15 Apr 2004, 1:00pm - 2:45pm

Failure Investigation of a Fill Slope in Putrajaya, Malaysia

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Proceedings: Fifth International Conference on Case Histories in Geotechnical Engineering
New York, NY, April 13-17, 2004

FAILURE INVESTIGATION OF A FILL SLOPE IN PUTRAJAYA, MALAYSIA

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ABSTRACT

On 6th of January 2001, a fill slope collapsed in Putrajaya, Malaysia. The failed slope was 25m in height. The failure caused the slope to pushed two reinforced earth walls and the recently completed jetty and boat docking facilities to collapse. The depth of the failure scar was about 2m with a failure length of about 50m. A failure investigation was then carried out to determine the causes of failure. A total of thirteen new boreholes, fifteen Mackintosh probes and three hand augers were carried out to determine the soil profile. A desk study of existing information and records, site reconnaissance and mapping of the failure area was also carried out to determine the causes and the extent of the failure.

Some of the findings of the failure investigation are there were no pile slab found at reinforced earth wall W2 as stated in the drawings and the groundwater table has risen as a result of the filling of the lake, which was carried out after the construction of the fill slope. The groundwater table at failure was found to be much higher than those measured during the site investigation works. Seepages of water were also seen from the failed area.

INTRODUCTION

On 6th of January 2001, a 25m-fill slope, which was constructed in 1998 failed after an overnight duration of heavy rainfall. The failure caused part of the road at the top of the fill slope to collapse and crack resulting in the failure of two reinforced earth walls as well as the collapse of the quite recently completed jetty and boat docking facilities located at the bottom of the fill slope.

The Public Works Department of Malaysia was then requested to conduct a failure investigation to determine the extent and causes of the failure. This paper summarizes the work that was carried out during the failure investigation works and the findings of the investigation. Remedial measures were then proposed.

LOCATION OF THE SITE

The failure site is located in Putrajaya, the new administrative capital of Malaysia. Putrajaya, which have been declared a Federal Territory in Malaysia, houses most of the government departments. It is located about 35km south of Kuala Lumpur the capital of Malaysia, Fig. 1. The Putrajaya area was developed as a result of the last economic boom and the rapid growth that occurred in Malaysia in the 1990's. Putrajaya is still currently having ongoing development although most of the government offices have been completed.

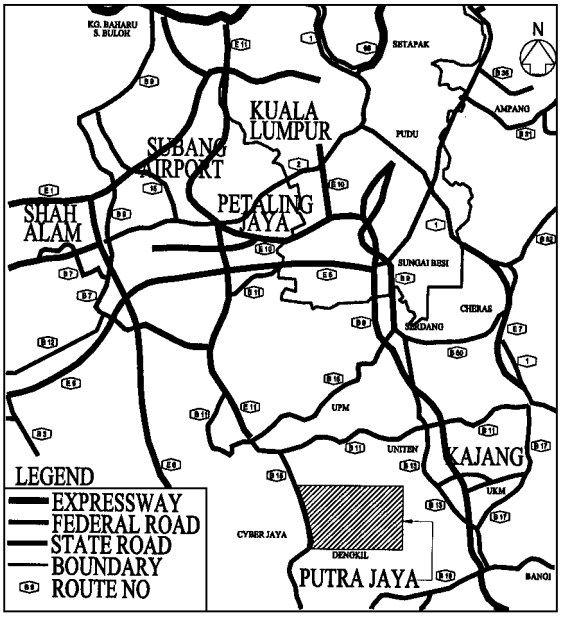

Fig. 1. Location of the failed site

FAILURE RECONNAISANCE AND DESK STUDY

Failure reconnaissance of the area showed that the depth of the failure scar was approximately 2m deep and the length of the failure about 50m. The total height of the failed slope was

about 25m and the angle of the failed slope was about 22 to 25 degrees. The extent of the fill slope failure is shown in Fig. 2.

Fig. 2. Extent of the failed area

The failure caused half of the road at the top of the fill slope to collapse, Fig. 3.

Fig. 3. The top portion of the failed slope

Seepages of water was also observed both at the toe of the fill slope and at the bridge abutment. Cracks were also observed on the road near the bridge area. The failure also caused two reinforced earth walls and a recently constructed small jetty berth located at the bottom of the fill slope to collapse, Fig. 4.

Fig. 4. Collapse of the two RE wall due to the slope failure

Interviews carried out with the site staff involved in the construction of the fill slope indicated that about 3m of soft clay have been excavated and removed during the construction of the fill slope. Prior to this failure, cracks had been observed at the top of the fill slope but no investigation was carried out as the cracks were treated as pavement cracks and the road was then resurfaced.

Desk study carried out shows that in September 1996, 8 numbers of boreholes were drilled and the groundwater table monitored. An additional 3 boreholes, 20 Mackintosh probes and 10 hand augers were then carried out to supplement the previous site investigation works. The subsoil profile obtained from the site investigation works showed the presence of soft silty clay underlain by stiff sandy clay. The groundwater was measured between 1.3 to 2.2 meters below the original ground level. However there was discrepancy between the results obtained from boreholes with those obtained from probes and hand augers. No confirmatory boreholes were carried out to verify the discrepancy between the results. Details of the site investigation works carried out in 1996 are described in the geotechnical report submitted by the design consultant[1].

However there were no slope stability analysis and geotechnical design report submitted by the design consultant. Slope stability analysis that was carried out by the contractor prior to the construction of the fill slope showed that the factor of safety (FoS) of the slope ranged from 1.4 to 1.5 but the values of the soil parameters used in the analysis was not given. Other records such as for the piling works and compaction were also not obtainable.

The desk study also shows that the height of the two reinforced earth wall constructed namely RE wall W1 and W2 was about 7m and 3.35m. Both walls were supposed to have been constructed on piles with a pile slab on top of the pile group. Details of the RE wall design that was to been constructed is shown in Fig. 5.

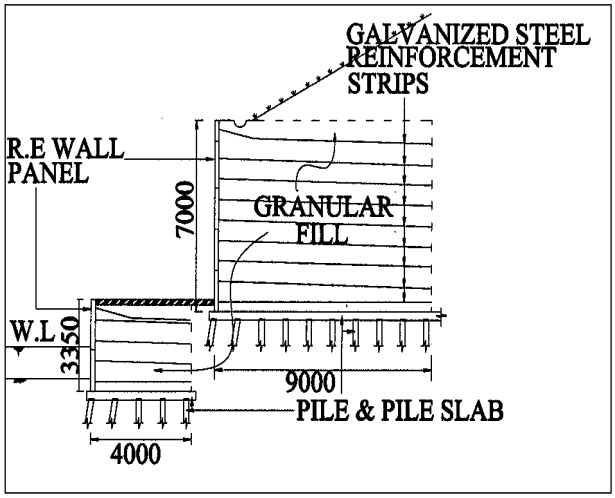

Fig. 5. RE wall design

SITE INVESTIGATION AND FAILURE INVESTIGATION WORKS

After the failure, 13 new boreholes (BH1 to BH13), 15 Mackintosh probes (MP1 to MP15) and 3 hand augers (HA1 to HA3) were carried out by the soil subcontractor to determine the soil profile of the failed area. The generalized soil profile obtained from the boreholes shows that the subsoil consists of medium stiff to stiff silty clay or clayey silt. The locations of the site investigation works are shown in Fig. 6.

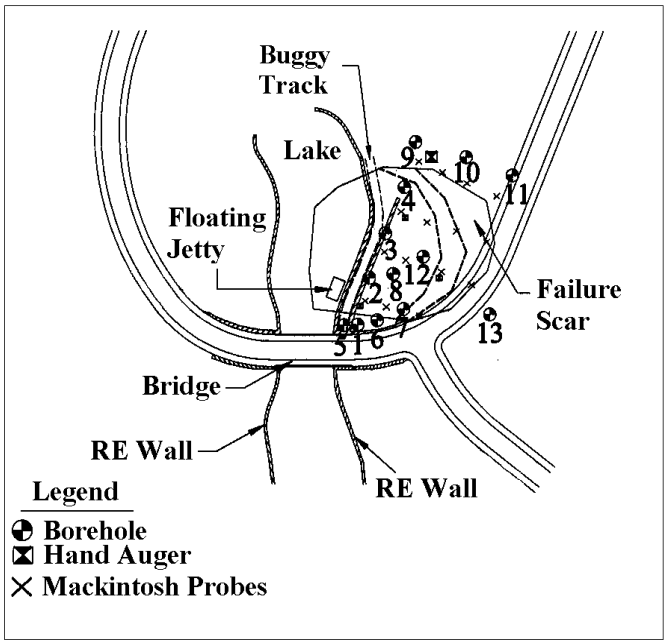

Fig. 6. Location of the site investigation works

BH5 was carried out at RE wall W1. During drilling of the borehole, the pile slab at RE wall W1 was encountered at a depth of about 6m from the present ground level. Underneath the slab was a layer of soft dark brown silt.

At the RE wall W2 location, BH1 to BH3, which was carried out near the wall location indicated the presence of very soft to soft clayey silt up to 8m deep. However no pile slab was encountered.

Three boreholes (BH9 to BH11) carried out outside the failure scar at the non-effected area showed that the material was well compacted as the SPT value was found to be high however no compaction records for the fill slope was obtained. The subsoil profile at this area showed the presence of soft clayey silt for the first 6m from the present ground level.

Three Mackintosh probe results carried out on the same location also confirmed the presence of loose material up to 6m below the original ground material.

Table 1 Depth of groundwater level

Location	Depth of groundwater level (m) from top of borehole
BH 10	5.6 to 9.45
HA 3	0.45 to 1.2
HA 2	0.7 to 0.98
HA 1	0.8 to 1

Open PVC tubes were also installed to determine the groundwater profile. The groundwater table was taken for 15days. Results of the groundwater table measured are shown in Table 1.

A detail mapping of the cross section of the failed site was carried out as shown in Fig. 6. It can be seen that the groundwater table has risen to about 9 to 10m from the original groundwater table prior to the construction of the man made lake.

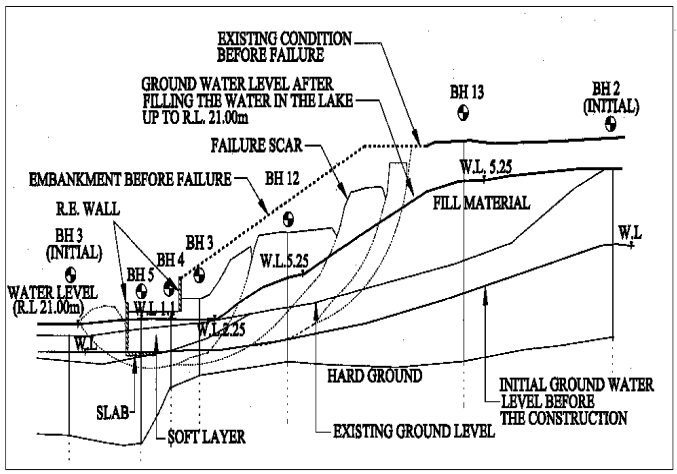

Fig. 6. Cross section of the failed area

Detail investigation of the site shows the presence of a thin layer of soft clay that have been squeezed out at the bottom of the slope indicating that not all the soft material have been excavated during the construction of the fill slope as mention by the contractor's site staff.

Details of the failure investigation works of the fill slope is described in the Roads Branch Public Works Department Report[2] (2001)

FINDINGS OF THE FAILURE SITE INVESTIGATION WORKS

The findings of the failure investigation works showed that

1. Pile slab was found encountered underneath the RE wall W1 but there was no pile slab found under the RE wall W2 as indicated in the design drawing

2. A soft clay layer was found to be present at the bottom of the fill slope. The soft clay layer was squeezed out during failure of the fill slope.

3. Groundwater level was found to have risen after the filling of water into the man made lake.

BACK ANALYSIS OF THE FAILED SLOPE

Back analysis of the failed slope was carried out using the slope software Slope-W. The back analysis was carried out for two cases using typical soil parameters used in Malaysia.

i. The fill slope prior to the construction of the lake
ii. After filling of water in the lake have been carried out

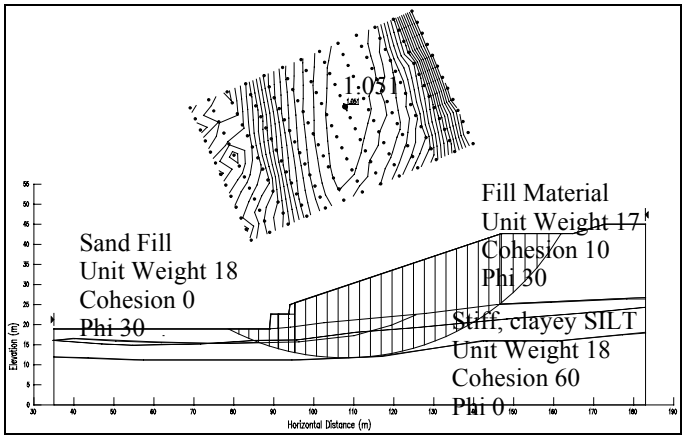

Fig. 7. Case I: Prior to Construction of the lake

For Case 1, Fig. 7, the Factor of Safety (FoS) was found to be about 1.051. This was much lesser than those obtained from the initial analysis carried out by the contractor, which was about 1.4 to 1.5. The differences in the Factor of Safety could be due to the difference in values of the soil parameters use in the analysis although this could not be confirmed. Standard typical Malaysian soil parameters values were use as there was a delay in getting values from laboratory tests.

For the second case, Fig. 8, the FoS was found to be just below one (0.935). This indicates that the slope was unstable, as the groundwater level has risen as a result of the filling of water into the lake.

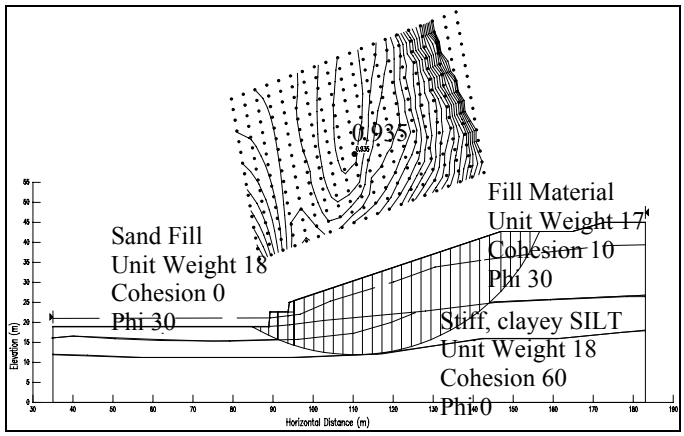

Fig. 8. Case II: After filling of water into the lake

CAUSES OF THE FAILURE

The probable causes of failure can be attributed to the following reasons

1. The presence of a thin layer of soft clay layer which was squeezed out during the failure. This soft layer could have cause instability and settlement of the fill slope to occur.
2. The presence of loose material indicating that if proper compaction have been carried out during construction; the condition of the material could have been cause by water infiltrating into the slope which had loosened the material.

3. There was a rise in the groundwater level in the failed slope after the filling of water into the lake. The rise in the groundwater level was about 9m as compared to previous readings of groundwater level before the construction of the fill slope. This has caused the slope to be unstable as the factor of safety (FoS) was reduced from 1.051 to 0.935 using assumed soil parameters.

4 The failure was triggered by heavy rainfall, which resulted in infiltration of water into the slope and helped to increase the groundwater level to a critical level and caused the slope to be unstable.

ACKNOWLEDGEMENT

The authors would like to thank Putrajaya Cooperation for their contribution and permission to publish this paper.

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