TIME DOMAIN REFLECTOMETRY TO MONITOR TAILINGS DAM STABILITY

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ABSTRACT

The Canada Centre for Mineral and Energy Technology (CANMET) is currently monitoring the stability of three tailings dams using Time Domain Reflectometry (TDR) technology. TDR cables 100 metres in length were installed horizontally in all three dams. The first dam was instrumented in October of 1998. Field installation, data acquisition and software modifications will be presented.

INTRODUCTION

Time Domain Reflectometry (TDR) technology has been used successfully for a variety of applications. They include the measurement of soil moisture, rock and soil stability, structural stability, water level, and contaminant leakage. Most applications have utilized vertical or near-vertical placement of the cables, and usually in a grouted borehole (Aston et al., 1991 and 1992, and Charette et al., 1993). Horizontal placement of cables allows for monitoring of movement along the periphery of a tailings dam (Gorski et al., 1996 and 1998).

THEORY

TDR was first developed during the 1950s to locate and identify cable faults in the power and telecommunications industries (O’Connor et al., 1999). A fast rise time electromagnetic pulse is sent down a coaxial cable at a velocity that is specific to the cable. A portion of the pulse will be reflected back to the beginning of the cable if a change in the characteristic impedance of the cable is detected. These “signatures” can be analyzed over time to monitor changes in the cable deformation.

Coaxial cables are composed of a central metallic conductor surrounded by an insulating material, a metallic outer conductor surrounding the insulation, and a protective jacket. The TDR cables have a characteristic impedance determined by the thickness and type of insulating material between the conductors. This insulating material is called the dielectric, and is commonly composed of PVC foam, Teflon, or air (Cablewave Systems, 1999). If the cable is deformed, the distance between the inner and outer conductors changes, as does the impedance at that point.

A change in impedance may be caused by several factors, including a crimp, kink, a foreign substance (e.g. water), or a break in the cable. Measurement of the amplitude of the reflected waves over time can be used to determine the nature of the observed change in impedance. Knowing the length of the cable and the time interval between launching of pulses and detection of the reflected pulses provides an exact measurement of location.
CABLING AND SIGNATURE OPTIMIZATION

Copper coaxial TDR cable 0.5 inches in diameter was selected for the tailings dams. The cable consists of a protective polyethylene jacket, corrugated copper outer conductor, foam polyethylene dielectric, and a copper clad aluminum center conductor. The jacketing provides protection against moisture and corrugated copper was considered sufficiently deformable for this field application (Hill et al., 1996).

TDR shear signatures are readily identified as opposed to tensile deformation. The cable will experience tension if dam movement occurs. Movements may occur due to downslope piping, seepage or gullying. The cabling was configured in such a way that tension would be translated to shear signatures by installing “shear inducers” at regular intervals along the length of the cable. The inducer works as a choker loop under tension. In tension the loop tightens up on a double edged wedge. This action leaves a distinctive double shear spike.

INSTRUMENTATION AND SOFTWARE

TDR cable testing was performed using a Tektronix 1502B time domain reflectometer (Tektronix, 1990). The 1502B displays TDR cable waveforms directly on a LCD screen. Tektronix SP232 host application software was used to control the 1502B and transfer data to a laptop (Tektronix, 1993). The software was installed in DOS on the laptop.

New data acquisition software was written six months into the field program of data collection. Labview software was written to collect data from the 1502B in Windows 95 environment.

FIELDWORK

A 100 metre length of cable was installed at each of the three tailings dams. Cabling was placed directly into a trench parallel to the toe of slope and above the toe drain. Shear inducers were installed at 15 metre intervals along the length of the cable. The inducers were wrapped in fine geo-fabric to prevent fill intrusion during backfilling. The free end of the cable was pre-crimped as a distance marker. The cable was backfilled in granular fill material to a maximum depth of one metre. A 30 metre long BNC cable protected with 25 mm PVC tubing was connected to the TDR cable and run to a secure location for subsequent long-term monthly field measurements.

DATA RETRIEVAL

Data was initially retrieved at all three sites monthly using SP232 host software. Data was reduced using a Fortran program to units of reflection coefficient (mho) versus distance (metres). The data was imported into Sigmaplot. Subsequent data sets were offset so that all monthly waveforms could be displayed on the same plot. Data acquired using Labview software was imported directly into Sigmaplot.

DISCUSSION

Data was retrieved at each of the three sites by different CANMET personal using different Tektronix 1502B units and laptops. Tektronix waveform settings were identical for all three sites. The TDR cable and BNC cable lengths and type were identical for all three sites. Personal and equipment changes did not affect the quality or repeatability of field measurements.

Site 1: Val d’Or Test Area

The TDR cabling was installed during phase 1 of the construction of this tailings dam. The dam is basically pit run fill with a clay core founded on bedrock. Although the cable was installed in October of 1998, data collection methodology was not finalized until August of 1999. The well defined shear spikes are the result of construction equipment activity over the cable trench during the second lift of the dam construction. Several noise troughs in the data are attributed to poor field connections to the 1502B. The troughs did not appear in the subsequent sets of readings.

Site 2: Elliot Lake Test Area

The TDR cabling was installed in a new toe drain under construction for this tailings dam. The first set of readings show considerable noise in the waveform. This was attributed to a diesel backhoe that was idling at the time of the readings and was located over the backfilled TDR trench. Readings taken in December of 1999 compare data retrieval methods using SP232 software and Labview. The glitches in the Labview curve have since been resolved as erroneous data and the software rewritten.
Site 3: Timmins Area

This is our most recent site. The tailings dam is low in height and the tailings are submerged. The site is underlain by New Liskeard clay. The TDR cable was installed in October of 1999. Monthly readings taken to October of 2000 have been consistent at this site.

CONCLUSIONS

There are several devices on the market developed specifically to monitor movements of earthfill structures. Movements are detected normally in vertical localized areas of a structure. TDR cable however, may be used to monitor long horizontal segments of earthfill embankments. Embankments may be monitored remotely on-line using a TDR cable as the sensing method is electronic.

Off the shelf Labview is a typical software tool capable of acquiring data and controlling TDR electronics in Windows95 or better. Labview acquires the data at 13 bit resolution versus SP232 8 bit. Data acquired over time is readily compared to baseline readings. Data is acquired at a receive/transmission speed of 19200 baud. SP232 software speed was 1200 baud. Labview may be configured to trigger alarms when embankment movements are detected.

REFERENCES


