

REVIEW OF NOTABLE LANDSLIDE INCIDENTS DURING SLOPE WORKS

GEO REPORT No. 171

H.W. Sun & H.M. Tsui

**GEOTECHNICAL ENGINEERING OFFICE
CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT
THE GOVERNMENT OF THE HONG KONG
SPECIAL ADMINISTRATIVE REGION**

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**This report was originally produced in July 2003
as GEO Landslide Study Report No. LSR 5/2003**

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First published, September 2005

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PREFACE

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. The GEO Reports can be downloaded from the website of the Civil Engineering and Development Department (<http://www.cedd.gov.hk>) on the Internet. Printed copies are also available for some GEO Reports. For printed copies, a charge is made to cover the cost of printing.

The Geotechnical Engineering Office also produces documents specifically for publication. These include guidance documents and results of comprehensive reviews. These publications and the printed GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the last page of this report.



R.K.S. Chan

Head, Geotechnical Engineering Office
September 2005

FOREWORD

Notable landslides have occurred at slope work sites in Hong Kong. Apart from posing a risk to the personnel on site and causing delay and cost overrun to projects, slope failures during the construction phase can also affect public safety and cause social disruption as the landslide debris may affect facilities outside the site boundary.

This report presents the findings of a review of the notable landslides that occurred during slope works, which were reported to the Geotechnical Engineering Office (GEO) from 1981 to 2002. Areas that warrant attention are identified and suggestions made to minimise the chance of occurrence of significant landslides during slope works.

This report was prepared by Dr H.W. Sun and Mr H.M. Tsui under my supervision. Halcrow China Limited, the 2002 landslide investigation consultant, provided valuable support in the compilation of the information on the case histories. Their contribution and assistance are gratefully acknowledged.



Ken Ho
Chief Geotechnical Engineer/Landslip Investigation

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1. INTRODUCTION

1.1 Background

Notable landslides have occurred at construction sites involving slope works. Apart from posing a risk to the site workers and causing delay and cost overrun to projects, slope failures at construction sites can also threaten public safety as the failures can affect facilities beyond the site boundary as well as causing social disruption. There have been cases that resulted in casualties as well as near-miss incidents whereby casualties were fortunately avoided.

This report presents the findings of a review of some of the notable landslides that occurred during slope works. The landslides reviewed were incidents reported to the Geotechnical Engineering Office (GEO) between 1981 and 2002.

The key objectives of the study were as follows:

- (a) to collate published information and file records on notable landslide incidents that occurred within active construction sites involving slope works, and
- (b) to identify key areas that deserve attention in mitigating the risk of recurrence of similar landslides.

Notable incidents involving collapse of temporary deep excavations for basement construction and temporary trench excavations have been studied by Ove Arup & Partners Hong Kong Limited (2002) and Kwong (2001) respectively and are outside the scope of the present study.

1.2 Sources of Information

The information search has focused on readily available sources which include:

- (a) annual Hong Kong Rainfall and Landslide Reports for the years 1984 and 2001 published by the GEO,
- (b) GEO landslide incident reports and landslide cards,
- (c) Landslide Study Reports, Special Project Reports and Annual Landslide Review Reports published by the GEO, and
- (d) relevant files in GEO and other Government Departments.

It should be noted that whilst some of the notable landslide cases were subject to detailed post-failure technical investigation, a proportion of the cases covered under the present review was not previously subject to detailed investigations and hence some of the relevant information may not be available for this review. Notwithstanding this constraint,

the present overall review has allowed a broad appreciation of the key areas that deserve attention in order to avoid recurrence of similar failures.

2. NOTABLE LANDSLIDE INCIDENTS DURING SLOPE WORKS

2.1 Statistics of Landslides at Construction Sites involving Slope Works

The initial information search using the sources noted in Section 1.2 above identified about 90 landslide incidents involving construction sites. A further scrutiny revealed that 60 incidents between 1981 and 2002 are relevant to this review. The other incidents involved construction sites that were affected by slope failures outside the site boundary instead of failures on slopes within active construction sites.

The overall statistics of landslides within construction sites involving slope works are summarised in Table 1 and Figure 1 for landslide data since 1984 (an annual report on rainfall and landslides was prepared by the GEO from 1984 to 1998 and since 2001). In total, there were 58 reported landslides that occurred during slope works for the period 1984 to 2002. Of these 58 incidents, 23 (40%) were major landslides with a failure volume of $\geq 50 \text{ m}^3$.

The consequences of the reported incidents between 1984 and 2002 are summarised in Figure 1 and Table 2. Between 1984 and 2002, one fatality and eight injuries had resulted from five separate incidents. The 18 August 1995 Tuen Mun Highway incident which resulted in one fatality and one injury to passengers in a passing van was a construction site accident whereby a rock block was dislodged accidentally by the site workers during excavation works for the road widening project. Six of the injuries involved construction site workers. Other notable failure consequences have included blockages or closures of public roads (38%), temporary evacuation of buildings or schools (16%), and evacuation of squatter structures (12%), see Table 2.

Thirty-two of the above 58 landslide incidents between 1984 and 2002 as identified above had comparatively more serious consequences (see Tables 3 and 4). A summary sheet containing the key information and a cross section through the failed area for each of these 32 landslide incidents between 1984 and 2002 together with two notable incidents in 1981 and 1982 is given in Appendix A.

Of the above 32 incidents, 20 were classified as 'landslide', three as 'rock/boulder fall', four as 'retaining wall failure' and five as 'washout'. Seventeen of the incidents involved failure of insitu soil material, six involved rock material and nine involved fill.

Seven (22%) of the 32 incidents occurred on private construction sites whereas 25 (78%) occurred on public works construction sites.

Of the 32 incidents, 22 involved formation of new slopes and 10 involved landslip preventive works to existing slopes that were assessed to be marginally stable.

During the period of the landslide incidents that were reviewed under this study, site works were more tightly controlled than that before the establishment of the Geotechnical Control Office in 1977, at which time geotechnical control was lacking and serious failures

had occurred as a result of inadequate control of site works (e.g. the 1972 Po Shan landslide which resulted in 67 deaths). Overall, the consequences of the landslide incidents during slope works that have been reviewed in this study were not as serious as the consequences of failures on existing man-made slopes over the same period (i.e. 19 fatalities in the period of 1984 to 2002). However, in terms of failure rate (taking the number of slopes of concern into account), the failure of slopes during construction is not a rare occurrence and there have been casualties and near-miss incidents and hence this category of slopes deserves attention.

It should be noted that the present review does not cover failures of slopes when construction of urgent repair works is in progress. This can be a vulnerable category of slopes as evidenced by the 23 July 1994 Milestone 14½ Castle Peak Road landslide which resulted in one injury (Chan et al, 1996) and the 2 July 1997 Lido Beach landslide which resulted in eight injuries (HAP, 1998).

2.2 Details of Selected Notable Incidents

The salient details of 21 of the 32 more serious incidents, for which fairly detailed information is available, are presented below to illustrate the range of factors that contributed to the failures.

Of the above 21 incidents, seven involved GEO sites. Incidents occurring in GEO sites are likely have been recorded and many with some follow-up investigation. This is not necessarily the case for other sites, some of which were probably not reported to the GEO, except for those with relatively big off-site impacts.

2.2.1 Incident No. 1 - The 12 July 1981 Incident at Yip Kan Street, Aberdeen

(A major landslide on a soil/rock cut slope resulted in the complete closure of Yip Kan Street and temporary evacuation of the affected buildings)

A major landslide occurred on a 16 m high soil/rock cut slope on a dry Sunday night on 12 July 1981, a week after heavy rainfall associated with tropical storm Lynne. The landslide involved a detached mass of about 1,200 m³ of soil and rock that failed along daylighting, continuous, chlorite coated rock joints dipping at 20° to horizontal out of the slope (see Plates 1 and 2).

Following the passage of tropical storm Lynne on 7 July 1981, cracks appeared on the chunamed slope surface and these were subsequently repaired. Blasting was carried out at an adjacent construction site on 10 July 1981. On the following day, cracks in the chunam cover and the exposed rock cut were noted and inspections were undertaken by staff from the GCO and GCB. Minor rockfalls also occurred and the slope showed signs of imminent collapse. On the recommendations of GCO and GCB, two multi-storey blocks of industrial buildings on Yip Kam Street were evacuated and the road was closed before the landslide occurred at 2:30 a.m. on 12 July 1981.

An investigation of the landslide was carried out by the GCO (Hencher, 1981). The study revealed that the angle of friction on the chlorite coated joints could be as low as 17° at low normal stress levels. The study suggests that the failure was due to a combination of

factors. Disturbance due to blasting at the adjacent construction site and the development of cleft water pressure during tropical storm Lynne was sufficient to cause slope distress and ultimately slope failure.

2.2.2 Incident No. 2 - The 29 May and 17 August 1982 Incidents at South Bay Close, Repulse Bay
(Two major landslides on a rock cut slope)

Two major landslides involving sliding failures occurred on a partially completed rock cut slope within an active construction site for a private residential development project (see Plates 3 and 4). The first failure occurred on 29 May 1982 following an estimated 525 mm of rainfall on the day. The landslide involved approximately 3,800 m³ of closely jointed weathered rock which failed along a persistent, rough but thickly infilled daylighting discontinuity over an approximate length of 70 m. The landslide debris deposited at the slope toe was maximum 17 m thick. A second landslide (700 m³) occurred to the south of the previous detachment on 17 August 1982 after an estimated 500 mm rainfall on the day.

Prior to the May and August 1982 landslides, the design of the slope had been through the slope safety system when the geotechnical submission was checked and approved by the Buildings Ordinance Office. The cut slope was cut back in accordance with the approved design and preventive measures, including rock bolts and raking drains, had been installed. An investigation of the landslides was carried out by the GCO (Hencher, 1983). An important contributory factor to the landslides was the presence of a major, adversely orientated infilled discontinuity that was not identified from the ground investigation and not taken into account in the design. In addition, the groundwater levels measured using Halcrow buckets in piezometers in August 1982 following the initial landslide were also higher than the design groundwater level.

2.2.3 Incident No. 3 - The 25 June 1985 Incident at King's Road, Tin Hau
(Incident No. HK 85/6/1: A major rockfall resulted in blockage of two westbound lanes and the pedestrian pavement of King's Road)

This incident involved an LPM site supervised by GEO in-house staff. The landslide occurred soon after heavy rainfall at about 8:00 a.m. on 25 June 1985 at a soil/rock cut slope above the busy road. At the time of the incident, trimming works were being carried out near the crest of the slope for the construction of a retaining wall (which was being built in panels). The failure occurred suddenly and involved planar sliding of granite rock blocks along adversely orientated joints which were partly coated with kaolin (see Plate 5). The slipped mass, comprising large rock fragments up to 5 m³, demolished a 7 m long section of the safety fence at the slope toe along King's Road (see Plates 6 and 7). The total volume of debris was estimated to be about 70 m³ and fortunately there were no casualties.

2.2.4 Incident No. 4 - The August and September 1985 Incidents at Tin Wan Hill Road
(Deep-seated movements and detachment of failed mass from a 37 m high soil cut slope during construction of slope upgrading works).

The incident occurred on a 37 m high cut slope when permanent stabilisation works were being constructed in 1985. Slope movements began after the formation of the cut slope in 1963. Slope remedial works including regrading, surface protection and subsurface drainage were carried out on a number of occasions between 1968 and 1982. Further instabilities were observed in October 1983 and permanent slope stabilisation works were designed by the GCO. The works consisted of a reinforced concrete retaining wall at the slope toe, trimming of the slope face and installation of 20 m maximum length horizontal drains and surface drainage channels. Site works began in early 1985 and slope movement was re-activated in June 1985 following heavy rainfall. The slope movement accelerated in July 1985 during excavation near the slope toe for the construction of the toe retaining wall. The slope was stabilised temporarily by placing rock fill at the slope toe. Following intense rainfall on 26 and 27 August 1985, the instability progressed further upslope with the formation of new tension cracks up to 9 m deep and failure of the near-surface materials. Rapid slope movement of up to 800 mm per day was recorded between 26 and 29 August 1985. On three occasions about 100 m³ to 200 m³ of material detached from the steep colluvial cut face which had been standing at about 56° and the landslide debris was deposited on both lanes of Tin Wan Hill Road (see Plate 8). There were no reported casualties.

Further instability occurred on 6 September 1985. The landslide was investigated by the GCO (Irfan, 1986). Failures occurred in the colluvium as well as along relict failure surfaces in the deeply weathered profile. The slope has a complex geological and hydrogeological setting, involving effects of shear and fault zones and adversely orientated discontinuities with weak, slickensided infill. Slope deterioration occurred over the years involving opening up of the subvertical joints. The total volume of the unstable groundmass was estimated to be about 19,200 m³.

2.2.5 Incident No. 5 - The 27 July 1987 Incident at Wai Tsuen Road, Tsuen Wan (Incident No. MW 87/7/7: Two consecutive landslides resulted in three injuries and road closure)

The incident occurred on a private building construction site and involved the failure of a 6 m high unsupported excavation for pile cap construction during rainfall at a time when eight workers were working in the excavation (see Plate 9). The workers were installing planking to the temporary cut as a precautionary measure because of the heavy rainfall preceding the failure. The failure (about 45 m³) occurred on a 45° steep temporary slope in granitic saprolite and trapped two workers who were subsequently rescued by firemen. The two workers suffered injuries as a result of the incident. Another worker who had escaped injury in the collapse was injured when he went to assist with the rescue. About four hours after the first failure, the north-western face of the excavation also collapsed, releasing about 30 m³ debris and resulting in temporary closure of the road above and beyond the construction site.

In the subsequent report by the contractor, it was noted that six days before the failure, the soil near the toe of the temporary cut in completely decomposed granite was observed to have been “severely disturbed” by prolonged heavy rainfall. The report stated that the infiltration and seepage of rainwater had caused the soil near the toe to flow outwards “like a liquid” followed by “slumping” of the upper part of the cut. Because of the above

observation, the contractors proceeded to install planking to the cut to provide some temporary support and the landslide occurred when this work was in progress.

2.2.6 Incident No. 6 - The 30 July 1987 Incident at Jordan Valley Estate, Kowloon
(Incident No. K 87/7/25: A major landslide resulted in temporary evacuation of 20 flats of a housing block)

The landslide occurred at about 2:30 a.m. during heavy rainfall and involved excavated materials which had been placed on the lower batter of a soil cut slope behind Block 10 of Jordan Valley Estate to form a temporary access ramp. Slope upgrading works involving trimming back the existing cut slope were being carried out by the Housing Department and the works were supervised by a consultant engineering firm. The debris, with a volume of about 300 m³, caused the hoarding and safety fence at the toe of the cut slope to partially collapse and then came to rest against the first floor of the public housing block below (see Plates 10 to 12). Part of the external building wall and some of the windows and doors of several flats on the ground floor were damaged in the incident and some “soil mud” was washed into two of the ground floor flats. No casualties were reported but 20 flats of the housing block were temporarily evacuated.

2.2.7 Incident No. 7 - The 28 June 1988 and 31 August 1988 Incidents at Island Road Government School, Aberdeen

(Incidents No. HK 88/6/4 & HK 88/8/4: Two major landslides occurred at the site in 1988. Debris from the second incident encroached upon a school building at the slope toe and resulted in temporary closure of the school and permanent evacuation of squatter dwellings at the slope crest)

Two major landslides occurred on 28 June 1988 and 31 August 1988 respectively when a soil cut slope was being upgraded under the LPM Programme by the GCO. Prior to the upgrading works, the ground surface was covered with dense vegetation. The area at the crest of the slope was occupied by several squatter huts and a two-storey school building was located about 5 m away from the slope toe. The original design of the slope upgrading works included provision of a cut-off drain at the colluvium/weathered rock interface and hydroseeding following removal of the undergrowth.

The first major failure occurred after prolonged rainfall from 23 to 27 June 1988. Prior to the first failure, the site works included stripping of the pre-existing dense surface vegetation cover, excavation of two trial pits, cutting for access and excavation for a cut-off drain. About 100 m³ of debris slid downhill and a 17 m long tension crack developed on the slope face near to the slope crest. As a result of this failure, ten squatter dwellings at the slope crest near the tension crack were permanently evacuated (see Plate 13). After this failure, it was considered by the designer that it was impractical to proceed with the construction of the cut-off drain and consequently the design was revised, involving excavation and replacement of the upper 3 m of material from the slope surface by rockfill, in stages.

At approximately 8:30 a.m. on 31 August 1988, a tension crack was observed in the northwest corner of the slope following intense rainfall. The crack further opened up over

the next few hours. The slope failed rapidly at about 11:45 a.m. The failed mass (about 800 m³) impacted against the ground floor of the school building causing the screen wall of a store room to collapse and breaking a window in a classroom (Pates 14 and 15). The wet landslide debris was very mobile and some of the debris flowed into some of the rooms on the ground floor of the building (see Plate 16). The failure occurred one day before the new school term was to start and therefore the building was unoccupied at the time of the incident. As a result of this failure, eight of the rooms in the school were temporarily closed.

An investigation of the landslides was carried out by the GCO (Irfan, 1989). It suggested that this failure was caused by removal of toe support and a rise in groundwater pressure due to infiltration from the bare slope faces that had been stripped of vegetation during construction. Irfan (op cit) postulated that the second failure occurred along an irregular surface of a pre-existing shear plane (i.e. relict landslide) which might have developed as a result of creep movement of the weathered tuff layer in the geological past. The pre-existing slip surface associated with the relict instability was not identified in the ground investigation.

2.2.8 Incident No. 8 - The 31 July 1989 Incident at Kwai Shing Engineering Centre, Kwai Chung

(Incident No. MW 89/7/32: A major rockslide resulted in one injury, closure of a road and rupture of a watermain)

The incident involved a major rockslide of about 50 m³ at a private construction site (see Plate 17). Site formation works, which involved excavation of rock in stages, were being carried out. Permanent stabilisation works to the excavated face included installation of rock bolts. According to the report (MMBP, 1989) on the landslide incident prepared by the geotechnical consultant responsible for the design, “cavities” and an open planar joint were revealed on a 90° steep temporary rock cut on 27 July 1989, four days before the incident. The contractor was verbally instructed by the consultant to cease excavation. On 28 July 1989, the contractor was instructed to carry out precautionary works which comprised grouting up of the cavities and installation of additional rock bolts. These works had not commenced at the time of the landslide.

As a result of the landslide, one person was injured, a watermain at Kwai Shing Circuit was fractured and one lane of Kwai Shing Circuit was closed for seven months for the construction of the remedial works (see Plate 18).

2.2.9 Incident No. 9 - The 24 November 1989 Incident at Victoria Road

(Incident No. HK 89/11/4: A minor landslide resulted in two injuries)

This incident occurred on the Victoria Road Improvement Project. A 6 m high, sub-vertical temporary soil cut slope had been formed for the construction of a cantilevered retaining wall. The Engineer's Representative noted that the construction procedures had deviated from the approved “alternate bay” method and instructed the contractor in a memo on 18 November 1989 to carry out “every possible immediate protective works” for the temporary cut. The contractor was also requested to submit detailed engineering design and drawings for the temporary cut for approval.

Six days later, a landslide of about 5 m³ occurred on the temporary cut slope (see Plate 19) and caused injuries to two site workers.

2.2.10 Incident No. 10 - The 1989 and 1992 Incidents at Siu Sai Wan, Hong Kong
(Major ground distress resulted in major re-design of the slope works)

Signs of distress involving tension cracks were observed in the lower 27 m portion of a 47 m high soil cut slope during site formation works by the Civil Engineering Office in late November 1989. A subsequent investigation by the Advisory Division of the GEO concluded that the mode of instability was related to stress relief as a result of slope formation, leading to toppling of soil blocks bounded by predominantly sub-vertical relict joints. The recommended remedial measures involved re-grading the original design slope profile to a flatter angle of 30°, together with surface drainage measures and shotcreting, whilst the design of the slope portion near the southern end adjacent to a rock slope was revised from unsupported cut to soil nails. The above works were completed in early 1991.

Further extensive signs of distress were reported in April 1992 (see Plates 20 and 21), about one year after completion of works. The failure of the slope took place progressively and was slow-moving. Most of the displaced ground mass (about 4,000 m³) remained on the slope. Signs of major ground movement and development of tension cracks were observed (see Plate 22). The failure was investigated by the Special Projects Division of the GEO (Ho & Evans, 1993). The mechanism of failure was diagnosed to be probably associated with deep-seated failure of a thick profile of hydrothermally altered, relict-jointed tuff caused by the build-up of high base groundwater pressure in a complex hydrogeological regime.

2.2.11 Incident No. 11 - The 10 January 1990 Incident at Po Lo Che Service Reservoir, Sai Kung
(A landslide resulted in temporary closure of the public access road above the site)

A major slope failure occurred at about 4 a.m. on a temporary cut within a Water Supplies Department (WSD) site for the construction of a service reservoir. Geotechnical design advice was given by the Advisory Section of the Mainland West Division of GCO and the works were supervised by in-house supervisory staff. The contractor had formed an unsupported temporary cut slope up to 15 m high at 60° in completely decomposed volcanic rock (CDV) and then undercut the slope toe to 75° for construction of the reservoir walls and manholes. Although the works were carried out in the dry season, about 400 m³ of this temporary cut slope failed despite the absence of any rainfall during the 24 hours prior to the failure (see Plate 23). There was also no obvious indication that the failure was related to leakage from water-carrying services. As the failure occurred in the early morning, the site workers were not affected but part of a village access road beyond the slope crest was undermined.

On 7 December 1989 (i.e. several weeks before the slope failure), the designer of the permanent slope works from the GCO visited the site and reported that the temporary slopes were “unsafe”. It was noted that the groundwater table, even during the dry season, could be “considerably high” based on observation of seepage from drainage pipes near the slope toe and standing water in a 2 m deep sump pit at the toe. Also, it was noted that the exposed

CDV had distinct subvertical relict joint planes. The WSD was informed by the GCO that the temporary cut slope was unsafe and outline recommendations on major support measures were made by the GCO. In the event, work continued without installation of temporary support up to the failure on 10 January 1990.

2.2.12 Incident No. 12 - The 28 February 1991 Incident at Shau Kei Wan East

(Incident No. HK 91/2/2: A major landslide resulted in one injury, closure of two schools and damage to six site office units and four vehicles)

A major landslide occurred at about 1:15 p.m. at the crest of a 50 m high disused quarry face. At the time of the failure, blasting was taking place behind the quarry face as part of the site formation works for the Housing Department's Shau Kei Wan East housing development. The landslide was reported to have occurred within one minute of a blast at a location within 3 m of the failure plane. Approximately 2,000 m³ of rock was dislodged and fell onto the site office compound at the base of the quarry (see Plates 24 to 26). All the debris landed within the construction site boundary. As a result of the failure, six container office units and four vehicles were damaged, two primary schools adjacent to the site were closed for three days, and one worker from a nearby garage sustained a minor injury by a flyrock.

The incident was studied by Evans & Irfan (1991) who concluded that the failure involved a planar rock slide on an unfavourably orientated discontinuity and was triggered by blasting.

2.2.13 Incident No. 13 - The 16 June 1993 Incident at Northwest Tsing Yi

(A washout failure occurred during the construction of a reinforced fill wall)

A washout failure (20 m³) occurred during heavy rainfall on a reinforced fill wall which was under construction under a Highways Department's project. Fill material behind the facing panels was washed out by concentrated water flow during heavy rainfall, resulting in significant distress/disruption to the panels (see Plate 27).

At the time of the incident, the reinforced fill wall was partially completed reaching a height of about 24 m. Behind the wall panels, a large fill platform was formed with no protection against surface infiltration. Along the edge of the fill platform adjacent to the natural hillside, a surface channel was formed to direct and discharge stormwater runoff from the hillside. About one hour prior to the incident, the channel was found to be blocked by boulders and water overspilled onto the platform area and the reinforced fill wall below. The concentrated water flow eroded part of the compacted fill behind the wall panels causing progressive failure of the reinforced fill wall. The failed section of the reinforced fill wall was subsequently re-built.

2.2.14 Incident No. 14 - The 18 August 1995 Incident at Tuen Mun Highway, Siu Lam

(Incident No. MW 95/8/21: A construction site incident accident occurred during scaling works of a rock slope which caused detachment of a rock block on to Tuen

Mun Highway, resulting in one fatality and one injury to members of the public and closure of Kowloon-bound lanes of Tuen Mun Highway)

The incident occurred at about 6:50 p.m. and involved the detachment of a rock block (about 2 m by 2 m by 2.5 m) from a rock cut slope during the operation of scaling works under the Tuen Mun Highway widening project. The works formed part of a design and build contract administered by the Highways Department. The detached rock block landed on the highway and a van travelling along on the road hit the rock block causing a traffic accident which killed the driver and injured the only other passenger in the van. Three Kowloon-bound lanes of Tuen Mun Highway were closed for six days as a result of the incident. In addition, the works for the Tai Lam section of the road widening project were suspended for about 11 months. This incident was technically classified as a construction site accident. However, the detachment of a rock block from the rock cut slope gave rise to serious consequences and affected public safety outside the construction site, with major lessons learnt from a risk management point of view in addition to that from an industrial accident perspective.

The scaling works involved rock splitting using drilling and feathering and wedging. The method involved drilling holes from the side of the rock face, inserting ‘feathers’ and then wedges to split the rock. On the day of the accident, two of the workers who were carrying out the rock splitting work had not successfully split off a top segment of a rock as they intended. They finished work for the day, leaving the wedges in place. Within minutes of them stopping work, a very large piece of rock block became detached and fell. No precautionary measures, such as cabling or dowelling, were carried out prior to the rock splitting operation.

In the subsequent Coroner Inquest, the Coroner noted that the rock breaking work was largely unsupervised and that the workers were “left very much to their own devices how they split the rock”. The report also stated that the site had been inspected on the day of the rockfall by four “qualified” men, two from the client office and two from the contractor and that they had not seen fit to draw attention to the offending rock, although they did arrange for a nearby rock to be stabilised by dowelling.

The Coroner also noted some apparent confusion between the contractor and the consultants, who it was intended be employed by the contractor as their Independent Checking Engineer (ICE) to check temporary geotechnical works pursuant to the requirement stipulated in the design and build contract. However, the consultants contended that they were only employed by the contractor as design checkers but not as the ICE. This apparent misunderstanding meant that in the event no one was acting as the ICE for the contract.

2.2.15 Incident No. 15 - The July and September 1996 Incidents at Victoria Road, Pok Fu Lam

(Incident No. HK 96/7/4: A major landslide resulted in closure of Victoria Road; Incident No. HK 96/9/1: A minor landslide resulted in temporary evacuation of three floors of a residential flat; Incident No. HK 96/9/2: A minor landslide resulted in accumulation of debris in a car park, toilets and other areas of a school, and Incident No. HK 96/9/3: A minor landslide resulted in partial closure of a cemetery)

A major landslide (about 75 m³) occurred within a construction site near No. 212 Victoria Road at about 8:00 a.m. on 25 July 1996. The landslide occurred on a sub-vertical temporary soil cut slope for the construction of a retaining wall on the downhill side of Victoria Road as part of a road improvement project managed by the Highways Department. The temporary cut was about 10 m in height with an average slope angle of 80°. The landslide debris was trapped behind the partially completed concrete retaining wall and caused complete closure of Victoria Road for two days (see Plate 28). The failure was probably caused by inadequate temporary support to the sub-vertical soil cut which was formed in the wet season. It was noted in a GEO file note that no rainfall was recorded in the 24 hour period preceding the failure and that the incident was believed not to be caused by heavy rainfall.

The temporary support measures to the excavation were designed by the contractor, checked by their Independent Checking Engineer and the design was accepted by Highways Department's consultant as the designer. Before the landslide, the GEO had expressed concerns to the Highways Department about the level of geotechnical control on the temporary works after a site visit in March 1996. Following the July 1996 landslide, the GEO further reminded the Highways Department regarding the importance of geotechnical input and construction control on site.

At about 4 p.m. on 14 September 1996, three more landslides occurred within the same project site during a rainstorm. The first landslide (Incident No. HK 96/9/1) was a rockfall (about 24 m³) from a 6 m high sub-vertical temporary soil/rock cut slope adjacent to Felix Villa, No. 61 Mount Davis Road. This incident resulted in temporary evacuation of the residents of three floors of Flat 1, Felix Villa.

The second landslide (Incident No. HK 96/9/2) occurred near to West Island School and involved a 30 m³ washout failure which resulted in the accumulation of mud and debris in the car park, toilets and other areas of the school.

The third landslide (Incident No. HK 96/9/3) occurred near the Chinese Christian Cemetery and involved a failure volume of about 45 m³ on an 8 m high sub-vertical temporary soil cut slope with soil nails. At the time of failure, two rows of the soil nails had been installed at the top portion of the slope but the soil nail heads had not yet been constructed (see Plate 29). The landslide resulted in partial closure of the cemetery behind the slope crest (see Plate 30). The inspection carried out by the Special Projects Division of the GEO noted that a large amount of surface water could have flowed towards the slope crest, ponded behind the parapet and overflowed onto the slope. It was also reported that the grouting between the soil nail steel bars and the soil was possibly poor. Two nails at the back scarp of the landslide were inspected by digging about 0.2 m into the scarp around the nails and no grout was found between the bars and the surrounding soil (see Plate 31). Inspection of the nails exposed at the scarp also revealed little grout cover to the underside of the steel bars, which might indicate that the bars did not have sufficient centralisers in the drillholes. In addition, the grout appeared to be fairly weak and could easily be broken up by "knocking with a hammer".

2.2.16 Incident No. 16 - The 4 December 1997 Incident at Sau Mau Ping Road

(Incident No. K97/12/1: A major rockfall resulted in complete closure of Sau Mau Ping Road)

A major rockfall occurred on a rock slope along Sau Mau Ping Road at about 2:20 p.m. on 4 December 1997, when site formation works for a public housing development were being carried out under the supervision of resident site staff managed by the consultant. A view of the site three months before the failure occurred is presented in Plate 32. The failure happened during or immediately following blasting at the east portion of the slope. The failure volume was about 1,000 m³ and the detached rock mass destroyed a section of a 7.1 m high rockfall protective fence erected along the slope toe (see Plate 33). The detached rock mass blocked the entire four lanes of Sau Mau Ping Road, covering 25 m of its length. The metal hoarding on the far side of the road was punched through at several locations. This section of Sau Mau Ping Road was temporarily closed to traffic and the area was cleared of people at the time of the blast and there was no reported injury. The road was subsequently closed for 17 days.

A detailed investigation was carried out by the GEO (Leung et al, 1999). It was concluded that the blasting which took place within the site at about 3 m from the crest of the failed slope was the only possible trigger for the failure. The detached rock slid on pre-existing adverse joints within the rock face. The investigation established that although the blast was located within the permitted blasting area limits, the amount of explosives used had exceeded the permitted value, derived on limiting the vibration at a gas main at the slope toe. Theoretical analysis indicated that the blast-induced ground vibration alone was unlikely to have resulted in complete detachment of the largest rock block involved in the incident but that the slope failure could have been triggered by the shock waves and gas pressure generated by the blast. Details of the blast assessment submitted by Housing Department's consultant to GEO are given in a report by Leung et al (op cit).

2.2.17 Incident No. 17 - The 27 April 1998 Incident at Po Lam Road

(Landslide resulted in closure of three lanes of a road for three days)

This incident occurred at about 12:00 p.m. on 27 April 1998 during relatively light rain and involved the failure (about 26 m³) of a reinforced fill embankment which was under construction (see Plate 34). The works formed part of a Government site formation project under a design and build contract with the site works supervised by resident site staff engaged by the Client Department. The majority of the debris from the failure came to rest on the berm below but some of the facing blocks from the reinforced fill embankment reached the road at the toe of the slope.

In the post-failure investigation (HAP, 1998), it was noted that the mortar beneath the unfailed facing blocks at the margins of the exposed failure scar was locally weak and friable. Also, no tie bars, which according to the design were intended to hold the stone facing onto the slope surface, were observed within the failed area or in the landslide debris. In the subsequent ground investigation, it was established that there was a major non-conformance of the construction with the design, in that the geogrid reinforcement was set back from the face by up to about 5 m and hence there was an unreinforced zone of soil fill between the geogrids and the slope face, where the landslide occurred. The vertical spacing of the

geogrids also did not conform to the design as observed in an investigation trial trench, in that up to four layers of reinforcement were missing. Furthermore, post-failure insitu density tests showed that some of the fill material was not compacted to the required standard.

Follow-up investigation was also carried out on an adjacent newly recompacted fill slope and a rock slope treated with stabilisation measures under the same project. In the fill slope, foreign materials including an old car tyre (see Plate 35) were encountered and that the state of compaction of the fill did not conform to the required standard. In the rock slope, it was found that some of the rock dowels were not properly grouted and that some were of shorter length than the design length.

2.2.18 Incident No. 18 - The June 1998 Incidents at Tai Mong Tsai Road

(A series of landslides on a temporary cut slope resulted in substantial remedial works)

Between 4:00 p.m. and 6:00 p.m. on 9 June 1998, a landslide occurred on the northern portion of a temporary soil nailed cut slope within an LPM site during heavy rainfall. On the following afternoon, a second landslide, probably a delayed response to the rainstorm on 9 June 1998, occurred at the lowest 6 m of the southern portion of the cut slope. This southern landslide extended progressively upslope to the full slope height of 24 m by 29 June 1998. The total volume of the landslides was about 2600 m³ (see Plate 36). Debris from the landslides was deposited at the toe of the slope within the construction site and part of the displaced material remained on the slope. No casualties were reported as a result of the landslides.

The LPM works were designed by the GEO and included the construction of a reinforced concrete retaining wall at the slope toe together with rock fill behind the wall and provision of raking drains. Soil nails were used to support the temporary cut for the construction of the L-shaped wall in front. The LPM works were supervised by in-house supervisory staff of the GEO.

A detailed investigation of the landslides was carried out by GEO's landslide investigation consultant (FSWJV, 1999). The ground conditions at the site were complex with persistent relict infilled discontinuities, high and complex groundwater regime and, possible subsurface drainage concentration due to the presence of a depression in the rockhead, history of major failures, etc. The actual groundwater condition during the construction of the works was more severe than that assumed in the design of the temporary works which were programmed to be carried out in the dry season. In the event, the works were delayed and critical slope works had to be carried out in the wet season but the corresponding design assumption in relation to the groundwater conditions was not reviewed. The detailing of the temporary soil nail heads only incorporated small (150 mm) steel plates and in addition, some of the heads for the temporary, as well as permanent nails had not been constructed at the time of the failure (see Plate 37). This meant that soil nail failure in the active zone dominated, which was exacerbated by the progressive deterioration of the condition of the active zone through cracking as a result of rainfall and inadequate surface confinement.

2.2.19 Incident No. 19 - The 3 April 2000 Incident at Prince Edward Road

(Incident No. K 2000/4/1: Excessive discharge of surface water onto a brick wall which subsequently collapsed (about 6 m³) and resulted in the temporary evacuation of a residential building).

The incident occurred at around 8:00 p.m. on 3 April 2000 at an active LPM site and involved the collapse of a 1.5 m high brick wall just outside the site during heavy rainfall (see Plates 38 and 39). A loose fill slope above the unregistrable brick wall was being upgraded by means of recompaction under the supervision of a consultant to the GEO. No casualties were reported as a result of the incident but all of the 12 units of a residential building below the toe of the fill slope had to be temporarily evacuated.

At the time of the incident, rainwater collected within the construction site flowed down the haul road towards the western end of the site. Temporary drainage was not effective and permanent drainage provisions had not yet been completed. A substantial amount of muddy water was brought down, bringing with it a large quantity of eroded materials (as evidenced by the gully along the western extremity of the site). This resulted in blockage of the temporary/permanent drainage provisions. Rows of sand bags and timber boards were placed by the contractor on top of the brick wall as barrier following an earlier incident of over-topping of surface water onto the area of residential blocks below. The surface water ponded behind the brick wall and the temporary barrier. As a result, the brick wall collapsed, releasing muddy water (mixed with eroded materials trapped behind the wall), and causing flooding of some of the residential building blocks below. A certain amount of outwash was also deposited at Prince Edward Road West further below.

2.2.20 Incident No. 20 - The 24 August 2000 Incident at Lung Ha Wan Road

(Incident No. ME 2000/08/17: A major failure resulted in closure of Lung Ha Wan Road)

Sometime before 6:30 a.m. of 24 August 2000, a temporary sheet pile wall failed during heavy rainfall causing major subsidence of Lung Ha Wan Road. The temporary cut was to enable the construction of a reinforced concrete retaining wall as part of the Highways Department's road widening works project supervised by resident site staff managed by the consultant. The failure resulted in the closure of Lung Ha Wan Road until the afternoon of 25 August 2000. The incident involved significant deformation and tilting, by up to 30° from the vertical, of an approximately 5.5 m high, 20 m long portion of the sheet pile wall (see Plates 40 and 41). The volume of failed groundmass behind the sheet pile wall was estimated to be 200 m³. No casualties were reported as a result of the incident.

Although the sheet piles had been installed to the specified embedment depths, the lateral support to the section of the sheet pile wall which failed did not conform to that stipulated in the design drawings which had been checked by an Independent Checking Engineer. The resident site staff had previously observed the non-conformities of the shoring system for the sheet pile wall and repeatedly warned the contractor over the six months preceding the failure. No action was taken by the contractor to rectify the non-conformities and the work proceeded. A detailed study of the landslide was carried out by the GEO's landslide investigation consultants. The landslide study report (HCL, 2001) concluded that the failure was probably due to the build-up of groundwater pressure behind

the sheet pile wall and inadequate lateral support provided to the wall. The build-up of groundwater pressure was likely to be partly associated with the driving of the sheet piles through, and blockage of, a culvert that connected to a natural drainage line.

2.2.21 Incident No. 21 - The 9 April 2001 Incident at Tam Kon Shan Road

(A washout failure resulted in temporary closure of one lane of Tam Kon Shan Road and the reconstruction of a section of reinforced fill wall)

A washout failure (about 35 m³) occurred at approximately 6:00 p.m. on 9 April 2001 during heavy rainfall within the construction site of the Tsing Yi North Coastal Road project of the Highways Department. The construction was supervised by Highways Department's in-house supervisory staff and geotechnical design advice was given by the Advisory Division of the GEO. The incident involved a reinforced fill wall which was being constructed. The foundation of the wall was undermined by concentrated surface runoff following heavy rainfall, resulting in significant distress/deformation of the wall. Landslide debris was deposited on Tam Kok Shan Road below resulting in temporary closure of the road. Also, the undermining of the partly completed reinforced fill wall resulted in wall movement (see Plates 42 and 43).

Surface runoff from the upper cut slopes and natural hillside flowed towards a temporary excavation for the construction of an end wall and into an open trench in front of the reinforced fill wall. The concentrated surface water flow eroded part of the compacted fill behind the reinforced fill wall as well as the filter material beneath the wall foundation.

The incident was reviewed by GEO's landslide investigation consultant. It was noted that inadequate temporary drainage had been provided. Despite repeated requests by Highways Department to implement precautionary measures against heavy rainfall prior to the incident, insufficient action was taken by the contractor up to the time of the failure. Following the failure, a 19-m long section of the reinforced fill wall had to be demolished and re-built.

3. DISCUSSION

Slopes can be vulnerable to failure during formation or construction of upgrading works (e.g. formation of temporary cuts, vegetation clearance, etc.), especially if the works are carried out in the wet season. Adequate planning, scheduling and supervision of the works is important. As noted before, the majority of the failure cases presented in this review were not subjected to a detailed investigation. It is considered inappropriate to postulate the key causative and contributory factors involved in the individual cases. Based on an overall review of the cases taken together, the key areas that warrant attention are discussed below:

- (a) Temporary site drainage (e.g. Incident Nos. 13, 19 and 21) - Sufficient temporary drainage must be provided especially during the wet season to avoid the adverse effects of uncontrolled concentrated surface water flow. The temporary site drainage needs to be maintained and cleared

of blockages on a regular basis to ensure that the drains will remain functional. Consideration should be given to requiring the contractor to construct part of the permanent drainage measures at an early stage of the works (e.g. crest drain and the associated discharge points) to enhance the drainage provision during construction.

- (b) Temporary support (e.g. Incident Nos. 5, 10, 11, 15 and 18) – Sufficient support must be provided to temporary cuts to maintain their stability. Instability of major temporary cuts could occur even in the dry season if there are adverse geological materials and unfavourable groundwater conditions. Potential difficulties including slope stability during construction should be considered in the option assessment stage. The need for high temporary cuts, especially unsupported cuts, should be avoided as far as possible. Apart from stability of the cut face, consideration should also be given to assessing the possibility of excessive ground movement being caused by the formation of a temporary unsupported open cut to the adjacent facilities.
- (c) Non-compliance/poor workmanship (e.g. Incident Nos. 9, 15, 17 and 20) – Non-compliance with respect to temporary works (e.g. support system for temporary cuts) and permanent works (e.g. fill compaction, reinforced fill, etc.) can reduce the safety margin and lead to slope failure. It is important to ensure adequate site control through the provision of sufficient supervisors who are suitably experienced, trained and briefed. Independent audits without prior warning will assist to upkeep the standard of workmanship and the standard of supervision. Where non-compliances are identified, prompt and effective actions must be taken. Follow-up actions should be progressively stepped up against repeated non-compliances, such as ordering the rectification of observed non-compliance to be completed within a short period of time, suspension of the works or undertaking emergency measures where necessary (e.g. backfilling of uncontrolled excavations).
- (d) Management of earthworks (e.g. Incident No. 6) – For sites involving earthworks, the excavated material or imported fill must be managed properly through proper planning and good house-keeping to avoid the formation of significant soil heaps that are unprotected against infiltration, as these are loose material and vulnerable to failure upon water ingress.
- (e) Site supervision (e.g. Incident Nos. 14, 15, 16, 17 and 20) – For slope works, adequate site supervision, which should be

commensurate with the scale and complexity of the works, must be provided. The competence of the site staff and their familiarisation with the contractual and technical requirements of the project should be continually reviewed. The site supervisory staff should have a sufficient appreciation of the geotechnical contents of the works and the key design assumptions. For geologically complex sites, the qualified supervision personnel should bear in mind the possible need to seek further specialist advice from an experienced engineering geologist where considered appropriate. The site supervisory staff should be fully briefed of their respective responsibilities, in particular their role with respect to the qualified supervision system as appropriate and the day-to-day checks on the compliance with the specifications and the working procedures in order to ensure a high standard of workmanship and materials. The site supervisory staff should be alert to potential anomalous and prepare comprehensive records on relevant observations, such as signs of ground distress, suspected deviations from the design assumptions (e.g. high level seepage) or discovery of unexpected water-carrying services and request for assistance from the Cat. 1 or Cat. 2 qualified supervision personnel.

4. CONCLUSIONS

A review of the reported case histories with notable failures during slope works has been carried out. Landslides during construction can threaten the safety of the site workers as well as the general public that are using the facilities close to the construction sites. The failures can also lead to significant project delay and cost overrun.

The review has identified some areas that warrant particular attention in order to mitigate the risk of slope failures during the construction phase (viz. temporary site drainage, temporary support, non-compliance/poor workmanship, management of earthworks and site supervision). Some suggestions are made to minimise the chance of occurrence of significant landslides during construction.

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Table 1 - Annual Statistics of Landslide Incidents and Landslide Incidents during Slope Works (between 1984 and 2002)

Year	Annual genuine landslide incidents ⁽²⁾			Identified annual landslide incidents during slope works		
	Major ⁽¹⁾	Minor ⁽¹⁾	Total	Major	Minor	Total
1984	8	98	106	-	1	1
1985	9	201	210	4	2	6
1986	11	186	197	1	3	4
1987	9	270	279	2	3	5
1988	5	126	131	3	2	5
1989	56	497	553	3	2	5
1990	6	71	77	1	1	2
1991	3	82	85	1	-	1
1992	26	615	641	0	2	2
1993	93	734	827	1	3	4
1994	36	400	436	-	1	1
1995	27	268	295	1	1	2
1996	4	149	153	1	4	5
1997	60	499	559	1	2	3
1998	26	202	228	1	1	2
1999	64	338	402	-	3	3
2000	45	277	322	2	3	5
2001	16	198	214	1	1	2
2002	9	112 [17 ⁽³⁾]	138	-	-	-
Total	513 (9%)	5340 ⁽⁴⁾ (91%)	5853 (100%)	23 (40%)	35 (60%)	58 (100%)
<p>Legend:</p> <p>504 (9%) 504 landslide incidents and its corresponding percentage of the total incidents shown in brackets.</p>						
<p>Notes: (1) Major incidents: Volume greater than or equal to 50 m³. Minor incidents: Volume less than 50 m³.</p> <p>(2) Genuine landslide incidents refer to those having been verified by GEO.</p> <p>(3) In 2002, a new category of ‘very minor’ landslide was introduced. Very minor landslide is defined as a failure that is small in scale (i.e. ≤5 m³ for failure involving soil or ≤0.1 m³ for rock/boulder fall) and does not give rise to notable consequences.</p> <p>(4) Figure includes 17 very minor landslides in 2002.</p>						

Table 2 - Consequences of Identified Landslide Incidents which Occurred during Slope Works (between 1984 and 2002)

Year	Road closed or blocked	Footpath or access road affected	Squatter structures evacuated	Building or school temporarily evacuated	Injury	Fatality
1984	1	-	-	-	-	-
1985	3	3	1	-	-	-
1986	1	-	1	2	-	-
1987	1	-	-	1	3	-
1988	1	1	1	1	-	-
1989	2	-	-	-	3	-
1990	1	1	1	-	-	-
1991	1	-	-	1	1	-
1992	-	-	-	-	-	-
1993	1	-	-	-	-	-
1994	-	-	-	-	-	-
1995	2	-	-	-	1*	1*
1996	2	1	1	2	-	-
1997	1	1	-	1	-	-
1998	1	-	-	-	-	-
1999	2	-	1	-	-	-
2000	2	-	-	1	-	-
2001	1	-	1	-	-	-
2002	-	-	-	-	-	-
Total	23	7	7	9	8*	1*
<p>Legend:</p> <p>* 1 injury and 1 fatality due to construction accident</p>						
<p>Note: The statistics are based on reported landslide incidents (for those incidents where there is sufficient information available to determine whether the landslides occurred during slope works) from 1984 to 2002.</p>						

Table 3 - Summary of Selected Notable Landslide Incidents during Slope Works (Sheet 1 of 5)

Case No.	Location	Public or Private Works	Formation of New Slope/ Slope Upgrading Works	Date of Failure(s)	Volume of Failure(s) (m ³)	Consequence of Failure	Type of Failure
1	Yip Kan Street, Aberdeen	Private	Formation of new slope	12 July 1981	1,235	Complete closure of Yip Kan Street and evacuation of buildings	Landslide
2	South Bay Close	Private	Formation of new slope	29 May 1982 17 August 1982	3,800 (1 st) 700 (2 nd)	Deposition of landslide debris within the construction site	Landslide
3	A Kung Ngam Road	Public	Slope upgrading works	21 May 1984	8	Complete closure of A Kung Ngam Road for 1 day	Rock fall
4	King's Road	Public	Slope upgrading works	25 June 1985	70	Blockage of 2 westbound lanes and pedestrian pavement of King's Road	Rock fall
5	Tin Wan Hill Road	Public	Slope upgrading works	August 1985 September 1985	19,200	Delay and disruption to the slope upgrading works	Landslide
6	Pak Shek Wo	Private	Formation of new slope	6 September 1985	100	Closure of the access road at crest and falling down of parked cars	Retaining wall collapse
7	Tai Lam Centre for Women	Public	Formation of new slope	4 December 1986	400	Temporary evacuation of punishment block cells	Landslide

Table 3 - Summary of Selected Notable Landslide Incidents during Slope Works (Sheet 2 of 5)

Case No.	Location	Public or Private Works	Formation of New Slope/ Slope Upgrading Works	Date of Failure(s)	Volume of Failure(s) (m ³)	Consequence of Failure	Type of Failure
8	Wai Tsuen Road, Tsuen Wan	Private	Formation of new slope	27 July 1987	45 (1 st) 30 (2 nd)	3 injuries, closure of 1 lane of Texaco Road North	Landslide
9	Jordan Valley Estate	Public	Slope upgrading works	30 July 1987	300	Temporary evacuation of 20 flats	Landslide
10	Island Road Government School	Public	Slope upgrading works	28 June 1988 31 August 1988	100 800	Temporary partial closure of the School and permanent evacuation of 10 squatter huts at crest	Landslide
11	Tai Wan, Sai Kung	Private	Formation of new slope	Unknown (likely occurred in mid August 1988)	65 (1 st) 10 (2 nd)	Blockage of the access road to Lot 796 DD 216	Landslide
12	Peak Road	Public	Slope upgrading works	29 July 1989	Not applicable	Closure of the uphill lane of Peak Road for 30 days	Wall distress
13	Kwai Fuk Road/ Kwai Shing Circuit	Private	Formation of new slope	31 July 1989	50	1 injury, closure of 1 lane of Kwai Shing Circuit for 7 months	Landslide
14	Victoria Road (1989)	Public	Formation of new slope	24 November 1989	5	2 persons injured	Landslide
15	Siu Sai Wan	Public	Formation of new slope	Between November 1989 and April 1992	4,000	Major redesign of slope works	Slope distress

Table 3 - Summary of Selected Notable Landslide Incidents during Slope Works (Sheet 3 of 5)

Case No.	Location	Public or Private Works	Formation of New Slope/ Slope Upgrading Works	Date of Failure(s)	Volume of Failure(s) (m ³)	Consequence of Failure	Type of Failure
16	Po Lo Che Service Reservoir, Sai Kung	Public	Formation of new slope	10 January 1990	400	Closure of half width of the villagers access road	Landslide
17	Shau Kei Wan East	Public	Formation of new slope	28 February 1991	2,000	Closure of 2 primary schools for 3 days, 1 injury, closure of Hoi Ching Street	Landslide
18	Northwest Tsing Yi	Public	Formation of new slope	16 June 1993	20	Reconstruction of a large section of the reinforced fill wall	Washout
19	Tuen Mun Highway	Public	Formation of new slope	18 August 1995	10	Closure of 3 eastbound lanes of Tuen Mun Highway, 1 injury, 1 fatality, suspension of major rock cuts for the Tai Lam section	Rock fall
20	Near 212 Victoria Road	Public	Formation of new slope	25 July 1996	75	Complete closure of Victoria Road for 2 days	Landslide
21	Victoria Road	Public	Formation of new slope	14 September 1996	45	Temporary evacuation of 1 hut and 1 pavilion, partial closure of the Chinese Christian Cemetery	Landslide
22	Sau Mau Ping Road	Public	Formation of new slope	4 December 1997	1,000	Closure of Sau Mau Ping Road for 17 days	Landslide

Table 3 - Summary of Selected Notable Landslide Incidents during Slope Works (Sheet 4 of 5)

Case No.	Location	Public or Private Works	Formation of New Slope/ Slope Upgrading Works	Date of Failure(s)	Volume of Failure(s) (m ³)	Consequence of Failure	Type of Failure
23	Po Lam Road	Public	Formation of new slope	27 April 1998	26	Closure of 3 lanes of a major road for 3 days	Landslide
24	Sai Sha Road	Public	Slope upgrading works	9 and 10 June 1998	900 (1 st) 1,700 (2 nd)	Deposition of landslide debris within the construction site	Landslide
25	An Unnamed Site	Private	Formation of new slope	12 August 1999	25	Closure of a major road for about 12 hours	Landslide
26	Victoria Road (1999)	Public	Formation of new slope	23 and 24 August 1999	40	Washout debris covered Victoria Road	Landslide
27	Prince Edward Road	Public	Slope upgrading works	3 April 2000	6	Temporary evacuation of residential building	Washout and Collapse of wall
28	Clear Water Bay Road	Public	Formation of new slope	23 April 2000	50	Closure of Clear Water Bay Road for half day	Washout
29	Ching Hong Road	Public	Slope upgrading works	12 June 2000	35	Tilting of a backhoe excavator	Washout
30	Chung Hau Street	Public	Slope upgrading works	12 June 2000	30	Deposition of debris within the site boundary	Washout
31	Lung Ha Wan Road	Public	Formation of new slope	24 August 2000	200	Closure of Lung Ha Wan Road for 2 days	Collapse of sheet pile wall

Table 3 - Summary of Selected Notable Landslide Incidents during Slope Works (Sheet 5 of 5)

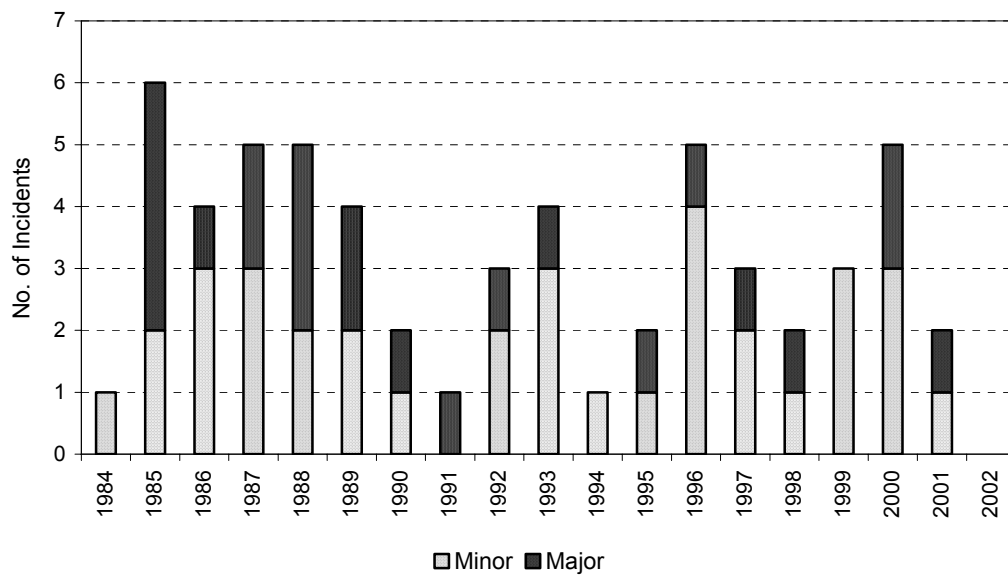
Case No.	Location	Public or Private Works	Formation of New Slope/ Slope Upgrading Works	Date of Failure(s)	Volume of Failure(s) (m ³)	Consequence of Failure	Type of Failure
32	Tam Kon Shan Road	Public	Formation of new slope	9 April 2001	35	Closure of 1 lane of Tam Kon Shan Road for 2 hours, reconstruction of a large section of the reinforced fill wall	Washout

Table 4 - Consequences of Selected Notable Landslide Incidents during Slope Works

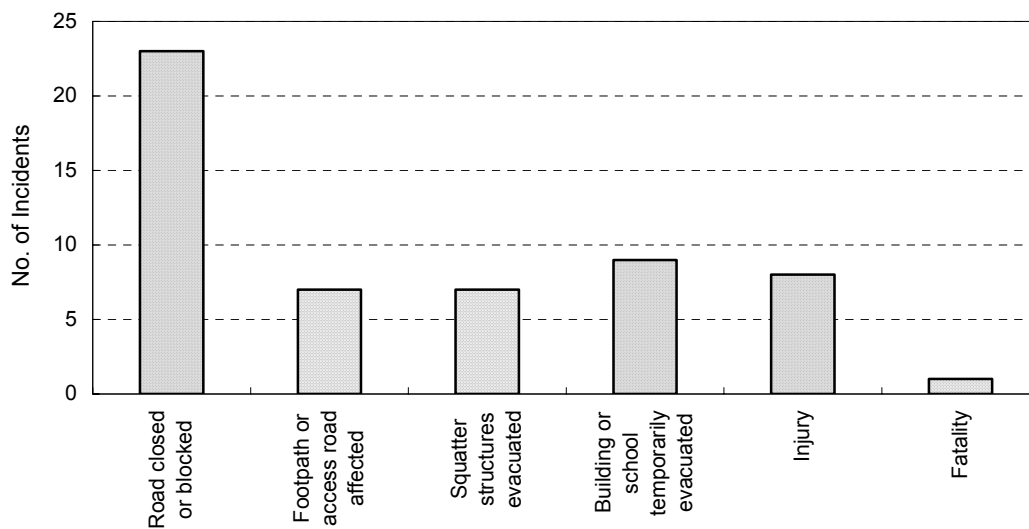
Consequences	Number of Incident
1. Injury	5 (8)*
2. Fatality	1 (1)*
3. Road Closed or Blocked	16
4. Building or school temporarily evacuated	6
5. Squatter or structures evacuated	2
6. Footpath or access road affected	3
7. Others (closure of cemetery and delaying of construction progress, etc)	11
<p>Legend:</p> <p>5 (8) 5 incidents of which 8 persons were injured</p> <p>* 1 casualty and 1 fatality due to construction accident</p>	

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(a) Identified Annual Landslide Incidents during Slope Works (between 1984 and 2002)



(b) Consequences of Identified Landslide Incidents Which Occurred during Slope Works (between 1984 and 2002)

Figure 1 - Statistic of Landslide Incidents during Slope Works

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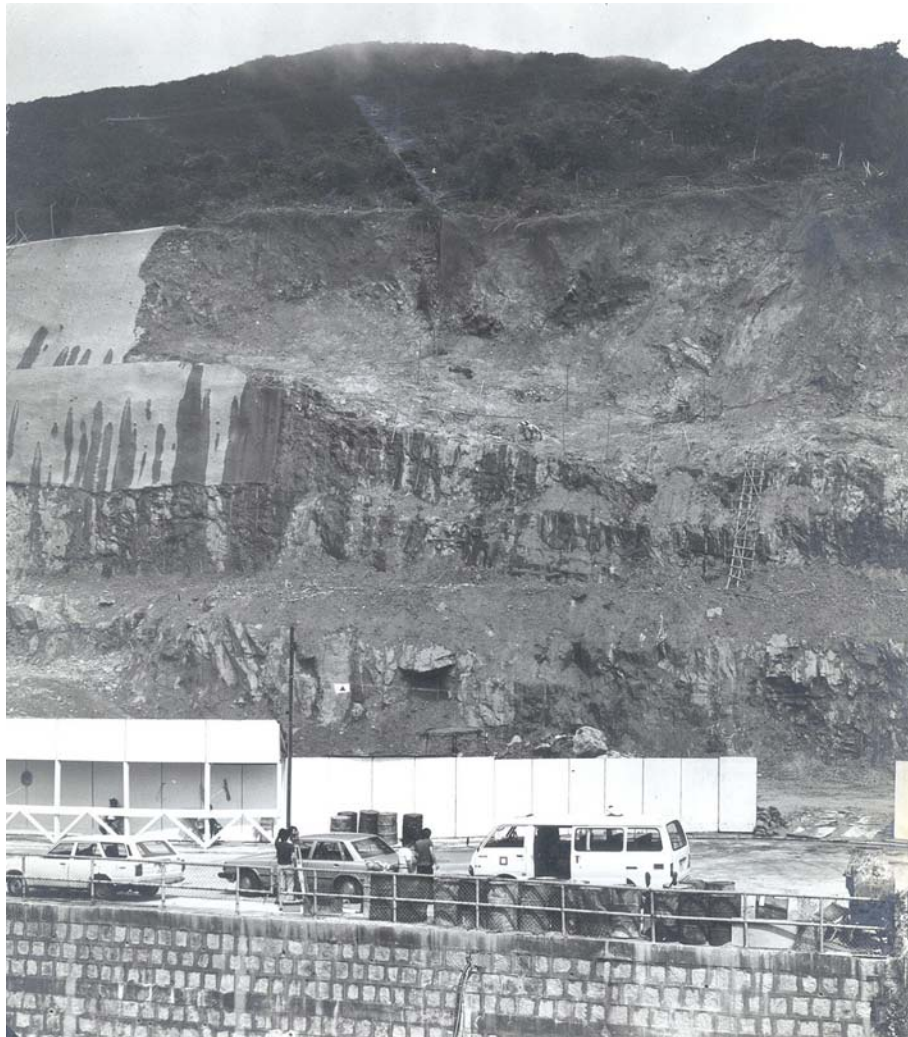
Note: General view of the landslide

Plate 1 - The 12 July 1981 Incident at Yip Kan Street, Hong Kong



Note: Bird's eye view of the landslide

Plate 2 - The 12 July 1981 Incident at Yip Kan Street, Hong Kong



Note: General view of the landslide

Plate 3 - The 29 May 1982 Incident at South Bay Close, Repulse Bay



Note: General view of the landslide

Plate 4 - The 29 May 1982 Incident at South Bay Close, Repulse Bay



Note: General View of the Landslide Site

Plate 5 - The 25 June 1985 Incident at King's Road, Hong Kong



Note: Slipped mass comprising large rock blocks up to 5 m³ demolished a safety fence erected at the slope toe on King's Road

Plate 6 - The 25 June 1985 Incident at King's Road, Hong Kong



Note: Fallen rock blocks were broken up into smaller pieces prior to removal

Plate 7 - The 25 June 1985 Incident at King's Road, Hong Kong



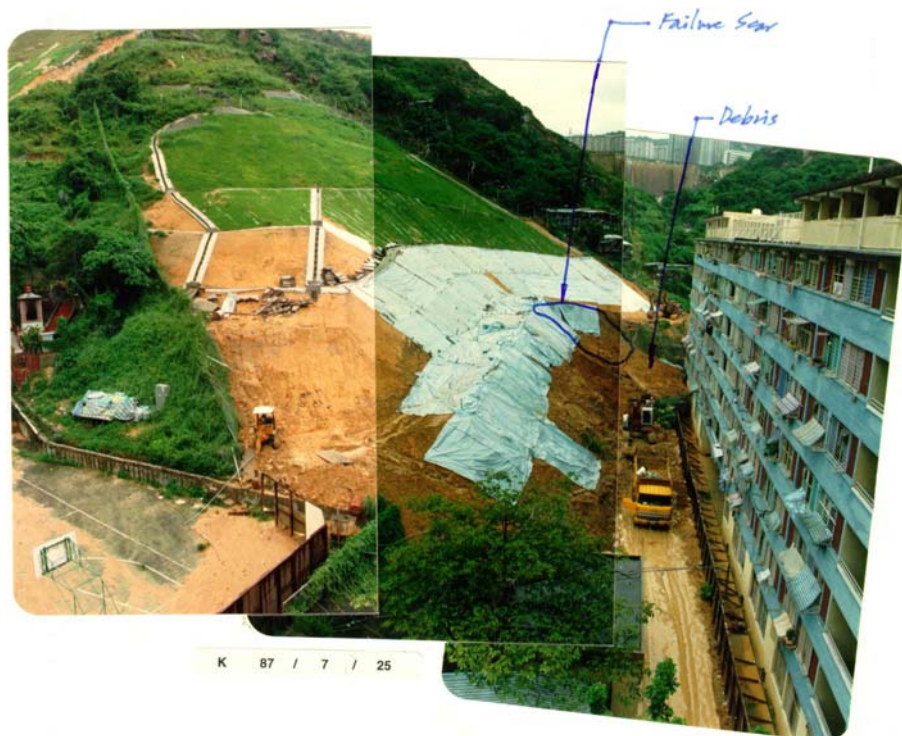
Note: General view of the landslide

Plate 8 - The August 1985 Incident at Tin Wan Hill Road, Hong Kong



Note: The failure occurred on a 6 m high unsupported excavation for pile cap construction

Plate 9 - The 27 July 1987 Incident at Wai Tsuen Road, Tsuen Wan



Note: General View of the Landslide

Plate 10 - The 30 July 1987 Incident behind Block 10, Jordan Valley Estate



Note: The debris (about 300 m³) damaged the hoardings and safety fence and came to rest against the housing block. Part of the external building wall, windows and doors of several flats were damaged.

Plate 11 - The 30 July 1987 Incident behind Block 10, Jordan Valley Estate



Note: A close-up view of the damaged hoardings and safety fence at the toe of the cut slope

Plate 12 - The 30 July 1987 Incident behind Block 10, Jordan Valley Estate



Note: Ten huts at the crest near a 17 m long and up to 1 m deep tension crack were permanently evacuated.

Plate 13 - The 28 June 1988 Incident at North of Island Road Government School



Note: A 17 m long and up to 1 m deep tension crack developed on the slope face near the crest

Plate 14 - The 28 June 1988 Incident at North of Island Road Government School



Note: General view of the landslide debris in the school yard

Plate 15 - The 31 August 1988 Incident at North of Island Road Government School



Note: Landslide debris flooded into a room on the ground floor of the school

Plate 16 - The 31 August 1988 Incident at North of Island Road Government School



Note: General view of the landslide

Plate 17 - The 31 July 1989 Incident at Kwai Shing Engineering Centre, Kwai Chung



Note: One lane of Kwai Shing Circuit was closed as a result of the landslide

Plate 18 - The 31 July 1989 Incident at Kwai Shing Engineering Centre, Kwai Chung



Note: The failed mass, about 5 m^3 , slid into the trench excavated for the retaining wall foundation construction

Plate 19 - The 24 November 1989 Incident at Victoria Road, Hong Kong



Note: View of the subject slope from a nearby housing development site

Plate 20 - The November 1989 and April 1992 Incidents at Siu Sai Wan, Hong Kong



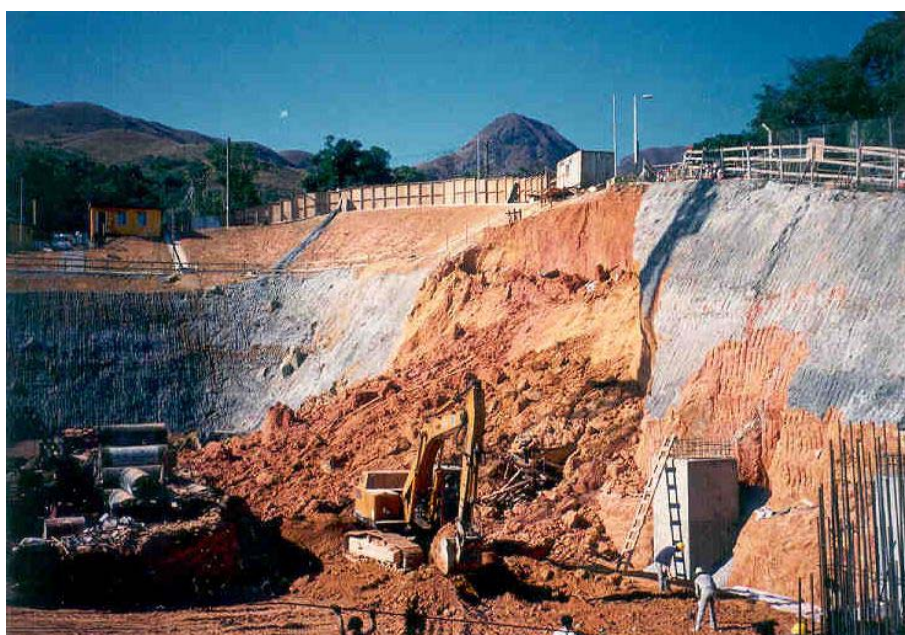
Note: View towards North from the subject slope

Plate 21 - The November 1989 and April 1992 Incidents at Siu Sai Wan, Hong Kong



Note: View of a sealed-up tension crack

Plate 22 - The November 1989 and April 1992 Incidents at Siu Sai Wan, Hong Kong



Note: General view of the landslide

Plate 23 - The 10 January 1990 Incident at Po Lo Che Service Reservoir Site, Sai Kung



Note: Major failure of a disused rock quarry face overlooking Hoi Ching Street
(about 2,000 m³ of rock)

Plate 24 - The 28 February 1991 Incident at Shau Kei Wan East Housing Development Site



Note: A close view of the source of failure

Plate 25 - The 28 February 1991 Incident at Shau Kei Wan East Housing Development Site



Note: All landslide debris landed within the construction site boundary

Plate 26 - The 28 February 1991 Incident at Shau Kei Wan East Housing Development Site



Note: Front view of the damaged facing panels of the reinforced fill wall

Plate 27 - The 16 June 1995 Incident at Northwest Tsing Yi



Note: Debris was trapped behind the partially completed concrete retaining wall

Plate 28 - The 25 July 1996 Incident at Victoria Road, Pok Fu Lam



Note: The landslide resulted in the partial closure of the cemetery behind the slope crest

Plate 29 - The 14 September 1996 Incident at Victoria Road, Pok Fu Lam



Note: Two rows of soil nail heads not installed at the top portion of the slope at the time of failure

Plate 30 - The 14 September 1996 Incident at Victoria Road, Pok Fu Lam



Note: Poorly constructed grouting between the soil nail steel bars and the surrounding soil

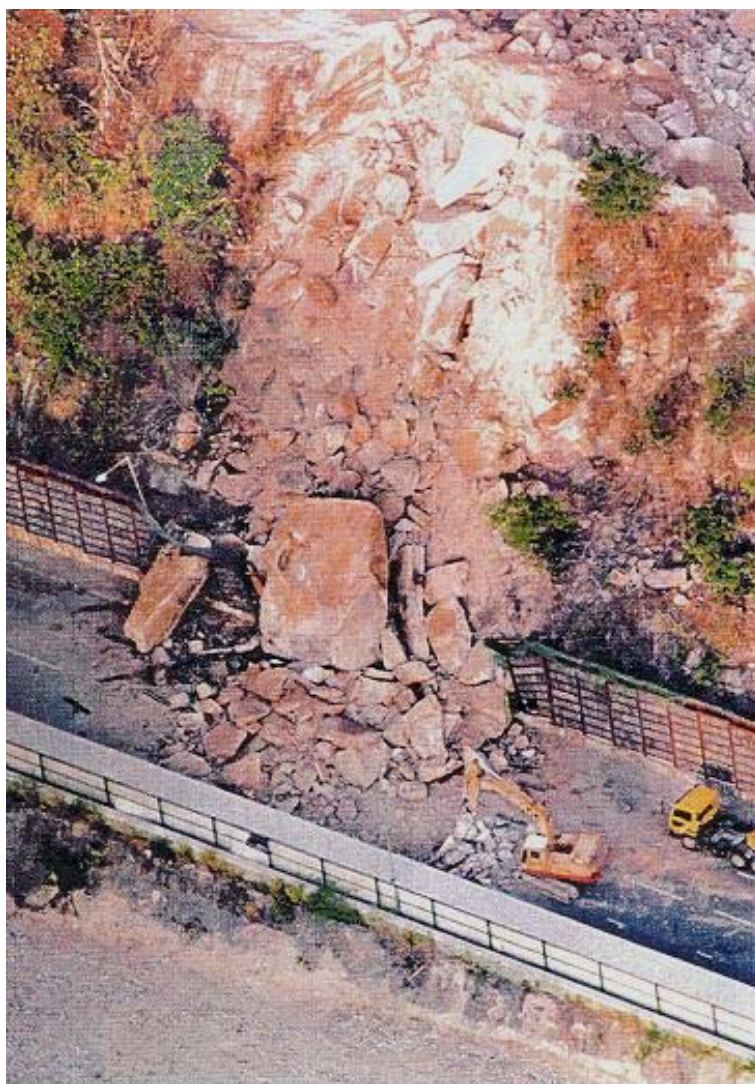
Plate 31 - The 14 September 1996 Incident at Victoria Road, Pok Fu Lam



The portion of the
slope failed on
4 December 1997

Note: View of the failure site about three months before the failure

Plate 32 - The 4 December 1997 Incident at Sau Mau Ping Road



Note: General view of the landslide

Plate 33 - The 4 December 1997 Incident at Sau Mau Ping Road



Note: General view of the landslide

Plate 34 - The 27 April 1998 Incident at Po Lam Road



Note: A car tyre was encountered in the fill material

Plate 35 - The 27 April 1998 Incident at Po Lam Road



Note: General view of the landslide

Plate 36 - The June 1998 Incidents at Junction of Sai Sha Road and Tai Mong Tsai Road



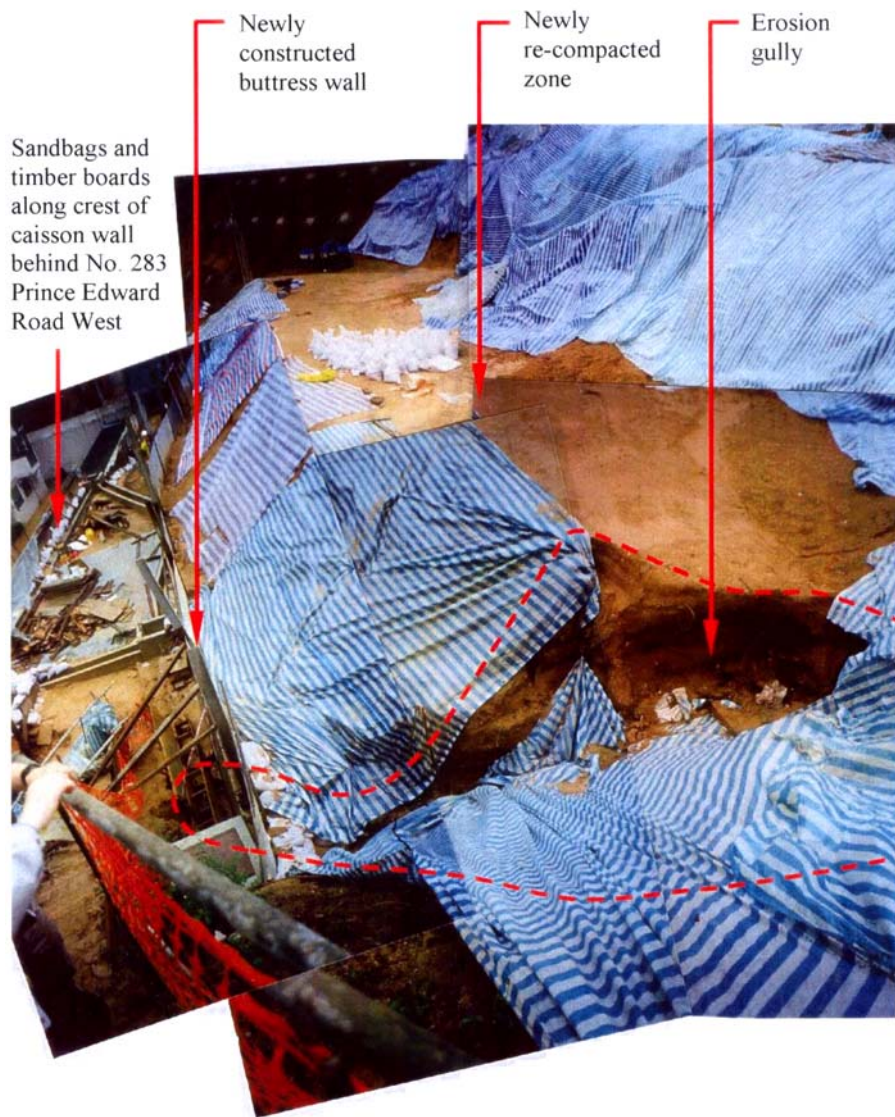
Note: General view of the landslide

Plate 37 - The June 1998 Incidents at Junction of Sai Sha Road and Tai Mong Tsai Road



Note: General view of the landslide

Plate 38 - The 3 April 2000 Incident behind No. 279 Prince Edward Road West



Note: A major erosion gully caused by concentration surface water flow

Plate 39 - The 3 April 2000 Incident behind No. 279 Prince Edward Road West



Note: Significant deformation and tilting of a portion of sheet pile wall

Plate 40 - The 24 August 2000 Incident below Lung Ha Wan Road



Note: Lateral support system provided to the sheet pile wall

Plate 41 - The 24 August 2000 Incident below Lung Ha Wan Road



Note: Undermining of the reinforced fill wall

Plate 42 - The 9 April 2001 Incident at Tsing Yi Northern Coast Road Site
above Tam Kon Shan Road



Note: Dislocation of a stepped channel in front of the reinforced fill wall

Plate 43 - The 9 April 2001 Incident at Tsing Yi Northern Coast Road Site
above Tam Kon Shan Road

APPENDIX A
SUMMARY OF THE INCIDENTS

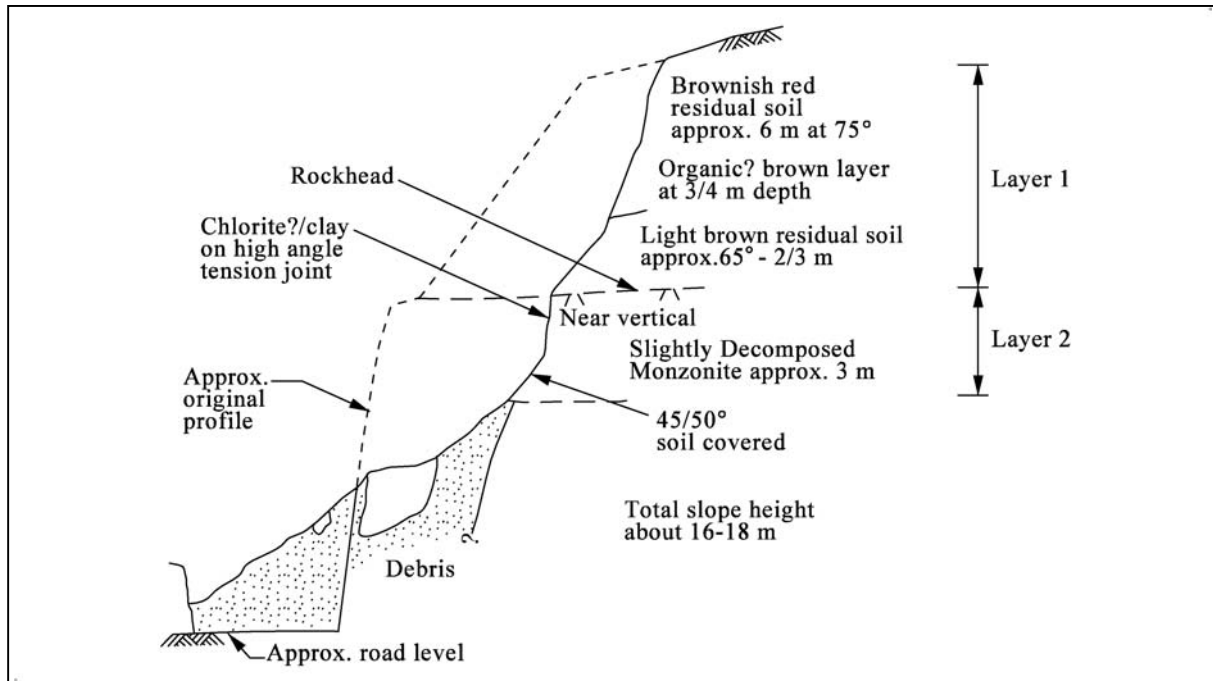
**Case No. 1 - The 12 July 1981 Incident at 399 Yip Kan Street, Aberdeen, Hong Kong
(Sheet 1 of 2)**

Basic Data

Date of Failure:	12 July 1981	Failure Volume/ Materials	1,235 m ³ rock and soil
Weather at Date of Failure:	Dry	Type of Failure:	Landslide
Feature Affected:	11SW-D/C86	Consequences:	Complete closure of Yip Kan Street and evacuation of buildings
Type of Work:	Site formation works	Type of Supervision:	AP/Geotechnical Consultant's staff
Client:	Private developer		



**Case No. 1 - The 12 July 1981 Incident at 399 Yip Kan Street, Aberdeen, Hong Kong
(Sheet 2 of 2)**



Description

The failure occurred on an approximately 16 m high soil and rock cut slope on a dry Sunday night, a week after heavy rainfall associated with tropical storm Lynne. The failure involved a composite landslide mobilised on daylighting, continuous chlorite coated rock joints dipping at 20° to the horizontal out of the slope through monzonite, together with slumping of an overlying residual soil layer. The failure volume was approximately 1,235 m³ and contained individual blocks of rock up to 10 m³. Direct shear testing confirmed that the angle of friction on the chlorite coated joints could be as low as 17° at low normal stress levels.

Following the passing of tropical storm Lynne on 7 July 1981, cracks appeared on the chunamed surface and were repaired. Blasting had been carried out at the

adjacent construction site at 399 Yip Kan Street on 10 July 1981. Cracks in the chunam and rock section were noted on the following day and road closure was recommended by the geotechnical consultant to the developer. On the evening of 11 July 1981, the GCO and GCB engineers visited the site and noted minor rockfalls and concluded that the slope was showing signs of imminent collapse. The police were advised to evacuate buildings in Yip Kan Street and to fence off the area. The final failure occurred on 12 July 1981.

It is apparent that disturbance due to blasting and perhaps cleft water pressure developed during tropical storm Lynne was sufficient to cause the initial movements. The failure was then a matter of gradual deterioration followed by final detachment.

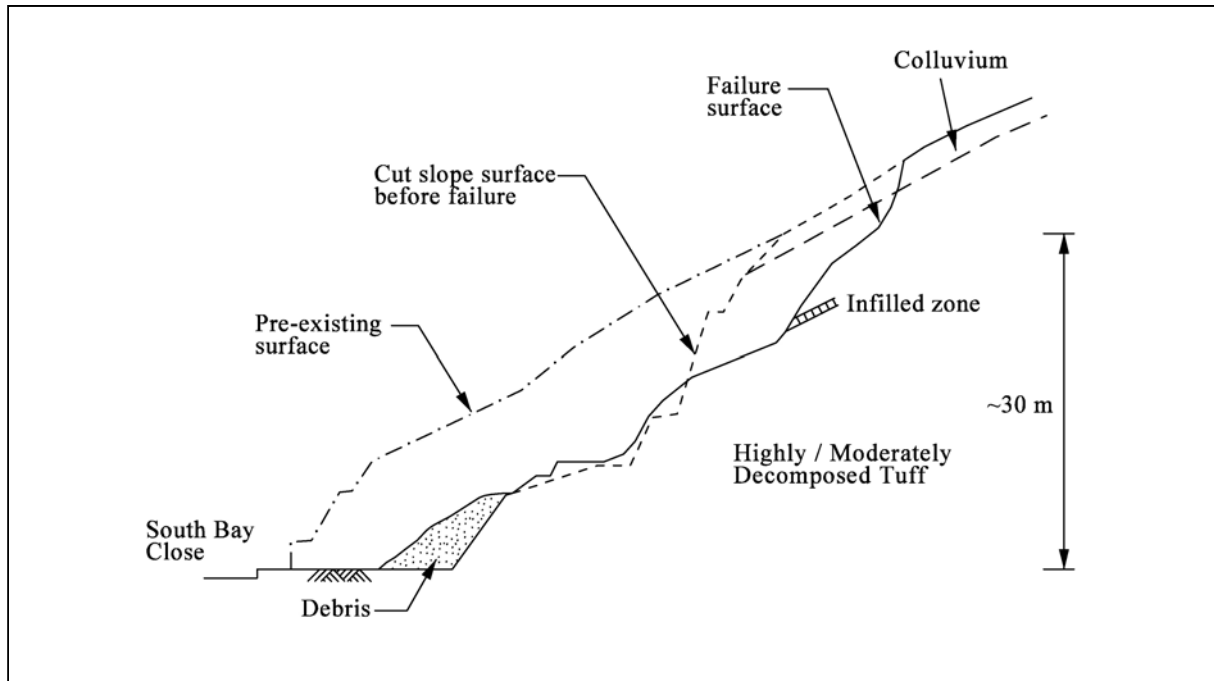
**Case No. 2 - The 29 May 1982 and 17 August 1982 Incidents at South Bay Close
(Sheet 1 of 2)**

Basic Data

Date of Failure:	29 May 1982 and 17 August 1982	Failure Volume/ Materials	3,800 m ³ of rock (1 st) 700 m ³ of rock (2 nd)
Weather at Date of Failure:	Heavy rainfall	Type of Failure:	Landslide
Feature Affected:	15NE-A/CR10	Consequences:	Landslide debris deposited within the construction site
Type of Work:	Site formation works	Type of Supervision:	AP/Geotechnical Consultant's staff
Client:	Private developer		



**Case No. 2 - The 29 May 1982 and 17 August 1982 Incidents at South Bay Close
(Sheet 2 of 2)**



Description

Two major landslides involving sliding failures occurred on a partially completed rock cut slope within an active construction site for a private residential development project. The first failure occurred on 29 May 1982 following an estimated 525 mm of rainfall on the day. The landslide involved approximately 3,800 m³ of closely jointed weathered rock which failed along a persistent, rough but thickly infilled daylighting discontinuity over an approximate length of 70 m. The landslide debris deposited at the slope toe was maximum 17 m thick. A second landslide (700 m³) occurred to the south of the previous detachment on 17 August 1982 after an estimated 500 mm rainfall on the day.

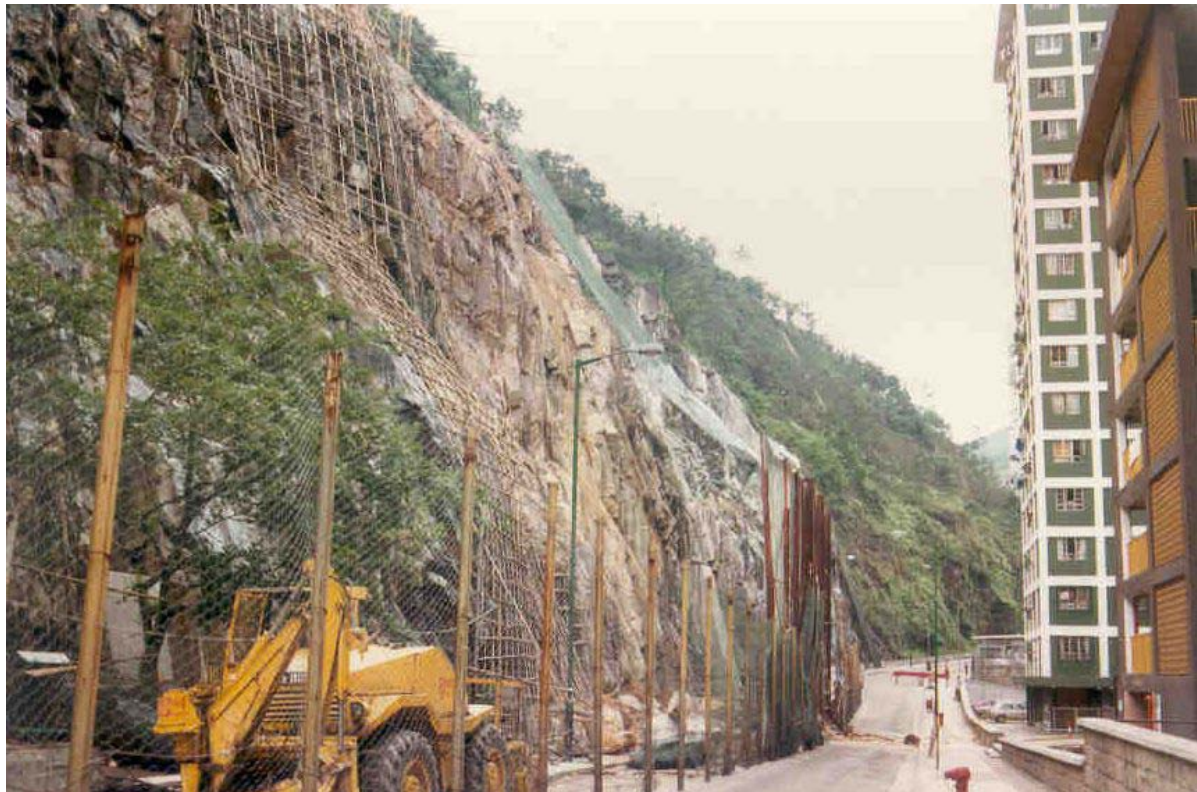
Prior to the May and August 1982 landslides, the design of the slope had been

through the slope safety system when the geotechnical submission was checked and approved by the Buildings Ordinance Office. The cut slope was cut back in accordance with the approved design and preventive measures, including rock bolts and raking drains, had been installed. An investigation of the landslides was carried out by the GCO (Hencher, 1983). An important contributory factor to the landslides was the presence of a major, adversely orientated infilled discontinuity that was not identified from the ground investigation and not taken into account in the design. In addition, the groundwater levels measured using Halcrow buckets in piezometers in August 1982 following the initial landslide were also higher than the design groundwater level.

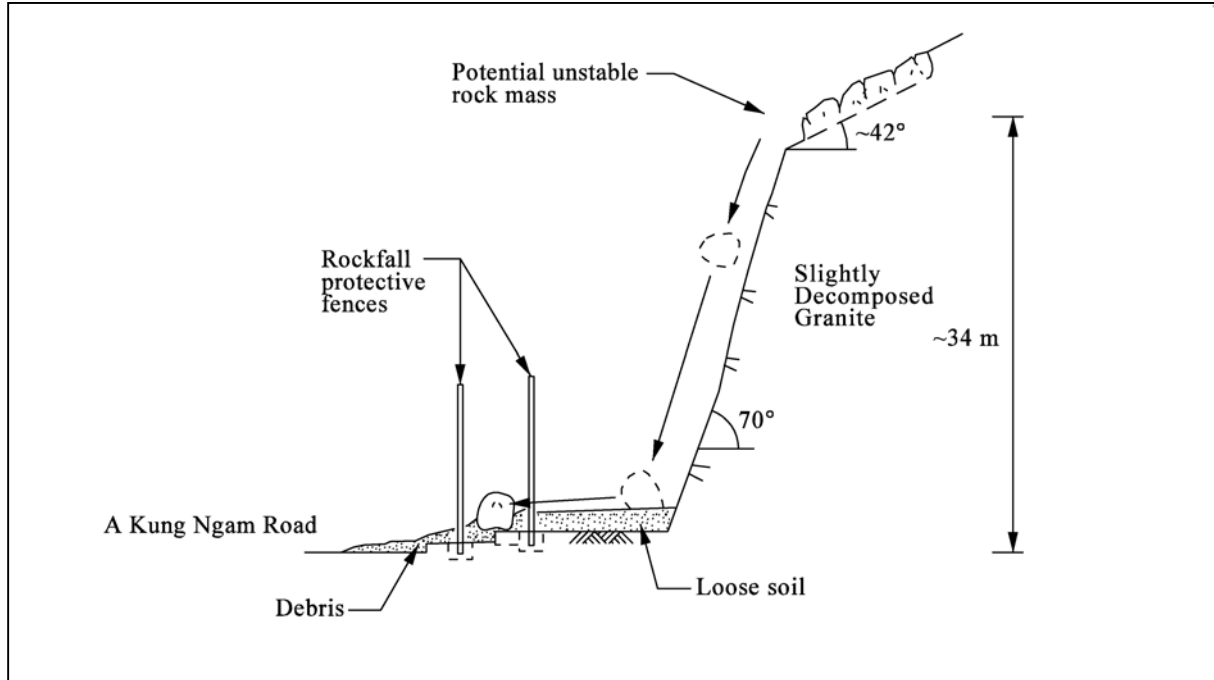
**Case No. 3 - The 21 May 1984 Incident at A Kung Ngam Road, Hong Kong
(Sheet 1 of 2)**

Basic Data

Date of Failure:	21 May 1984	Failure Volume/ Materials	8 m ³ of rock
Weather at Date of Failure:	Unknown	Type of Failure:	Rock fall
Feature Affected:	11SE-B/C87	Consequences:	Complete closure of A Kung Ngam Road for one day
Type of Work:	Slope upgrading works	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



**Case No. 3 - The 21 May 1984 Incident at A Kung Ngam Road, Hong Kong
(Sheet 2 of 2)**



Description

The rockfall occurred during the removal of a potentially unstable rock mass at the slope crest about 34 m above A Kung Ngam Road. The rock mass was about 150 m³ to 180 m³, resting on an inclined plane of 42°, and being split into small pieces by pneumatic and hand tools.

At the time of the rockfall, the pedestrian and vehicular traffic along the road were temporarily stopped for the dislodgement of a small rock block. A much larger rock block of about 8 m³ fell from the crest of the slope immediately following the removal of the small rock block. Two layers of protective fence at the slope toe were badly damage, and A Kung Ngam Road was blocked by rock debris. The road was closed to allow the clearance of the rockfall debris and the removal of large

volume of remaining unstable rock blocks at the crest of the slope.

This failure was a planar slide on an unfavourably orientated joint and was probably triggered by the removal of the key blocks following splitting of the rock mass.

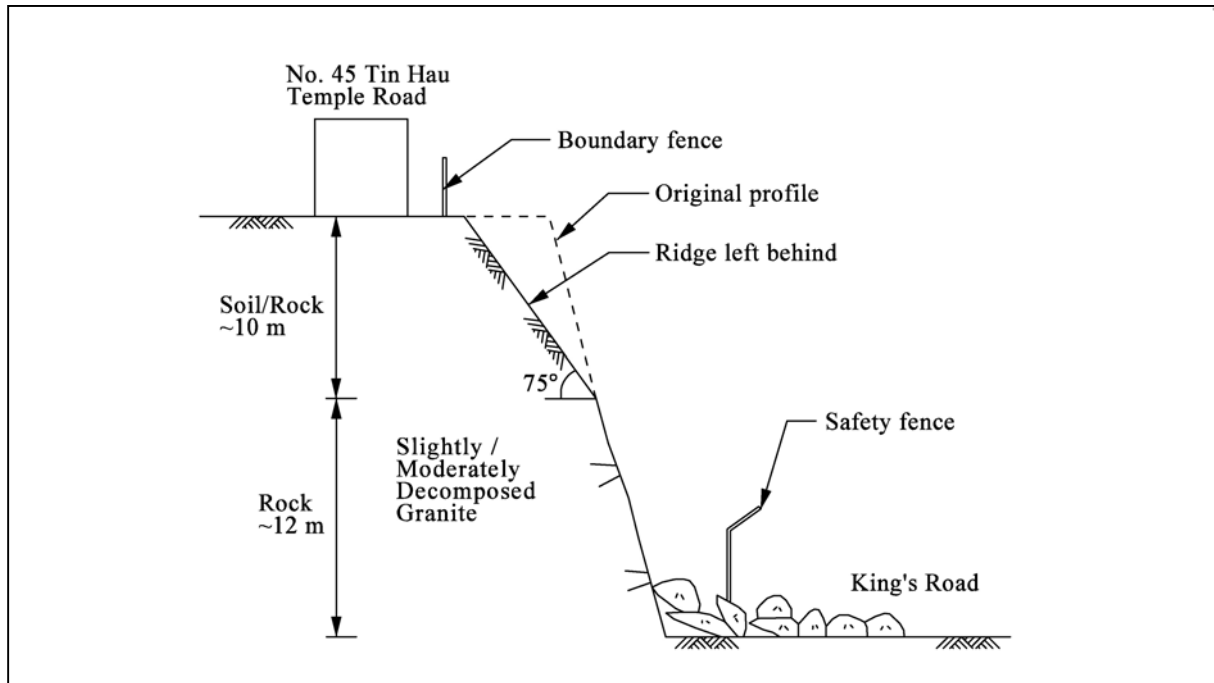
**Case No. 4 - The 25 June 1985 Incident at King's Road, Hong Kong
(Sheet 1 of 2)**

Basic Data

Date of Failure:	25 June 1985	Failure Volume/ Materials	70 m ³ of rock
Weather at Date of Failure:	Heavy rainfall	Type of Failure:	Rock fall
Feature Affected:	11SE-A/C14	Consequences:	2 westbound lanes and pedestrian pavement of King's Road temporarily blocked
Type of Work:	Slope upgrading works		
Client:	Government	Type of Supervision:	Full-time supervision by Resident Site Staff



**Case No. 4 - The 25 June 1985 Incident at King's Road, Hong Kong
(Sheet 2 of 2)**



Description

The rockfall occurred soon after heavy rainfall on a soil/rock cut slope where excavation works at the crest at about 22 m above King's Road were being carried out. The failure involved the sliding of granite blocks along adverse joints in decomposed granite. The slipped mass comprising large rock fragments up to 5 m³ demolished a 7 m long safety fence erected at the slope toe on King's Road. The volume of debris was estimated to be about 70 m³. Two westbound lanes and the pedestrian pavement of King's Road were blocked. This failure was a planar slide on unfavourably orientated joints partly coated with kaolin. Very slight seepage was observed on the scar during post-failure inspection by the GCO on the same day of the failure. The failure was probably triggered by heavy rainfall which resulted

in water ingress in the crest area which might have been exacerbated by excavation work being carried out in an area adjacent to the source of the rockfall.

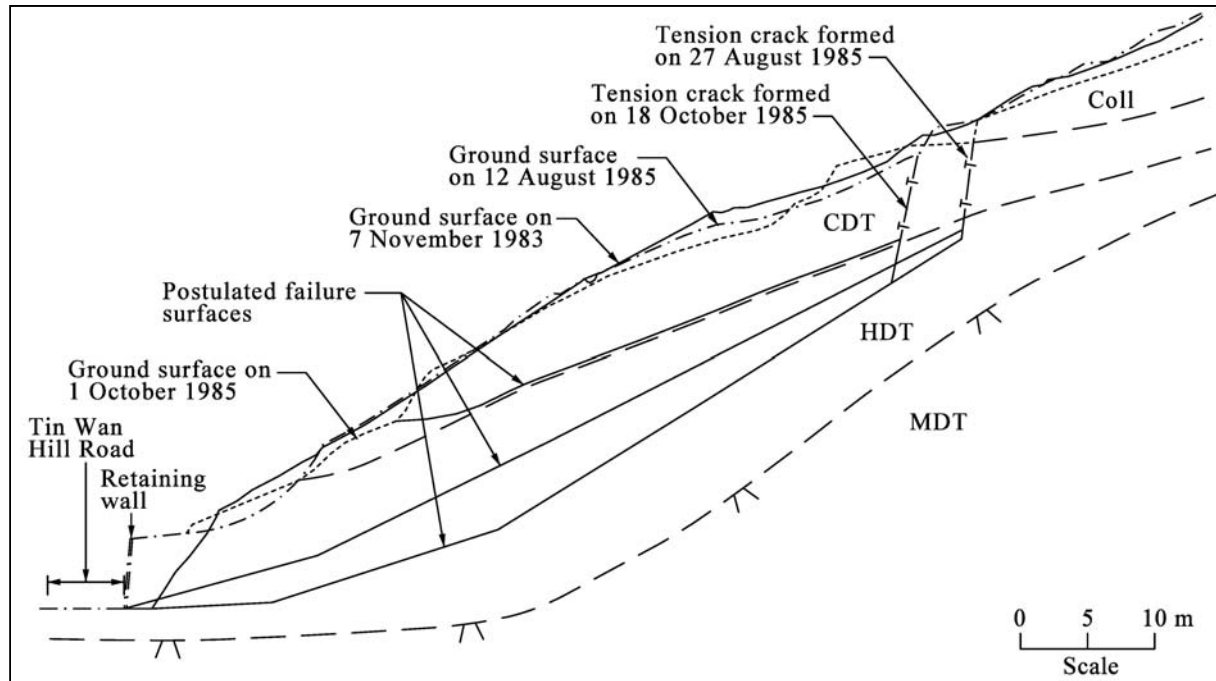
**Case No. 5 - The August and September 1985 Incidents at Tin Wan Hill Road, Hong Kong
(Sheet 1 of 2)**

Basic Data

Date of Failure:	<i>Unknown (likely to have occurred before October 1983)</i>	Failure Volume/ Materials	<i>19,200 m³ of soil</i>
Weather at Date of Failure:	<i>Not applicable</i>	Type of Failure:	<i>Progressive landslide</i>
Feature Affected:	<i>11SW-C/CR13</i>	Consequences:	<i>Delay and disruption to the slope upgrading works</i>
Type of Work:	<i>Slope upgrading works</i>	Type of Supervision:	<i>Full-time supervision by Resident Site Staff</i>
Client:	<i>Government</i>		



**Case No. 5 - The August and September 1985 Incidents at Tin Wan Hill Road, Hong Kong
(Sheet 2 of 2)**



Description

The incident occurred on a 37 m high cut slope when permanent stabilisation works were being constructed in 1985. Slope movements began after the formation of the cut slope in 1963. Slope remedial works including regrading, surface protection and subsurface drainage were carried out on a number of occasions between 1968 and 1982. Further instabilities were observed in October 1983 and permanent slope stabilisation works were designed by the GCO. The works consisted of a reinforced concrete retaining wall at the slope toe, trimming of the slope face and installation of 20 m maximum length horizontal drains and surface drainage channels. Site works began in early 1985 and slope movement was re-activated in June 1985 following heavy rainfall. The slope movement accelerated in July 1985 during excavation near the slope toe for the construction of the toe retaining wall. The slope was stabilised temporarily by placing rock fill at the slope toe. Following intense rainfall on 26 and 27 August 1985, the instability progressed further upslope with the formation of new tension cracks up to

9 m deep and failure of the near-surface materials. Rapid slope movement of up to 800 mm per day was recorded between 26 and 29 August 1985. On three occasions about 100 m³ to 200 m³ of material detached from the steep colluvial cut face which had been standing at about 56° and the landslide debris was deposited on both lanes of Tin Wan Hill Road. There was no reported casualties.

Further instability occurred on 6 September 1985. The landslide was investigated by the GCO (Irfan, 1986). Failures occurred in the colluvium as well as along relict failure surfaces in the deeply weathered profile. The slope has a complex geological and hydrogeological setting, involving effects of shear and fault zones and adversely orientated discontinuities with weak, slickensided infill. Slope deterioration occurred over the years involving opening up of the subvertical joints. The total volume of the unstable groundmass was estimated to be about 19,200 m³.

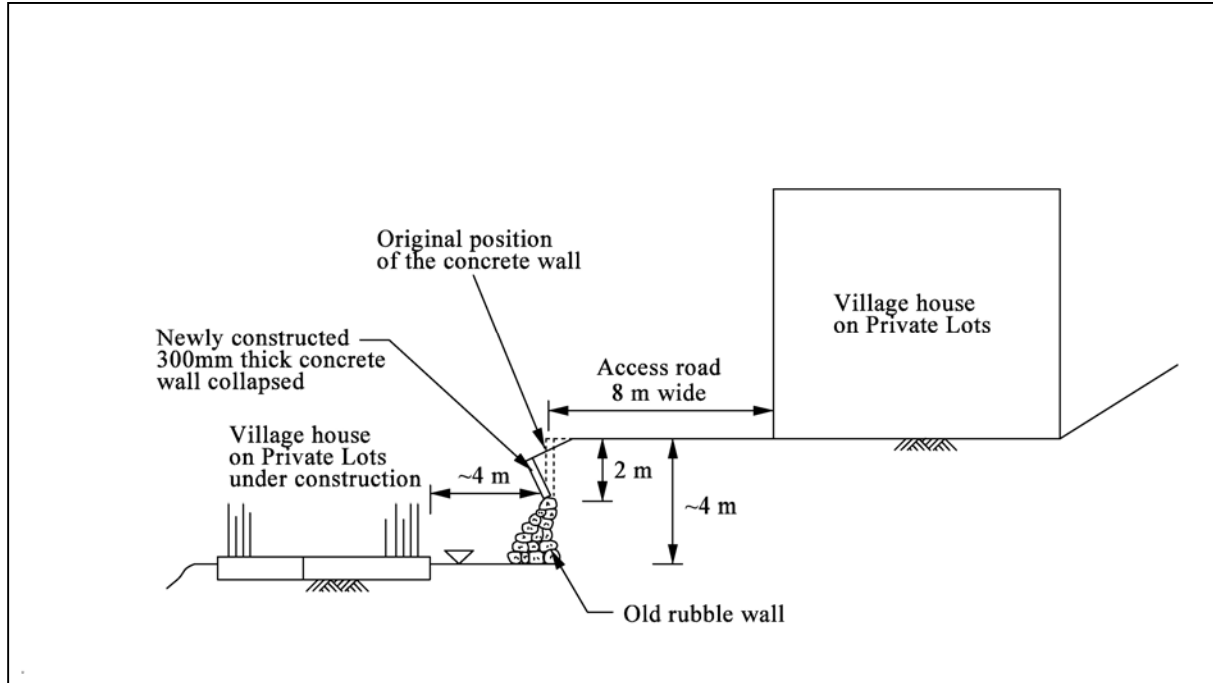
Case No. 6 - The 6 September 1985 Incident at No. 3-6 Pak Shek Terrace, Pak Shek Wo, Sai Kung (Sheet 1 of 2)

Basic Data

Date of Failure:	6 September 1985	Failure Volume/ Materials	100 m ³ of fill
Weather at Date of Failure:	Heavy rainfall	Type of Failure:	Retaining wall collapse
Feature Affected:	11NE-B/C397	Consequences:	Temporary closure of the access road at the crest and falling down of parked cars
Type of Work:	New Territories Exempted House construction works	Type of Supervision:	No record available
Client:	Private developer		



Case No. 6 - The 6 September 1985 Incident at No. 3-6 Pak Shek Terrace, Pak Shek Wo, Sai Kung (Sheet 2 of 2)



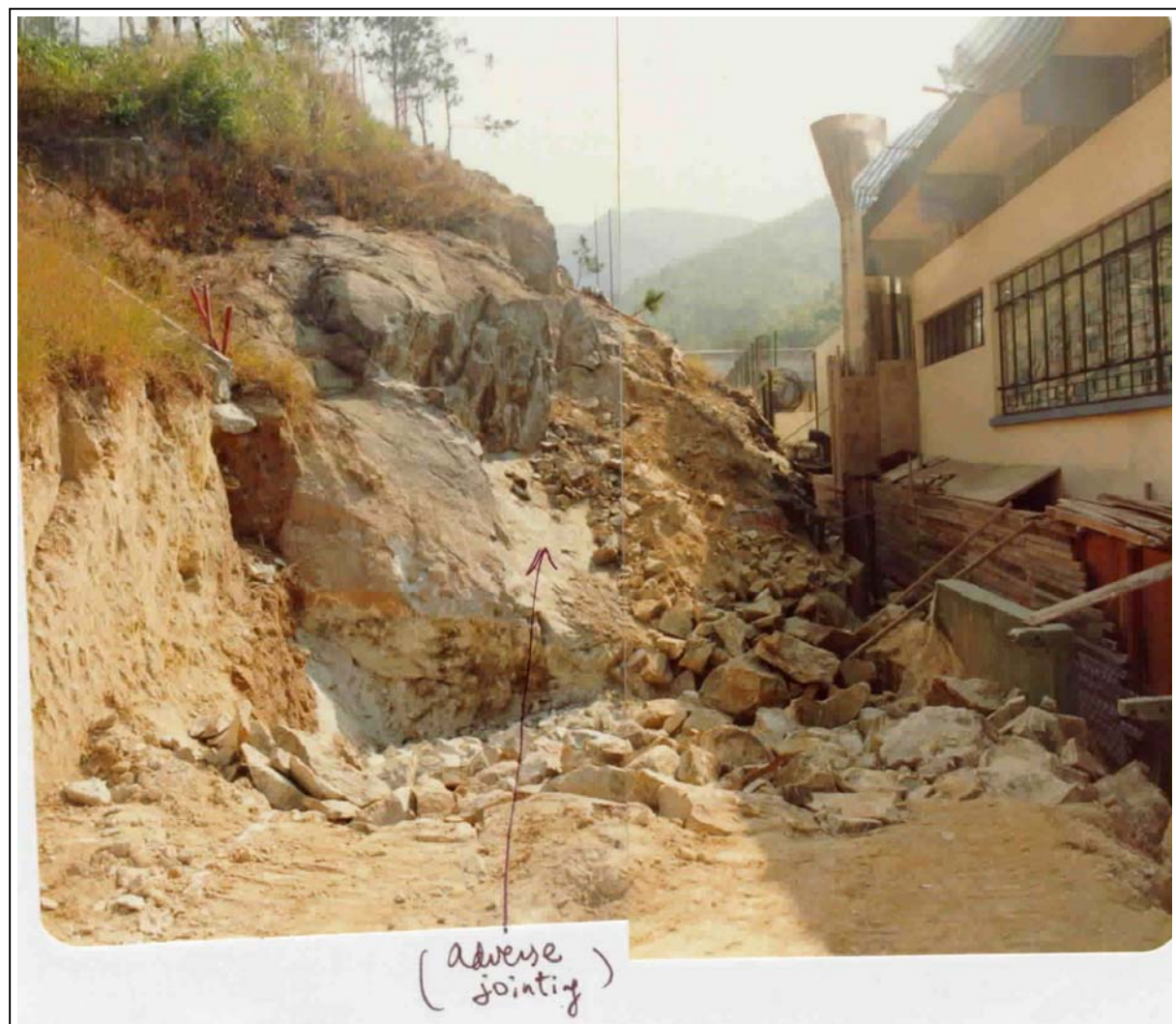
Description

The failure occurred during heavy rainfall, involved the collapse of a 24 m long section of a 3 to 4 m high retaining wall, comprising a 2 m high, 300 mm thick concrete wall founded on top of a 1 to 2 m high rubble wall. This retaining wall supported an 8 m wide access road and immediately below it was an active construction site for two small village houses on a 15 m wide platform. At the time of the failure, three parked cars together with about 40 bags of cement and a small drum concrete mixer were on the access road near the crest of the concrete wall. They all fell down with the debris into the construction site. The volume of the debris was about 100 m³. A large flow of water from a hole on the remaining uncollapsed portion of the wall was observed. A PVC pipe running

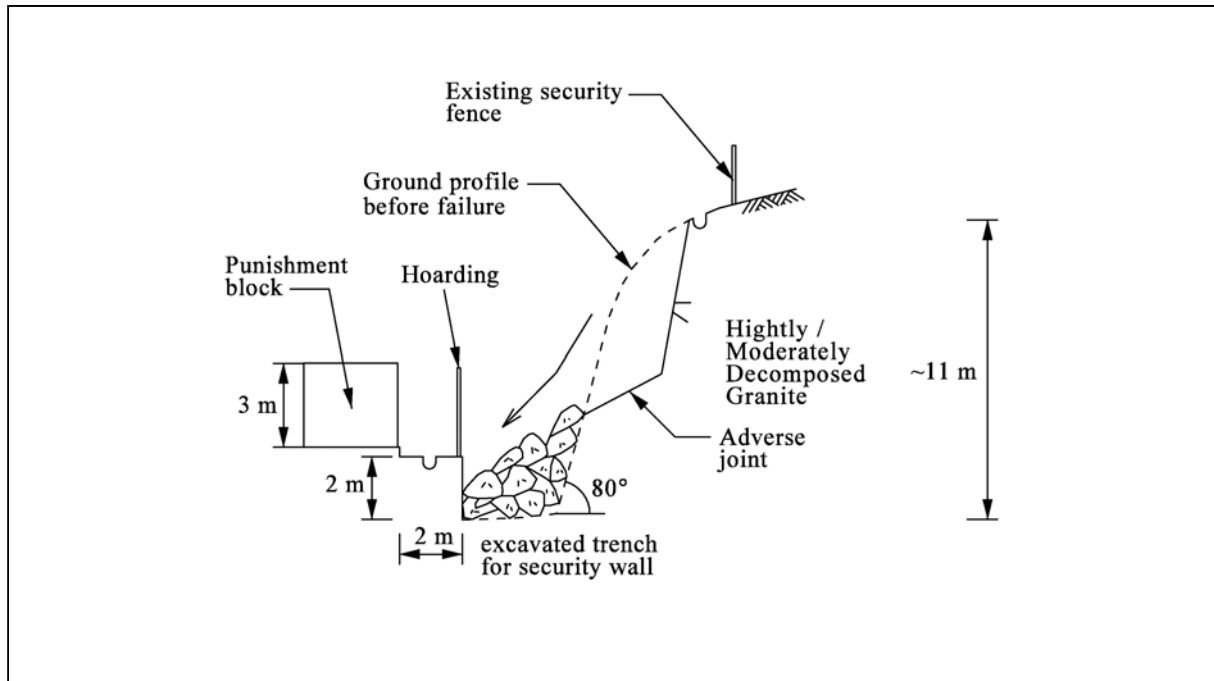
perpendicular to the wall was also broken behind the collapsed wall and was discharging water into the area of the failure. The access road was subsequently closed. The failure was probably due to surcharge from the parked cars and construction materials, and possibly leaking water carrying services. Heavy rainfall during the day of the failure, may have led to a rise in groundwater level and could have been a contributory factor, noting that there was no weepholes provided on the collapsed section of the wall. Based on the post-failure inspection by the GCO, the concrete wall itself was considered inherently unstable as it was founded on a wall of uncertain stability and was too thin to be a proper retaining structure.

**Case No. 7 - The 4 December 1986 Incident at Tai Lam Centre for Women, Tai Lam Chung
(Sheet 1 of 2)**

Basic Data			
Date of Failure:	4 December 1986	Failure Volume/ Materials	400 m ³ of soil and rock
Weather at Date of Failure:	Dry	Type of Failure:	Landslide
Feature Affected:	6SW-D/CR29	Consequences:	Temporary evacuation of Punishment Block Cells
Type of Work:	Security walls & guard towers construction	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



**Case No. 7 - The 4 December 1986 Incident at Tai Lam Centre for Women, Tai Lam Chung
(Sheet 2 of 2)**



Description

The failure occurred on an 80° temporary cut slope which had been formed to allow the construction of security wall along the hillside boundary of the Tai Lam Women's Prison, Tai Lam Chung. There was no rainfall on the day of the failure but some moderate rainfall 2 days earlier.

About 24 hours prior to the failure, a less extensive slip had been observed by the Resident Site Staff on the temporary cut slope, and at the same time a 5 mm wide and 5 m long tension crack was identified above the crest of the failure scar. A geotechnical engineer from Arch SD visited the site on the same day and advised the Resident Site Staff of the potential instability of the temporary cut slope and the need for urgent precautionary measures. On the following day, the temporary cut

slope failed along an adversely dipping rock joint. The failed debris of about 400 m³ came to rest in a 2 m deep trench at the toe of the slope which had been excavated to facilitate the construction of the security wall foundation. Part of the punishment block of the Prison, located at about 2 m from the excavated trench, was also evacuated.

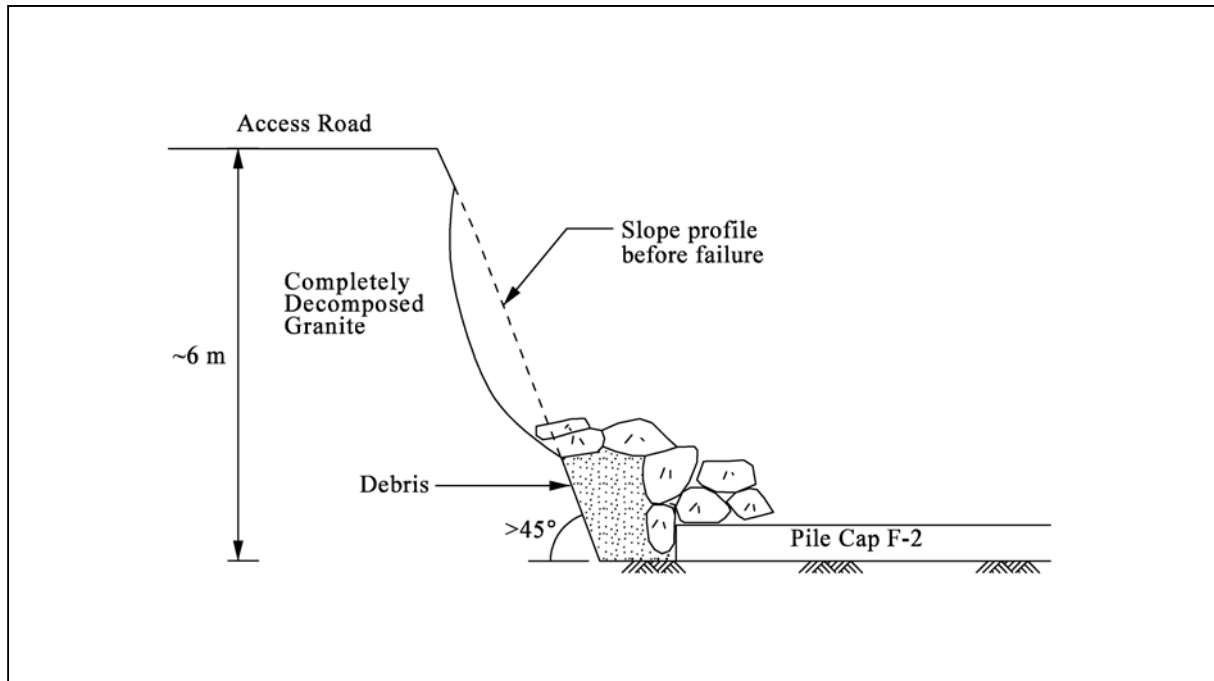
The failure was probably caused by over-steepened and unsupported excavation, and the presence of unfavourable orientated rock joints.

**Case No. 8 - The 27 July 1987 Incident at Fairview Garden, Wai Tsuen Road, Tsuen Wan
(Sheet 1 of 2)**

Basic Data			
Date of Failure:	27 July 1987	Failure Volume/ Materials	45 m ³ of soil (1 st slip) 30 m ³ of soil (2 nd slip)
Weather at Date of Failure:	Heavy rainfall	Type of Failure:	Landslide
Feature Affected:	Not applicable	Consequences:	3 construction workers injured, temporary closure of 1 lane of Texaco Road North closed
Type of Work:	Temporary excavation for a pile cap as part of building works	Type of Supervision:	AP/Geotechnical Consultant's staff
Client:	Private Developer		



**Case No. 8 - The 27 July 1987 Incident at Fairview Garden, Wai Tsuen Road, Tsuen Wan
(Sheet 2 of 2)**



Description

Two failures occurred during heavy rainfall on a building construction site in Tsuen Wan where a 6 m deep excavation for a pile cap was being carried out. The first failure occurred on the unsupported south-eastern face of the excavation when 8 workers were working in the excavation, releasing about 45 m³ of soil debris and as a result 2 workers were injured. Another worker who escaped injury in this initial collapse was also injured when he went to assist with the rescue.

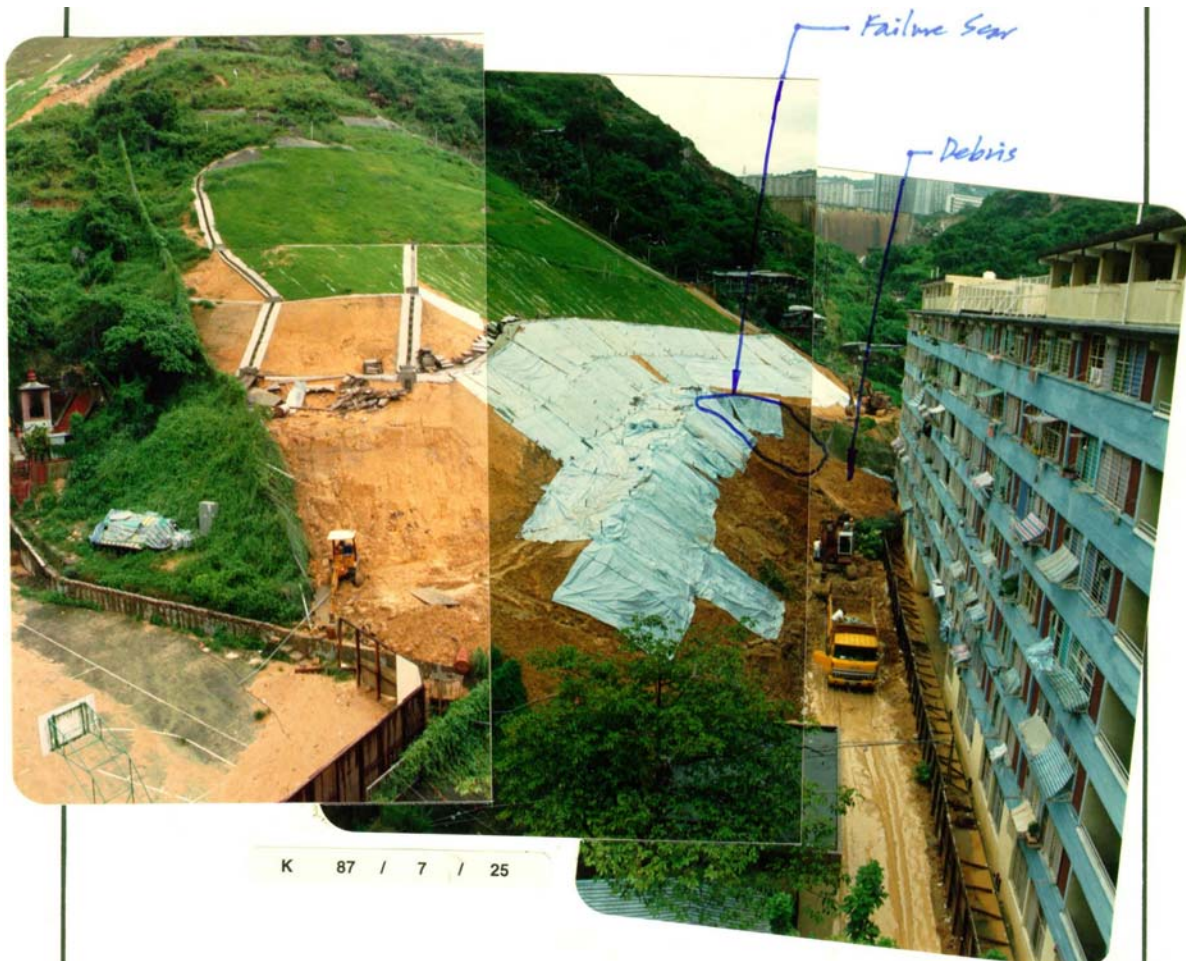
The second failure occurred four hours later on the north-western face of the excavation and releasing soil debris of about 30 m³. This failure affected an existing slope which supported Texaco Road North above the northern face of the excavation. One lane of the road was closed as a precautionary measure.

The causes of the two failures were probably due to the over-steepening of the excavation faces and lack of temporary support. Rapid increase in groundwater pressure due to rain infiltration might also have contributed to the failures.

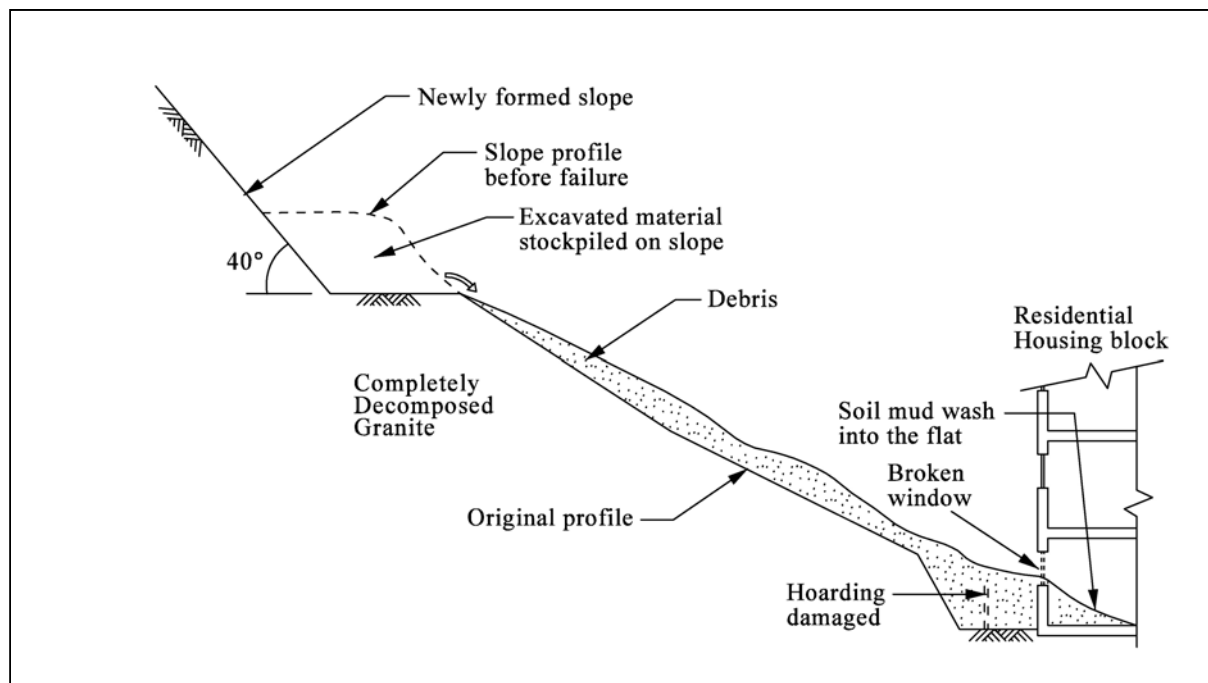
**Case No. 9 - The 30 July 1987 Incident behind Block 10, Jordan Valley Estate, Kowloon
(Sheet 1 of 2)**

Basic Data

Date of Failure:	30 July 1987	Failure Volume/ Materials	300 m ³ of soil
Weather at Date of Failure:	Heavy rainfall	Type of Failure:	Landslide
Feature Affected:	11NE-C/C12	Consequences:	20 flats temporarily evacuated
Type of Work:	Slope upgrading works	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



**Case No. 9 - The 30 July 1987 Incident behind Block 10, Jordan Valley Estate, Kowloon
(Sheet 2 of 2)**



Description

The landslide occurred during heavy rainfall on 30 July 1987 at about 2:30 a.m., on stockpiles of excavated materials on the lower batter of a soil cut slope behind Block 10, Jordan Valley Estate. At the time of failure, the slope was being upgraded under the LPM Programme. The failure involved sliding down of excavated materials which was stockpiled on the lowermost batter of the cut slope to form a temporary access ramp. The debris with a volume of about 300 m³ damaged the hoardings and safety fence at the toe of the cut slope and came to rest against the housing block. Part of the external building wall, windows and doors of several flats on the ground floor were damaged by the landslide debris and some debris was washed into residential flats. No casualties were reported but the landslide caused temporary evacuation of 20 flats of the housing block.

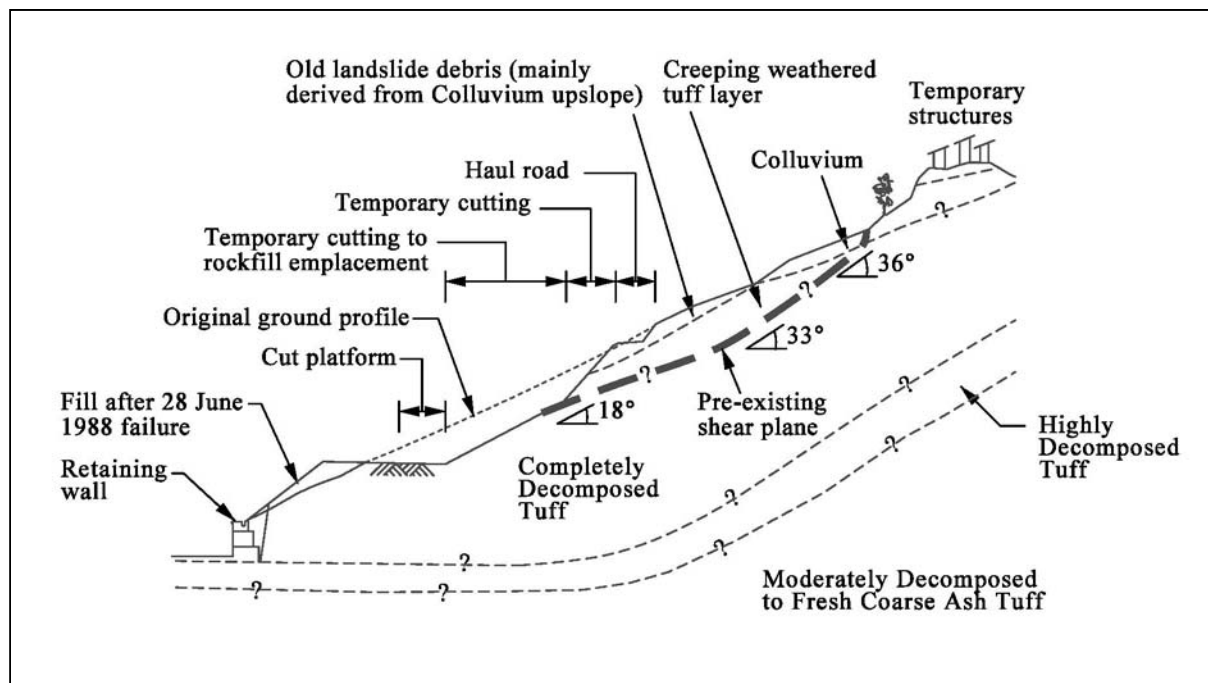
The failure was probably caused by infiltration of water during heavy rainfall into the excavated material stockpile. The improper location of the stockpile might also have been a contributory factor to this severe consequence failure.

Case No. 10 - The 28 June 1988 and 31 August 1988 Incidents at North of Island Road Government School (Sheet 1 of 2)

Basic Data			
Date of Failure:	28 June 1988 and 31 August 1988	Failure Volume/ Materials	100/800 m ³ of CDV and Colluvium
Weather at Date of Failure:	Heavy rainfall	Type of Failure:	Landslide
Feature Affected:	11SW-D/CR52	Consequences:	Temporary partial closure of the School and permanent evacuation of 10 huts at crest
Type of Work:	Slope upgrading works		
Client:	Government	Type of Supervision:	Full-time supervision by Resident Site Staff



Case No. 10 - The 28 June 1988 and 31 August 1988 Incidents at North of Island Road Government School (Sheet 2 of 2)



Description

Two failures occurred above Island Road Government School, at a 25 m high soil cut slope with an average gradient of 25°, which was being upgraded under the LPM Programme. On 28 June 1988 after a prolonged period of rain, the first failure occurred on the upper portion of the slope involving 100 m³ of soil debris. A 17 m long and up to 1 m deep tension crack of approximately crescent shape developed on the slope face near the crest of the slope. Ten squatter huts at the crest were subsequently permanently evacuated and the school playground behind the school was also closed off. The failure was probably caused by rapid infiltration due to removal of vegetation on the slope.

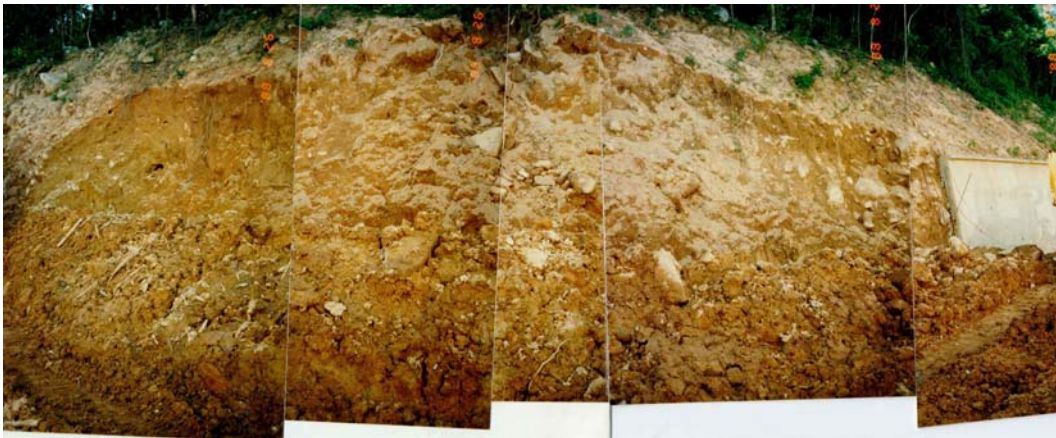
Following the first failure, the original upgrading works for this slope had been revised to replacing the top 3 m of soil with rockfill.

The second failure, involving about 800 m³ of debris, occurred during moderate rain on 31 August. The debris piled up against the rear wall of the school building causing the collapse of a screen wall of a ground floor workshop. The debris also flowed into the workshop and the surrounding area of the school. Eight rooms in the school were temporarily closed. According to Special Project Report No. 4/89, the second failure was caused by removal of toe support and a moderate rise in groundwater pressure due to rapid infiltration from the slope face stripped of vegetation and previous instability in the form of creep. As suggested by the post-failure investigation by the GCO, the second failure was found to have occurred along an irregular surface of a pre-existing shear plane which was formed as a result of rupture of a weathered tuff layer due to creep.

Case No. 11 - The Incident at Tai Wan, Sai Kung (Sheet 1 of 2)

Basic Data

Date of Failure:	<i>Unknown (likely to be in mid-August 1988)</i>	Failure Volume/ Materials	<i>65 m³ of soil (1st slip) 10 m³ of soil (2nd slip)</i>
Weather at Date of Failure:	<i>Persistent rainfall</i>	Type of Failure:	<i>Landslide</i>
Feature Affected:	<i>8SW-A/CR264</i>	Consequences:	<i>Access road to Lot 796 DD 216 temporarily blocked</i>
Type of Work:	<i>Retaining wall construction as part of site formation work</i>	Type of Supervision:	<i>AP/Geotechnical Consultant's staff</i>
Client:	<i>Private Developer</i>		

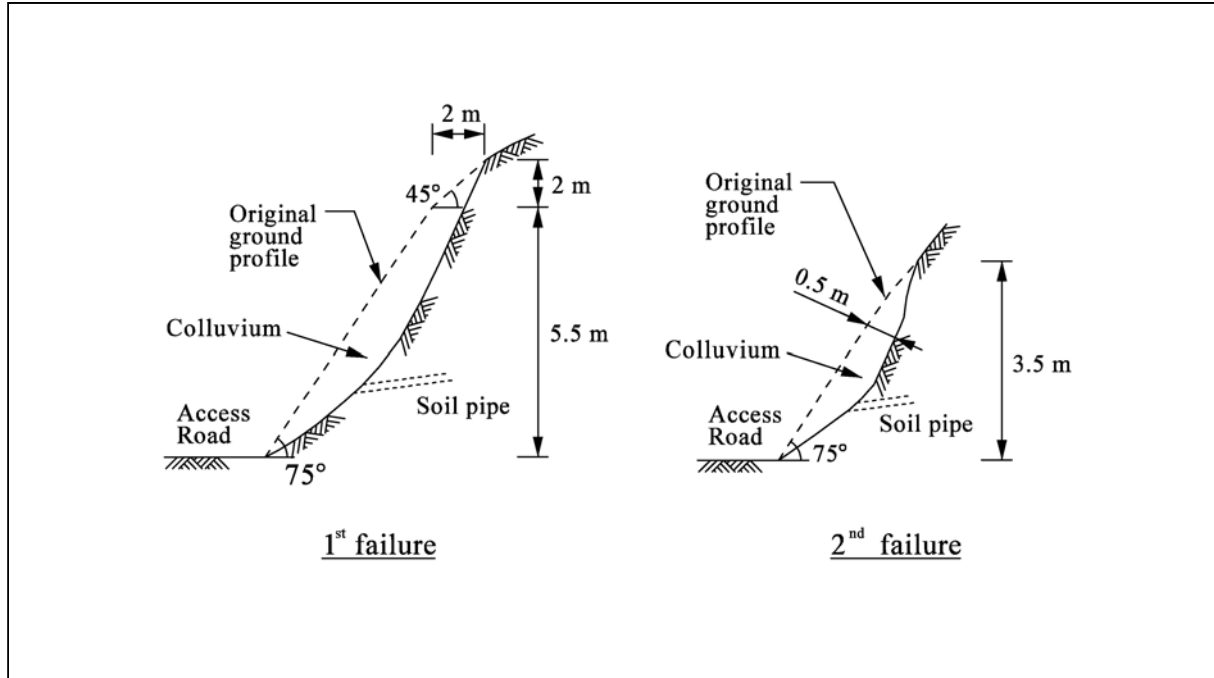


First failure



Second failure

Case No. 11 - The Incident at Tai Wan, Sai Kung (Sheet 2 of 2)



Description

Two landslides occurred in mid-August 1988 during a prolonged period of rainfall. They occurred in a temporary sub-vertical cut slope which was to provide access and to facilitate the construction of a retaining wall, as part of the site formation works for a private building development. The cut slope was formed before the design was accepted by the GCO.

The first failure occurred to the south of a partly completed retaining wall and involved a failure mass of about 65 m³. About 8 days later, a second failure occurred to the north of the first failure and involved soil debris of about 10 m³. A number of natural soil pipes with very significant seepage flows were observed on the failure scars at both locations after the failures. The two failures resulted in the

blockage of the access road to the construction site.

The causes of the two failures were probably the over-steepening of the temporary cut slope and lack of temporary support. Rapid increase in groundwater pressure due to seepage flows from the natural soil pipes also probably contributed to the failures.

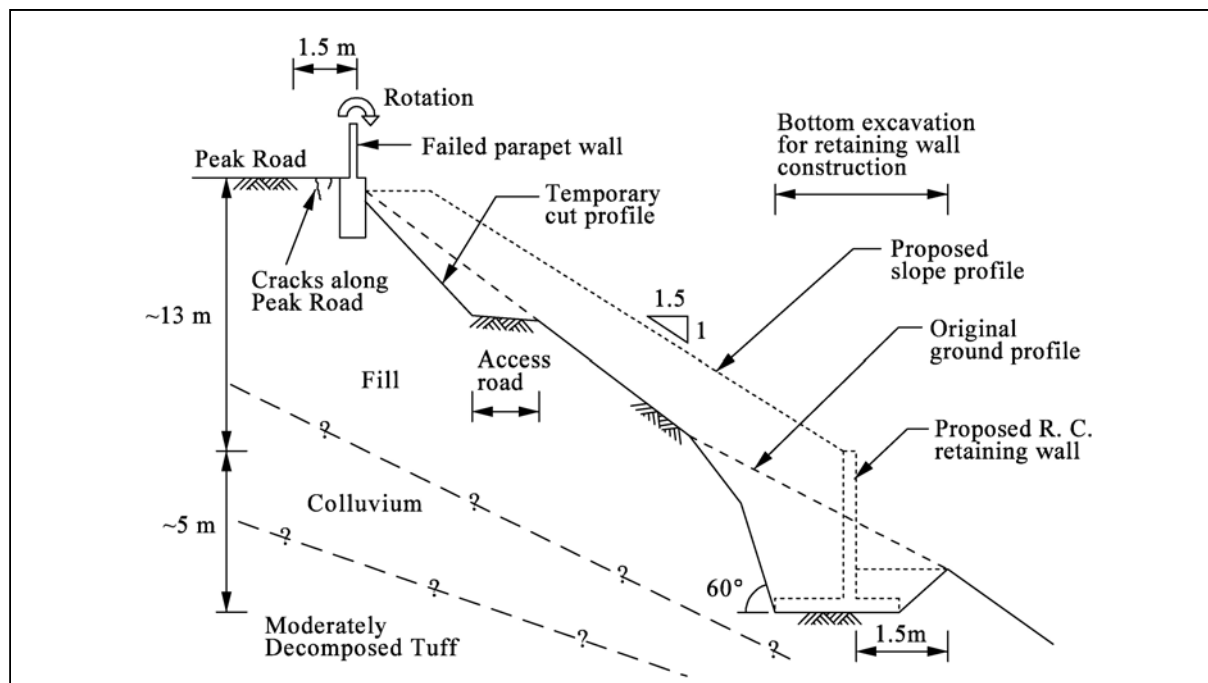
Case No. 12 - The 29 July 1989 Incident at Peak Road, Hong Kong (Sheet 1 of 2)

Basic Data

Date of Failure:	29 July 1989	Failure Volume/ Materials	Not applicable
Weather at Date of Failure:	Unknown	Type of Failure:	Retaining wall failure
Feature Affected:	11SW-D/F33	Consequences:	Closure of the uphill lane of Peak Road for 30 days
Type of Work:	Slope upgrading works	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



Case No. 12 - The 29 July 1989 Incident at Peak Road, Hong Kong (Sheet 2 of 2)



Description

The failure involved severe cracking on Peak Road and significant movements of a parapet wall along the crest of a fill slope on the downhill side which at the time was being upgraded under the LPM Programme. The slope upgrading works included the construction of a 5 m high reinforced concrete cantilevered retaining wall along the slope toe and recompaction of the top 3 m of loose fill.

Cracks on Peak Road were initially observed on 29 July 1989. The cracking was seen to have worsened subsequently, with a maximum crack width of 5 mm being observed on 2 August 1989. The parapet wall was measured to have moved 16 mm vertically and 12 mm horizontally between 31 July 1989 and 2 August 1989.

The failure resulted in the closure of the uphill lane of Peak Road.

A subsequent investigation into the failure by the GCO suggested that the stability conditions of the parapet wall were well below standard even before the works were started, and that the observed cracking on Peak Road and the movements of the parapet wall were triggered by the LPM construction activities.

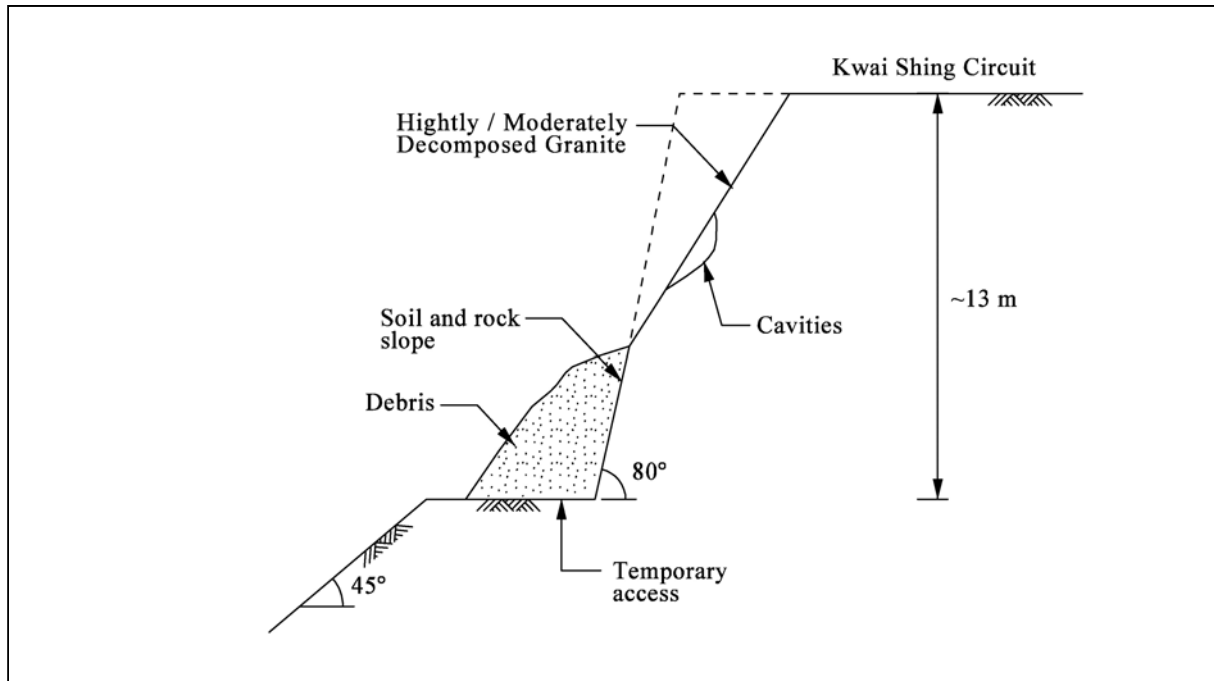
**Case No. 13 - The 31 July 1989 Incident at Kwai Shing Engineering Centre, Kwai Chung
(Sheet 1 of 2)**

Basic Data

Date of Failure:	<i>31 July 1989</i>	Failure Volume/ Materials	<i>50 m³ of soil and rock</i>
Weather at Date of Failure:	<i>Dry</i>	Type of Failure:	<i>Landslide</i>
Feature Affected:	<i>7SW-C/R259</i>	Consequences:	<i>1 injured, 1 lane of Kwai Shing Circuit closed for 7 months</i>
Type of Work:	<i>Temporary rock cutting as part of site formation work</i>	Type of Supervision:	<i>AP/Geotechnical Consultant's staff</i>
Client:	<i>Public Utilities Company</i>		



**Case No. 13 - The 31 July 1989 Incident at Kwai Shing Engineering Centre, Kwai Chung
(Sheet 2 of 2)**



Description

The failure occurred on a dry day, on an 80° temporary rock cut slope which was being formed as part of the site formation for Kwai Shing Engineering Centre along Kwai Shing Circuit (KSC). The failure involved a rock slide of about 50 m³ along a 45° plane near the crest of the rock cut slope. Cavities were observed in the backscar, water was seen flowing from a fire hydrant on KSC and an underground power line was found broken. No groundwater was observed. As a result of the landslide, one person was injured and one lane of KSC was closed for 7 months.

Site formation works, which involved excavation in rock in stages, were being carried out. Stabilisation works to the excavation face included installation of rock bolts. Cavities and open planar joints

were observed on the cut slope on 27 July 1989, four days before the incident. The contractor was instructed by the consultant on 28 July 1989 to carry out precautionary works, comprising grouting up of the cavities and provision of additional rock bolts. These stabilisation works had not been carried out up to the time of failure which resulted in one person being injured.

The failure was probably due to the presence of unfavourable orientated open joints in the rock cut slope.

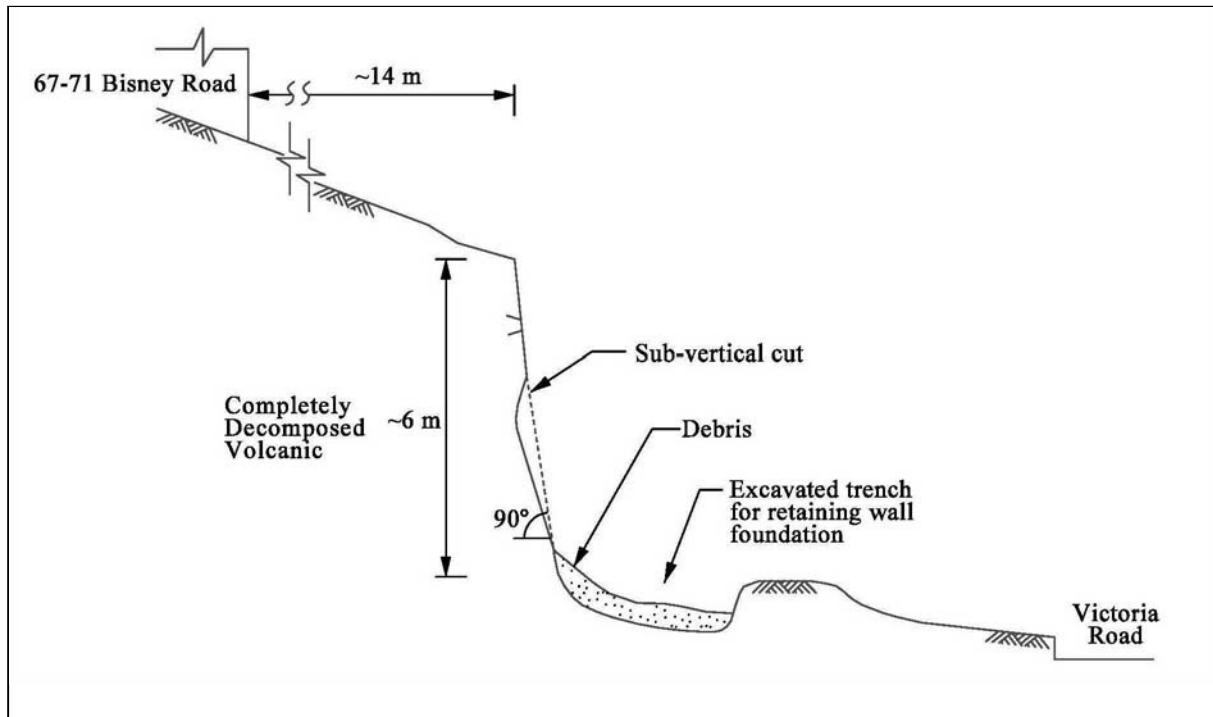
**Case No. 14 - The 24 November 1989 Incident at Victoria Road, Hong Kong
(Sheet 1 of 2)**

Basic Data

<i>Date of Failure:</i>	<i>24 November 1989</i>	<i>Failure Volume/ Materials</i>	<i>5 m³ of fill and CDV</i>
<i>Weather at Date of Failure:</i>	<i>Unknown</i>	<i>Type of Failure:</i>	<i>Landslide</i>
<i>Feature Affected:</i>	<i>11SW-C/C176</i>	<i>Consequences:</i>	<i>2 persons injured</i>
<i>Type of Work:</i>	<i>Road improvement works</i>	<i>Type of Supervision:</i>	<i>Full-time supervision by Resident Site Staff</i>
<i>Client:</i>	<i>Government</i>		



**Case No. 14 - The 24 November 1989 Incident at Victoria Road, Hong Kong
(Sheet 2 of 2)**



Description

The failure occurred on a sub-vertical temporary cut for a cantilevered retaining wall construction below 67-71 Bisney Road, as part of a road improvement project. The failure mass, about 5 m³ of soil, slid into a trench excavated at the toe of the temporary cut slope for the retaining wall foundation construction. The temporary cut was about 6 m high without any temporary supporting measures. Two workers were injured as a result of the failure.

The main trigger of this failure was the over-steepness of the temporary cut and the lack of temporary support. The open cut method for the retaining wall construction adopted by the contractor deviated from the approved “alternate bay” method. The Engineer’s Representative had reminded the contractor via a memo 6 days before the

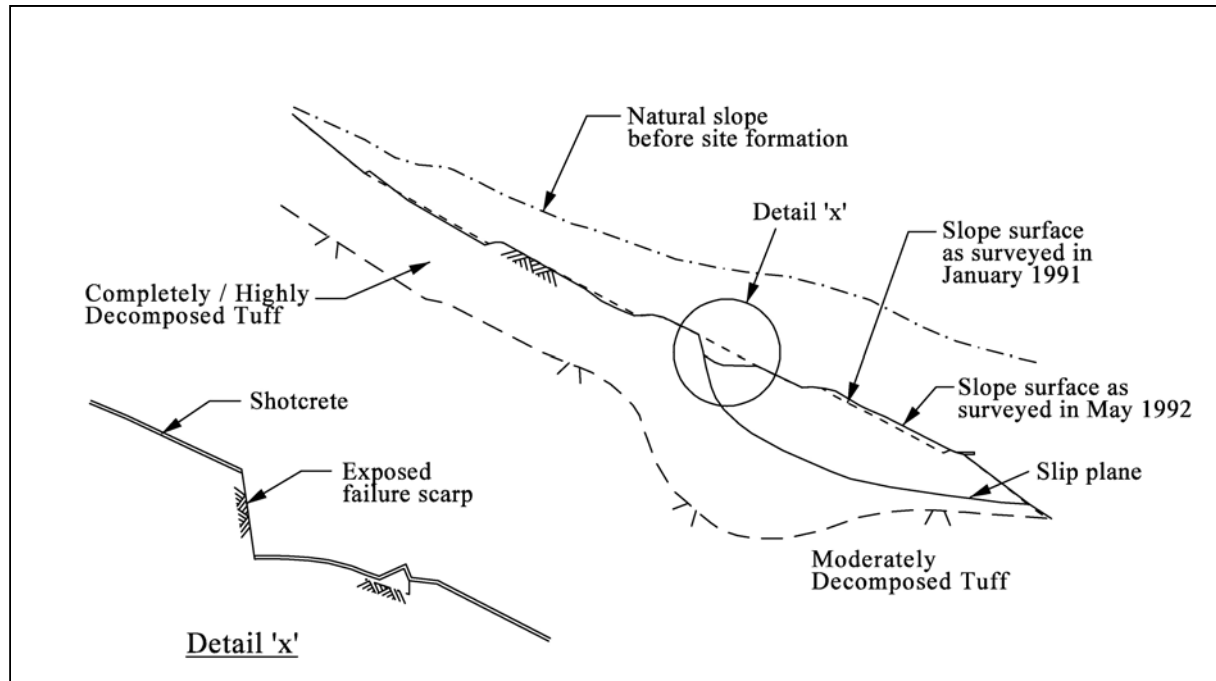
failure, regarding the observed non-compliance of construction method and requested the contractor to submit detailed engineering design and drawings for the temporary cut for approval.

**Case No. 15 - The November 1989 and April 1992 Incidents at Siu Sai Wan, Hong Kong
(Sheet 1 of 2)**

Basic Data			
Date of Failure:	November 1989 and April 1992	Failure Volume/ Materials	4000 m ³ of soil and rock
Weather at Date of Failure:	Not applicable	Type of Failure:	Progressive landslide
Feature Affected:	11SE-D/C182	Consequences:	Major redesign of slope works
Type of Work:	Site formation works	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



**Case No. 15 - The November 1989 and April 1992 Incidents at Siu Sai Wan, Hong Kong
(Sheet 2 of 2)**



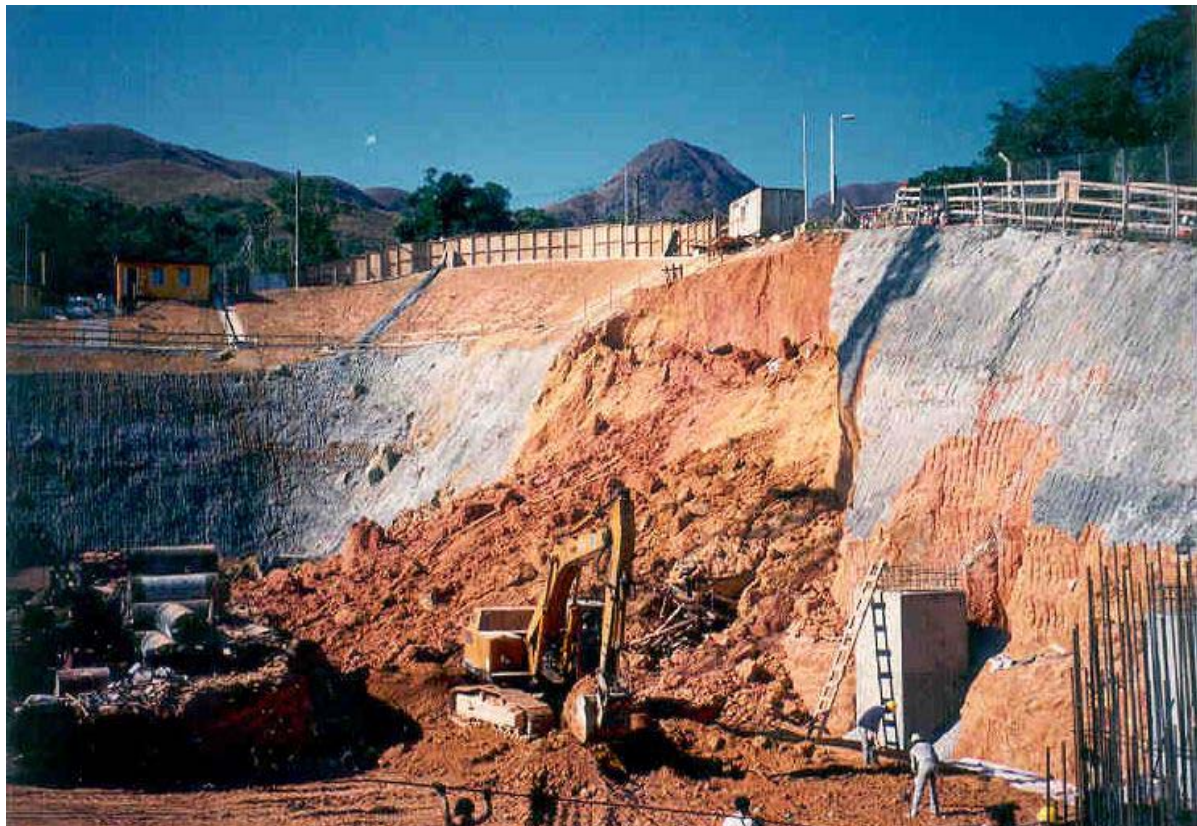
Description

Signs of distress involving tension cracks were observed in a 47 m high soil/rock cut slope during site formation works in late November 1989. The bottom batter of the slope was cut at a gradient of 72° and the upper batters were formed from 34° to 45° . An investigation by the GEO suggested that the mode of instability was related to stress relief as a result of slope formation, leading to toppling of blocks of soil bounded by predominantly sub-vertical relict joints. Remedial measures involved re-grading the slope to a flatter gradient of 30° , together with surface drainage measures and shotcreting. Parts of the slope in the southern end adjacent to a rock slope was revised from unsupported cut to soil nails. The remedial works was completed in early 1991.

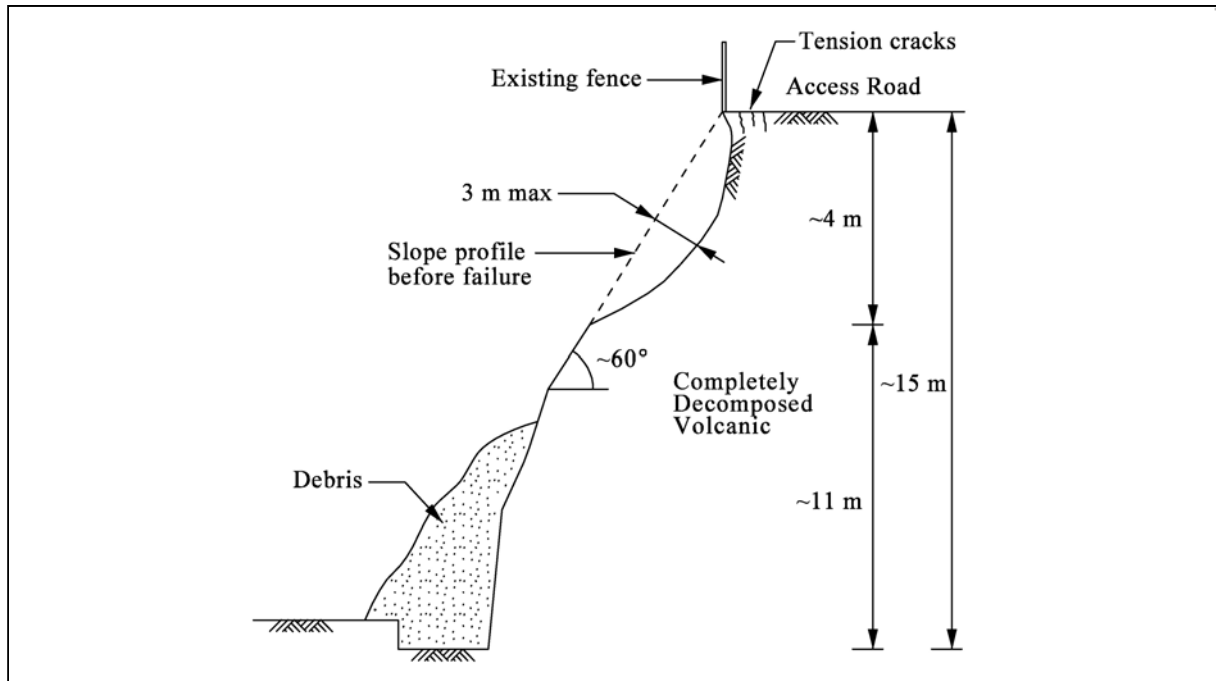
No signs of distress were reported on the slope until April 1992, a failure was observed to be taking place progressively. Most of the displaced ground mass remained on the slope. The failure was reported in detail in the GEO Special Project Report No. SPR 3/93. The mechanism of failure was diagnosed to be probably associated with deep-seated failure of a thick profile of hydrothermally altered relict-jointed tuff. The principal cause of the failure was believed to be a combination of high pore water pressure, low mass strength of soils and a relatively large thickness of completely weathered rock. The major factors in the failure were not considered in the original design nor when the cut slope was redesigned following the November 1989 failure.

**Case No. 16 - The 10 January 1990 Incident at Po Lo Che Service Reservoir Site, Sai Kung
(Sheet 1 of 2)**

Basic Data			
Date of Failure:	10 January 1990	Failure Volume /: Materials	400 m ³ of CDV
Weather at Date of Failure:	Fine	Type of Failure:	Landslide
Feature Affected:	8SW-A/F18	Consequences:	Half width of the villagers access road closed
Type of Work:	Temporary cut slope for service reservoir construction	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



**Case No. 16 - The 10 January 1990 Incident at Po Lo Che Service Reservoir Site, Sai Kung
(Sheet 2 of 2)**



Description

The failure occurred during dry weather in January 1990 at the crest of a 15 m high, 60° steep temporary cut slope in completely weathered volcanics when it was being formed for the construction of a service reservoir. The failure debris was about 400 m³. A sub-vertical scar, about 4 m high, was exposed at the crest of the slip. Major tension cracks up to 150 mm wide developed at the slope crest adjacent to the slip scar. A section of the village access road pavement at the crest was slightly undermined and half width of the access road was closed as a result of the failure.

The cause of the failure was probably due to the over-steepening of the temporary cut in CDV material with relict joints. The GCO had inspected the temporary cut slope a few weeks before the failure occurred,

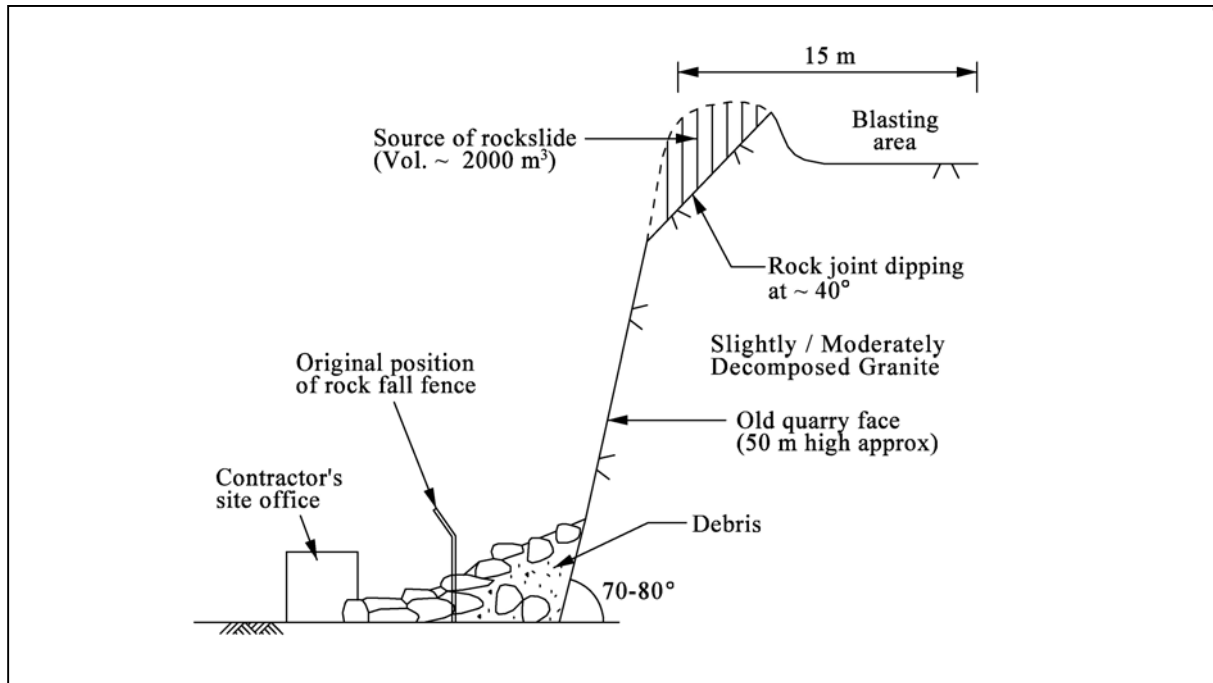
and had expressed their concern in writing to WSD about the potential instability of the cut slope. However, the contractor disagreed and argued at the time that the cut slope was stable. The works continued until failure occurred on 10 January 1990.

Case No. 17 - The 28 February 1991 Incident at Shau Kei Wan East Housing Development Site (Sheet 1 of 2)

Basic Data			
Date of Failure:	28 February 1991	Failure Volume/ Materials	2,000 m ³ of rock
Weather at Date of Failure:	Fine	Type of Failure:	Landslide
Feature Affected:	11SE-A/C4	Consequences:	2 primary schools closed for 3 days, 1 person slightly injured, Hoi Ching Street temporarily closed
Type of Work:	Site formation works		
Client:	Government	Type of Supervision:	Full-time supervision by Resident Site Staff



Case No. 17 - The 28 February 1991 Incident at Shau Kei Wan East Housing Development Site (Sheet 2 of 2)



Description

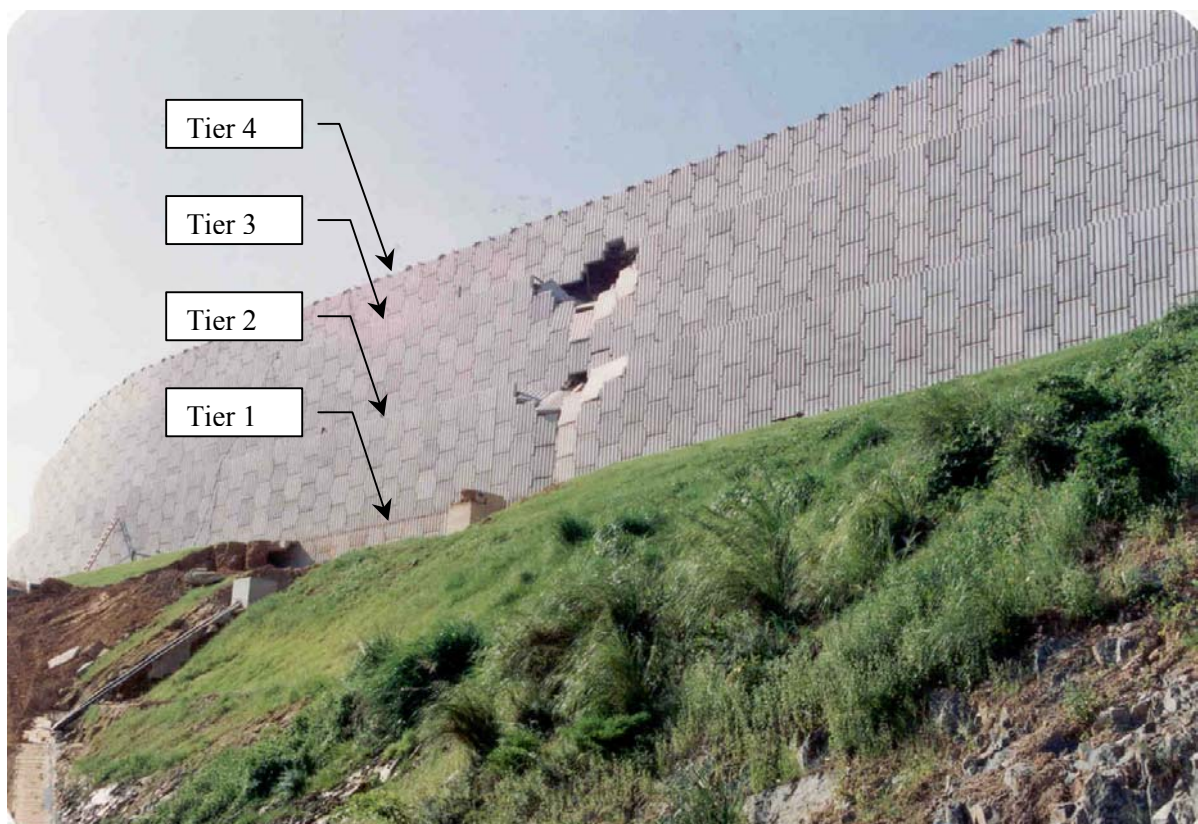
The failure occurred during dry weather near a 50 m high disused quarry face. At the time of failure, blasting was taking place at the crest of the rock slope as part of the site formation works for the adjacent housing development. The failure was reported to have occurred within one minute of a blast which took place within 15 m from the blasting area. About 2000 m³ of rock block was dislodged and fell onto the works area located at the toe of the quarry face. Six container office units and four vehicles parked nearby were damaged as a result of the landslide. The failure also caused the closure of two primary schools for three days, slight injury to one worker from a nearby garage and the closure of the northern end of Hoi Ching Street until completion of the site formation works behind the quarry face.

The failure was a planar slide on an unfavourably orientated discontinuity and was triggered by the blasting at the quarry crest. Rainfall was not a factor in this landslide.

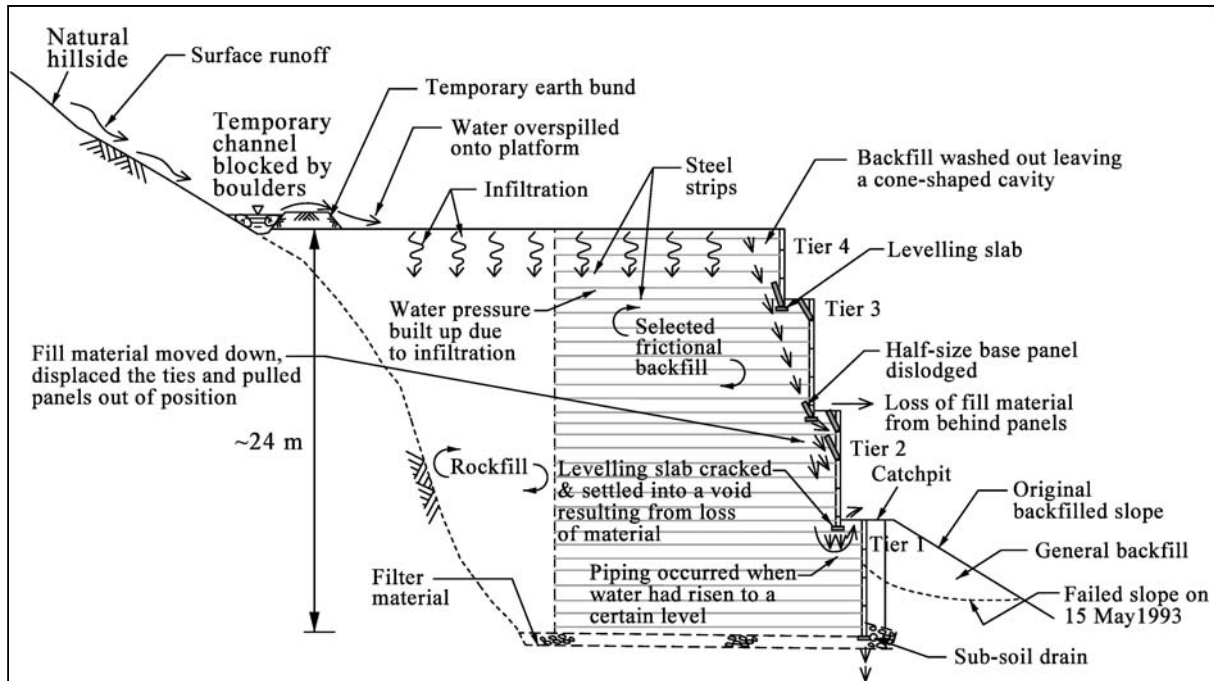
Case No. 18 - The 16 June 1993 Incident in Northwest Tsing Yi (Sheet 1 of 2)

Basic Data

Date of Failure:	16 June 1993	Failure Volume/ Materials	20 m ³ of fill
Weather at Date of Failure:	Black Rainstorm Warning	Type of Failure:	Washout
Feature Affected:	Not applicable	Consequences:	Reconstruction of a large section of the reinforced fill wall
Type of Work:	Site formation works	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



Case No. 18 - The 16 June 1993 Incident in Northwest Tsing Yi (Sheet 2 of 2)



Description

The failure occurred during heavy rainfall on a 6-tier, about 36 m high, reinforced fill wall (No. 1) which was under construction as part of the Advanced Earthworks in Northwest Tsing Yi (under HyD's Works Contract No. HY/91/21). At the time of failure, the wall construction had reached the forth tier (about 24 m high), behind the top of which was a large platform (with no protection against direct infiltration) formed for the upper tiers construction of the wall. Along the edge of the platform, adjacent to the natural hillside, an earth bund was formed to provide a temporary drainage channel to direct and discharge the stormwater runoff from the hillside. About 1 hour prior to the failure, the channel was found to be blocked by boulders and water overspilled onto the platform area and the reinforced fill wall below. It was reported that the failure was initiated at the base of Tier 2, with a loss of fill material under the Tier 2 levelling slab. This resulted

in the formation of a void into which the Tier 2 levelling slab settled. The fill from behind the facing panel also moved down and displaced the top ties of Tier 1 over the erosion scar. Following the loss of fill material at the base of Tier 2, the fill material above then moved down behind the panels, displaced the ties and pulled the panels out of position. At Tier 3, the base levelling slab failed completely due to the loss of material below, and one half-size base panel then dislodged, creating a hole through which a large quantity of fill material was washed out. This caused a cone-shaped cavity right up to the top of the wall and major disruption to the panels adjoining the void, which either fell into the cavity or were pulled there by the displacement of their ties. The failure was probably caused by the high water level built up within the fill material, resulting in piping at the base of Tier 2 and the subsequent collapse of parts of Tiers 3 and 4.

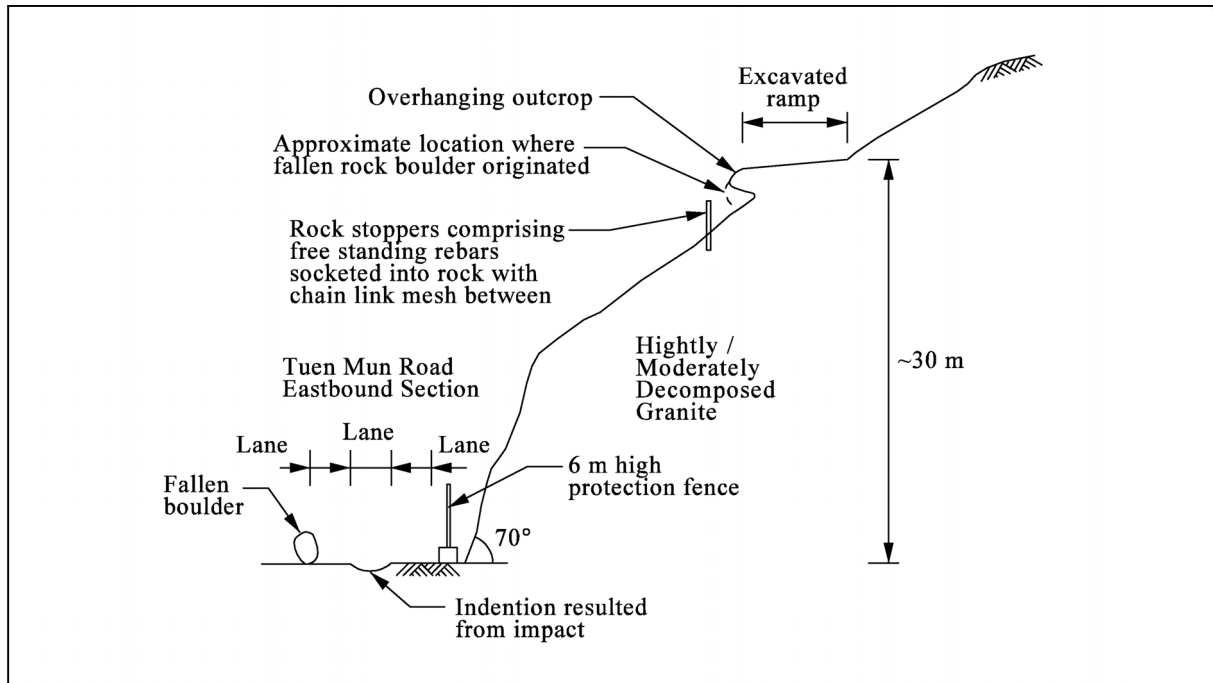
**Case No. 19 - The 18 August 1995 Incident at Siu Lam, Tuen Mun Highway, N.T.
(Sheet 1 of 2)**

Basic Data

Date of Failure:	18 August 1995	Consequences:	1 fatality and 1 injury to members of the public, 3 east-bound lanes of Tuen Mun Hwy temporarily closed, major rock cuts for Tai Lam section of the Improvement to Tuen Mun Road Project suspended
Weather at Date of Failure:	Partly cloudy, fair		
Feature Affected:	6SW-D/C18		
Type of Work:	Road improvement works		
Client:	Government	Type of Supervision:	Full-time supervision by Resident Site Staff
Failure Volume/ Materials	10 m ³ of rock		
Type of Failure:	Rockfall		



**Case No. 19 - The 18 August 1995 Incident at Siu Lam, Tuen Mun Highway, N.T.
(Sheet 2 of 2)**



Description

The rockfall occurred during scaling works on a rock outcrop some 30 m above the Tuen Mun Highway. The excavation works were part of Highways Department's Improvement to Tuen Mun Road Project which was being carried out under a design-and-built contract. The rockfall involved falling of a rock block of about 2 m x 2 m x 2.5 m in size from the overhanging rock outcrop at the crest of the slope onto the highway below outside the site boundary. The detached rock block rolled and landed in the middle eastbound lane of the highway and was hit by a van before coming to rest at the edge of the outer lane. This failure caused one fatality and one injury to members of the public, the closure of three eastbound lanes, and the suspension of rock cuts for the Tai Lam section of the project for about eleven

months. The scaling works involved rock splitting using drilling and feathering and wedging. On completion of work on the day of the incident the workers left wedges in place on a block they had not successfully split. Shortly after, the rock block detached and fell.

The incident was classified as a construction accident.

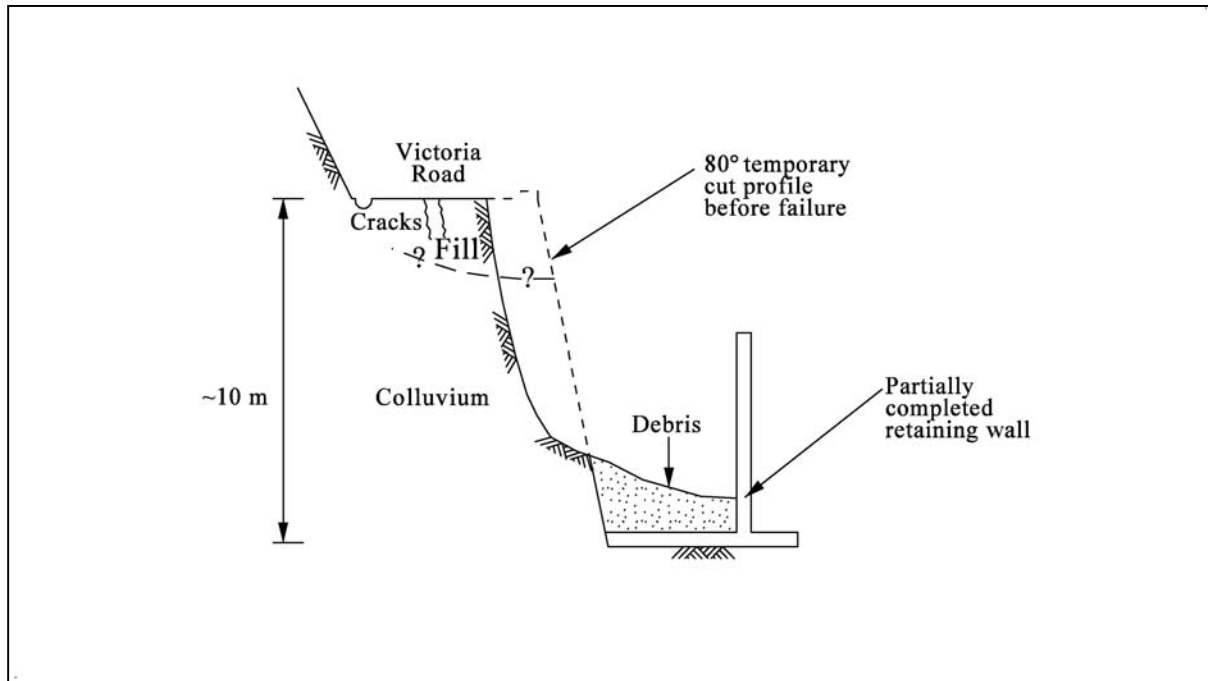
**Case No. 20 - The 25 July 1996 Incident Near 212 Victoria Road, Hong Kong
(Sheet 1 of 2)**

Basic Data

Date of Failure:	25 July 1996	Failure Volume/ Materials	75 m ³ of fill and colluvium
Weather at Date of Failure:	Dry	Type of Failure:	Landslide
Feature Affected:	11SW-C/R544	Consequences:	Complete closure of Victoria Road for 2 days
Type of Work:	Road improvement works	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



**Case No. 20 - The 25 July 1996 Incident Near 212 Victoria Road, Hong Kong
(Sheet 2 of 2)**



Description

The failure occurred during a dry day, at an 80° temporary cut for a retaining wall construction below Victoria Road, as part of Highways Department's Victoria Road Improvement Project Stage II Phase I. The failed mass, estimated to be 10.5 m wide, 4 m long and 1.8 m deep, came to rest behind the partially completed retaining wall. The temporary cut was about 10 m high without any temporary hard surface protection or support. Cracks were formed in the carriageway of Victoria Road parallel to the crest of the temporary cut. No temporary measures to divert surface runoff away from the temporary slope surface were provided. The failure resulted in complete closure of Victoria Road for two days. The temporary works were designed by the contractor, checked by the Independent Checking Engineer and

accepted by the consultant. GEO had expressed their concern on the over-steepened and unsupported temporary cut after a site visit in March 1996, about four months before the failure, and about the level of geotechnical control on site following a further three landslides which occurred on 14 September 1996.

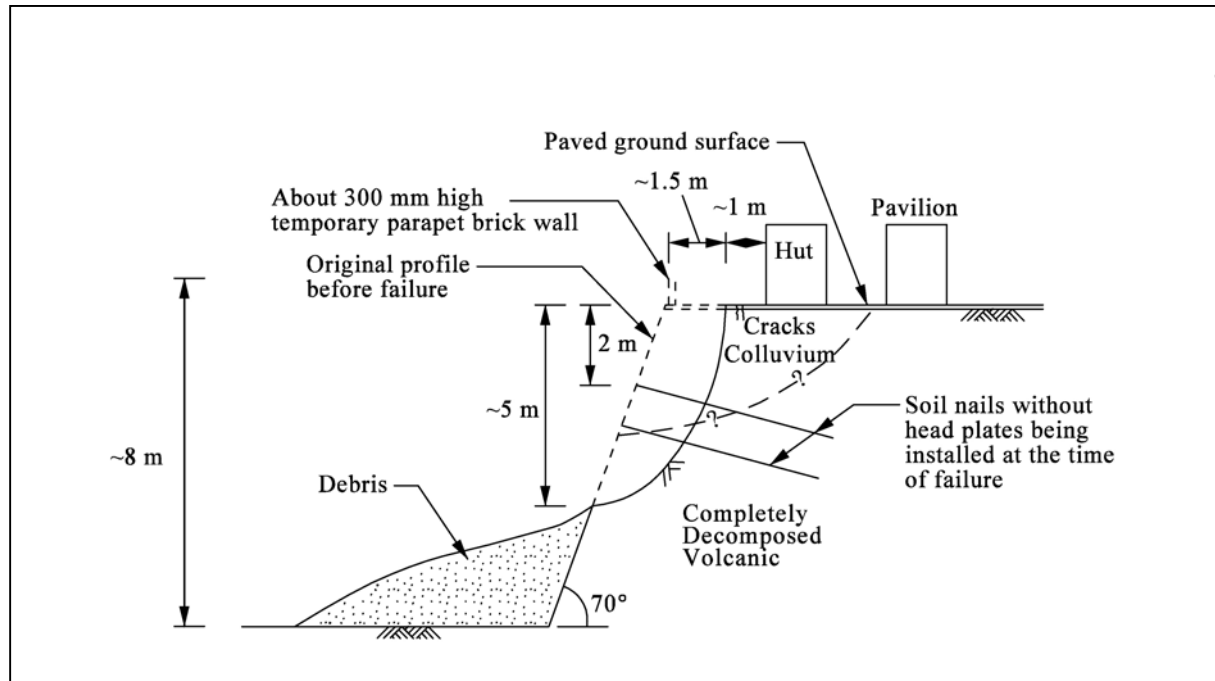
The weather at the time of the failure was fine and no rainfall was recorded in the 24 hours preceding the failure. This failure was probably caused by over-steepness of the temporary cut without any temporary support.

Case No. 21 - The 14 September 1996 Incident near the Junction of Victoria Road and Sandy Bay Road (Sheet 1 of 2)

Basic Data			
Date of Failure:	14 September 1996	Failure Volume/:	45 m ³ of colluvium and CDV
Weather at Date of Failure:	Heavy rainfall	Materials	
Feature Affected:	11SW-C/C186	Type of Failure:	Landslide
Type of Work:	Road improvement works	Consequences:	Temporary evacuation of 1 hut and 1 pavilion, partial closure of the Chinese Christian Cemetery
Client:	Government	Type of Supervision:	Full-time supervision by Resident Site Staff



Case No. 21 – The 14 September 1996 Incident near the Junction of Victoria Road and Sandy Bay Road (Sheet 2 of 2)



Description

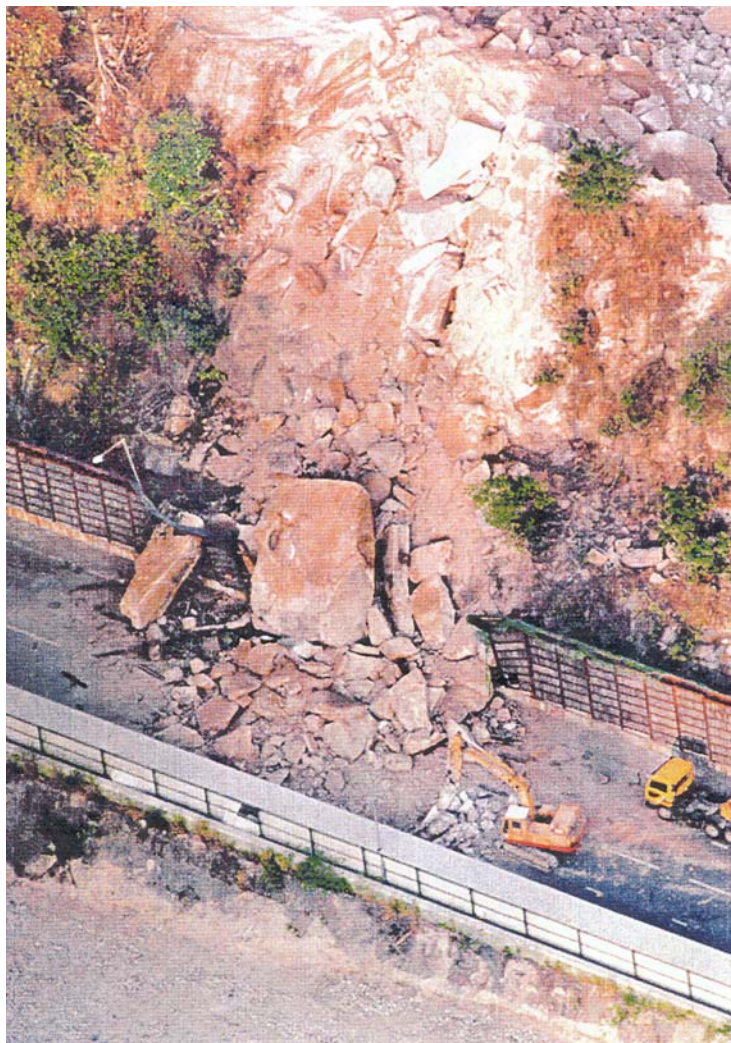
The failure occurred during heavy rainfall on an 8 m high sub-vertical temporary soil cut slope with soil nails for the construction of a reinforced concrete retaining wall, as part of Victoria Road Improvement Project. Two rows of widely-spaced soil nails had been installed at the top portion of the cut slope at the time of failure, but the nail heads had not yet been constructed. The cut slope failed with the debris sliding down leaving the nails in position at the scarp. The volume of the failure debris was about 45 m³. It was observed by the GEO staff during a post-failure inspection that grouting between the steel bars and the surrounding soil in the soil nails had been poorly constructed. Cracks about 20 mm wide were noted on the paved surface over the slope crest. One hut and one pavilion near the crest were evacuated and the

Chinese Christian Cemetery behind the slope was partially closed as a result of the landslide. The landslide was probably caused by ingress of surface water into the temporary cut slope, thereby resulting in wetting and erosion of the soil, and possible development of seepage pressure. The contributory factors to the failure were considered to include convergent flow and heavy discharge of surface water into the slope, the absence of nail heads, the top row of soil nails being too low below the crest, wide nail spacing, and lack of surface protection to the temporary cut face.

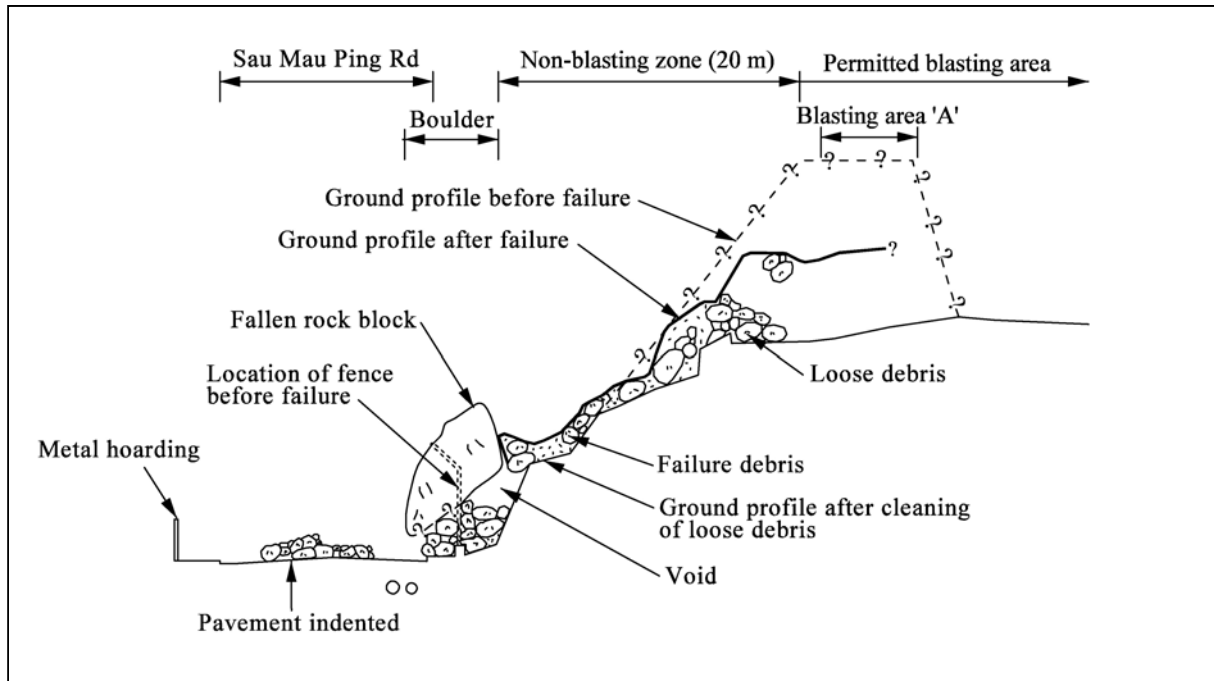
**Case No. 22 - The 4 December 1997 Incident at Sau Mau Ping Road, Kowloon
(Sheet 1 of 2)**

Basic Data

Date of Failure:	4 December 1997	Failure Volume/ Materials	1,000 m ³ of rock
Weather at Date of Failure:	Fine	Type of Failure:	Landslide
Feature Affected:	11NE-D/C7	Consequences:	Closure of Sau Mau Ping Road for 17 days
Type of Work:	Site formation works	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



**Case No. 22 - The 4 December 1997 Incident at Sau Mau Ping Road, Kowloon
(Sheet 2 of 2)**



Description

The failure occurred on a 25 m high rock slope adjacent Sau Mau Ping Road. The rock slope was located at the lower part of slope No. 11NE-D/C7, the top portion of which was being removed under on-going site formation works. The failure happened a few seconds after blasting had taken place behind the crest of the slope. As a normal safety precaution measure, the road section was closed to the traffic and was kept clear of people during blasting. The volume of the failure debris was about 1000 m³ and contained some large angular blocks of rock, the largest being about 150 m³. The debris destroyed a section of the protective fence erected along the toe of the slope and completely blocked Sau Mau Ping Road for a length of 25 m. The metal hoarding on the far side of the road was punched through at several locations. The failure

resulted in the complete closure of Sau Mau Ping Road for 17 days. No casualties were reported.

According to the detailed landslide study by the GEO (GEO Report No. 94), blasting was carried out at a close distance to the crest of the failed slope and the amount of explosives used was found to have exceeded the permitted value. The slope failure was caused by the shock waves and gas pressures generated by the blast which took place close to the crest of the slope.

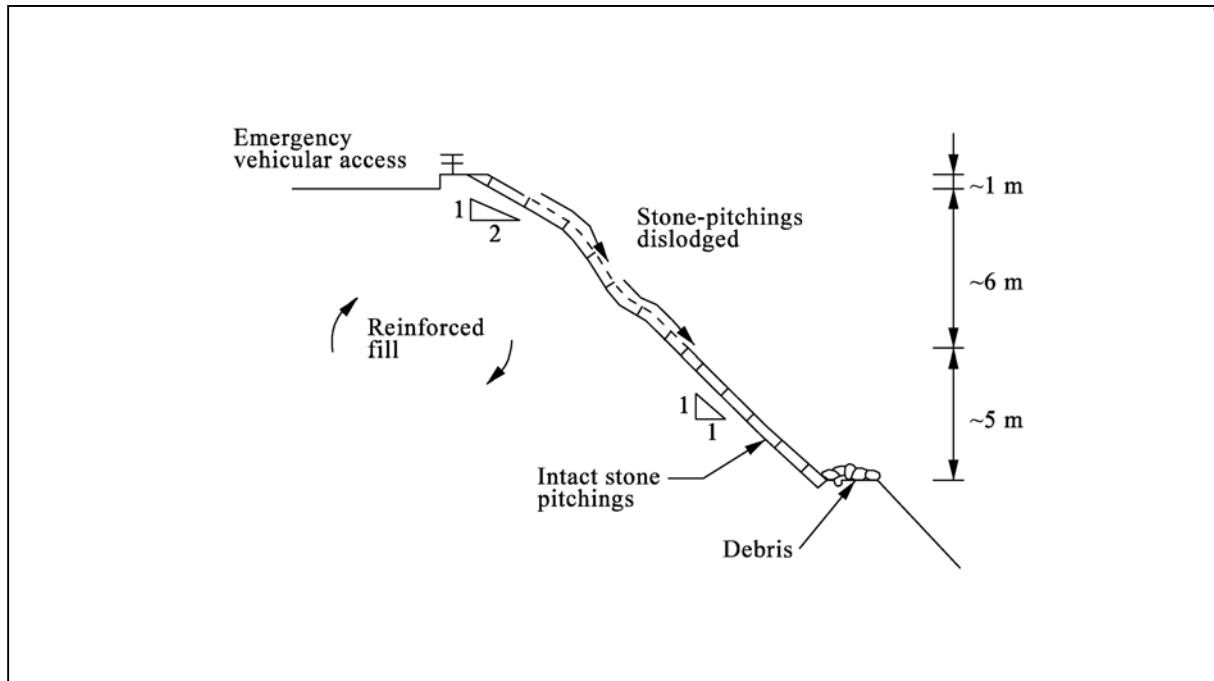
Case No. 23 - The 27 April 1998 Incident at Po Lam Road (Sheet 1 of 2)

Basic Data

Date of Failure:	27 April 1998	Failure Volume/ Materials	26 m ³ of fill and facing blocks
Weather at Date of Failure:	Light rain	Type of Failure:	Landslide
Feature Affected:	Not applicable	Consequences:	Temporary road closure for entire 3 lanes of major road (closed for 3 days)
Type of Work:	Reinforced fill embankment	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



Case No. 23 - The 27 April 1998 Incident at Po Lam Road (Sheet 2 of 2)



Description

The landslide occurred during relatively light rain, on a reinforced fill embankment under construction for a Government site formation project. The embankment was about 12 m in height with a slope angle of 45°, except for the upper about 1 m which was locally inclined at 26° to the horizontal. The surface of the slope was protected with stone facing. The failure involved deformation of soil mass over an area of 7 m by 11.5 m and a tension crack sub-parallel to and about 2 m below the embankment crest. The deformed soil mass, about 20 m³ in volume, remained substantially on the embankment and about 6 m³ of debris slid onto a berm below. A few facing blocks travelled as far as the road at the toe of the slope, resulted in three lanes of the road being closed for three days.

The post-failure investigation concluded that the failure was probably due to poor horizontal positioning or absence of geogrids, which left a zone of unreinforced fill behind the facing blocks. Testing also showed that some of the fill had not been compacted to the required standard. The effects of rain infiltration and poor workmanship of the stone facing construction are also considered contributory factors to the failure. The works were being supervised by full-time resident site staff engaged by the Client Department.

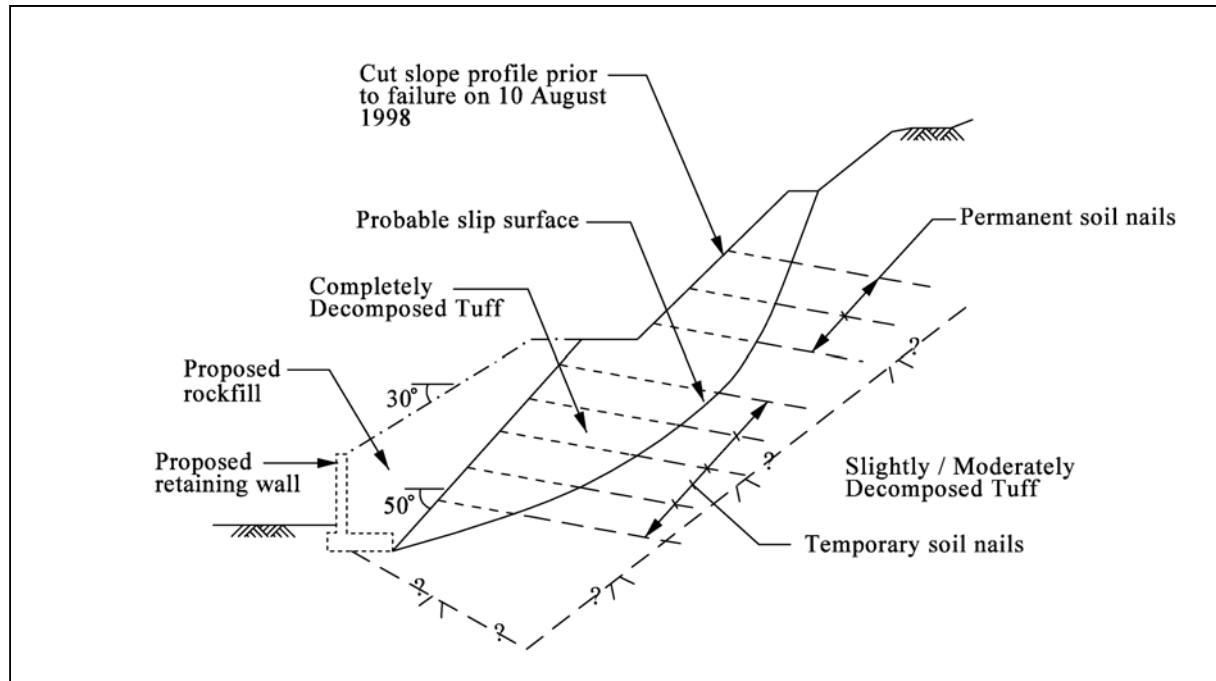
Case No. 24 - The 9 and 10 June 1998 Incidents at Junction of Sai Sha Road and Tai Mong Tsai Road (Sheet 1 of 2)

Basic Data

Date of Failure:	9 and 10 June 1998	Failure Volume/ Materials	900 m ³ of soil (1 st) 1,700 m ³ of soil (2 nd)
Weather at Date of Failure:	Heavy rainfall	Type of Failure:	Landslide
Feature Affected:	8SW-A/C8	Consequences:	Landslide debris deposited within the construction site
Type of Work:	Slope upgrading works	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



Case No. 24 - The 9 and 10 June 1998 Incidents at Junction of Sai Sha Road and Tai Mong Tsai Road (Sheet 2 of 2)



Description

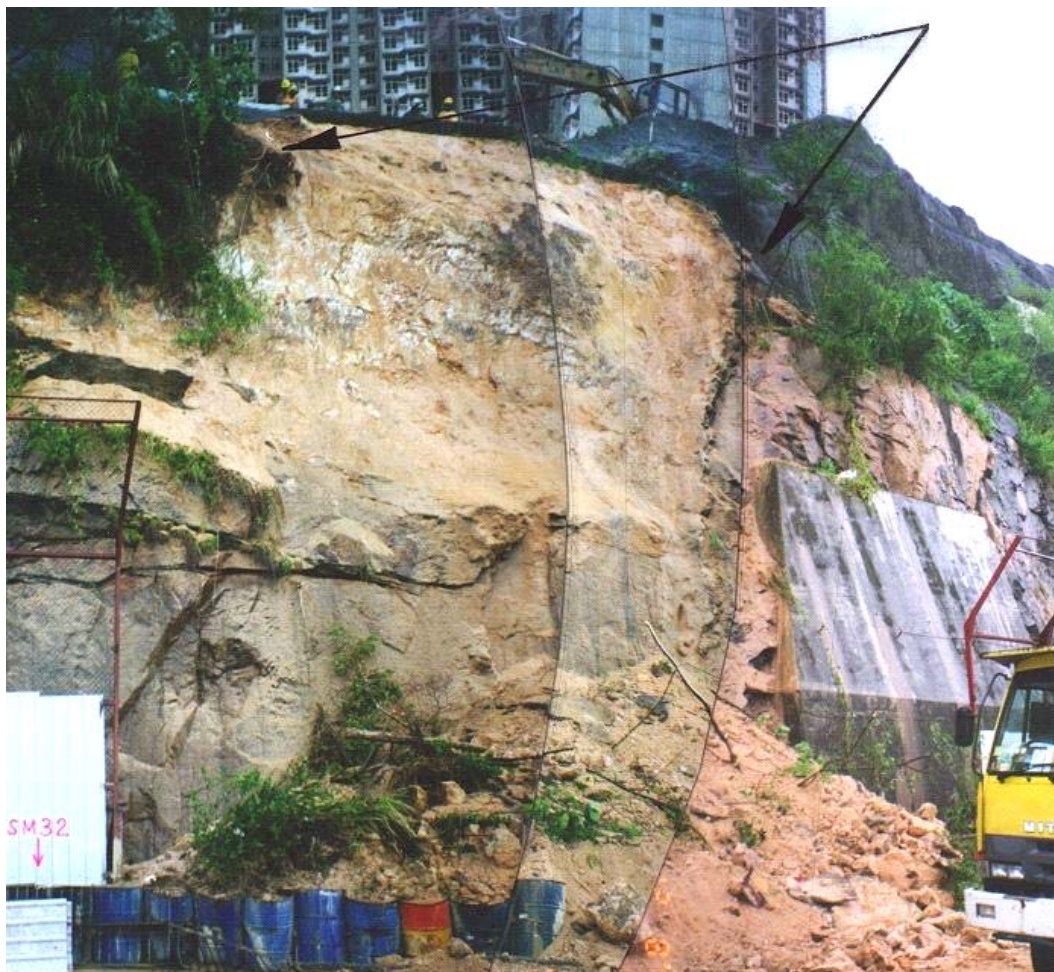
The two landslides occurred consecutively on a soil cut slope where LPM works were in progress, which included the construction of a RC retaining wall at the slope toe with rockfill behind the wall backfilled up to about 2 thirds of the slope height. Permanent soil nails were proposed in the upper third of the slope and temporary soil nails were included in the design to reinforce a 50° temporary cut to provide space for the RC wall construction. Both landslides occurred when the soil nails were being installed during the temporary works stage. No casualties were reported as a result. The landslides were caused by the groundwater conditions much more severe than those assumed in the temporary works design, which relied on the works being carried out during the dry season. The construction was delayed and temporary

slope works had to be carried out during the wet season, hence exposing the temporary slopes to conditions not being envisaged and allowed for in the original design, and such effects also not subsequently being assessed in construction reviews. The absence of some of the nail heads at the time of failure and the nail head detailing incorporating small (150 mm square) steel plates, were probably not effective in providing support to the temporary slopes.

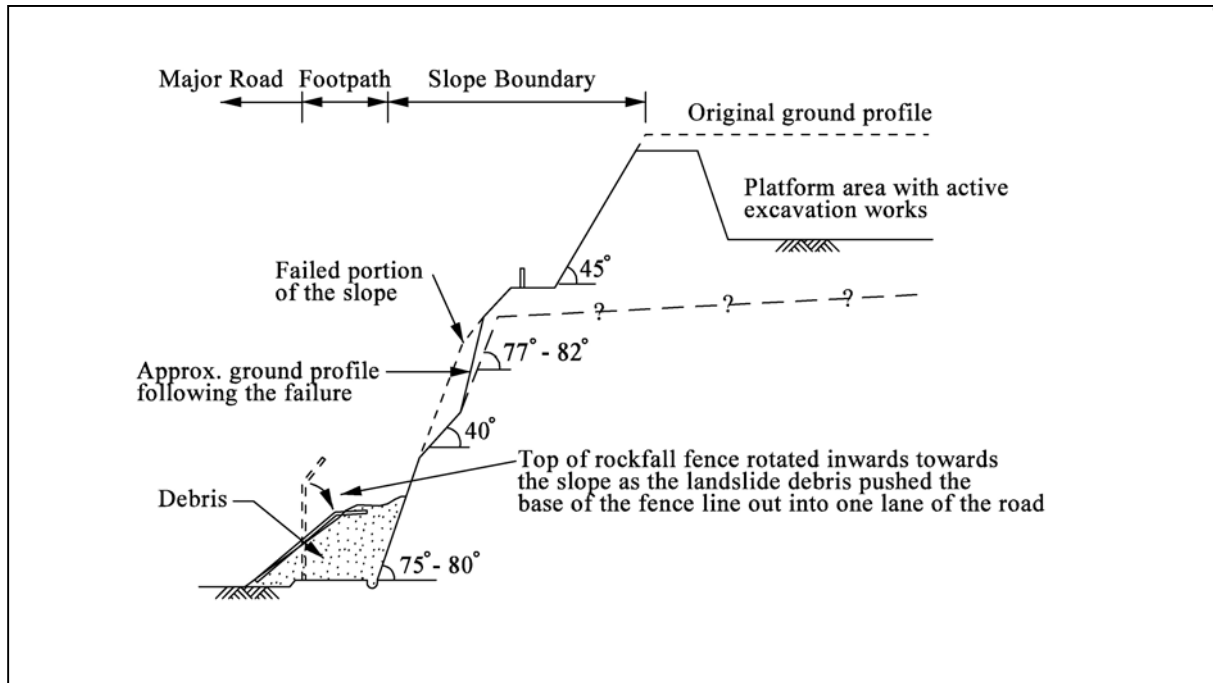
Case No. 25 - The 12 August 1999 Incident at a Private Development Site (Sheet 1 of 2)

Basic Data

Date of Failure:	12 August 1999	Failure Volume/ Materials	25 m ³ of soil/rock debris
Weather at Date of Failure:	Light rainfall	Type of Failure:	Landslide
Feature Affected:	Not applicable	Consequences:	Road closed for about 12 hours
Type of Work:	Excavation works at crest of slope in progress	Type of Supervision:	AP/Geotechnical Consultant's staff
Client:	Private Developer		



Case No. 25 - The 12 August 1999 Incident at a Private Development Site (Sheet 2 of 2)



Description

The landslide involved the failure of a 25 m high slope previously upgraded under the 1988/89 LPM Programme. At the time of the failure, the slope was within an active construction site and excavation works were in progress at the crest of the slope. The landslide resulted in temporary closure of a major road.

protective measures against direct infiltration across the formation being excavated above the slope where the landslide occurred. Intense weathering and clay infilled discontinuities were present locally within the cut slope at the failure location.

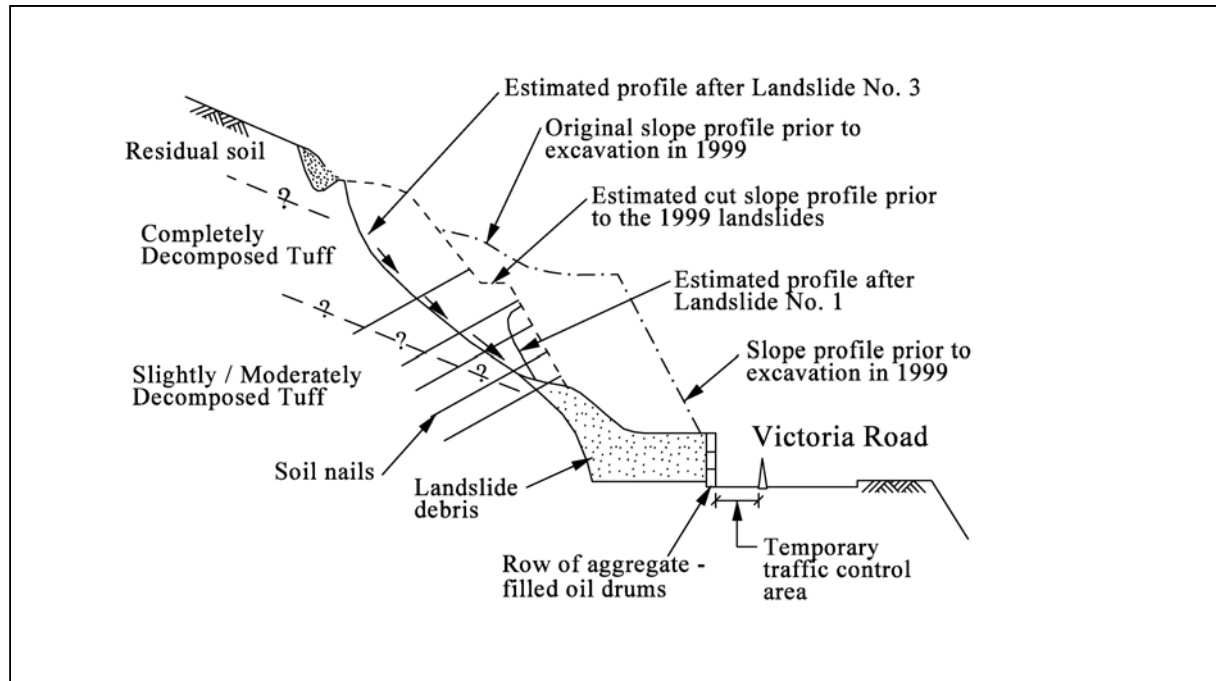
The landslide was triggered by moderate rainfall (estimated maximum return period of less than 2 years). The rainstorm was less severe than other rainstorms experienced at the site in the past. The cause of the landslide is probably related to recent changes in the site setting associated with the active construction site. Observations made shortly after the landslide revealed that there were no proper drainage provisions or precautionary

Case No. 26 - The 23 and 24 August 1999 Incidents at Victoria Road Opposite the Access Road to the Pok Fu Lam Kennels (Sheet 1 of 2)

Basic Data			
Date of Failure:	<i>23 & 24 August 1999</i>	Failure Volume/ Materials	<i>40 m³ of decomposed volcanic rock</i>
Weather at Date of Failure:	<i>Moderate rainfall</i>	Type of Failure:	<i>Landslide</i>
Feature Affected:	<i>Not applicable</i>	Consequences:	<i>Washout debris covered Victoria Road</i>
Type of Work:	<i>Road widening, slope works in progress</i>	Type of Supervision:	<i>Full-time supervision by Resident Site Staff</i>
Client:	<i>Government</i>		



Case No. 26 - The 23 and 24 August 1999 Incidents at Victoria Road Opposite the Access Road to the Pok Fu Lam Kennels (Sheet 2 of 2)



Description

Three landslide incidents occurred at a 10 m high section of a cut slope where slope works were being carried out at the time of failure and soil nails had been installed (but with the nail head lattice structure yet to be constructed). Most of the debris was impeded by aggregate-filled oil drums placed at the slope toe but washout debris covered both lanes of Victoria Road. No casualties were reported as a result of the landslide.

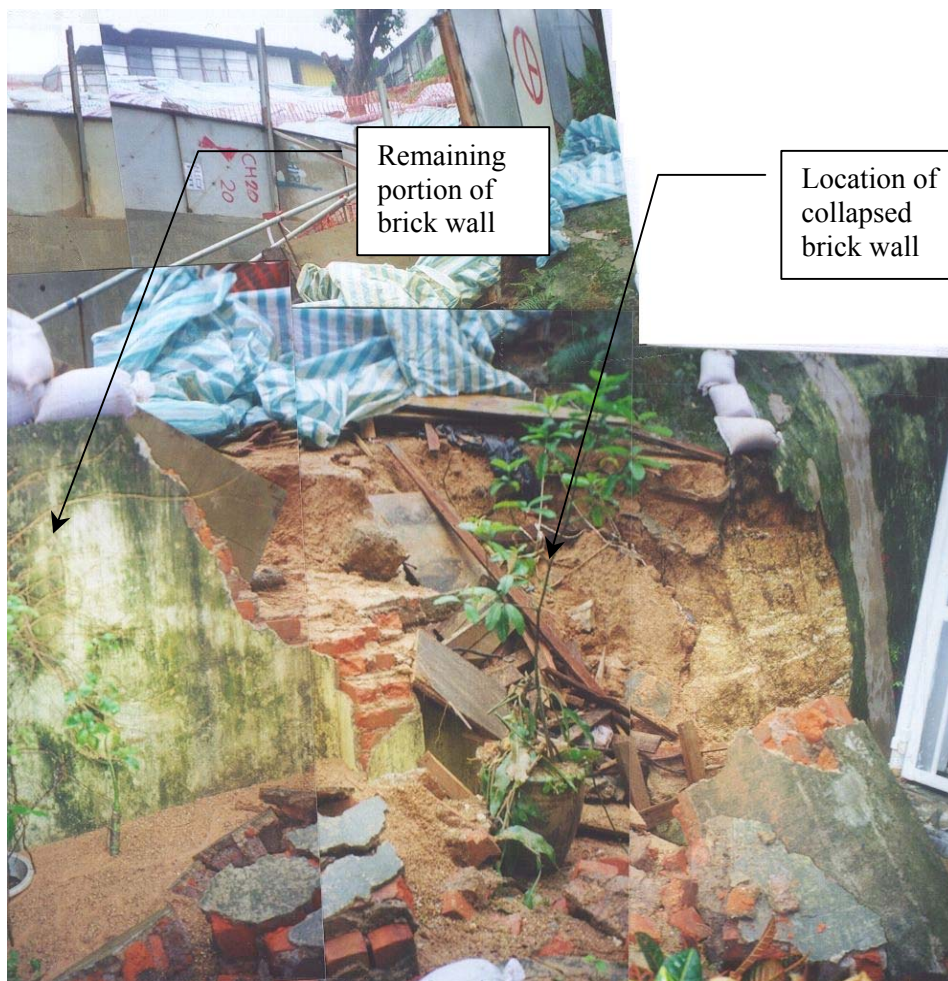
The rainfall that triggered the failures was moderate (estimated maximum return period of about 4 years). Contributory factors to the failures included blockage of surface water drainage provisions, inadequate surface protection against infiltration, and presence of erosion pipes and open joints (exposed in the landslide scar).

There were also adverse geological features (i.e. steep orthogonal relict joints forming the side release surfaces, a shallowly to moderately-inclined relict joint dipping out of the slope face forming the basal surface of rupture and the possible presence of a fault through the cut slope). The absence of structural nail heads at the time of failure would probably have prevented the nailed slope from acting effectively as an integrated mass.

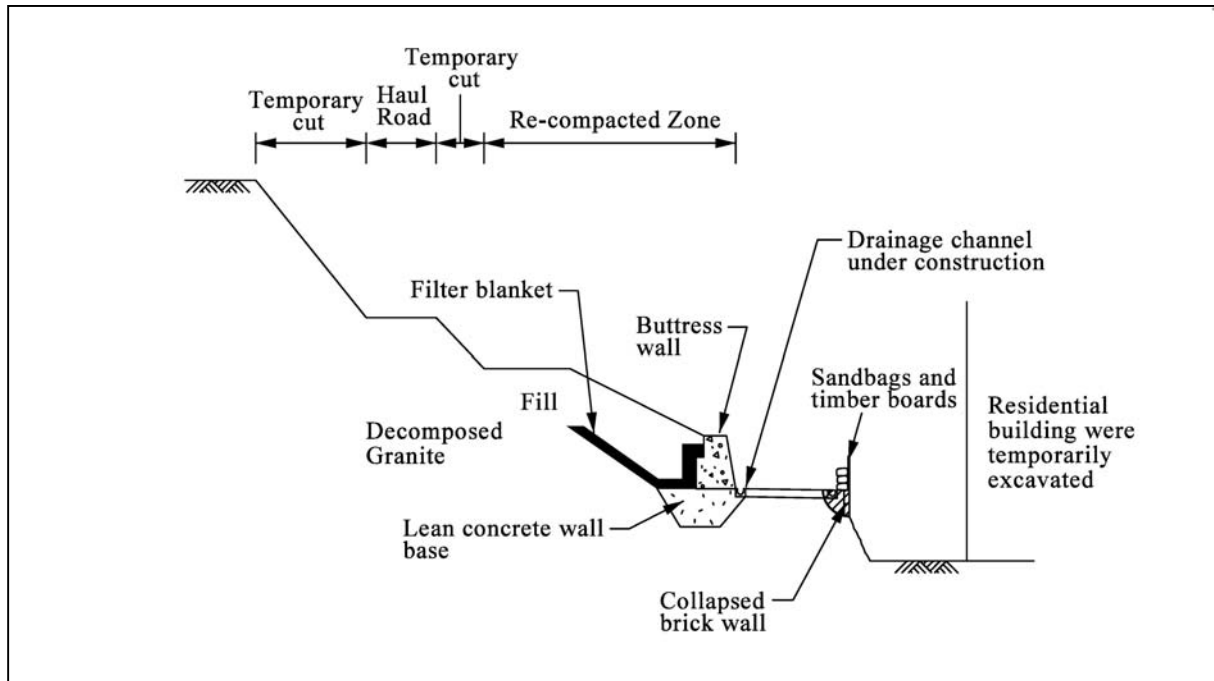
**Case No. 27 - The 3 April 2000 Incident behind No. 279 Prince Edward Road West
(Sheet 1 of 2)**

Basic Data

Date of Failure:	<i>3 April 2000</i>	Failure Volume/ Materials	<i>6 m³ of debris</i>
Weather at Date of Failure:	<i>Fairly heavy rainfall</i>	Type of Failure:	<i>Washout and collapse of brick wall</i>
Feature Affected:	<i>11NW-D/FR183</i>	Consequences:	<i>Residential building temporarily evacuated</i>
Type of Work:	<i>Slope upgrading works</i>	Type of Supervision:	<i>Full-time supervision by Resident Site Staff</i>
Client:	<i>Government</i>		



**Case No. 27 - The 3 April 2000 Incident behind No. 279 Prince Edward Road West
(Sheet 2 of 2)**



Description

The incident occurred at around 8:00 p.m. on 3 April 2000 at an active LPM site and involved the collapse of a 1.5 m high brick wall just outside the site during heavy rainfall. A loose fill slope above the unregistrable brick wall was being upgraded by means of recompaction under the supervision of a consultant to the GEO. No casualties were reported as a result of the incident but all of the 12 units of a residential building below the toe of the fill slope had to be temporarily evacuated.

At the time of the incident, rainwater collected within the construction site flowed down the haul road towards the western end of the site. Temporary drainage was not effective and permanent drainage provisions had not yet been completed. A substantial amount of muddy

water was brought down, bringing with it a large quantity of eroded materials (as evidenced by the gully along the western extremity of the site). This resulted in blockage of the temporary/permanent drainage provisions. Rows of sand bags and timber boards were placed by the contractor on top of the brick wall as barrier following an earlier incident of over-topping of surface water onto the area of residential blocks below. The surface water ponded behind the brick wall and the temporary barrier. As a result, the brick wall collapsed, releasing muddy water (mixed with eroded materials trapped behind the wall), and causing flooding of some of the residential building blocks below. A certain amount of outwash was also deposited at Prince Edward Road West further below.

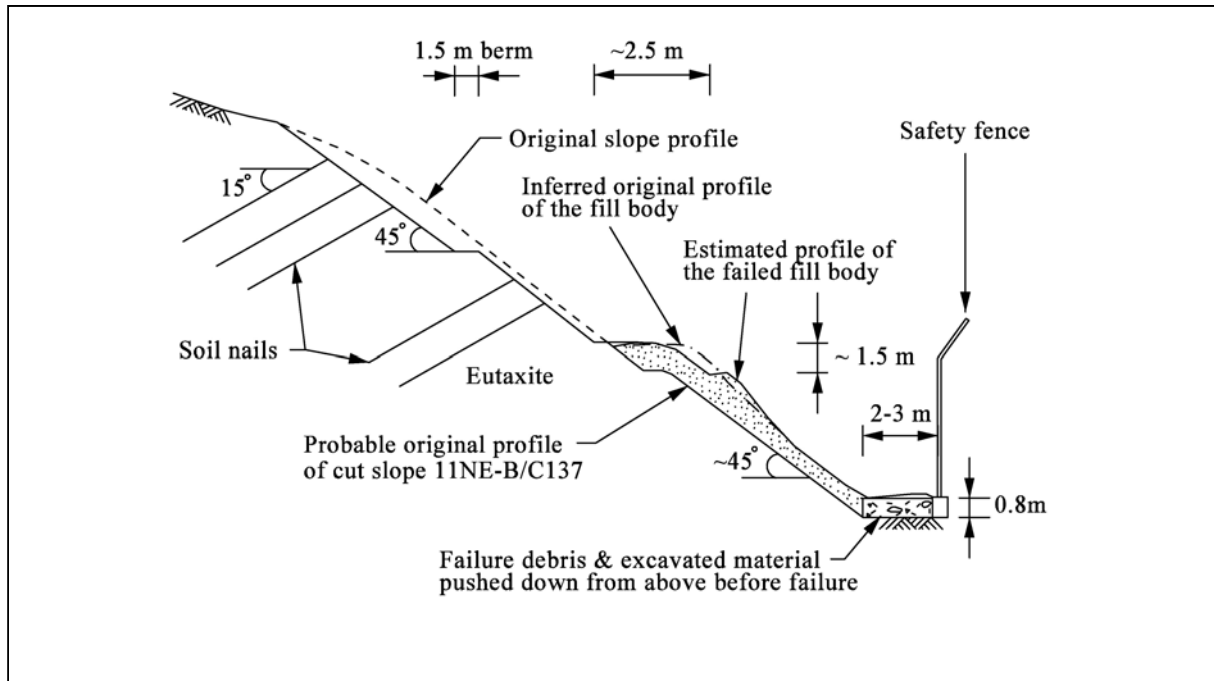
Case No. 28 - The 23 April 2000 Incident at Clear Water Bay Road (Sheet 1 of 2)

Basic Data

Date of Failure:	<i>23 April 2000</i>	Failure Volume/ Materials	<i>50 m³ of fill</i>
Weather at Date of Failure:	<i>Moderate rainfall</i>	Type of Failure:	<i>Washout</i>
Feature Affected:	<i>11NE-B/C137</i>	Consequences:	<i>Temporary road closure</i>
Type of Work:	<i>Road improvement works</i>	Type of Supervision:	<i>Full-time supervision by Resident Site Staff</i>
Client:	<i>Government</i>		



Case No. 28 - The 23 April 2000 Incident at Clear Water Bay Road (Sheet 2 of 2)



Description

The incident involved the failure of a loose fill body perching on a cut slope, which was being upgraded under a road improvement project. The failure debris was all contained within the boundary of the active construction site. No casualties were reported as a result of the incident.

The loose fill body involved in the failure was formed by end-tipping of materials over the cut slope in providing a platform for drilling of the proposed soil nails. Also, materials excavated from the upper slope were pushed over the haul road onto the lower slope and trucked away at the slope toe. There were no temporary or permanent drainage provisions at the time of the incident. The fill body slumped and partly slipped during the incident.

Case No. 29 - The 12 June 2000 Incident at Ching Hong Road, Tsing Yi (Sheet 1 of 2)

Basic Data

Date of Failure:	12 June 2000	Failure Volume:/ Materials	35 m ³ of soil
Weather at Date of Failure:	Black rainstorm warning	Type of Failure:	Washout
Feature Affected:	10NE-B/C2	Consequences:	Washout debris covered the public road, no road closure
Type of Work:	Slope upgrading works	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



Case No. 29 - The 12 June 2000 Incident at Ching Hong Road, Tsing Yi (Sheet 2 of 2)

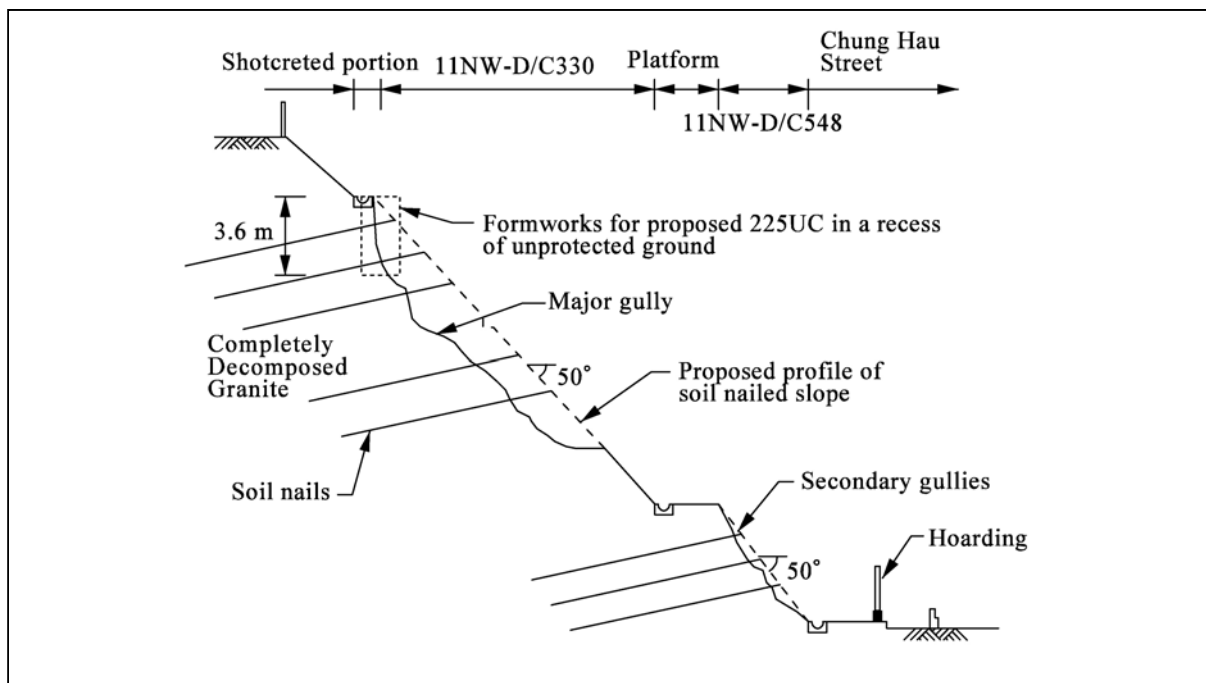
**Case No. 30 - The 12 June 2000 Incident at Chung Hau Street, Ho Man Tin
(Sheet 1 of 2)**

Basic Data

Date of Failure:	12 June 2000	Failure Volume/ Materials	30 m ³ of fill
Weather at Date of Failure:	Moderate rainfall	Type of Failure:	Washout
Feature Affected:	11NW-D/C330 and C548	Consequences:	Debris deposited within the site boundary
Type of Work:	Slope upgrading works	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



**Case No. 30 - The 12 June 2000 Incident at Chung Hau Street, Ho Man Tin
(Sheet 2 of 2)**



Description

The incident involved a washout failure on a cut slope during rainfall, which was being upgraded under the LPM Programme. Majority of the washout debris remained within the boundary of the active construction site. No casualties were reported as a result of the incident.

Located above the cut slope was a WSD service reservoir, around which was a perimeter drain. Part of the surface water collected by this perimeter drain was designed to discharge off site via a system of permanent drains on the cut slope. At the time of the washout failure, part of the permanent drains on the cut slope was being replaced. The original concrete channels had been demolished leaving unlined trenches. At the time of the incident surface water from the perimeter

drain in the WSD compound discharged off site into the incomplete drainage system on the slope, and this resulted in the washout failure.

A similar washout failure, but less severe, occurred at the same location about 2 months before the incident, indicating that the drainage provisions had been inadequate for some time.

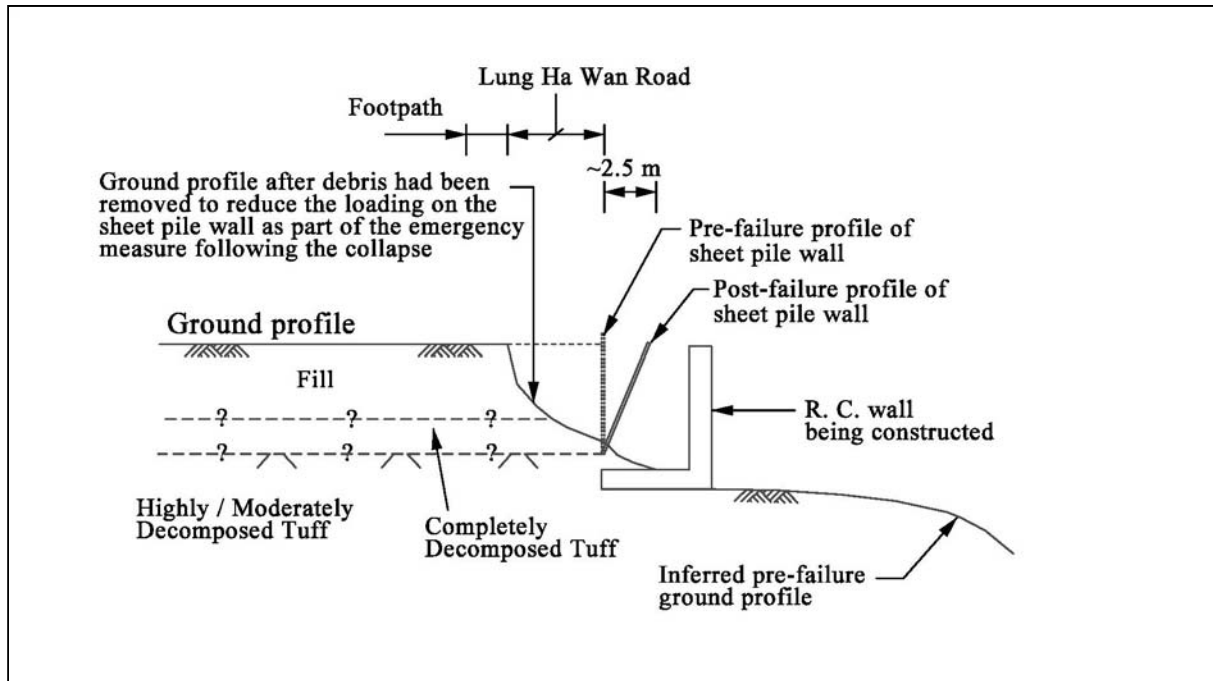
Case No. 31 - The 24 August 2000 Incident Below Lung Ha Wan Road (Sheet 1 of 2)

Basic Data

Date of Failure:	24 August 2000	Failure Volume/ Materials	200 m ³ of fill
Weather at Date of Failure:	Heavy rainfall	Type of Failure:	Sheet pile failure
Feature Affected:	Not applicable	Consequences:	Temporary road closed for two days
Type of Work:	Road widening, sheeting in progress	Type of Supervision:	Full-time supervision by Resident Site Staff
Client:	Government		



Case No. 31 - The 24 August 2000 Incident Below Lung Ha Wan Road (Sheet 2 of 2)



Description

The incident occurred during heavy rainfall on a road improvement works site. A section of a 55 m long temporary sheet pile wall collapsed resulting in the closure of Lung Ha Wan Road for two days. No casualties were reported as a result of the incident. The sheet pile wall was being constructed to provide temporary support to Lung Ha Wan Road during the construction of a new reinforced concrete retaining wall to widen the road.

The failure of the wall was probably due to the build-up of groundwater pressure behind the wall and inadequate lateral support provided to the wall. Build up of groundwater pressure was considered likely to have been associated with the driving of the sheet pile wall through, and blockage of, a reinforced concrete culvert

that provides drainage from a natural drainage line.

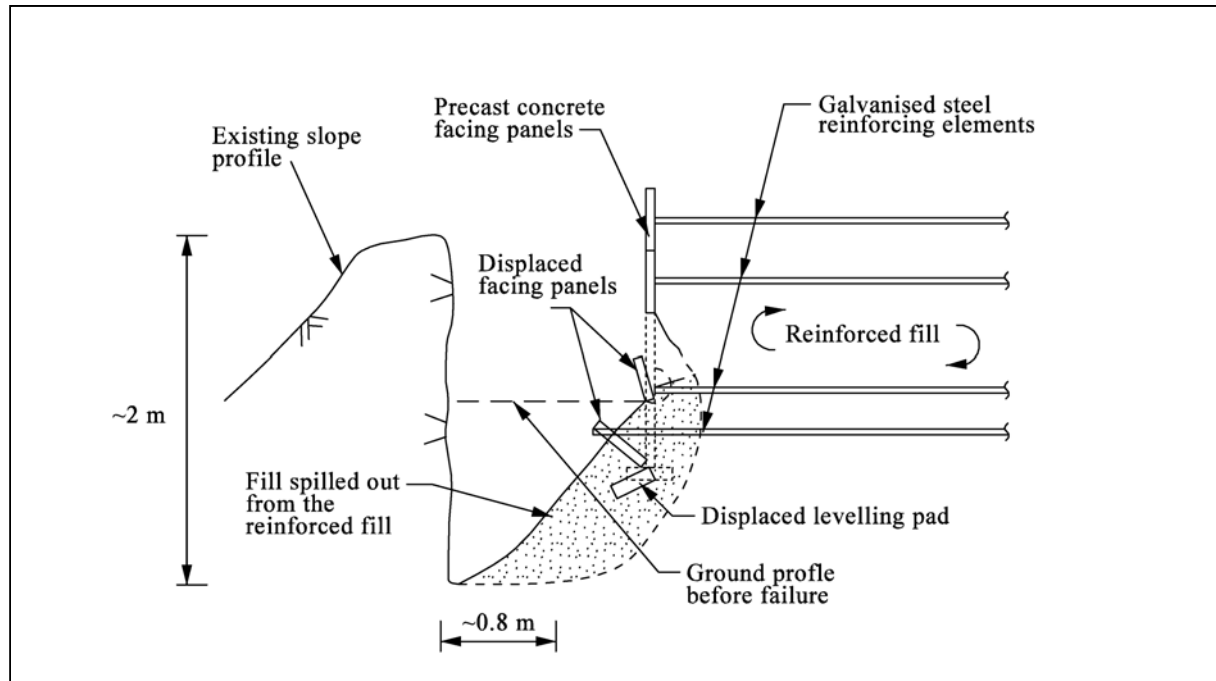
The temporary sheet pile wall system was designed by the contractor and was certified by an Independent Checking Engineer. The design was also accepted by the Engineer. However, the construction of the sheet pile wall did not conform to the approved design drawings. The Resident Site Staff had previously observed the non-conformities of the shoring system for the wall and repeatedly warned the contractor over the 6-month period preceding the failure. No action was taken by the contractor and the works proceeded despite the non-conformities.

**Case No. 32 - The 9 April 2001 Incident at Tsing Yi Northern Coast Road Site above
Tam Kon Shan Road (Sheet 1 of 2)**

Basic Data			
Date of Failure:	9 April 2001	Failure Volume/ Materials	35 m ³ of fill
Weather at Date of Failure:	Heavy rainfall (Amber Rainstorm)	Type of Failure:	Washout
Feature Affected:	Reinforced fill wall failure	Consequences:	Temporary Tam Kon Shan Road closure and a large section of the reinforced fill wall was reconstructed
Type of Work:	Reinforced fill wall for road construction		
Client:	Government	Type of Supervision:	Full-time supervision by Resident Site Staff



Case No. 32 - The 9 April 2001 Incident at Tsing Yi Northern Coast Road Site above Tam Kok Shan Road (Sheet 2 of 2)



Description

The incident occurred during heavy rainfall during construction of a reinforced fill wall which was part of the works for a road construction project. The reinforced fill wall was being constructed to support a link road to connect the proposed carriageway of Tsing Yi Northern Coast Road to Tam Kon Shan Road. The foundation of the reinforced fill wall was undermined by concentrated surface runoff resulting in significant distress and movement of the wall. Out wash material was deposited on Tam Kok Shan Road and the road was closed for two hours.

Surface runoff from the cut slopes and natural hillside (with a catchment of about 10,000 m²) uphill of the reinforced fill wall flowed towards a temporary excavation and into a trench in front of the wall. The

surface runoff flow eroded part of the compacted fill behind the wall as well as the ground material beneath the wall foundation. The failure of the wall was probably due to lack of an adequate system of temporary drainage.

Despite requests from the Engineer to implement precautionary measures against heavy rainfall, no action was taken by the contractor.

GEO PUBLICATIONS AND ORDERING INFORMATION

土力工程處刊物及訂購資料

A selected list of major GEO publications is given in the next page. An up-to-date full list of GEO publications can be found at the CEDD Website <http://www.cedd.gov.hk> on the Internet under "Publications". Abstracts for the documents can also be found at the same website. Technical Guidance Notes are published on the CEDD Website from time to time to provide updates to GEO publications prior to their next revision.

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Information Services Department,
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- Calling the Publications Sales Section of Information Services Department (ISD) at (852) 2537 1910
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1:100 000, 1:20 000 and 1:5 000 maps can be purchased from:

Map Publications Centre/HK,
Survey & Mapping Office, Lands Department,
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土力工程處之主要刊物

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 300 p. (English Version), (Reprinted, 2000).

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

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TECHNICAL GUIDANCE NOTES

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