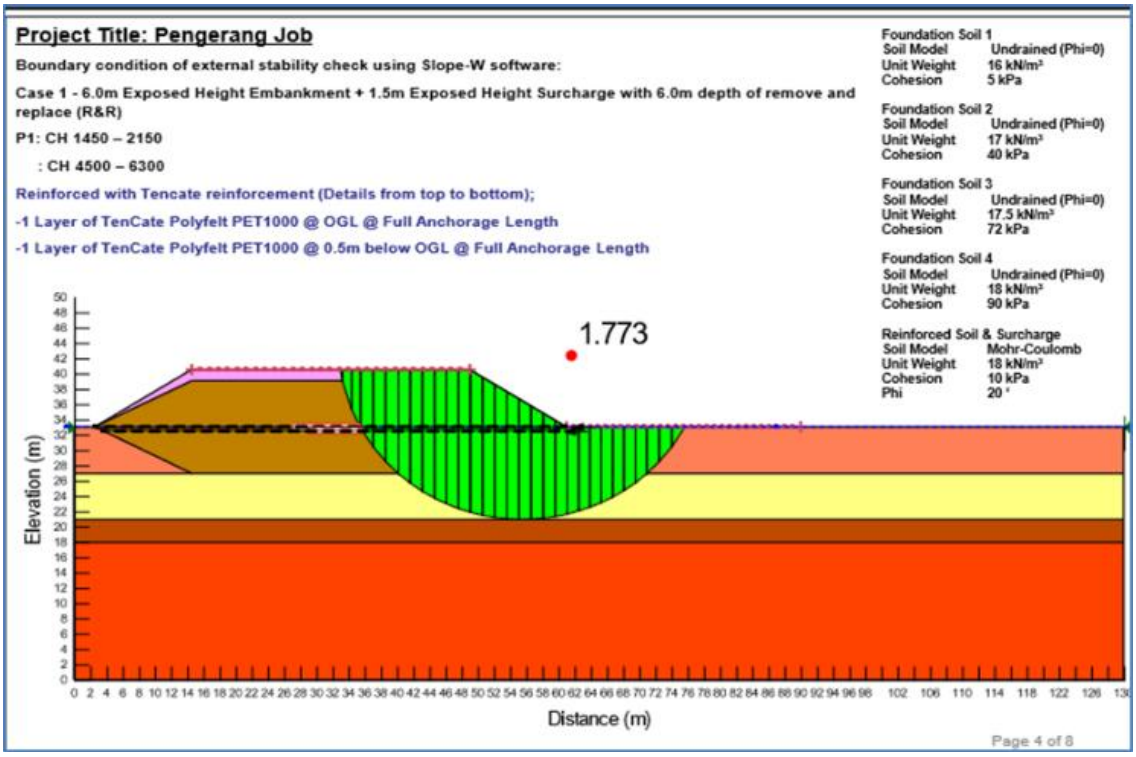

Fig. 3 - Slope stability analysis Case 1

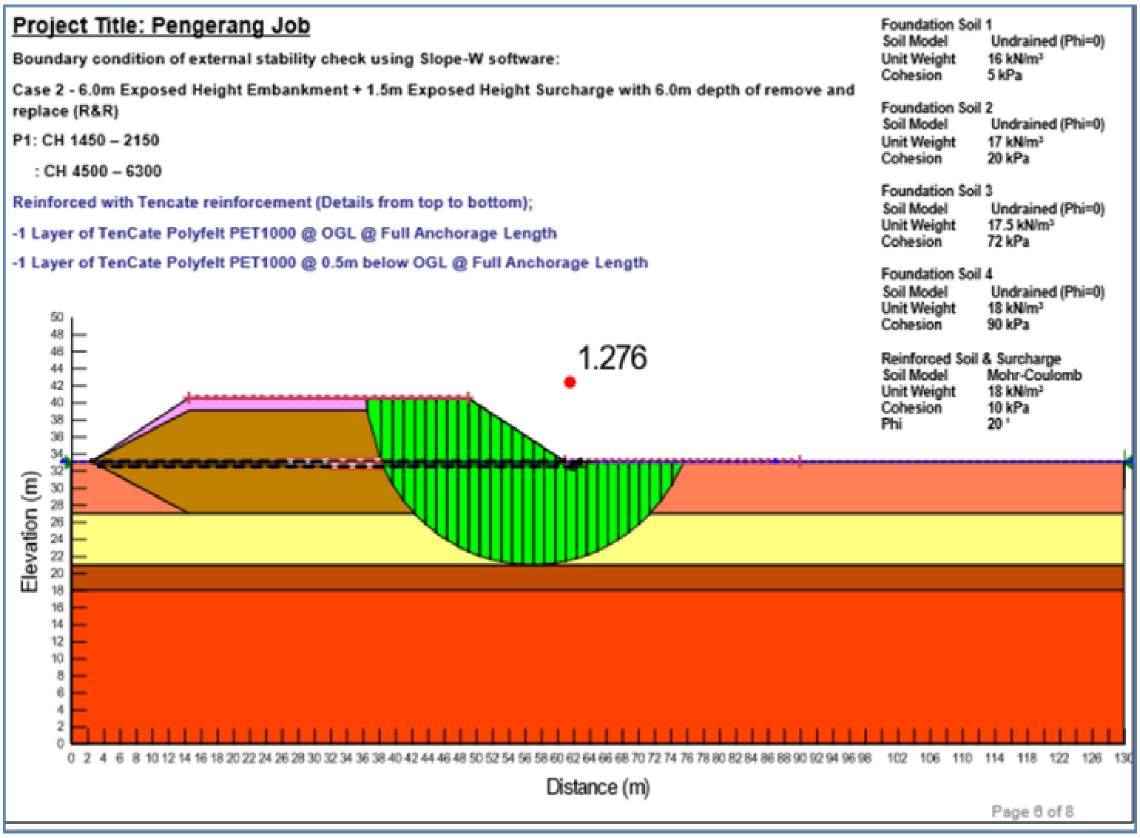

Fig. 4 - Slope stability analysis Case 2

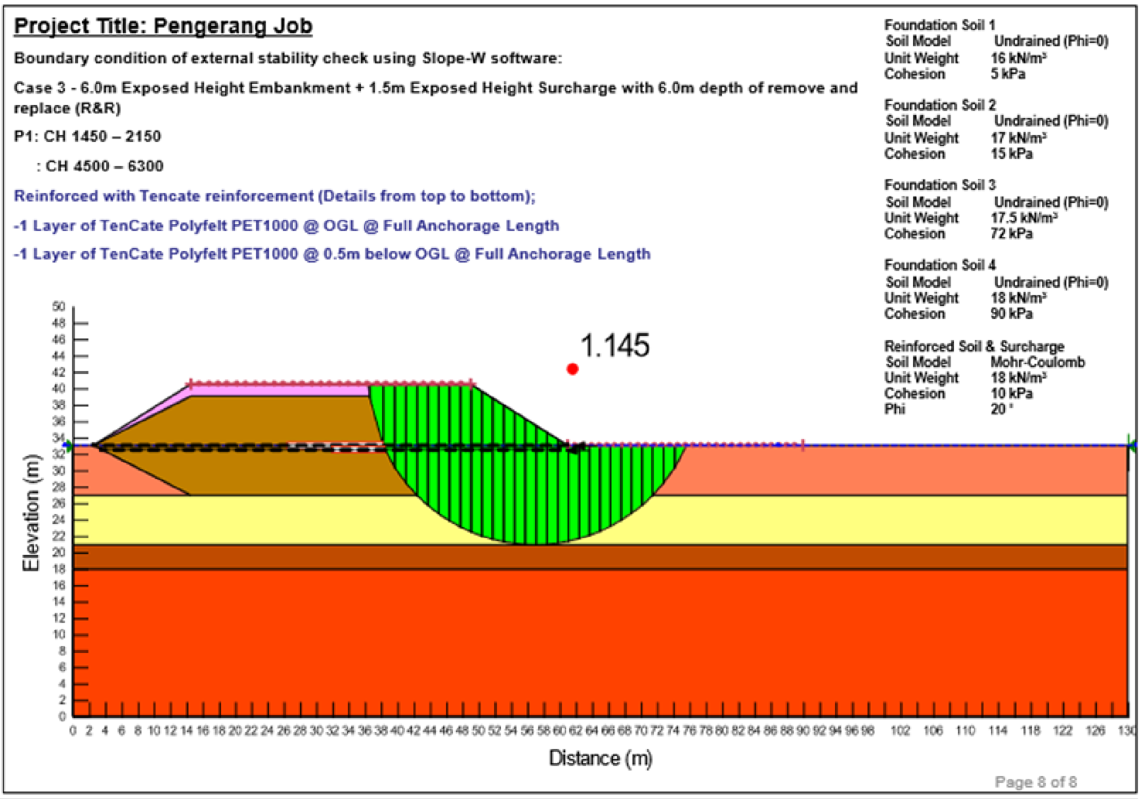

Fig. 5 - Slope stability analysis Case 3

3. Discussion and Conclusion

It can be concluded that the tension cracks embankment need to be excavated at certain level (the remove and replace level) and further soil investigation need to be carried out.

Based on the aspects presented in the previous sections, some recommendations potentially relevant for this case study are proposed:

i) Mackintosh probe tests are conducted for every 25 m length, and four numbers of penetration using field vane test are required.

ii) Soft materials with Mackintosh probes reading less than 40 blows need to be removed and results from field vane need to be confirmed with the design parameters.

iii) Instrumentation monitoring is installed and monitoring data is checked on the regular basis.

iv) High strength geotextile as basal reinforcement is used followed by 2nd layer of high strength geotextile and built embankment up to formation level.

v) As the drain level is now lowered at CH 5700 to reduce level 8 and CH 6700 to reduce level 5, therefore it is recommended that the road profile level to be revised accordingly and the embankment height is also reduced.

vi) The rate of filling material is placed at every 0.6 m height per week (not exceeding 0.3 m per day) until the embankment has reached a height of 6.0 m above the original ground level. This is followed by a resting period of 6 weeks.

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