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ROCKMUR FOR SLOPE REHABILITATION

Lee Chee Hai and Oh Yong Ching
Nehemiah Reinforce Soil Sdn. Bhd., Selangor, Malaysia

ABSTRACT

A slope failure occurred at the side of an access road leading up to a new 4.54 ML water reservoir during the peak of monsoon rain season in December 1994. A site investigation was carried out to determine the subsoil condition and the possible causes of failure. The landslide was found to be of the translational type. A remedial solution was proposed using RockMur as a buttress at the toe of the slope. RockMur is a type of mechanically stabilised backfill structure whereby the reinforcement consists of high strength composite geotextile with rock stones contained in steel fabric panels as facing. This composite geotextile is made of high strength woven polyester yarn stitched bonded onto a nonwoven needlepunched continuous filament geotextile. The unique feature of the geotextile is that the nonwoven component serves the in-plane drainage function in addition to the reinforcing function of the woven component. The in-plane drainage function of the geotextile is of particular importance for the stability of RockMur because the backfill material of poor draining lateritic cohesive frictional fill. This paper describes in detail the design and construction of RockMur and the overall scheme of the slope rehabilitation works.

INTRODUCTION

An access road leading to a new 4.54 ML water reservoir for a water supply scheme in Maran, Pahang was completed in February 1992. During the monsoon season of December 1994, the slope adjacent to the access road slumped carried with it about 700 m3 of earth. The location and extend of the failed slope is shown in Fig. 1.

SITE INVESTIGATION

A simple site investigation was carried out to determine the subsoil condition and cause of failure. One borehole was sunk to a depth of 18 m. Six MacKintosh probes were carried down to point of refusal. The layout plan of the location of the borehole and the probes are shown in Fig. 1. The borehole log and the probe results are shown in Fig. 2. From the borehole, it is seen that the top 8 m consist of residual soil underlain by highly decomposed sandstone with SPT value well exceeding 50 blows. The probe results show that the point of refusal is met at approximately 3.0 m depth where the blow count exceeds 400 blows per foot. Some water was found seeping out at 6 m below the formation level of the road.

POSSIBLE CAUSE OF FAILURE

From the site investigation results and the on site inspection, it is obvious that the failure is of the translational type that is common among residual soils. A typical section of the failed slope is shown in Fig. 3. The failure plane is approximately 3 m below the ground surface dipping at an angle of more or less parallel to the gradient of the existing slope before failure. The width of the failure is about 25m over an inclined slope of about 90m. About 700 m3 of material has slumped and slide down the slope. A photo of the failed slope is shown in Fig. 4. The likely cause of failure is due to the saturation of interparticular pores of the residual soil as a result of the infiltration of the monsoon rain water.

REMEDIAL SOLUTION

The proposed remedial solution is shown in Fig. 5. It involved the installation of a RockMur at the toe to serve as a buttress. Above the RockMur the earth slope is well compacted to 90 % Proctor density. The slope is trimmed to a gentle slope of 1V:1.75H and close turfed to prevent surface erosion. Berms of 1.25m width are provided at each slope height of 5.0 m. Cast-in-situ V-shaped berm drains are installed to provide drainage for surface runoff. In order to minimise the increase in pore water pressure due to the infiltration of rain water and to lower the ground water table, a drainage blanket of 300 mm thick is installed beneath the reinstated slope and behind and below the RockMur. The Bishop slip circle analysis (see Fig. 6) was carried out using soil parameters as shown. The analysis was carried out by using the computer program called STABGM developed by Duncan et al 1985. The program was able to take into consideration the effects of the geotextile reinforcement. The minimum factor of safety was found to be 1.535 which is acceptable.

DESIGN OF ROCKMUR

The design of RockMur follows the procedure recommended by Lee et al (1994). For the external stability check, the RockMur block is considered as a gravity block and the factors of safety of the block against failure due sliding, overturning, bearing and global stability were verified. The recommended factors of safety are as follows:

Factor of safety against sliding > 1.5
Factor of safety against overturning > 2.0
Factor of safety against bearing > 2.0
Factor of safety against global stability > 1.3

For internal stability check, the procedure basically relies on the design charts published by Jewell (1989). The chart was developed by assuming a two-part wedge failure mechanism with zero interslice friction angle. Large number of limit equilibrium analysis were carried out in order to develop the charts for various situations.

A typical section of the RockMur is shown in Fig. 7. The geotextile used is a composite material made of high strength woven polyester yarn stitched bonded onto a nonwoven continuous filament needlepunched Polyfelt geotextile. The advantage of such a composite material is that not only it has high tensile strength, the nonwoven component serve as a drainage medium for in-plane drainage. In Malaysian climatic conditions, drainage of pore water from the soil is just as important as strengthening the soil with reinforcement. The Polyfelt NH series composite geotextile serves the dual function of reinforcement and drainage. The mechanical and hydraulic properties of the NH series is shown in Table 1.

The geotextile were spaced at a constant vertical spacing of 500 mm with the heavier grade at the lower portion. The grade of geotextile gets lighter as the depth of overburden reduces. The backfill material consists of lateritic cohesive frictional soil. The typical grading curve of the backfill material is shown in Fig. 8. The facing consists rock stones loosely placed within steel fabric panel which is hot dipped galvanised to prevent corrosion. The gradient of the facing is 1H:4V. The height of the RockMur is 10 m.

CONSTRUCTION OF ROCKMUR

The first step in construction of RockMur and the whole remedial works is excavate to the base level of the RockMur and compact the subgrade so that the RockMur is founded on firm ground. A plate bearing test was carried out to verify the bearing capacity. The side slope of the excavation is benched as shown in Fig. 5. The first layer of geotextile was laid flat on the subgrade and stretched taut before installing the steel fabric facing panel. Suitable earth was then backfilled, levelled and compacted to 90% Proctor density. Rock stones were laid within the steel fabric facing panel while 20 mm diameter single size aggregates were placed at the back of the RockMur to form the drainage blanket. The suitable earth backfill were compacted at standard lift of 250 mm thick. The second lift of backfill was installed before the next course of geotextile, steel fabric, rock, and aggregates were laid. The whole process was repeated until the full height of RockMur was reached. The completed RockMur is shown in Fig. 9. Above the RockMur the earth slope is formed like any other normal earthwork.

CONCLUSION

RockMur provides a cost effective and quick solution to slope failure problem which is common in Malaysia with her intensive rainfall and rapid pace of development. The other advantage of RockMur is that the components can be easily transported to remote places like Maran.

REFERENCE

Duncan, J.M.; Low, B.K. and Schaefer, V.R. (1985) "STABGM: A Computer Program for Slope Stability Analysis of Reinforced Embankments and Slopes" Virginia Tech Geotechnical Engineering Research Report.

Jewell, R.A. (1989). "Revised Design Charts for Steep Reinforced Slopes" Proc Symp Reinforced Embankments: Theory and Practice in the British Isles, Cambridge, September. Thomas Telford.

Lee, C.H.; Loke, K.H. and Oh, Y.C. (1994) "Design and Construction of Slopes Reinforced With Geotextile" Forum on Geology and Hillside Development, Geological Society of Malaysia, University Malaya, Kuala Lumpur.

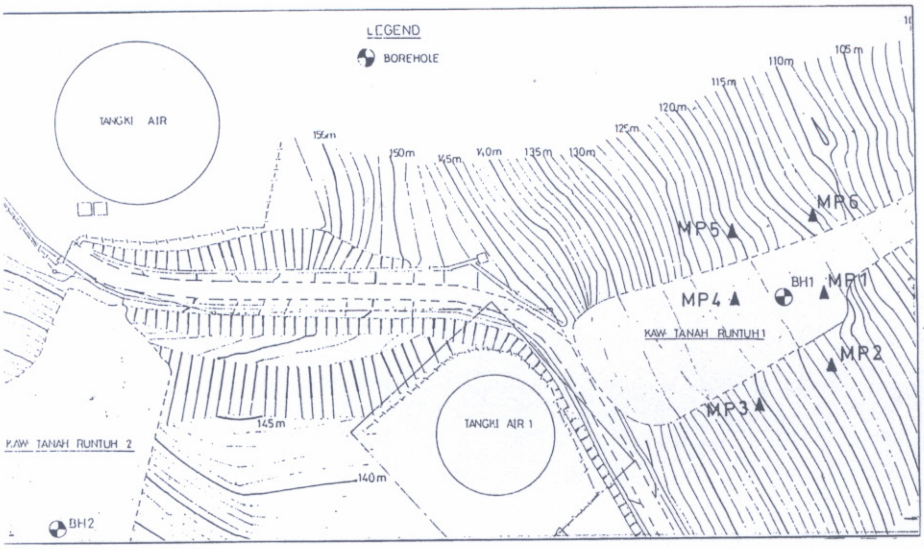

Fig. 1 Location of Landslide

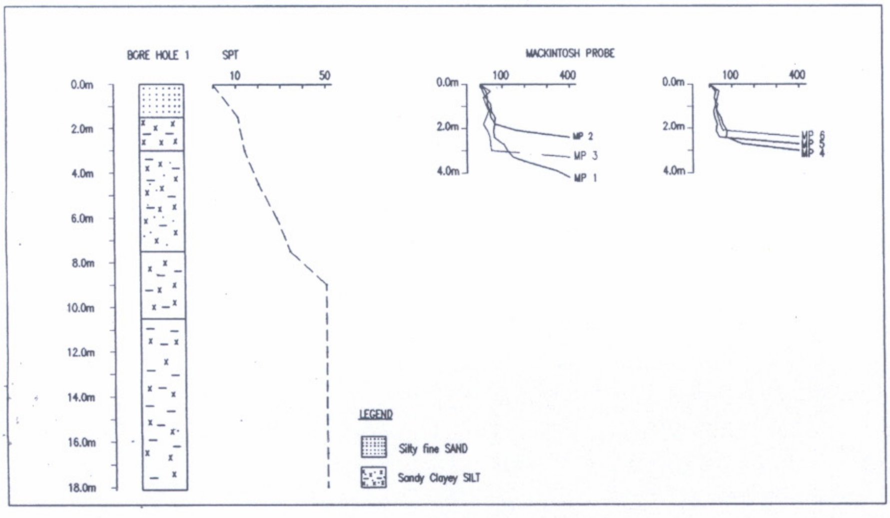

Fig. 2 Borehole Log and Mackintosh Probe Results

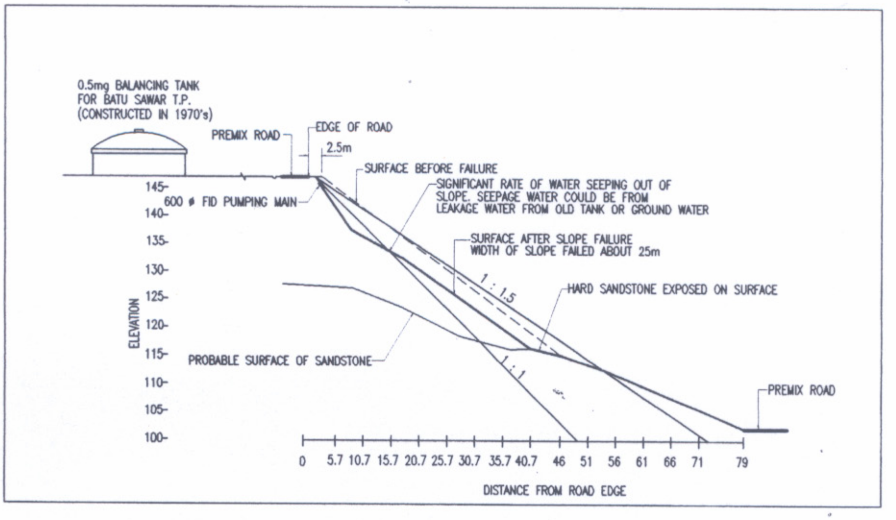

Fig. 3 Typical Section of the Failed Slope

Fig. 4 Photo of Failure Slope

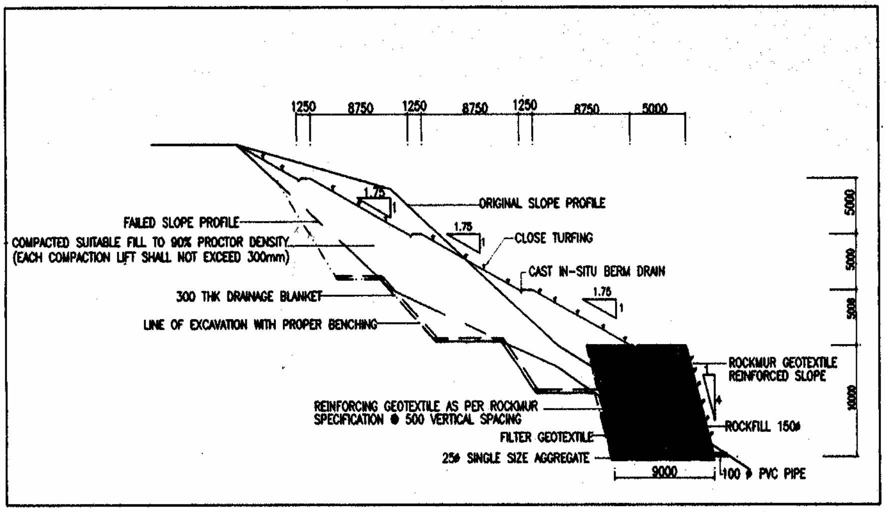

Fig. 5 Typical Section of the Slope Rehabilitation

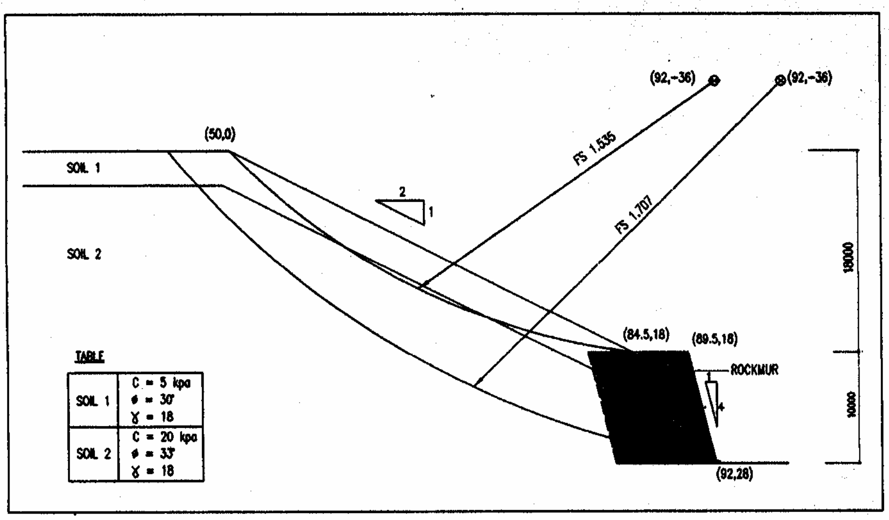

Fig. 6 Slip Circle Analysis with Rockmur as Butress at Toe

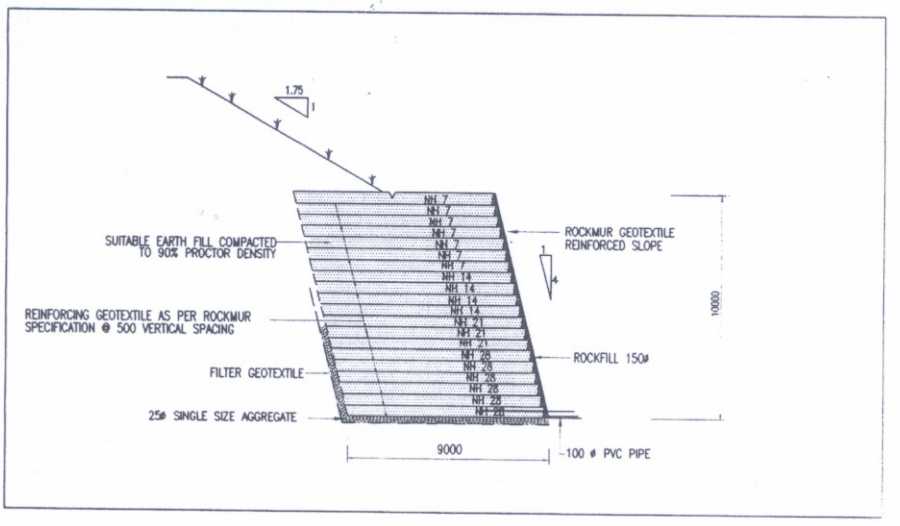

Fig. 7 Typical Section of RockMur

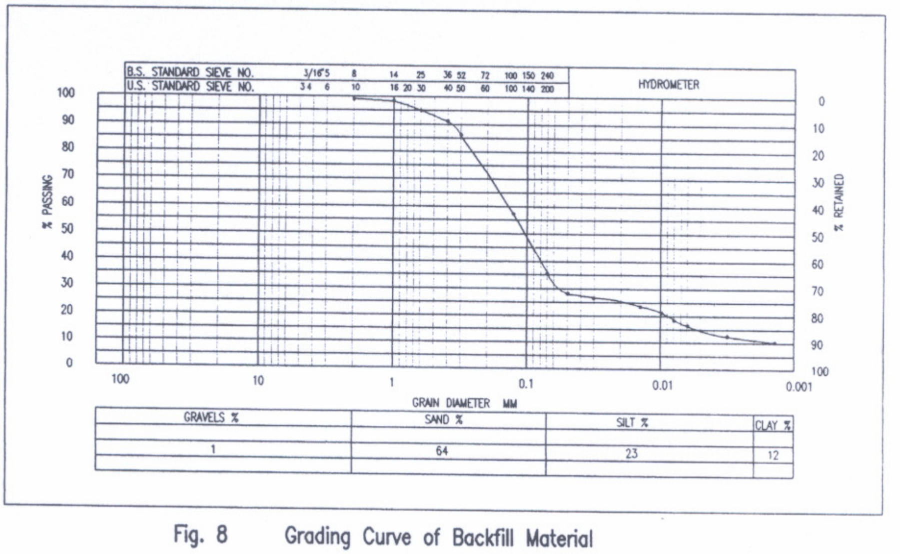

Fig. 8 Grading Curve of Backfill Material

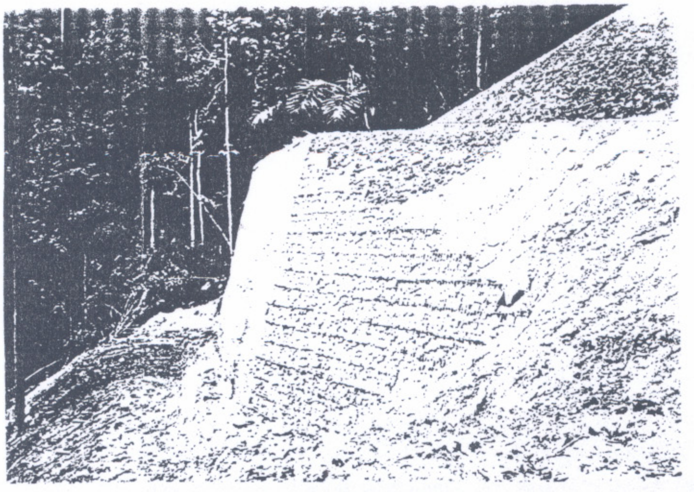

Fig. 9 Completed Rockmur

TEST	STD	UNIT	GRADES				
			NH35	NH28	NH21	NH14	NH7
Physical Properties							
Nominal Mass		g/m2	700	550	450	450	450
Thickness (2 kPa)		mm	2.4	2.1	1.7	1.7	1.7
Mechanical Properties							
Tensile Strength (MD)* at 5% Strain	ISO 10319	kN/m	70	50	33	30	20
CBR puncture resistance	BS 6906/4	kN	12.0	9.5	8.0	6.5	1.5
Hydraulic Properties							
Vertical permeability (2kPa)	DIN 53936-1-E	m/s	2.5×10^{-3}	2.5×10^{-3}	2.5 x 10	2.5 x 10	2.5 x 10
In-plane permeability MD* (20 kPa)	DIN 53937-1-E	m/s	0.02	0.02	0.02	0.02	0.02

Table 1 : Mechanical and Hydraulic Projection of Polyfelt NH Series High Strength Geotextile