REPORT ON THE SHUM WAN ROAD LANDSLIDE OF 13 AUGUST 1995

Volume 1

INDEPENDENT REVIEW OF THE INVESTIGATION BY THE GEOTECHNICAL ENGINEERING OFFICE

Sir John Knill
Berkshire, the United Kingdom

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First published, April 1996
Reprinted, May 1996

This Report is presented in two volumes. Volume 1 contains the independent findings of Sir John Knill on the Shum Wan Road landslide of August 1995 and the lessons to be learnt from it. Volume 2, prepared by the Geotechnical Engineering Office of the Civil Engineering Department, presents the detailed findings of the landslide investigation. The contents of Volume 2 have been reviewed and agreed by Sir John Knill who relies on them in his own assessment given in Volume 1.

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1. INTRODUCTION

Intense rainfall occurred in Hong Kong on 12 and 13 August 1995 in the wake of Typhoon Helen; there were reports of over 120 landslides. One of these landslides, at Shum Wan Road adjacent to Aberdeen Harbour, severely damaged three shipyards and a factory on the sea front; a fire subsequently occurred in the collapsed structures. There were two fatalities and five other people were injured.

The Geotechnical Engineering Office (GEO) of the Civil Engineering Department commenced an investigation of the landslide on the morning of 13 August 1995. The results of this investigation are reported in (GEO, 1996).

It was decided to have an independent review of the GEO investigation, which the writer was invited to carry out, reporting to the Government of Hong Kong. Three visits were made for this purpose over the periods 5-8 September, 31 October-3 November and 27 November-1 December 1995. During these visits the site was inspected twice, and discussions were held with GEO regarding the investigation programme and the results achieved. An advanced draft of the GEO report was reviewed directly with the GEO.

2. DESCRIPTION OF LANDSLIDE

The original hillside between Shum Wan Road and Nam Long Shan Road, some 70 m above, sloped at about 27° and was covered in dense vegetation. The slope failed at about 0400 on 13 August 1995, subsequently carrying away Nam Long Shan Road. The slide debris, which flowed across Shum Wan Road for a distance of about 70 m from the toe of the slope, damaged and then forced the buildings adjacent to Aberdeen Harbour into the sea.

The slide scar is about 140 m in plan length and varies from about 60 m in width at the level of Nam Long Shan Road to 90 m in width near the base of the slope. The form of the backscar, which is on the uphill side of the original location of Nam Long Shan Road, is defined by steep joints in the volcanic rocks. The ground falls away immediately below the backscar into a deep depression in the hillside which is concave in section (the "concave scar"). There were some exposures of partially weathered tuffs and a clay seam within the floor and sides of the depression although these had been mainly obscured soon after the failure by debris falling from the backscar. On the downhill side of the concave scar there was a pile of debris which included the bitumen surface of Nam Long Shan road surface and two lorries which had been parked in a passing bay on the outer side of the road. This parking bay, which had been constructed on fill, was about 5 m wide and immediately downhill from the road there had been three small retaining walls.

Farther downhill, the scar was composed of a sheet of slipped debris and fill resting on top of the original ground surface (the "planar scar").

A rock cliff is present at the toe of the slope and this was overridden by the slide debris. However, much of the debris at the slope toe itself and covering Shum Wan Road was composed of soft fluvial material washed down from the slope after the main failure had taken place and ponded between the cut and a mass of slide debris burying the site of the shipyards. Three prominent erosional channels were eroded through the slipped material

resting on the slope into the underlying formations. The sheet of slide debris on the reclaimed land occupied by the shipyards overlay, in part, organic material which had been stripped from the original slope surface and trapped below the debris.

The failure was progressive and was observed by an eye witness to be developing at about 0400 on 13 August. The main landslide occurred a few minutes later and Nam Long Shan Road failed at about 0430. Fluid debris was observed to be washed down by surface water after these failures.

The landslide involved about 26,000 m^3 of soil and rock debris. After the Po Shan Road landslide of 1972 this is the largest rapid onset slope failure within a hillside that has been affected by human activities recorded in Hong Kong.

3. REVIEW OF GEOTECHNICAL ENGINEERING OFFICE REPORT

The GEO report will now be reviewed on a section-by-section basis.

"1. Introduction

The introduction to the report provides the setting to the landslide event and outlines the main components of the investigation carried out. The method and scale of the investigation was wholly appropriate to the nature of the landslide.

2. The Landslide Site

This section describes the essential features of the form of the site prior to the landslide. Attention is drawn to the drainage measures, and sewer and water services, associated with Nam Long Shan Road.

3. History of the Site

A factual account of the history of the site is provided, as based primarily on the study of maps and air photographs. Attention is drawn to the limited information available on the construction of the retaining walls and passing bay next to Nam Long Shan Road, and reference is made to past squatter activities on the slope (cleared in 1988) and two small landslides which occurred in 1983.

The area was studied as a part of the GEO Geotechnical Area Studies Programme (GCO, 1987). The area of the Shum Wan Road landslide is specifically delimited as a "Zone of general instability associated with predominantly colluvial

terrain" on the Physical Constraints map in (GCO, 1987). A new aerial photographic interpretation of the development of the site has been carried out, drawing attention to the presence of relict landslide scars on the slope together with associated mass-wasting deposits. Whereas the more recent landslides on the slope had been small, the overall morphology of the slope was that of a degraded landslide complex associated with past slope movements.

4. Analysis of Rainfall Record

There are two rain gauges near the site, H20 some 1.8 km west of the site and H05 some 2 km north-west of the site; these gauges were installed in 1983 and 1979 respectively. The records from these gauges were used to evaluate the intense rainfall to which the slope was subjected in relation to previous events.

The rainfall in Hong Kong in August 1995 was the highest ever recorded for the month of August, the rainfall being particularly heavy in the early part of the month. The rainfall recorded at H05 was the highest 31-day rainfall recorded and the rainfall intensities for periods shorter than 12 hours were comparable to the highest intensities recorded in previous events.

5. Description of the Landslide

5.1 Field Observations and Measurements

The description of the landslide covers the geometrical form of the landslide, the nature and distribution of the different types of debris and the progressive nature of the failure.

Most of the slope is covered by colluvial and decomposed rock debris. There was a considerable amount of fill, construction materials and general rubbish. Much of the fill, presumably derived from the passing bay to Nam Long Shan Road, together with the fragments of the retaining walls, occurs mainly in the lower half of the slope. The original surface of Nam Long Shan Road could be identified together with the two vehicles which had been parked on the passing bay. Disintegration of the rock faces which formed the backscar created bouldery screes at the very top of the landslide which were contained within the concave scar.

An important, and indeed unexpected observation, was

the recognition that the debris which crossed Shum Wan Road onto the reclaimed land was a relatively intact "slab" of rock about 2 to 3 m in thickness. This "slab" consisted of partially weathered tuff with local infilling of joints by kaolinitic clay. Careful mapping of the "slab" revealed that there was continuity in the geological structures within the rock of the "slab" indicating that it moved from the hillside to the waterfront in essentially one piece. The surface of the "slab" was covered with rafts of vegetation identical to that formerly growing on the lower part of the hillside.

Reference is also made to the dislocation of the sewer and water pipes, and the observation of discharges from both pipes after the failure.

5.2 Witness Accounts

Somewhat unusually for a landslide failure at night, a detailed account of the sequence of events was obtained from eye-witnesses which has proved of considerable corroborative value in reconstructing the likely mode and sequence of failure.

6. Subsurface Conditions at the Site

6.2 Geology

The geological conditions have been investigated by means of mapping of the landslide area, trenches, trial pits, GEO probe tests, boreholes and a seismic reflection survey.

The landslide took place in volcanic rocks grading from completely to slightly decomposed tuff; the depth of weathering is somewhat greater at the top of the landslide. There was a thin cover of colluvium which was carried down by the landslide and does not appear to have contributed to the origin of the failure. Thermoluminescence tests on quartz particles suggests that this colluvium is of the order of 40,000 years old. There are uncertainties associated with the validity of such tests but calibration of the testing method against another site in Hong Kong, where C-14 dates are available, suggests that the thermoluminescence data for the Shum Wan Road landslide may be reliable.

The volcanic fabric in the tuffs dips mainly north-east, the strike being normal to the hillside. Within the landslide the dips are steep (70° to 90°), but outside the limits of the landslide the dips are more gentle (10° to 40°). There are a

number of joint sets and the sub-vertical joints become closely spaced within a 6 m zone striking north-west within the concave scar.

A planar layer of white kaolinitic clay, overlain by a buff, slightly laminated clay layer occurs within the floor of the concave scar. This thin clay seam dips downhill and is slickensided in a downslope direction.

6.3 Material Properties

A comprehensive series of classification and strength tests was carried out; in situ density and permeability tests were also completed. Some of the liquid limit values for the clay seam were unusually high, indicating an activity of about unity whereas kaolinite would normally give a value of about 0.4. X-Ray diffraction studies of the white and buff clays confirmed that their mineralogy was similar and both contained kaolinite with probably some halloysite; the presence of the halloysite could explain the relatively high activity values.

For the partially weathered tuff the shear strength parameters were determined to be $\phi' = 38°$ and $c' = 5$ kPa which is comparable to the range for similar material at other sites.

For the kaolinitic clay the peak shear strength parameters were determined to be $\phi' = 26°$ and $c' = 8$ kPa, and the strength parameters of the clay with slickensliding (probably close to the residual strength) were determined to be $\phi' = 21°$ and with zero apparent cohesion.

In situ permeability tests on the partially weathered tuff demonstrated that the tuff, where the jointing was very closely spaced, was relatively permeable.

The fill which formed the passing bay was completely removed by the landslide and its original in situ condition cannot be determined. Fill from an adjacent area, outside the limits of the landslide, was in a loose to very loose condition; such materials would be expected to be relatively permeable.

6.4 Groundwater Condition

Seepage was observed from a number of locations in the landslide. At about mid-height of the slope the seepages correspond to a base groundwater level of about 1 to 3 m below

the original pre-failure ground surface.

The regional groundwater level, in rock, is about 5 m below the base of the concave scar in the upper part of the landslide. Seepages above clay seams persisted for about a week after the landslide and recurred following rainfall, indicating the presence of perched water table conditions.

7. Condition of Drainage and Water-carrying Services at Nam Long Shan Road

Catchpits and drains were observed to be partially blocked after the landslide. During heavy rain on 14 August 1995 the surface of Nam Long Shan Road was observed to be carrying about 350 litres per second which discharged onto the top of the landslide. Comparison with the rainfall intensity on 13 August suggests that Nam Long Shan Road may have been carrying about 470 litres per second at the time of the landslide.

A closed-circuit survey of the existing sewer pipe indicated the presence of cracking and open joints. In situ inspection of an intact section of pipe indicated that only minor leakage was likely. The fresh water main was formed by threaded pipes and no evidence of leakage was observed.

8. Likely Mode and Sequence of Failure

This section integrates the information available from different sources to provide a coherent, consistent account of the landsliding process.

The main landslide was in weathered rock and was in two parts which probably moved together until the final stages of failure. However, it is probable that the failure was initiated by a small landslide in the fill, presumed to be in a loose state, underlying the passing bay. The small slip spread fill, together with fragments of the retaining walls, over the surface of the lower part of the landslide demonstrating that this debris was dislodged and carried well down the slope early in the failure sequence. The distribution of the fill and the retaining wall fragments would suggest that the failure was in the form of a rapid debris flow such as can originate from loose fill slopes. This slip would then have enabled water flowing down Nam Long Shan Road to also discharge directly onto the upper part of the slope.

The upper part of the main landslide mass took place as

a rotational (spoon-shaped) slip and this was in contact with the lower part which was a translational (planar) slip. The landslide initially moved relatively slowly. On the commencement of more rapid movement, the lower, translational, failure detached itself as the "slab", travelled down the slope, crossed Shum Wan Road and demolished the structures adjacent to Aberdeen Harbour. The upper part of the landslide mass remained on the slope. Large volumes of water continued to be discharged onto the top of the slope causing rapid erosion and washing of soft debris onto Shum Wan Road which collected between the rock cut and the eastern side of the "slab". Subsequently the remnants of Nam Long Shan Road collapsed on top of the slide mass followed by rock falls from the backscar.

9. Theoretical Stability and Seepage Analyses

9.1 General

Stability analyses of the two components of the landslide have been carried out.

9.2 Upper Part of Hillside

Stability analysis demonstrates that the upper part of the landslide would be stable under the normal regional groundwater conditions. Failure, however, could occur on the clay seam if perched water table conditions gave rise to water heads ranging from 1 to 5 m depending on whether the strength of the slickensided clay or the peak shear strength is adopted. A rapid rise in the perched water table, and the consequential heads, could have been induced by direct access of the water flowing down Nam Long Shan Road into the top of the landslide after the initial fill slope failure. It is unlikely that direct infiltration of rainfall into the ground, and improbable that any minor leakage from the sewer pipe, could have created the perched water table condition.

9.3 Lower Part of Hillside

In the lower part of the slope the base groundwater surface was close to the ground surface and the analysis demonstrates that the slope would theoretically be unstable under a range of groundwater conditions, and dependent on the proportion of clay-infilled joints within the sliding surface. This conclusion is consistent with the observation that the slope has been subject to movement in the geological past; major

instability has probably not occurred for hundreds and possibly thousands of years.

10. Diagnosis of the Causes of the Landslide

This section provides a comprehensive overview of the slope failure process as derived from the investigations. The writer is in agreement with this analysis.

The Shum Wan Road landslide was caused by the effect of elevated groundwater conditions, following an exceptionally wet period of days and during an intense rainstorm, on a slope which had moved previously in the geological (rather than historical) past. The landslide was initiated by a small fill failure at the top of the slope which then permitted the discharge of water from Nam Long Shan Road directly onto the slope. Rapid infiltration into the rock mass generated a local perched water table on a clay seam which rapidly reduced the stability of the upper part of the slope. The lower part of the slope was itself at marginal stability, being partially founded on clay-filled joints in rock, and this was made more severe by the enhanced groundwater conditions associated with the heavy antecedent and then-current rainfall. The lower part of the slope could provide no effective toe support to the upper part. Progressive movements then accelerated to carry away the lower part of the failure, in the form of a intact slab of altered rock across Shum Wan Road to demolish the structures on the reclaimed ground.

11. Other Conceivable Factors

This section reviews a number of factors which may have had an influence on the site condition such as previous squatter activities, illegal dumping and heavy vehicular traffic. The writer agrees that these factors can be regarded, in relative terms, as having an insignificant influence on the Shum Wan Road landslide.

12. Conclusions

The conclusions are a summary of the main contributory factors to the landslide with which the writer is in agreement."

4. CONCLUSIONS ON GEOTECHNICAL ENGINEERING OFFICE REPORT

The investigation carried out by the Geotechnical Engineering Office into the Shum

Wan Road landslide has been comprehensive, having been executed in a professional manner. The Report accurately reports the conclusions of the investigation, and reaches a logical conclusion as to the contributory factors to, and causes of, the landslide. The writer is in agreement with the report on all essential matters.

5. LESSONS TO BE LEARNT

The Shum Wan Road landslide has not identified any new features not previously recognised in geological or landslide prevention practice within Hong Kong. However, there are features relevant to the cause of the landslide which deserve to be highlighted.

5.1 Structural and Mineralogical Controls on Landsliding in Volcanic Rocks

The Shum Wan Road landslide was controlled by structures within the volcanic bedrock which were not bedding-related, and not obviously related to local joint and fault patterns. The presence of kaolinitic clay seams and clay-filled joints at shallow depth within the rock mass was a major contributory factor both to the relatively low shear strength as well as to controls on shallow groundwater flow.

5.2 Discharge of Water along Roads at Head of Potentially Unstable Slopes

The discharge of water into the top of a slope can be an important factor in triggering a landslide. Continued discharge into a slope following a failure will weaken and soften materials within a slope and can prolong the downhill movement of debris. There should be awareness as to the role of roads in acting as catchments for collecting and channelling water into the upper part of slopes.

5.3 Natural Slope Failures

The Shum Wan Road landslide was not a natural failure as it was caused by human influences. However, the landslide occurred in a slope which had moved in the past as identified by the GASP studies (GCO, 1987) and confirmed by more recent aerial photographic studies. In the assessment of the stability of a slope the possible role of natural processes should be taken into account.

6. REFERENCES

GEO (1996) Report on the Shum Wan Road Landslide of 13 August 1995. Volume 2: Findings of the Landslide Investigation. Geotechnical Engineering Office, Hong Kong, 51p.

GCO (1987) Geotechnical Area Studies Programme - Hong Kong and Kowloon (GASP Report 1), Geotechnical Control Office, Hong Kong, 170p, plus 4 maps.