Remedial Measures Adopted for Slope Failure at Bukit Antarabangsa, Malaysia

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ABSTRACT: A section of slope collapsed at the district of Gombak (Ulu Klang) Selangor, well known as Bukit Antarabangsa residential area, killing 4 residents and injuring 14 others. The debris from the landslides completely blocked the only access road, to the neighbouring residential areas, leaving about 2000 residents stranded without access. The landslide took place at approximately 3.30 am, on 6th December 2008, measuring about 109m width at the crest, 120m in length and 15m in depth. An estimated of 101,500 cubic meter of earth had translated to a maximum run off distance of about 214m from the toe of slope. Emergency measures were undertaken to perform search and rescue, to evacuate the houses next to failure, provide access to the stranded residents, reinstate damage monsoon drain and other major utilities. Most importantly is to repair the failed slope in order to prevent further failure or damage to the houses facing the failure crest. This paper address the details of the geotechnical remedial works carried out reinstate the failed slope and the type of remedial works were adopted to stabilize neighbouring section of un-failed slope. The solution adopted the usage of caisson, soil nailing and sufficient surface and subsoil drainage system.

KEYWORDS: Slope Failure, Caisson, Soil Nail, Stability Analysis, Factor of Safety, Sub soil drainage system.

1.0 INTRODUCTION

A section of slope along Jalan Wangsa 9 and Jalan Wangsa 11 which is part an abandon development of "The Proposed Development of Linkhouse Between Jalan Wangsa 9 and Wangsa 11, Wangsa Ukay, off Jalan Ulu Klang, Mukim Ulu Klang, Daerah Gombak, Selangor" by Messrs Superview Development Sdn B hd, has collapsed. The landslide took place at approximately 3.30 am, on 6th December 2008, measuring about 109m width at the crest, 120m in length and 15m in depth. An estimated of 101, 500 cubic meter of earth had translated to a maximum run off distance of about 214m from the toe of slope. The location plan of the failure is shown in **Figure 1.0**. The landslide has cause 14 numbers of bungalow houses to be damaged, 6 in Taman Bukit Mewah and 8 in Taman Bukit Utama. The landslide has also caused 4 fatalities with fourteen numbers of injured persons. The debris from the landslides has completely blocked the only access road via Jalan Bukit Antarabangsa to the neighbouring residential areas namely Taman Bukit Jaya, Impian Selatan Condominium, Wangsa Heights and Bukit Antarabangsa. Detail investigation of the failure and site investigations were carried out by Messrs Mohd Asbi and Associates and Kumpulan Ikram Sdn. Bhd, respectively. As for the remedial and restoration works the scope of works were divided into 4 packages, namely:

Package 1 – Stabilization of slope along Jalan Wangsa 9, by Messrs Kumpulan Ikram Sdn. Bhd, as consultant and Messrs HCM Engineering Sdn Bhd as contractor.

Package 2 – Stabilization works on the right hand side of failure by Messrs Mohd Asbi and Associates as consultant and Messrs Target Resources Sdn. Bhd, as contractor

Package 3 – Restoration of the failed slope by Messrs Enceal Consultants Sdn Bhd as consultants and Messrs MTD Group as Contractor

Package 4 - Stabilization works on the left hand side of failure Stability enhancement of retaining wall at Taman Bukit Jaya

- Stabilization works on the left hand side of failure
- Stability enhancement of retaining wall at Taman Bukit Jaya

- Stabilization of slope at Kyoto Garden.
  - Messrs Mohd Asbi and Associates as consultant and Messrs Jamil Ghani Construction Sdn Bhd as contractor.

This paper addresses the detail remedial design works carried out under Package 3 and Package 2.

Figure 1: Location of the failure

2.0 SUBSURFACE CONDITION AND SITE INVESTIGATION WORKS

Based on the geological map of Malaysia and the site investigation carried out, the failure area falls under the area of granitic bedrock formation (Acid intrusive rock) of the age Mesozoic or younger. A total of 25 numbers of boreholes were carried out within the failure zone and at the surroundings. The borehole layout plan within the failure area and the neighbouring sides is shown in **Figure 2.0**. Typical cross section of subsoil stratum along the slope profile at main failure area is shown in **Figure 3.0**. Based on the site investigation data and back analysis carried out, following subsoil stratification and parameters were identified as listed in **Table 1A** and **1B.**

3.0 PROPOSED REMEDIAL DESIGN FOR PACKAGE 2

After studying the area thoroughly, it is established that the existing right hand side slope the available Factor of Safety (FOS) is about 1.26. As the area contains many pockets of loose material and has high potential for ground water table and pore water pressure increase which could cause similar failure. Hence the area were also required to be rectified immediately with slope strengthening works.

Figure 4.0 shows the resistivity test result conducted by JMG (Department of Mineral and Geoscience) indicating pockets of loose material. The presents of these pockets of loose material indicates the slope is a filled slope with poorly or not compacted fill (end tripped slope)

Figure 2.0: Borehole layout plan within the failure area and the neighboring sides

Table 1A : Subsoil Parameters andSlope Stratum Between Jalan Wangsa 9 and Jalan Bukit Antarabangsa

Soil Stratum Along The Slope Profile Between	Depth	SPT Probe Value (Blows / 300mm)	Estimated Strength Parameters		
			Effective Cohesion (kN/ m²)	Effective Friction Angle (°)	Unit Weight (kN/m³)
Layer 1* Soft to Medium Stiff Clayey Sandy Silt	• 0 ~ 15m at crest and mid level of slope • 0 ~ 20m at toe of slope	0 ~ 5	5	28	17.5
Layer 2 Medium Stiff to Stiff Clayey Sandy Silt	• 15 ~ 25m at crest and mid level of slope • 20 ~ 30m at toe of slope	5 ~ 10	8	32	18
Layer 3 Hard Clayey Sandy Silt / Bedrock	• Beyond 25m at crest and mid level of slope • Beyond 30m at toe of slope	> 50	10	38	18.5
Compacted earth fill	-	-	5	30	18
Rock fill	-	-	2	38	19

Table 1B : Subsoil Parameters and Soil Stratum Fill Platform at Jalan Bukit Antarabangsa

Soft Layer Deposit At Slope Toe	Layer Thickness	SPT Probe Value (Blows / 300mm)	Estimated Strength Parameters		
			Total Cohesion (kN/ m²)	Total Friction Angle (°)	Unit Weight (kN/m³)
Layer 1* Very Soft to Soft Clayey Sandy Silt	8 ~ 10m	0 ~ 4	20	0	16
Layer 2 Medium Stiff to Stiff Clayey Sandy Silt	≃ 4m	4 ~ 5	25	0	17
Layer 3 Stiff to Very Stiff Clayey Sandy Silt	≃ 6m	5 ~ 15	75	0	18

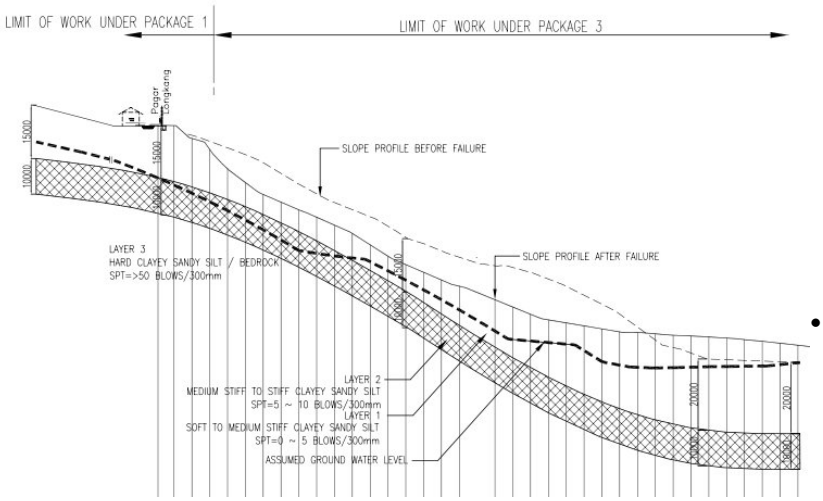

Figure 3.0: Cross section of subsoil stratum along the slope profile at main failure area

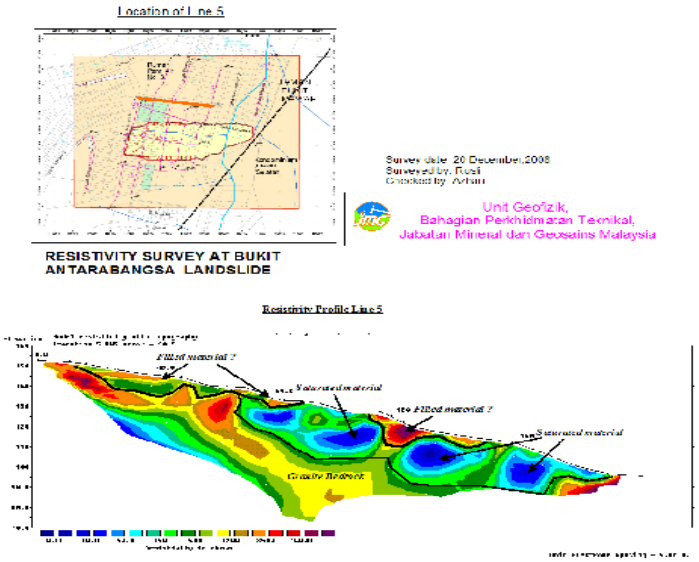

Figure 4.0: Shows the resistivity test result conducted by JMG (Department of Mineral and Geoscience)

3.1 Proposed remedial works for package 2

The remedial works proposed to rectify the existing conditions of right hand side slope are as follows :

- Construction of 30m deep caisson pile wall (diameter of 1.5m, spaced at 2m centers) to intercept the failure plane in order minimize potential global instability and to ensure sufficient socketing into hard stratum were obtained.
- Installation of soil nails with T32 tendon and pressure grouting the nails. This system was used to overcome the localized failure of the existing slope.
- Pressure grouting was proposed together with the soil nail installation to ensure the soil nails gain appropriate anchorage friction especially at the loose pockets. Based on the Resistivity Test by JMG, approximately 20% of the slope area contains loose pockets. Therefore this 20% of slope area has to be covered with grout, in order to strengthen the slope.
- **Table 2** shows the Factor of Safety obtained based on the studied cross section at Package 2, the Factor of Safety (FOS) achieves 1.5 with the usage of caisson pile. This in return, complies to the project requirement of FOS 1.5.

Table 2: Factor of Safety FOS for Package 2

Case	Slope Condition	Factor Of Safety
1	Existing Slope without Treatment	1.26
2	Soil Nailing and Caisson Pile	1.53

Figures 5.0 and **6.0**, shows the failure profile for Case 1 and 2 respectively for Package 2

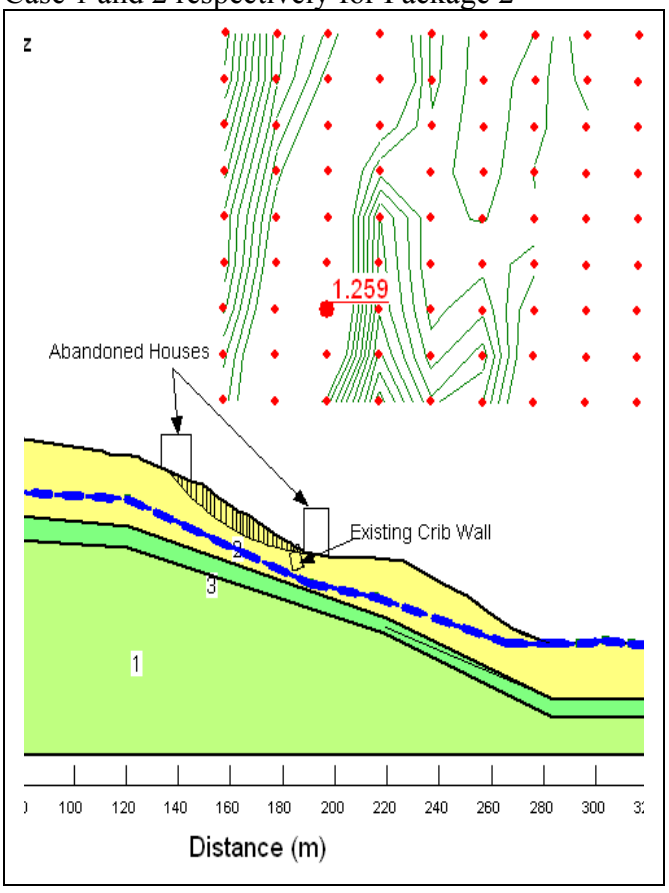

Figure 5.0: Case 1 – Existing slope without treatment (Package 2)

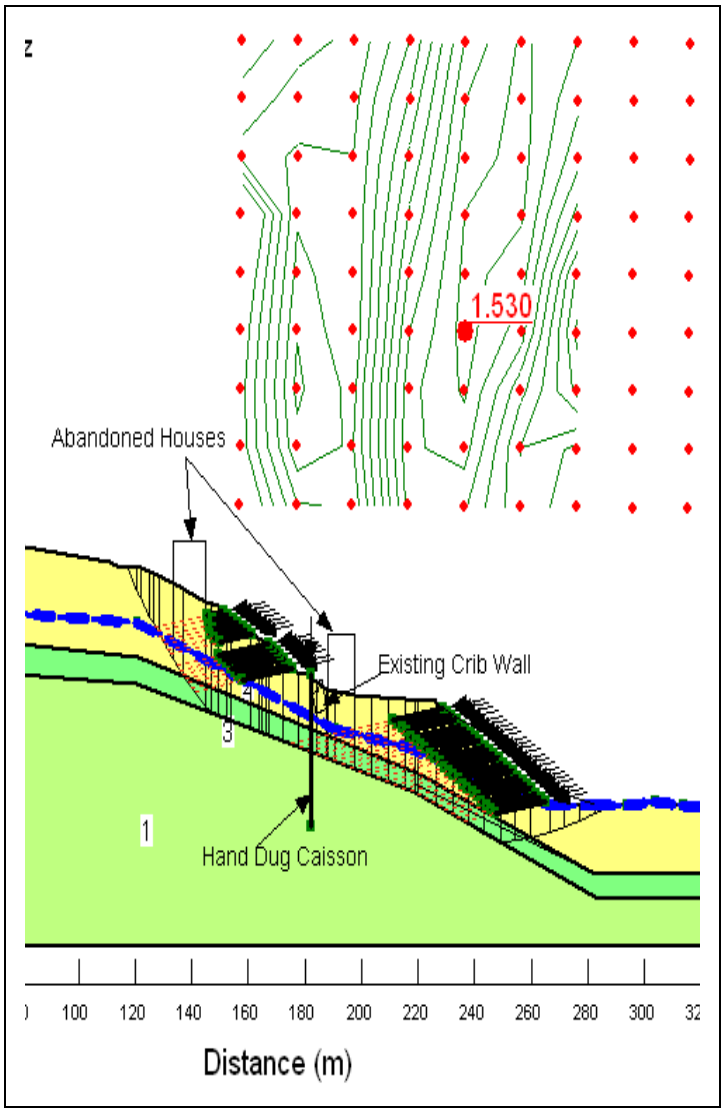

Figure 6.0 : Case 2 – Soil nailing and caisson pile (Package 2)

3.2 Package 3 Rectification Works (Main failure area)

The typical cross section of the proposed remedial works with in-cooperated subsoil stratification is shown in **Figures 10.0**. The proposed remedial slope is analysis for

- Internal Stability
- External and Overall stability

The results of the analysis performed on the said cases are tabulated below in term of minimum factor of safety against potential slip failure. Details of stability are tabulated under **Table 3.0**. Based on the above results, the reconstructed fill slope has adequate factor of safety for internal, external or overall stability. A typical failure analysis of case 5, 7 and 9 is shown in **Figure 7.0, 8.0** and **9.0.**

Table 3: Factor of Safety FOS for Package 3

Case	Description	Min. Factor of safety	Improvement Required	Remarks
Upper Fill Slope (between Jalan Wangsa 9 and Jalan Wangsa 11)				
1	Internal stability of the upper fill slope without reinforcement	1.39	Provide geogrid reinforcement 15m length of TT90 at every berm level of the fill slope to enhance the localised failure of upper fill slope	Marginally Adequate
2	Internal stability of the upper fill slope with reinforcement	1.46		Adequate (enhanced)
Lower Fill Slope (between Jalan Wangsa 11 and Taman Bukit Mewah platform)				
3	Internal stability of the bottom fill slope without reinforcement	1.48	Provide geogrid reinforcement 15m length of TT090 at every berm level of the fill slope to enhance the localised failure of lower fill slope	Adequate
4	Internal stability of the bottom fill slope with reinforcement	1.50		Adequate (enhanced)
Stability of Slope Toe (To Prevent Repetition of Toe Failure)				
5	Shallow basal failure of the toe without reinforcement	0.93	• Provide high strength geotextile reinforcement HS 400/50 • Caissons are required to be installed to a minimum depth of 25m to obtain deep sited failure	Insufficient
6	Shallow basal failure of the toe with high strength geotextile	1.11		Insufficient
7	Deep sited basal failure beyond the toe of bottom row caisson	1.67		Sufficient
Overall Stability				
8	Overall stability of the proposed remedial works	1.45	• Caisson at mid level and toe level • High strength geotextile at soffit of rock fill • Soil nails to stabilize temporary excavation • Geogrid at fill slope	Adequate
9	Overall stability of proposed remedial works with mid level caisson	1.65		Adequate (enhanced)

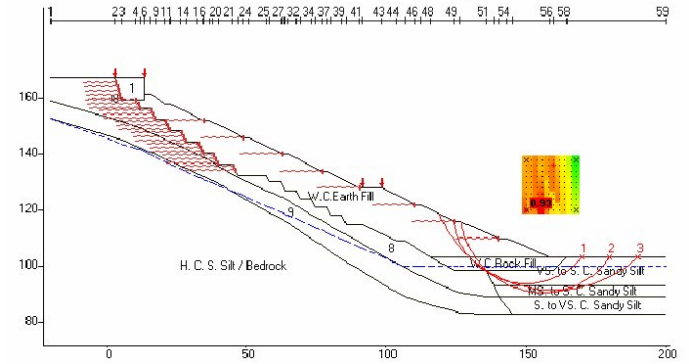

Figure 7.0 : Case 5 – Shallow basal failure of the toe without reinforcement

4.0 CONCLUSION

From the foregoing assessment, the following conclusions are drawn and recommendation made:

1. An assessment, on the stability of the failed slope has been performed based on site observations, survey measurement and subsoil stiffness data.

2. Subsurface stratification forming the slope profile is assumed to range from soft to hard clayey sandy silt.
3. Primary cause of slope failure is attributed to rise in ground water level due to prolong rainfall, continuous creep of slope over along period of time, sustained saturation of the slope at pockets of voids within the slope mass, as the slope were constructed by means of end tipping.

Package 3 rectification works

1. The failed slopes remedial works undr package 3 were proposed to be rebuilt using suitable well compacted earth fill and caissons to provide overall stability and also to prevent toe basal failure.

Package 2 rectification works

1. The un-failed section of slope were proposed to be strengthen using soil nails and pressure grouting with overall factor of safety improvement using a row of caisson.

The rectification works carried out under both packages adequately design and executed at site to provide long term stability for slope. The remedial works have also in cooperated subsoil drainage pipe network, horizontal drains and every berms are equipped with sand layers. These subsoil drains were design to reduce the level of ground water table and also prevent any buildup of pore water pressure. The rectification works will be able to allow the residents who lost their homes due to the landslides, will be able to return and reconstruct their lost homes.

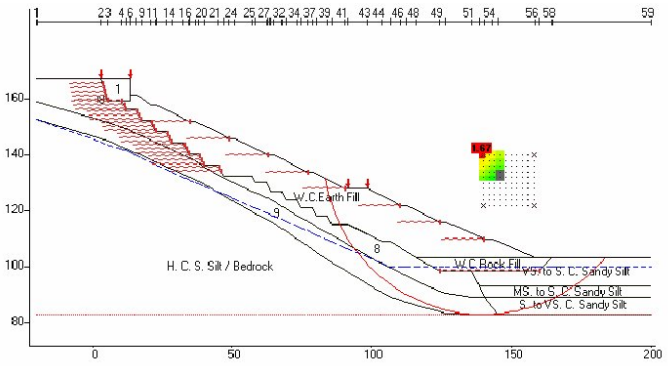

Figure 8.0 : Case 7 – Deep sited basal failure beyond the toe of bottom row caisson

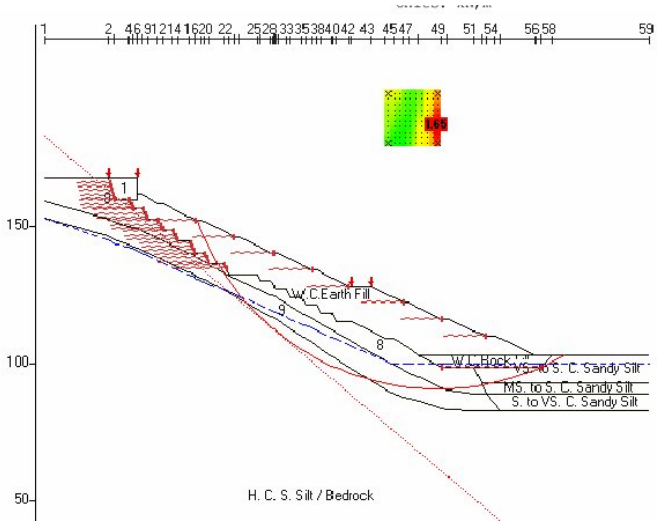

Figure 9.0 : Case 9 – Overall stability of proposed remedial works with mid level caisson

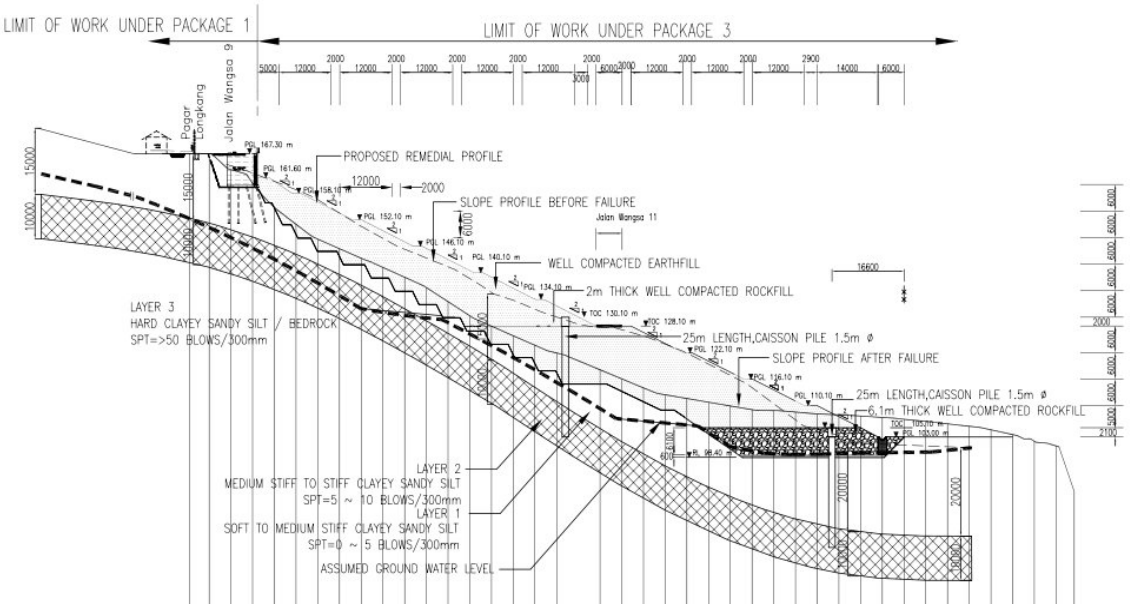

Figure 10.0: Typical cross section of the proposed remedial works incooperated with subsoil stratification