MTDR CONTINUOUS MONITORING SYSTEM

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Introduction

Time Domain Reflectometry (MTDR) was developed firstly by electrical engineers as a measure to locate discontinuities in transmission lines (Moffit, 1964). The technique has been applied to measurement of material properties in which conductors are embedded (Cole, 1975). In rock mechanics, the technique has been employed to identify zones of rock mass deformation (Dowding et al., 1989).

This technique can be applied to monitor fracturing within concrete structure (Su, 1990) and integrity of infrastructures (Su and Chen, 1999). When a coaxial cable is embedded in a concrete structure or on the surface of structure members, it works like a continuous sensor, which can detect fracturing and relative movement at any point along its length. An electromagnetic pulse is launched down the cable and reflection from point of cable deformation can be identified precisely. TDR monitoring provide a valuable tool when deformation points are not known in advance. Multiple reflection can cause difficulty in analyzing the reflected waveform. Su and Chen (1998) proposed the area integration method in calculating the effect of movement on waveform.

TDR basic

Figure 1 is a block diagram of the TDR system. There are pulser, sampler, scope and device under test. A fast rise time step function generated by the pulser propagates through the sampler to the transmission line under test. Travelling of the step function along the transmission line generate reflection when there's a cable fault or change in its characteristics. All reflected signals return to the scope and displayed as reflection coefficient versus time on CRT screen.

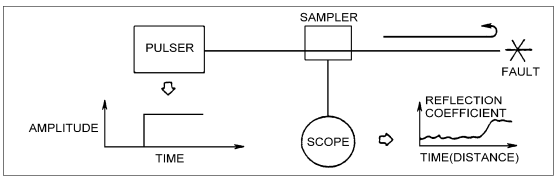


Fig.1 Basic components of TDR cable tester

TDR for Infrastructures

Monitoring system for the integrity of infrastructures was proposed by monitoring at the connection between elements (Su and Chen, 2000).

Slope stability problem is often a part of infrastructure safety. TDR monitoring can be applied to these kinds of problem as well as to infrastructure itself. A coaxial cable is grouted into a borehole drilled in slopes (Figure 2). When part of the slope slides, the grout between ground and cable will deform and so is the coaxial cable. The main difficulty in such a situation is the future breaking point or called sliding surface is not known in advance. MTDR is an available solution, when the semi-rigid coaxial cable is grouted in a borehole the whole cable works like a continuous sensor which is monitored all along its length.

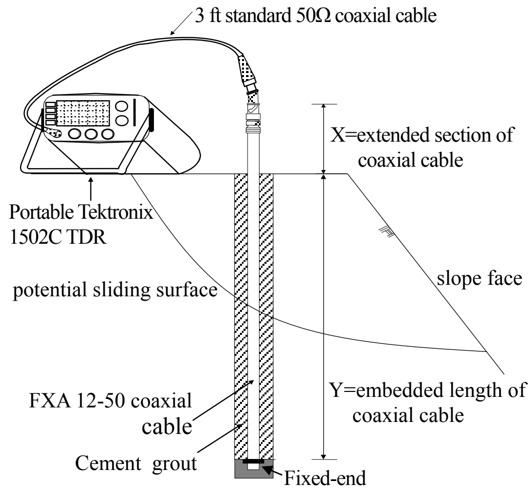


Fig.2 TDR set up in slope stability monitoring

Waveform's electrical length

Cable crimps marks to calculate the length change. No matter the relative movement is shear or extensive, it increase the length of cable so as the travelling time. Data reduced from original record are put together to show the change (Figure 3). Length between crimps are tabulated in Table 1 to give a clear view of the change. Total length of the embedded cable increases about 1 meter which is distributed in shallow depth and one concentrated in about 36 meters depth.

Details of waveform change

Four sections of waveform are enlarged to show the significance of waveform change development. In change #1, waveforms between 0 to 7 meters depth are put together to show a shallow sliding developing during monitoring period (Figure 4a). In change #2 waveform between 15 to 21 meters depth are shown to see an extension development(Figure 4b). In Figure 4c, a sliding signature shown at 26m depth is very easy to identify. At last in Figure 4d, extension signature shown at 36 meter depth clearly present the deepest sliding surface of the monitored slope.

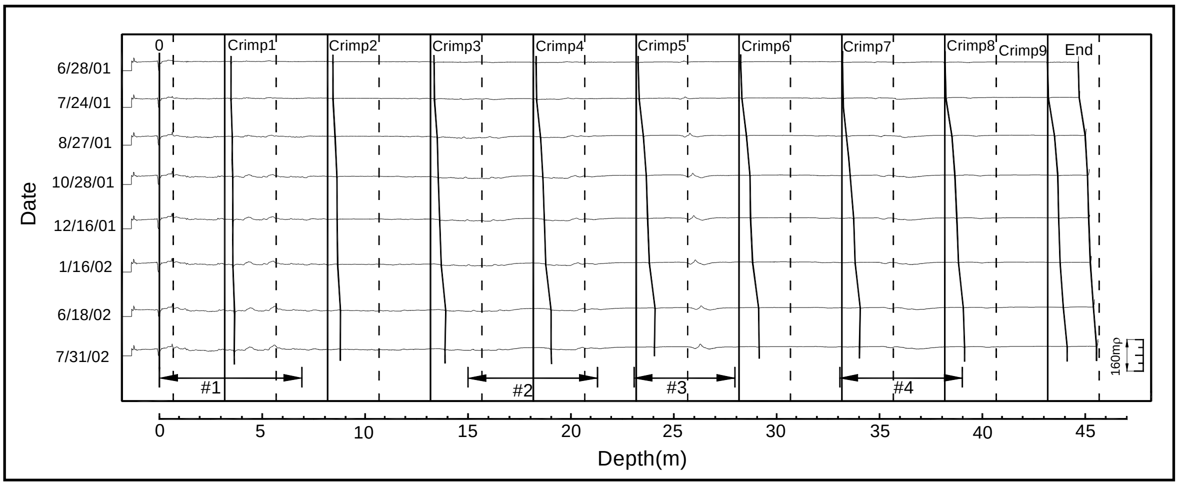
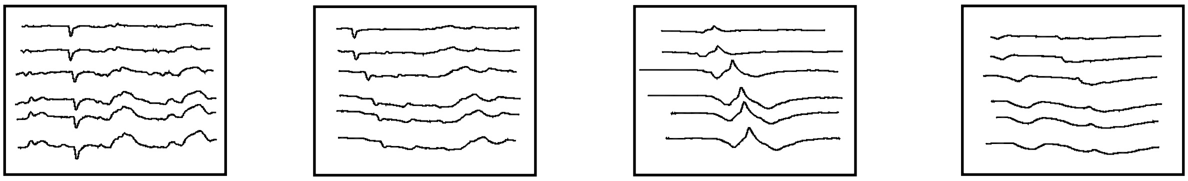


Fig. 3 Waveform recorded during monitoring period

Table 1 Distance between marks for the grouted cable

Date	mark1	mark2	mark3	mark4	mark5	mark6	mark7	mark8	mark9	end	Total Length(m)
06.28.01	3.50	4.95	4.92	4.96	4.96	5.00	4.94	4.97	5.00	1.49	44.69
07.24.01	3.51	4.96	4.93	4.96	4.98	5.00	4.94	4.97	5.01	1.49	44.75
08.27.01	3.57	4.99	4.97	5.10	5.00	5.02	4.94	5.01	5.01	1.49	45.10
10.28.01	3.59	5.06	5.00	5.10	5.00	5.02	4.94	5.04	5.01	1.49	45.25
12.16.01	3.60	5.07	5.00	5.10	5.00	5.03	4.94	5.04	5.01	1.49	45.28
01.16.02	3.61	5.09	5.03	5.10	5.01	5.03	4.94	5.04	5.01	1.49	45.35
06.18.02	3.67	5.15	5.12	5.12	5.02	5.03	4.94	5.06	5.02	1.49	45.62
07.31.02	3.70	5.15	5.12	5.13	5.03	5.03	4.94	5.06	5.02	1.49	45.67



(a) #1 change (0-7m) (b) #2 change (15-21m) (c)#3 change (23-28m) (d)#4 change (33-39m)

Fig. 4 Enlarged picture at different location

Conclusion

MTDR monitoring system can be used as a continuous monitoring system for infrastructure itself and for the ground conditions surrounding or supporting the structure. When deformation locations are not known in advance, continuous monitoring can be applied in stead of traditionally monitoring measure. Deformations including extension and sliding are easily identified from field monitored data to prove its applicability. Theoretical background for analyzing the monitoring system can be applied in many situation where deformation monitoring of infrastructure are needed.

Reference

Cole R.H. 1975, "Evaluation of dielectric behavior by time domain spectroscopy:1, dielectric response by real time analysis; 2,complex permeability; 3,precision difference methods," *Journal of Physical Chemistry*, Vol. 79(4), pp.1459-1474.

Dowding C.H., M.B. Su, and K.M. O'Connor 1989, "Measurement of rock mass deformation with grouted coaxial antenna cables," *Rock Mechanics and Rock Engineering*, Vol.22, pp.1-23.

Moffit L.R. 1964, "Time domain reflectometry —theory and applications," *Engineering Design News*, pp.38-44.

Su M.B. 1990, "Fracture monitoring within concrete structure by time domain reflectometry," Engineering Fracture Mechanics, Vol. 35, pp.313-320.

Su M.B. and Y.J. Chen 1998, "Multiple Reflection of Metallic Time Domain Reflectometry," Experimental Techniques, Vol. 22, No. 1, pp.26-29.

Su M.B. and Y.J. Chen 1999, "MTDR Monitoring Systems for the Integrity of Infrastructures," Journal of Intelligent Material Systems and Structures, Vol.10, No.3, pp.242-247.

Su M.B., and Y.J. Chen 2000, "TDR Monitoring for the Integrity of Structural Systems", Journal of Infrastructure Systems, ASCE, Vol.6, No.2, pp.67-72.