

Guidelines for the planning of soil investigations in relation to slope stability and swelling soils.

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Abstract

Guidelines for the planning of soil investigations in relation to slope stability and swelling soils in Tasmanian conditions are suggested. Each facet is discussed briefly in relation to short-term small scale and long-term longer investigations and a table of suggested approaches in a gamut of investigations is given.

The study of natural slope stability in soft rocks has developed within the Geological Survey of Tasmania to a stage where systematic acquisition and treatment of data is necessary. This presupposes that a range of testing equipment is available, and this is largely true. Some expansion and reorganisation are required and a small testing laboratory is being set up.

Swelling soils are also a known hazard and can conveniently be examined by the same techniques.

Systematic handling will ensure that data is not neglected or lost and that different investigations can be readily compared.

It is necessary to discuss the items of information which need to be collected for particular investigations. Different levels of investigation have evolved from the simple examination of a single house site to the long-term predictive slope stability analysis of a township. This may require a great deal of information which can only be accumulated over time.

It has become normal for boreholes to be used as the principal source of subsurface information and samples. Hand-dug or machine-dug pits or natural outcrops have been shown to be inadequate. They are not deep enough to show the full profile of a potentially moving mass and normally do not penetrate deep enough to intersect important piezometric surfaces.

Boreholes in this context are dry-augered by Proline Gemco or Triefus machine and are therefore limited to soft sediments. Harder materials require the use of diamond drilling gear and this normally implies the use of water for drilling. As this destroys some of the information required, its use should be sanctioned only when no other means is possible. Few such cases have occurred in the past.

Basing the investigation on boreholes the following list has been compiled as the maximum useful information that can be obtained. It can be used as an *aide-mémoire* together with Table 1.

FIELD INFORMATION

Location - usually referred to a map, street or subdivision plan or sketch plan. Aerial photographs or orthophotos are very suitable and have the additional advantage of providing a stereo model.

Landscape form - as defined by contours, slope description or best by geomorphic mapping.

Site geology - from regional surveys, augmented by local observation to include "basement" - that is those rocks lying below any conceivable

zone of movement, the hazardous and associated materials, as well as any later additions - alluvium, slope deposits, till, terrace deposits and fills or made ground.

Depth of investigation is dependent on geology, purpose of investigation and postulated failure mechanism but should not normally be less than 10 m. Drilling may be a combination of augering to give a preliminary section followed by an adjacent new hole to give drive tube or other samples. Sampling may follow both these techniques, samples every metre being taken from augered (disturbed) material and selected undisturbed samples from the new hole. The sampling programme will depend on the purpose of the investigation, but should embrace every significant soil type, change in moisture content, texture or state of disturbance.

Bore hole locations should give economical cover of the area of interest, be place to show sections in both disturbed and undisturbed areas if any and should show extremes of water conditions both in space and time. Bore holes which are to be preserved for monitoring should be in less vulnerable positions near fences or other boundaries. Plastic casing is cheap and easily installed.

Besides supplying subsurface information and samples, bore holes give access for pump testing, water sampling, geophysical measurements deformation measurements and the installation of supportive remedial devices such as *in situ* piers or piles.

Description of sections. Two systems should be used in conjunction. *Lithology*, oriented to the geological origin but with suitable emphasis on weathering or other alteration, and *Unified Soil Classification*, a physical description for engineering purposes, Casagrande diagram or other plot of properties.

Field moisture content is recorded qualitatively in logging and is sampled. Experience in relating this to liquid and plastic limits is useful.

In situ testing by vane using extension rods is desirable. Testing in drive tube samples is an acceptable alternative. The possibility of pressuremeter testing should be kept in mind.

Water levels are measured as they occur during drilling and again overnight or after a longer stabilisation period. For a large investigation slotted casing to retain the hole and monitoring for a year or years has proved its worth as the most powerful indicator of change of stability. Confined aquifers may require sealed-in piezometers but these have not usually been necessary in the past.

Pump testing - to reveal aquifer positions and permeabilities has proved its worth, using anomalies in the recovery curve.

Salinity is significant as an indicator of connate or meteoric water and for the effect of ion types and concentrations on clay behaviour. pH and Eh may also be influential. More work is required both in the laboratory, on the effect of different solutes on index properties, and *in situ*. Water samples may also be of interest for water supply purposes.

Fluoride is an important tracer if leaks from supply pipes are suspected.

LABORATORY INFORMATION ARISING FROM FIELD WORK

Atterberg limits still form a useful characterisation especially in a basin like the Tamar with much accumulated information. Liquid and plastic limit estimates should become personally familiar to workers, as an accurate estimate of a handspecimen is a useful accomplishment and is a guide to clay content in our material.

Mechanical analyses and clay contents. These will continue to be done by our Launceston laboratory or the Department of Main Roads; we shall not set up to do them.

Density. Some estimate of bulk wet density is required for stability analyses.

Shear box tests on undisturbed, pre-sheared, remoulded or otherwise prepared samples are the principal quantitative source of strength parameters. Back analysis is the complementary process.

Triaxial tests may be a useful adjunct if slow undrained tests are specified. We shall not set up to them ourselves.

Swelling pressure and swelling potential. These values can conveniently be measured using a shear box as an oedometer.

Dispersion. The Emerson test is useful.

X-Ray diffraction. Semi-quantitative work on clay minerals is well established and is necessary to characterise clays in new areas and to back up Atterberg values.

GEOPHYSICAL METHODS

Seismic refraction is often capable of locating the interface between disturbed and undisturbed material, in active movement zones. It may also show the presence of 'base' beds which may promote base failure and can often give additional detail of the general geology.

Vibration and attenuation studies show promise in active and dormant failure areas.

Resistivity has not been a success but may be worth trying in suitable situations.

Other more exotic methods such as self potential or geothermal need more work to qualify for routine use.

Down-hole methods. Resistivity using a 'spider' to show moist slip planes has been tried. Radiometric methods may be effective.

MONITORING

Monitoring of surface deformations, deformations of depth and of water levels are all of great importance. They are not easy to do, and require conscientious attention over periods of months or years to give useful results.

Surface deformations can be observed by repeated topographic survey, and by the installation of wire extension gauges. These latter are very cheap and simple, yet show movement convincingly.

Down-hole deformation either by block and string detectors or by strain gauge devices is more difficult to measure and interpret, but should be considered for major studies.

Water level monitoring is now being used on a routine basis and extensions to the network can readily be incorporated.

Oblique colour aerial views taken from light aircraft have been suggested and would have great value not only as a monitoring device but as a descriptive aid.

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Table 1. INFORMATION NEEDED FOR VARIOUS TYPES OF INVESTIGATION

	Subdivision Balance area	House site	Subdivision (up to 5 blocks)	Subdivision (more than 5 blocks)	Active rural failure (e.g. Bradys Lookout)	Active urban failure (e.g. Lawrence Vale)	Industrial area (e.g. Bell Bay)	Threatened installation (e.g. railway, pipeline)	Major construction site	Township (e.g. Beauty Point)
Location	•	•	•	•	•	•	•	•	•	•
Landscape form	••	•••	•••	•••	•••	•••	•••	•••	•••	•••
Site geology	•	•••	•••	•••	•••	•••	•••	•••	•••	•••
Bore hole(s)		o	•••	•••	•••	•••	•••	•••	•••	•••
Section descriptions			•••	•••	•••	•••	•••	•••	•••	•••
Soil classification			•••	•••	•••	•••	•••	•••	•••	•••
Field moisture content			o	•••	•••	•••	•••	•••	•••	•••
Vane in situ (Pressuremeter)				o	•••	•••	•••	•••	•••	•••
Water levels (see also monitoring)			•	•••	•••	•••	•••	•••	•••	•••
Pump testing				•••	•••	•••	•••	•••	•••	•••
Water sample chemistry				•••	•••	•••	•••	•••	•••	•••
Atterberg limits: LL, PL, LS			o	•••	•••	•••	•••	•••	•••	•••
Mechanical analysis				•••	•••	•••	•••	•••	•••	•••
Density				•••	•••	•••	•••	•••	•••	•••
Strength parameters (shear box)				o	•••	•••	•••	•••	•••	•••
Triaxial test					o	•••	•••	•••	•••	•••
Swelling potential and pressure		o	•••	•••	•••	•••	•••	•••	•••	•••
Dispersion			o	•••	•••	•••	•••	•••	•••	•••
X-ray diffraction						•••	•••	•••	•••	•••
Seismic refraction			o	•••	•••	•••	•••	•••	•••	•••
Seismic reflection				o	•••	•••	•••	•••	•••	•••
Vibration and attenuation					o	•••	•••	•••	•••	•••
Resistivity						•••	•••	•••	•••	•••
'Exotics'						•••	•••	•••	•••	•••
Down-hole geophysics						•••	•••	•••	•••	•••
Repeated survey					•••	•••	•••	•••	•••	•••
Extension gauges					•••	•••	•••	•••	•••	•••
Block and string					•••	•••	•••	•••	•••	•••
Strain gauge tubes					•••	•••	•••	•••	•••	•••
Water levels (short term)					•••	•••	•••	•••	•••	•••
Water levels (long term)				o	•••	•••	•••	•••	•••	•••
Oblique colour photographs					o	•••	•••	•••	•••	•••

• = Essential: unless special conditions apply this information would be required for an adequate investigation.

o = Optional: this information should be obtained if it is thought necessary.

This table indicates the coverage generally thought necessary.