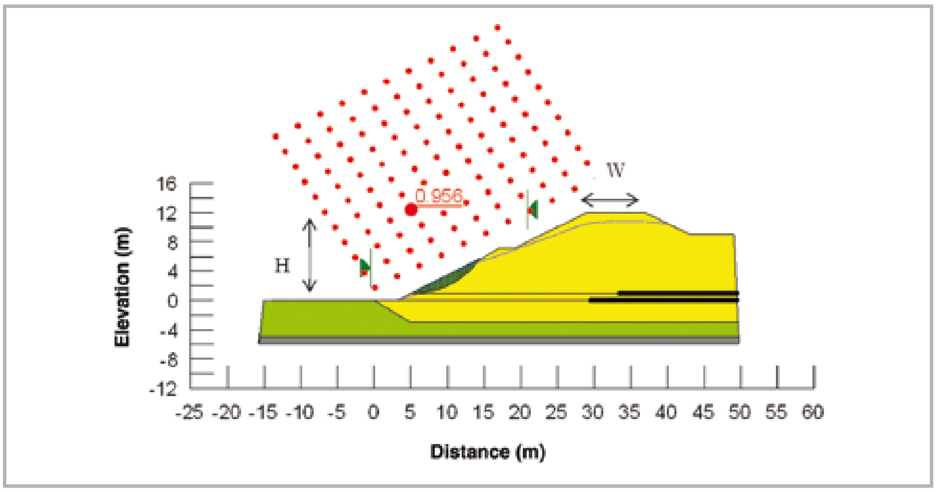

Figure 2(a): FOS after 30 minutes of hydraulic sand-filling (H=12m, W=8m)

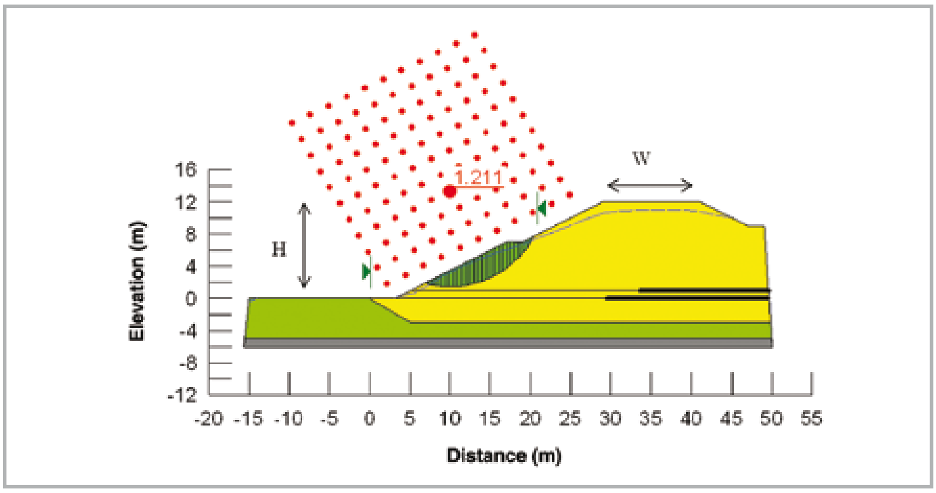

Figure 2(b): FOS after 30 minutes of hydraulic sand-filling (H=12m, W=12m)

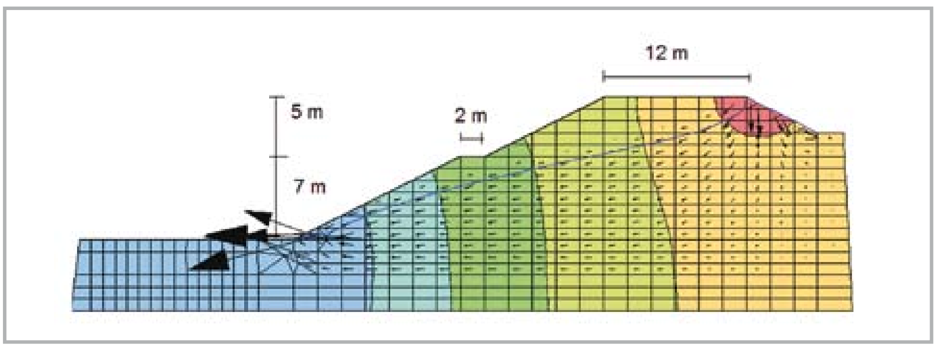

Figure 3(a): Equipotential lines, associated phreatic surface and exit gradient in analysed embankment

Table 1: FOS of embankment shoulder against failure during hydraulic sand-filling

Embankment	Quantity per linear m of wall as output by PLAXIS	Conversion to quantity per pile
H=12, W=8	30 mins	0.96
	12 hours	0.84
H=12, W=12	30 mins	1.21
	12 hours	0.98
	After suspension for 12 hours	1.27
	After suspension indefinitely	1.82

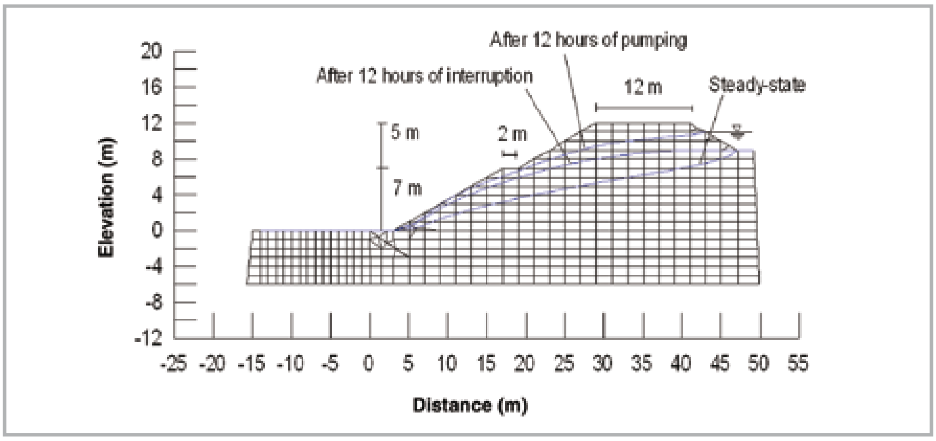

Figure 3(b): Drop of phreatic surface due to the suspension of sand-filling for 12 hours

be suspended 'indefinitely', the phreatic surface would approach 'steady-state' condition as shown in Figure 3(b).

Results, interpretation and discussion

Based on the detailed analyses, an improved embankment design as shown in Figure 4 was implemented. An instrumentation program that included water standpipes was also implemented to assist in monitoring the stability of the embankment to prevent further incidents. Figure 5(b) shows the computed and measured drop in phreatic levels. It is observed that the computed data for distances 7m and 22m away from the embankment toe generally provides values that are about the average of the measured values. However, at 11m from the embankment toe, the computed drop in phreatic level is slightly higher than the average measured values.

From Figure 5(b), it is also noted that the drop in phreatic levels increases with the distance away from the embankment toe, which is similar to the prediction made by SEEP/W as discussed earlier. The discrepancies between the computed and measured values could be due to the persistent rainfall that might have prevented the phreatic surface from dropping further.

From both the computed and measured data, it is evident that if the toe of the embankment is not strengthened and proper drainage paths are not provided, the embankment toe can easily fail due to pore water pressure build-up. Therefore, when the pore water pressure build-up was reduced by introducing an improved embankment design and proper construction method, the embankment was successfully constructed without any further incidents as shown in Figure 6. The importance of benchmarking using reliable field results is thus highlighted.

Concluding remarks for Case Study 3

The toe failure of the hydraulic sand-fill embankment was believed to be caused by wash water transporting the hydraulic sand-fill at the top of the embankment at that stage of the construction, seeping downwards through the embankment sand-fill. Detailed seepage and slope stability analyses based on FEA and limit equilibrium methods have been performed to determine the proper construction method and to establish an improved embankment design so that the construction of the embankment can be continued to its maximum height of 12m.

A field instrumentation program consisting of water standpipes was implemented during the construction stage to consistently monitor the fluctuations of the phreatic surface so that the

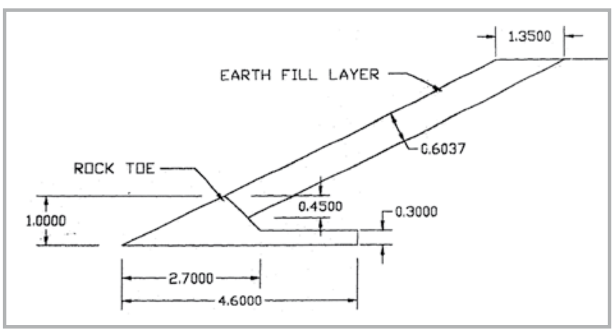

Figure 4: Improved design of embankment toe