Technical Note

Monitoring Slope Stability TN 79

Introduction

The purpose of this Technical Note is to provide a simple and practical guide to monitoring slope stability. Monitoring slope stability is an integral part of VicRoads' risk management of roadside geotechnical hazards. This Technical Note includes:

- An overview of common slope failure mechanisms on the Victorian road network
- An overview of factors contributing to slope failures on the Victorian road network
- A summary of common slope stability monitoring techniques adopted by VicRoads

Slope Failure Mechanisms

Common rock slope failure mechanisms on the Victorian road network are described in Technical Note 36.

Common soil slope failure mechanisms on the Victorian road network are described in Technical Note 80.

Factors Contributing to Slope Failures

Factors contributing to rock slope failures are described in Technical Note 36.

Factors contributing to soil slope failures are described in Technical Note 80.

Slope Stability Monitoring Techniques

Before undertaking slope stability monitoring, the slope failure mechanism and factors contributing to the slope failure must be identified. An appropriate and effective slope stability monitoring program can then be developed.

Slope stability monitoring techniques adopted by VicRoads are divided into three categories:

- Manual measurements of surface ground movement. These techniques indicate the rate of hazard development and are used to estimate the likelihood of hazard occurrence when undertaking risk assessments. These techniques include crack marking, survey points and survey monitoring.
- Manual and semi-automated measurements of subsurface ground movement and groundwater level fluctuation. These techniques indicate both the rate of hazard development and the volume and extent of the hazard, and are used to estimate the likelihood of hazard occurrence and the elements at risk when undertaking risk assessments. These techniques include standpipes and inclinometers.
- Automated measurement and analysis of subsurface ground movement, groundwater level fluctuation and rainfall. This technique is used to provide warning at sites where a Geotechnical Risk Management Plan has been adopted instead of undertaking medium-long term remedial works.

These techniques are described below and a relative comparison of these techniques is provided in Table 1.

Crack Marking

Crack marking consists of using spot marking paint to mark the ends of tension cracks through pavements. Crack marks are either dated or colour coded by date.

Crack marking provides a coarse indication of the magnitude and rate of development of tension cracking through pavements.

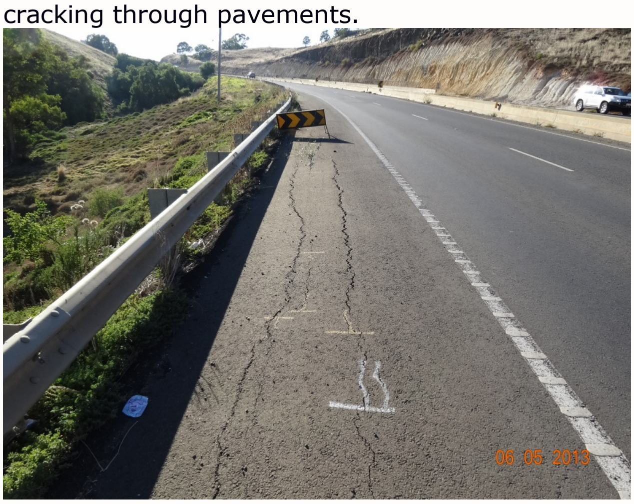

Figure 1: Crack marking.

Survey Points

Survey points consist of permanent markers installed on either side of tension cracks or rock mass joints, or on eroding surfaces. The type of permanent marker and type of measurement is entirely flexible; examples include:

- Pairs of survey nails installed in pavements on either side of a tension crack, with measurement of the distance between the centre of the survey nails using a rigid ruler undertaken to determine the combined horizontal and vertical displacement across the tension crack
- Pairs of rulers installed on rock outcrops on either side of a joint, with measurement of the relative displacement between the two rulers undertaken to determine the displacement across the joint
- Star pickets installed on eroded surfaces, with measurement of the exposed height of the star picket undertaken to determine the rate of erosion

Survey points provide an accurate measurement of the magnitude and rate of both relative displacement across tension cracks and rock mass joints, and of erosion.

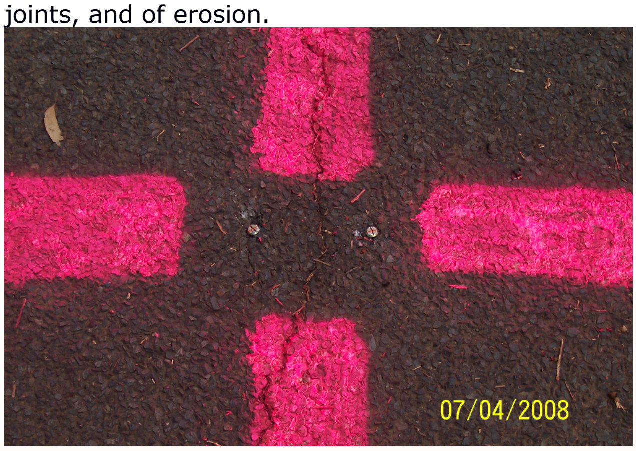

Figure 2: Survey point and location markers.

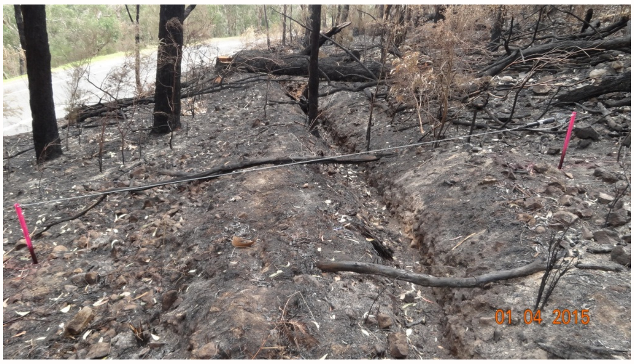

Figure 3: Survey point.

Survey Monitoring

Survey monitoring consists of using a total station to measure the coordinates and reduced level of survey monitoring points located both inside and outside the zone of movement. The type of survey monitoring point and location is entirely flexible; examples include:

- Pairs of survey nails installed in pavements on either side of a tension crack
- Steel markers installed on rock outcrops
- Reflectors mounted on star pickets on slopes

Survey monitoring provides an accurate measurement of the magnitude, direction and rate of surface ground movement.

Standpipes

Standpipes consist of a slotted PVC pipe installed in a borehole. Groundwater in the surrounding soil and rock flows into standpipes, and the standing water level in standpipes fluctuates in equilibrium with the adjacent ground water level.

Measurement of standing water levels in standpipes can be undertaken manually using a dip meter or can be semi-automated by installing a data logger inside the standpipe.

Standpipes provide an accurate measurement of the magnitude and rate of groundwater level fluctuations.

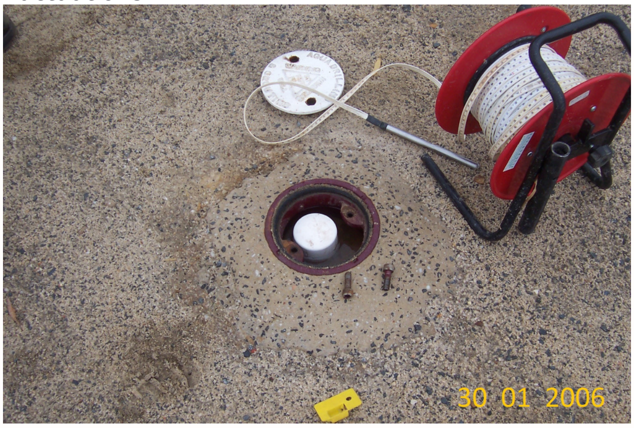

Figure 4: Standpipe and dip meter.

Inclinometers

Inclinometer casing consists of grooved PVC pipe installed in a borehole. Movement of the surrounding soil and rock results in the deformation of the inclinometer casing.

Measurements of inclinometer casing deformation can be undertaken with manual inclinometers or can be semi-automated by installing in-place inclinometers and a data logger.

Inclinometers provide an accurate measurement of the magnitude, direction and rate of surface and subsurface ground movement.

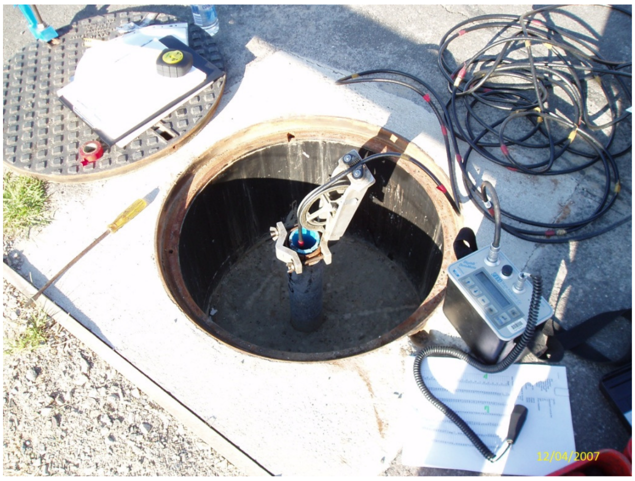

Figure 5: Inclinometer.

Automated Measurement and Analysis

Automated measurement and analysis consists of the following elements:

- Instruments measuring subsurface ground movement, groundwater level fluctuation and rainfall
- A data logger with power supply and means of transmitting data to a server
- Software on the server that analyses the data and sends alarms based on pre-programmed thresholds
- A Geotechnical Risk Management Plan specifying the response to alarms

VicRoads has previously used the following items:

- Instruments consisting of in place inclinometers, extensometers, piezometers and rainfall gauges
- Power supply from solar panels
- Data transmission via the mobile phone network
- Software developed in house that issues alarms by email and text message

This technique is only used at sites where a Geotechnical Risk Management Plan has been adopted instead of undertaking medium-long term remedial works.

Table 1. Relative comparison of slope stability monitoring techniques.

Technique	Installation		Operation			Maintenance	
	Lead time	Cost	Ease	Data Quantity	Data Quality	Life	Cost
Crack Marking	LOW	LOW	HIGH	LOW	LOW	LOW	NONE
Survey Points	LOW	LOW	LOW-MODERATE	LOW	LOW-MODERATE	LOW	NONE
Survey Monitoring	MODERATE	HIGH	MODERATE	MODERATE	HIGH	MODERATE	MODERATE
Standpipes	MODERATE	MODERATE	LOW-MODERATE	MODERATE-HIGH	MODERATE-HIGH	HIGH	LOW
Inclinometers	MODERATE	MODERATE	MODERATE	MODERATE-HIGH	MODERATE-HIGH	HIGH	LOW
Automated Measurement and Analysis	HIGH	HIGH	HIGH	HIGH	HIGH	MODERATE	HIGH

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Technical Note - Revision Summary

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Date	Clause Number	Description of Revision	Authorised by
December 2015	Full document	Major corrections made	MGS