

The Delayed Failure of a Large Cutting in Hong Kong

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SYNOPSIS A large cutting in decomposed granite failed after five days of dry weather following an extremely intense rainstorm in August 1982. The history of the slope and surrounding area is described and three theories that might explain the delayed nature of the failure are proposed.

INTRODUCTION

On 24th August 1982, a section of slope cut at 55° in weathered granite on Ching Cheung Road in Northwest Kowloon failed (see Figure 1). The landslide was unusual for Hong Kong in that it occurred on a dry day, 5 days after an intense rainstorm and in a noticeably 'dry' manner. Furthermore, two well-documented large, catastrophic failures occurred in nearby slopes in 1972 and similarly in an atypically dry, granular manner after up to 10 days without rain.

Three hypotheses were proposed to explain the delayed nature of the 1982 failure, viz :-

- (i) The initial failure occurred during the main rain storm, and was only noticed when it finally collapsed. This is considered unlikely on this busy stretch of road.
- (ii) The failure was due to a delayed rise in groundwater.

- (iii) There was a delayed loss of material strength due perhaps to volume changes causing loss of mineral bonding during drying-out.

INVESTIGATION

Aerial Photographs

Aerial photographs are particularly useful in this case and three are presented as Figures 2, 3 and 4. In 1949, the area comprised scrub-covered hills of decomposed granite exhibiting severe erosion, e.g. the major gully just north of the 1982 failure location. Uncontrolled borrowing operations were causing severe slope problems and in one case, a major tension scar is evident at the head of a discrete landslide.

By 1963 buildings had been constructed at the foot of the landslide which surprisingly had not moved further.

The remedial works to the failures of 1972 can be seen clearly in Figure 4. The locations coincide with the previous distress and the minor scar may have involved reactivation of the pre-1949 landslide. There are no signs of distress at the location of the 1982 failure however.

Engineering Geology

Exposed areas of slip scar were examined and described as illustrated in Figure 5, using the methods outlined by Hencher & Martin (1982). The failure occurred in highly decomposed granite (grade IV) with rare corestones of stronger granite. The granite is coarse-grained and is extremely friable due to extensive microfracturing which predates the failure (as shown by examination of resin-impregnated thin sections). The granite is intruded by a series of irregular but persistent dolerite dykes, decomposed to a relatively impermeable silt and their possible role is discussed below.

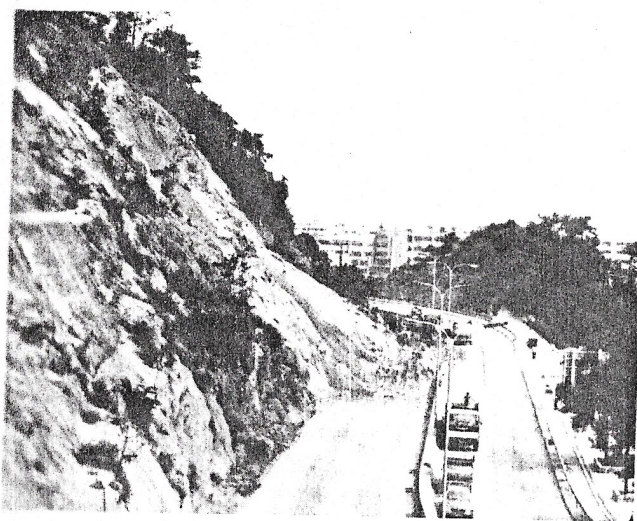


Figure 1 - General view of the failed slope taken on 24.8.82

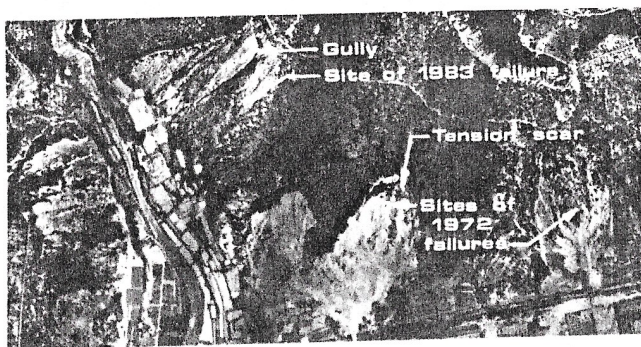


Figure 2 The area in 1949



Figure 3 The area in 1963

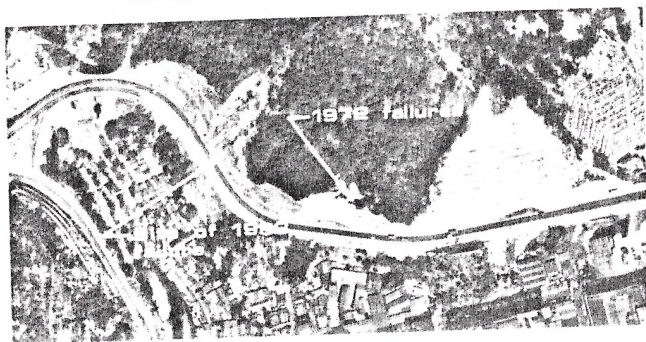


Figure 4 The area in 1972

Groundwater

The failure occurred in a dry manner and no seepage was seen on the day of the failure. Following initial clearing operations, however, water was found ponded on the road beneath the debris and later two minor seepage points were noted high up within and outside the failure scar (Figure 5).

DISCUSSION

The theory that the delayed nature of the failure was caused by a loss of strength on drying-out was tested by carrying out specialised direct shear and triaxial dead-load tests in which the samples were subjected to a series of flooding and drying cycles over a period of several days with the shear load held constant. In each of the direct shear tests it was found that significant shearing occurred on the first flooding cycle but not on any drying cycle. The single dead-load test that was carried out successfully showed no loss of

strength through repeated wetting and drying. The theory therefore remains unproved.

A theoretical explanation for the failure on the basis of a delayed rise in groundwater table is presented schematically in Figure 6. Analysis using Janbu's Rigorous method (Janbu, 1973) with strength values obtained from conventional testing, showed that the change in conditions from Figs. 6(b) to (c) could result in a reduction in Factor of Safety from 1.3 to 1.0.

CONCLUSIONS

The reasons for failure have not been established clearly. The delayed nature can be explained theoretically on the basis of a delayed rise in groundwater behind a dolerite dyke acting as an aquiclude. This theory however is unsatisfactory in that similarly complex geological solutions would be required to explain the two 1972 failures, and analyses carried out by authors of previous reports could not justify a delayed rise of up to ten days on the basis of assumed infiltration and storage characteristics. Perhaps other aspects such as previous instability were important and the delayed nature was only coincidental.

Alternatively the delayed failure may have been caused by a delayed loss of strength of materials but this has not been confirmed by the few specialised tests carried out for this study. Such a solution is attractive however in that it has wider application and is less dependent upon localised geology. The noted surface erosion, especially the major gully (Figure 2), indicates the generally weak and friable nature of the granite.

Finally it might be commented that the alignment of the road might have been better sited had aerial photographic interpretation been employed, which clearly indicates the geotechnical limitations of the route.

ACKNOWLEDGEMENTS

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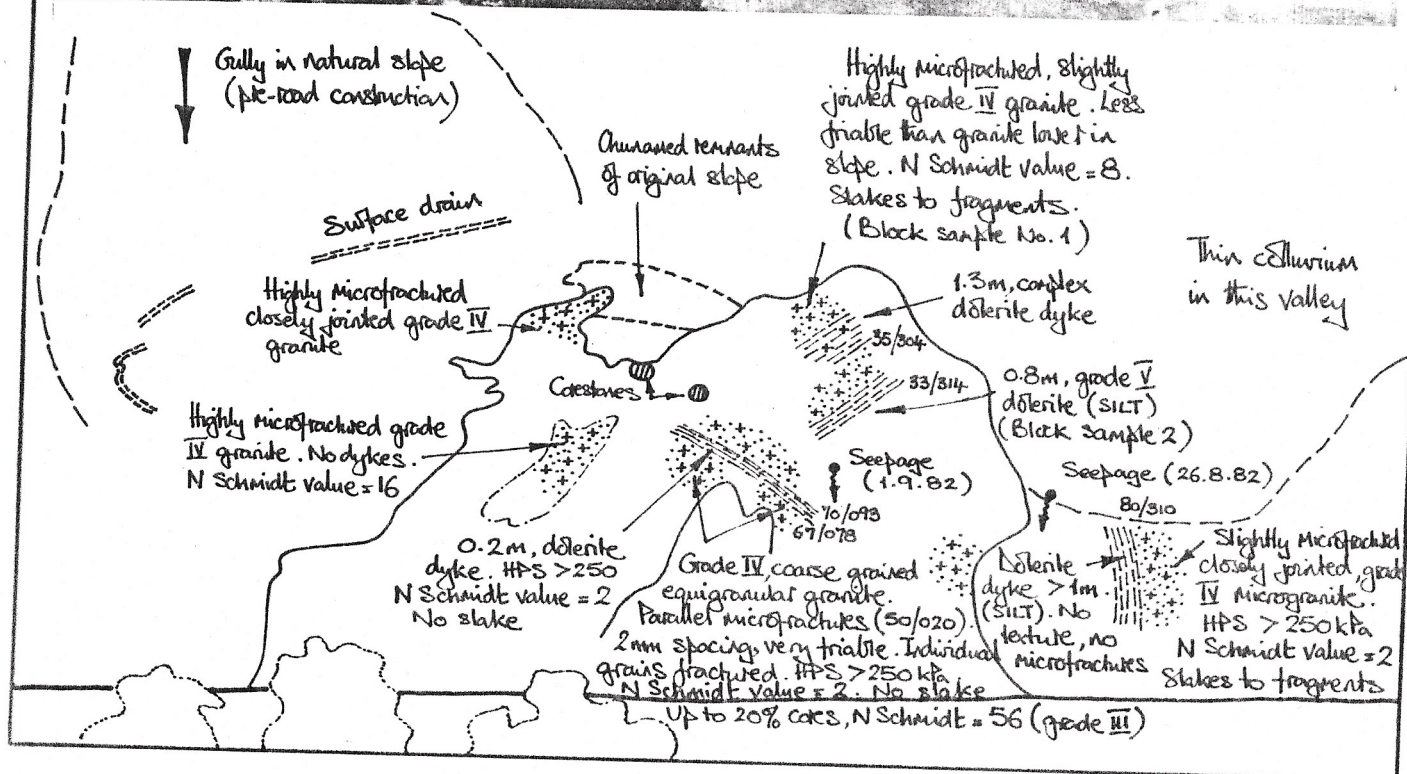
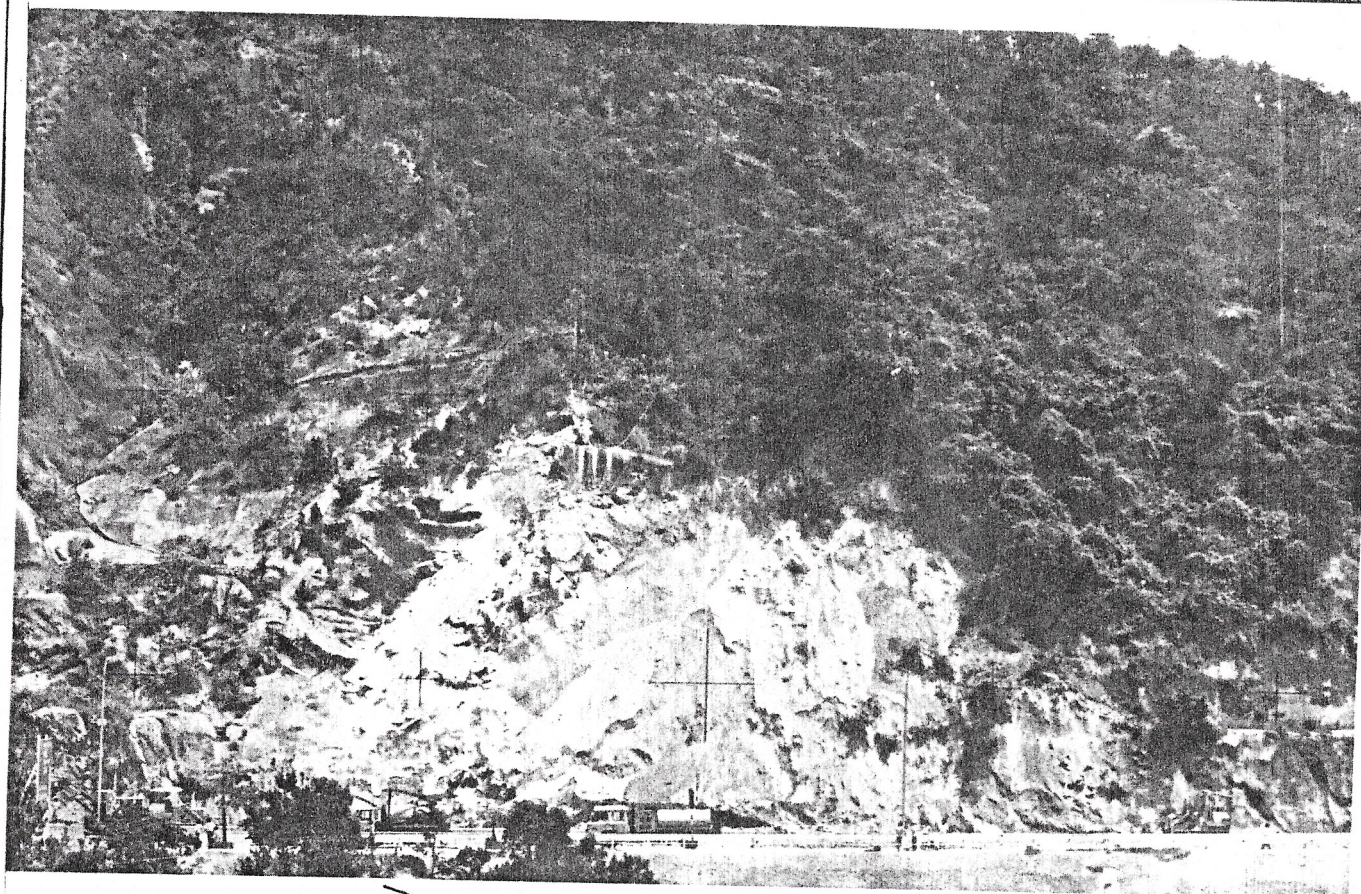


Figure 5 - View and annotated diagram of failure

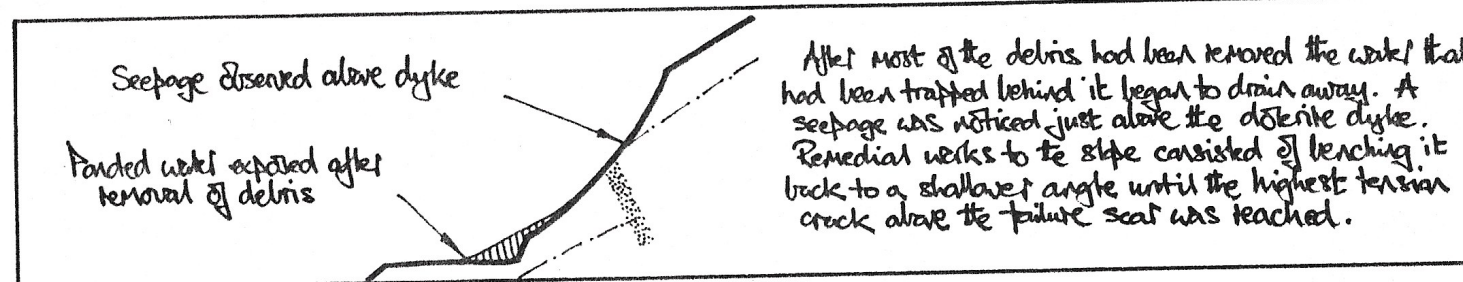
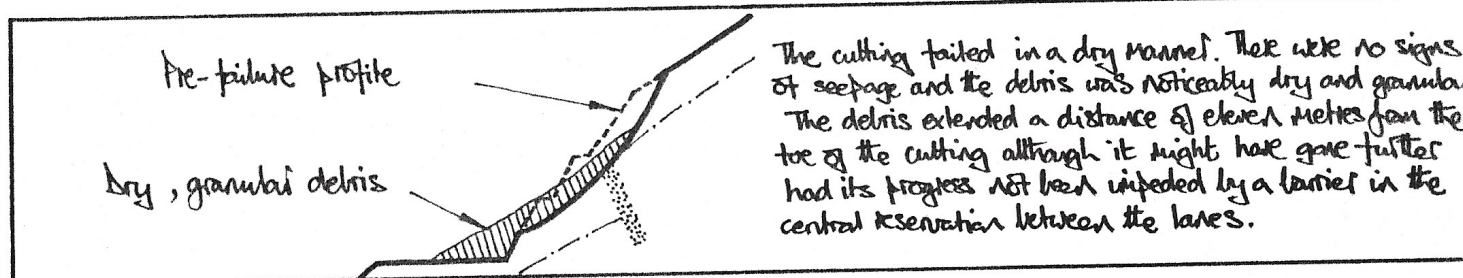
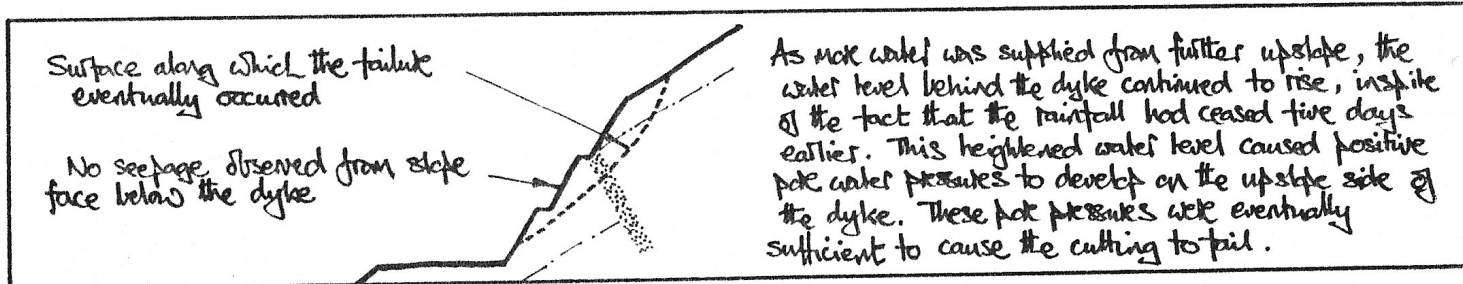
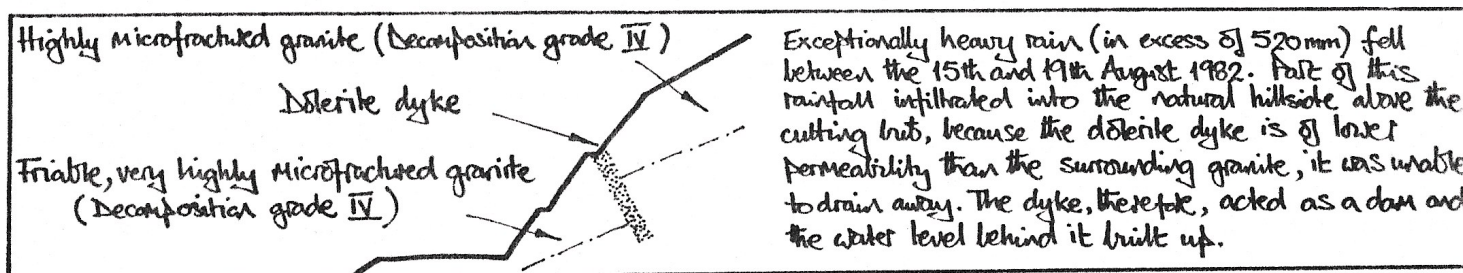
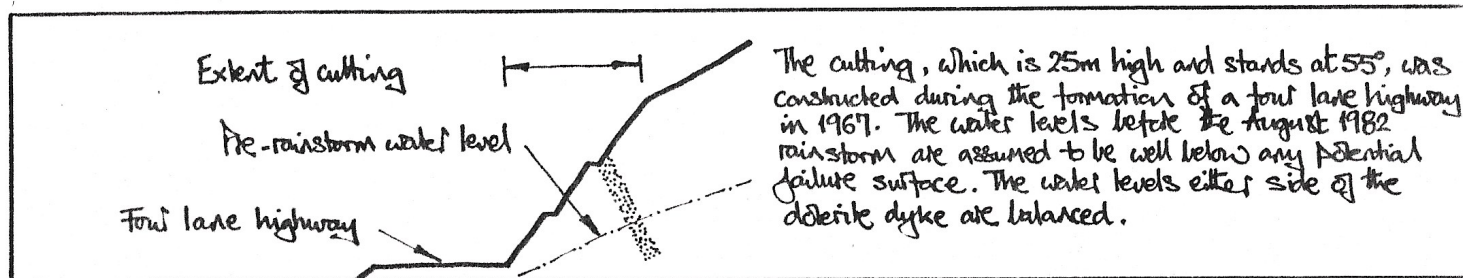


Figure 6 - Diagrammatic explanation for failure based on damming of groundwater