Geophysics in landslip areas

by D. E. Leaman

Introduction

There has been an increase in interest and activity in the problem of landslips in Tasmania in recent years. With the passing of various pieces of legislation relating to landslips much greater emphasis on recognition, appraisal and corrective recommendation has been required. Until a slip actually occurs geological recognition remains largely an intuitive process based on certain surface features which may not be pertinent to a correct conclusion. Appraisal of a failed area is also difficult, especially if the heel and toe are not physically obvious as in a very recent failure. Corrective recommendations are largely based on inferences deduced from a few types of observations such as ground cracking, wetness, topographic shape or slope, or material class. Very little quantitative measurement is currently undertaken and in order to gain some extra information on material properties, water content, potential failure sites, size of failed areas, indication of past failures and physical dimensions of recent failures, geophysical work has been suggested. This report presents a brief summary of methods which might be applied, the type of results to be expected and a discussion of the problems to be faced.

Form of landslips

There are two main types of landslip:

(1) a slide, slump or creep which is essentially a linear feature with the failure surface at shallow depth, and roughly parallel to the surface, and

(2) a rotated block which is more equidimensional and may involve quite massive material.

By their very nature landslips are a difficult problem to approach since the range of properties tends to be minimal and crucial features, such as the failure surface, are restricted and narrow. Many determinant features may be present, none of which might be serious alone.

Geophysical methods and their application

Seismic methods

Refraction

Conventional and fan-spread layouts can be used to determine slide thickness (presumes slump type). In such cases there is a thickening of the upper low velocity layers, although it must be noted that an increased thickness may be due either to localised weathering or a previous and perhaps not obvious failure. In the case of failures, the failed earth which is, or has been, waterlogged or is fractured has a distinctly lower seismic velocity and in the dry condition determination of the slump surface is possible. When saturated such determination will probably not be possible due to the hidden layer condition in that the failed wet soil may be denser or as dense as unfailed wet soil.

Where rotational slides involve soil and weathered material similar comments apply. Where relatively unweathered rock is involved no simple determination of slip scale will be possible as the narrow low velocity slip zone will be hidden. Various applications based on fan methods may be successful if shot downslope of the failure.

It is also possible to measure in situ the bulk modulus, Poisson's ratio and rigidity modulus using three-component geophones. Whether measurement of such properties is useful remains to be proven. There would be an obvious relationship between soil, slip material and rock etc.

Vibration dynamics

In this method two types of measurement are feasible. It is possible to determine the natural frequencies of a slab of earth, or the attenuation properties of the material. This method can be applied to very small areas — a problem with other methods — and can thus pick out localised zones which are vibration sensitive. Normally the more unconsolidated the material the lower the critical resonance frequency. Thus it is possible to locate areas where there are accumulations of soil or dislocated rock. Natural frequencies are determined from examination of records from pulse sources. Enhancement seismographs with display are ideal for this purpose. Having determined the set of frequencies induced in the material the critical resonance can be isolated using standard seismic equipment and a vibratory source adjusted across the required range.

Critical resonance is recognised by a large amplitude increase.

Electrical methods

Resistivity

Conventional traversing could be used to locate failed zones or zones which are water saturated and might fail in the future. Failed areas, in part at least, have a variation in texture, structure and fracturing and consequently a different resistivity. Old failures which may be present as a depression in soil would probably be detected by water content. The resistivity of any contained water contrasted with the soil resistivity is crucial to the success of the method and as a result the method may not be definitive.

Sounding methods cannot be expected to be of any great use due to the broad summation of effects. While it might be possible to make estimates of slide thickness, presuming a resistivity contrast between slide and base, it is unlikely to be sufficiently accurate in view of the scale of near surface errors. Rotation failures involving any large amount of earth could not be approached with this method.

Potential methods

Landslips in most materials are related to water content, water paths or leakage.

Small self potentials can be present in addition to piezo and electrokinetic potentials. The latter properties are probably dwarfed by the self potential and included in any such measurement.

In a clay-water situation induced potentials would probably yield the most reliable information as to water content as the chargeability will be related to the water content. A potentially very useful method which needs some development in this field.

Magnetic methods

Where magnetic rocks are involved it is possible to determine rotation movements by comparing the magnetic orientation of the supposed fragments with in situ material.

Summary

The problem reduces to two parts:

(1) identification of potential failure areas, and

(2) description of slip and slip material properties.

The first part requires location of thick accumulations with high water content in appropriate topographic situations. In certain cases resistivity surveys can indicate such zones. More reliable are the vibration methods and possibly also IP methods.

The second part requires description of physical scale and properties, and only seismic methods could be sufficiently reliable and even then only in some circumstances could the depth and shape of the failure zones be determined.

Some initial results

Results are expressed as periods rather than frequencies indicating the means of determination.

Batman Bridge

Seismic velocity	material in slip:	335 m/sec
	sub-slip:	750 m/sec
	Tertiary units:	1500 m/sec
On slip: vibration — natural periods		24–26, 32–36, 42–44, 52–56, 60–62, 64–70 – significant dispersion only of 42–44 group to 44–48 – all periods milliseconds (msec).
Resonance at 25 Hz, 55 Hz		
	Off slip periods:	24–26, 30–32, 34–36, 40 – no long periods
Maximum thickness of slip:		2.75 m

Rhyndaston

Pulse off slip	natural periods:	18, 24, 28, 32, 38 msec

St Helens

Soil velocity:	300 m/sec.
Tertiary unit velocity:	1300 m/sec (indicates high sand proportion as Tertiary clays are usually 1500–1650 m/sec).

There were very obvious changes in wave form as the margins of the slip area were crossed with the pulse source.

Most recorded periods in the range 20–40 msec with some dispersion.

Not all results have been examined to date.

Comparative results

Undisturbed Tertiary clay:	10–40 msec
Tertiary sand:	12–40 msec periods
Sand:	10–24 msec
Mathinna rocks:	3.4–9 msec
Basalt (Kelso):	6–18 msec
Dolerite (Domain):	8–32 msec
Recent fill (Cornelian Bay):	16–54 msec
Basalt talus (Hillwood):	14–40 msec
Basalt talus (Windermere):	19–45 msec
Resonant period:	24 msec

Sufficient is known thus far to state:

(i) The lower the natural periods (or higher frequencies) the more stable, compact and solid is the material. The presence of even one major joint makes a 33% variation.

(ii) Solid rocks have narrow ranges of low periods (see basalt).

(iii) Critical resonance is at low period (high frequency) in solid rocks. Normally >50–100 Hz.

(iv) Unconsolidated or poorly consolidated materials have a wide spectrum which normally terminates at 45–50 msec. The presence of ground cracking or water extends this range.

(v) The form of the transmitted vibration changes drastically with crossing of ground fractures. Longitudinal vibrations are reduced in favour of shear vibrations.

(vi) Slips can be detected if enough is known about the surrounding materials.

(vii) In Tertiary rocks a wide band, low resonance frequency and low velocity may well mean a slip — recent or potential.