

Briefing Notes on Landslide Prevention and Mitigation Works at Po Shan, Mid-Levels

Geotechnical Setting

- The Mid-Levels area in the vicinity of the Po Shan hillside is underlain by thick bouldery colluvium, which was old landslide debris deposited some 50,000 years ago. This colluvium is susceptible to development of high groundwater levels and to failure when disturbed by construction activities.
- The area was affected by significant historical landslides.

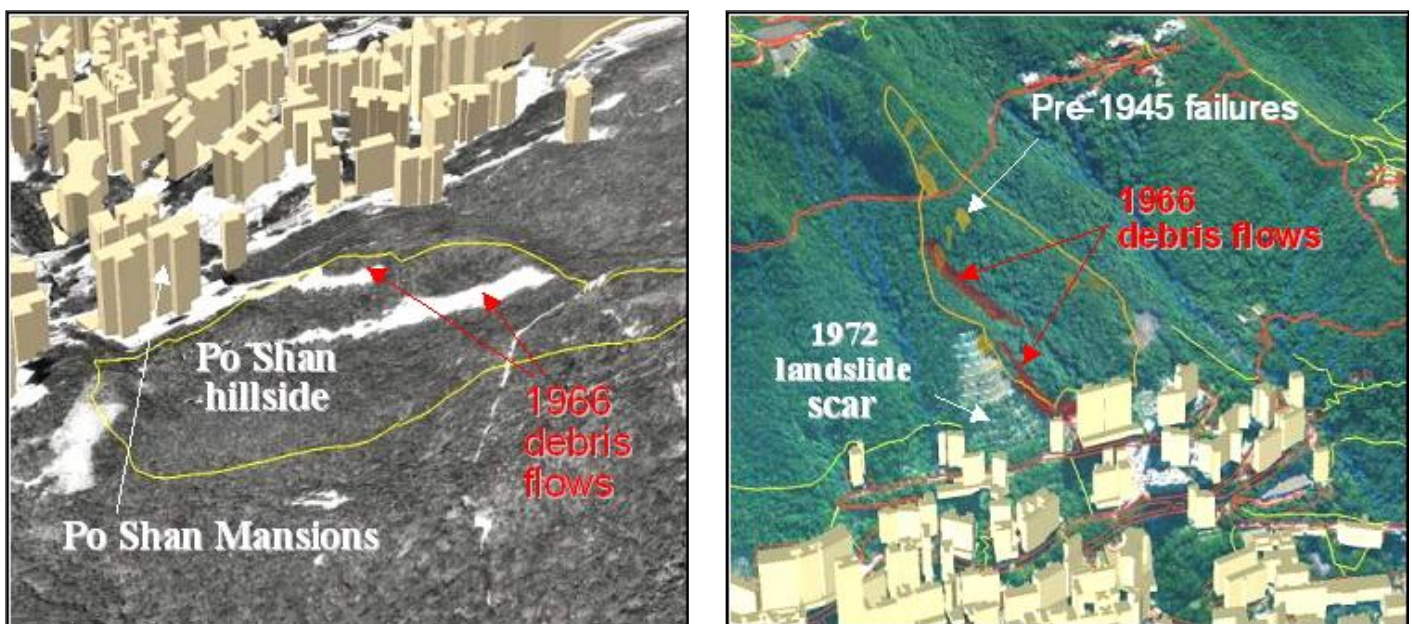


Fig. 1 Two debris flows occurred during the rainstorm of June 1966.

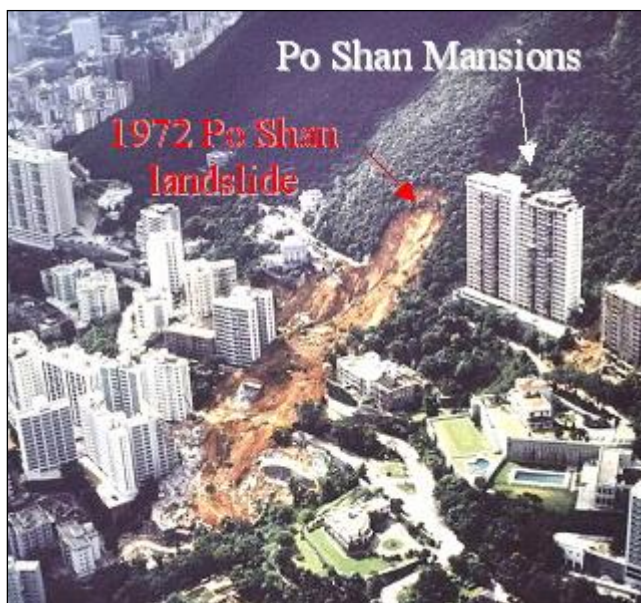


Fig. 2 The 1972 Po Shan landslide, which resulted in 67 fatalities, was caused by the construction activities at a site below Po Shan Road.

Past Studies and Works

- The regional stability study, the Mid-Levels Study completed in 1982, revealed that the Po Shan hillside was affected by high groundwater levels and was of marginal stability. The Study recommended that groundwater drainage works be carried out to lower the groundwater table.
- In 1984-85, 73 no. of long horizontal drains (up to 90 m long) were installed in the area to lower the groundwater table for improving the stability of the hillside against large-scale slope failure. The drains have served the intended purpose in drawing down the groundwater table and no large-scale instability occurred on the hillside since installation of the drains.
- However, recent monitoring data show that the groundwater levels could be rather high during period of heavy rainfalls and that some of the horizontal drains, which are more than 20 years old, exhibit a decreasing trend of outflow in recent years.
- With improved knowledge of natural terrain landslide hazards, it is recognized that the hillside is susceptible to shallow landslides that may result in mobile debris flows. In the event of such failure, the existing horizontal drains could be ruptured.

Reprovision of Groundwater Drainage System

- The reprovision scheme has to meet the following constraints:
 1. The function of the existing horizontal drains should be maintained during construction period.
 2. The new groundwater drainage system should not be affected by shallow landslides.
 3. The new system should have reliable long-term performance.
 4. The Po Shan hillside falls within the Pokfulam Country Park and there are many plants of conservation interest on the hillside.
 5. There is limited works space.
 6. Adjacent old buildings are sensitive to settlement, which may occur if the groundwater drawdown is excessive.
 7. Earthwork should be minimized due to regional stability and environmental concerns.
- From various alternatives, the drainage adits plus sub-vertical drains was identified as the most favourable scheme.

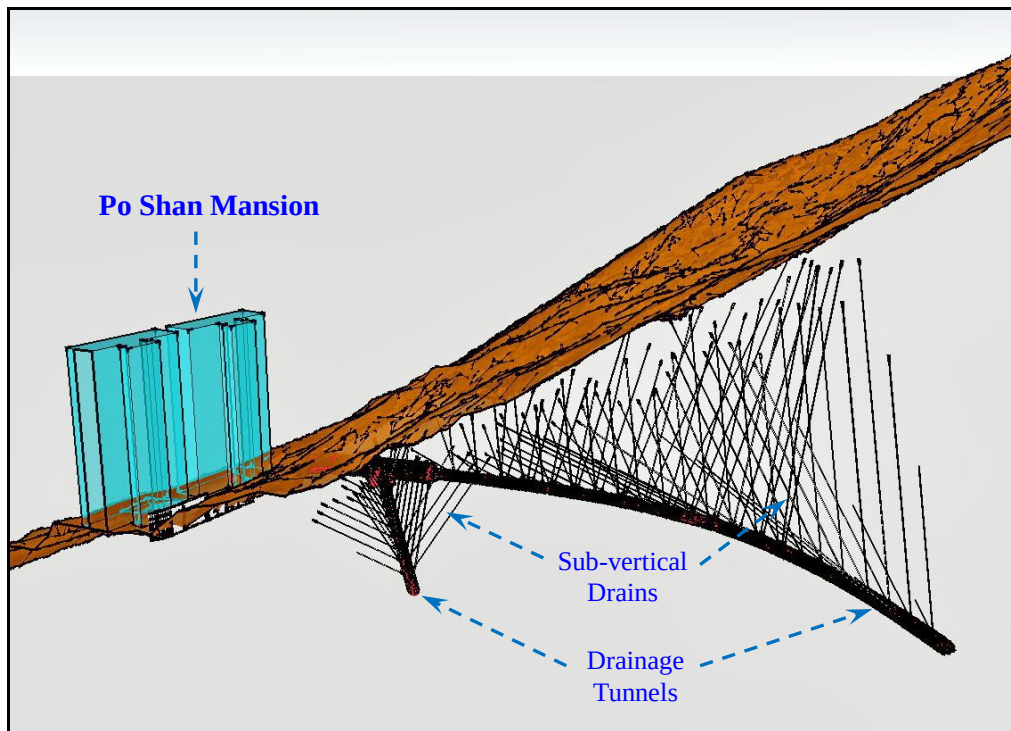


Fig. 3 Underground sub-vertical drains system

Works Contract

- The works contract commenced in July 2006 and it was completed and handed over to LandsD in November 2009. Works completed included the followings:
 1. Slope remedial works of the portal area (285 nos. of soil nails 15-29 m long)
 2. Flexible barriers (5m high, 3000kJ capacity, total 120 m in length)
 3. Drainage tunnels (3.5 m diameter, total 500 m in length)
 4. Sub-vertical drains (24-100 m long, total 172 nos.)
 5. Natural slopes stabilisation works with soil nails (20 m long, total 685 nos.)
- Consultants: AECOM Asia Company Ltd.;
- Contractor: China State – China Railway Joint Venture;
- Contract Sum: \$165M

Innovative Technologies Adopted

- A single retractable Tunnel Boring Machine was deployed for the excavation of the two drainage tunnels.
- Sub-vertical drains were installed upwards from the tunnel to a level of 5 m - 10 m below the ground surface.
- A real-time groundwater pressure monitoring system was implemented.

Geotechnical Engineering Office
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Fig. 6 Excavation of tunnel portal



Fig. 5 TBM being assembled on site



Fig. 6 Installation of sub-vertical drains



Fig. 7 Flexible barrier as part of mitigation works for shallow landslides



Fig. 8 Sub-vertical drains installed inside tunnel with permanent concrete lining



Fig. 9 Drainage tunnels - high tunnel on the left and low tunnel on the right.