YIELDPOINT WHITE PAPER:

Load and Displacement. The relation between an d_MPBX and d_Cable.

d_MPBX 100151004

The d_MPBX borehole extensometer measures how the ground is moving in mm. d^6MPBX 100151004 indicates that the majority of movement, around 13mm, is between anchors 1 and 2 at 1.9m and 3.5m from the excavation surface. Interestingly the 1m section nearest the surface is behaving like a “rigid beam”. This effect is presumably enhanced by the relatively stiff primary support (resin rebar?).

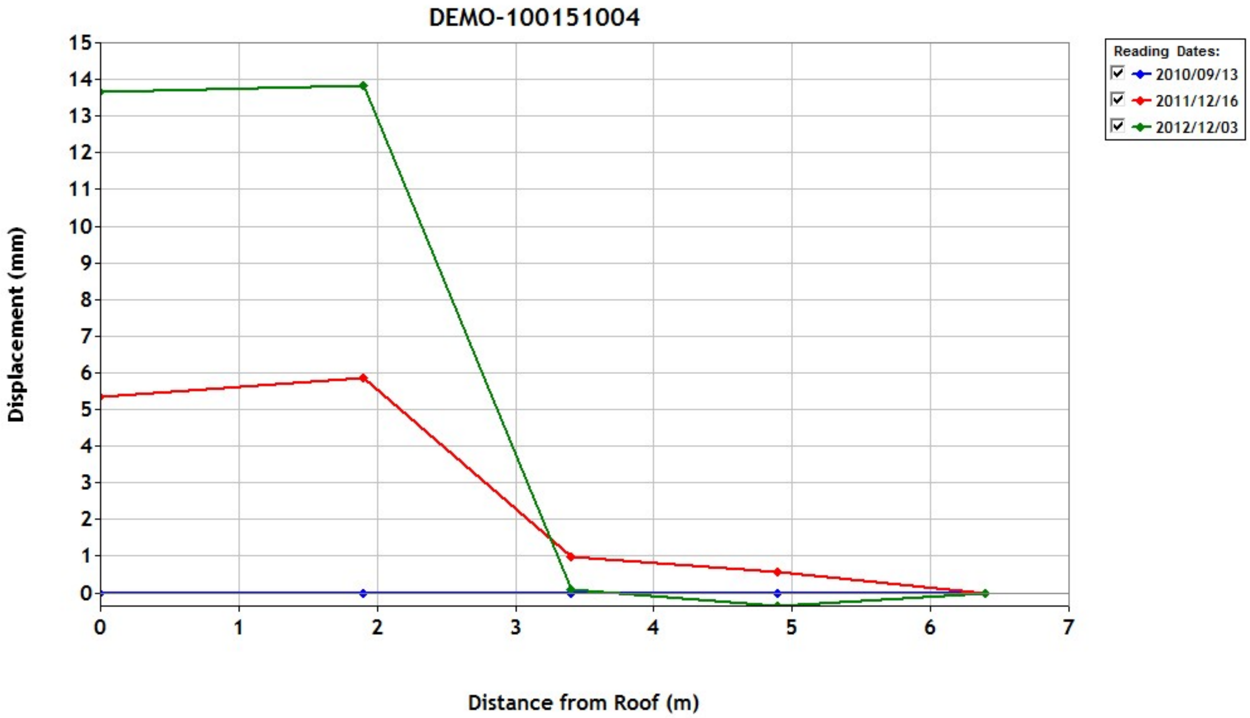


Figure 1: d_MPBX 100151004 up to 12/02/2012

d_CABLE 100155054

We presume the d4CABLE is unplated and fully grouted, in which case the load in the cable at the excavation surface must be zero (physical boundary condition). The d^4CABLE instrument indicates how a cable bolt is loading and stretching in response to those ground movements. These are not the same! If the cable were bonded to the rock by an “infinitely strong grout” then the stretch of the cable and the movement of the rock would be identical. However in reality the bond stiffness between the cable and the grout (determined by lab pull out tests) is finite and therefore in all cases the stretch of the cable should be somewhat less than that calculated for d^4CABLE.

How to calculate corresponding deformation for d_cable

Just as the SMART cable measures displacement which can be used to determine load (differentiation wrt length) so for the d4CABLE which measures load, the corresponding displacement can be calculated (integration wrt length). The latest version of MineScope Cable on our website does this for you.

http://www.yieldpoint.com/minescope.php

We have put the numbers into this latest version and the results are shown below. The first two plots in Figure 2 are temporal plots, the second two are spatial. Notice how the distribution of load (Fig. 2c) and displacement (Fig. 2d) along the cable are quite different. The load is actually proportional to the slope of the displacement plot (*i.e.* the strain Equation 11 in Hyett *et al*. paper.). This explains why the two plots are so completely different. However, the two instruments almost perfectly match with theory - the stretch of the cable (12mm) being slightly less than the ground movement (13.8mm measured by the MPBX d^6MPBX). Notice how the displacement in the cable is somewhat more distributed than the displacement in the rock. This represent some degree of bond breakage (if the bond were perfect the displacement in the cable would equal that of the rock). All of this makes complete sense and indicates that 1.8mm of the deformation is associated with bond slip and 12mm with cable stretch .The peak load occurs at what is called the "neutral point" of the fully grouted bolt which in this case is at around 2.5m, interesting just behind the primary support. At this point the cable and the rock and cable move together. In this case, although we do not have the spatial resolution to prove it, I bet there is a very distinct zone of fracturing which is loading the cable much like shown in Figure 2 – albeit the crack is at 2.5m as opposed to 5.0 as in the figure. Notice how different the load profile is from the displacement in figure 2 and that the displacement is highest at the excavation surface.

These are not easy concepts to understand, and I hope I have made myself clear. About "as clear as mud" probably.

Summary:

1. Excellent results with MPBX and cable validating each other.
2. Cable is relatively stiff 1 ton/mm of ground movement – though nothing compared to a resin rebar). This is a function of (i) the rock properties (high modulus) and (ii) the concentration of rock deformation at a single point (around 2.5m).
3. In terms of model calibration. Cable loading will be driven by cracking of the ground related to progressive rock failure in the back. They will not necessarily reflect simple stress changes but some kind of failure criterion. Therefore it may make sense that the cables begin to show load at a certain stage of mineby once (and only once) the back begins to fail. The interesting question is whether the load continues to increase as the mineby is completed and the ground presumably becomes more relaxed.

Overall the kind of results we are seeing seem to bear out some of what we described in our paper with some deeper fracturing going on in the back away from the excavation surface, which is very different from the walls and shoulders.

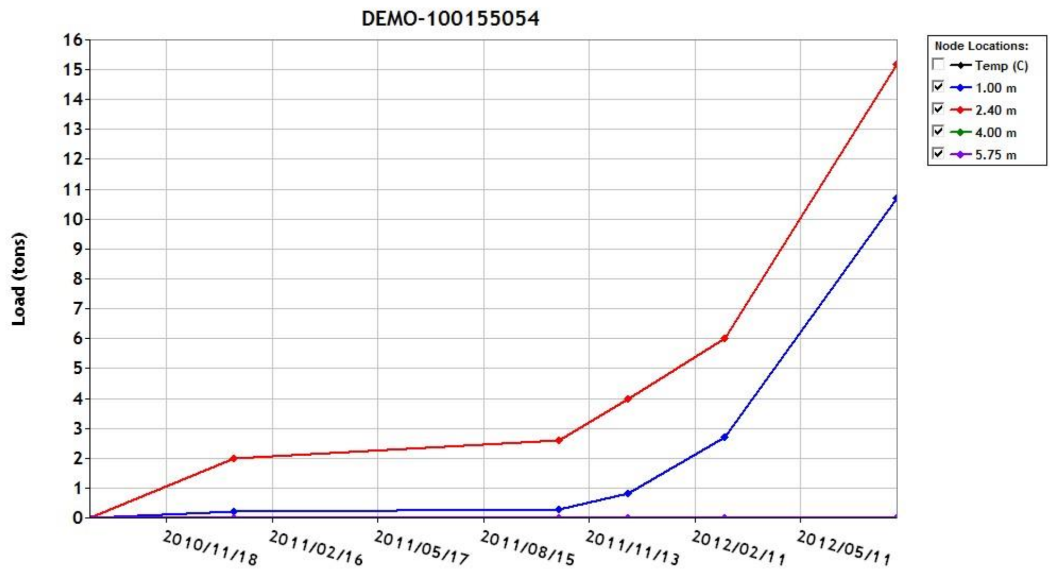


Figure 2a: Load versus time on Cable

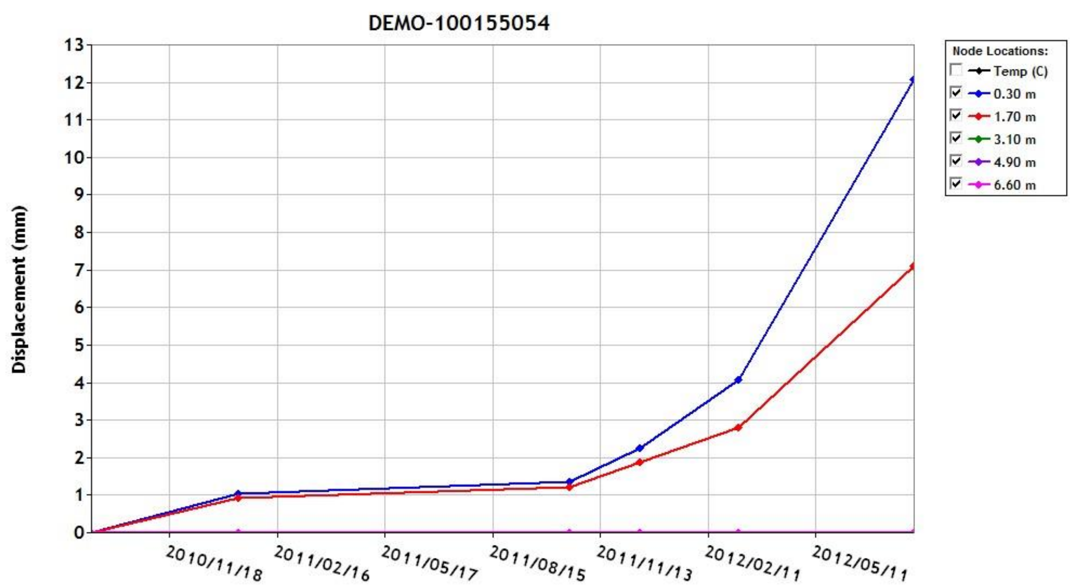


Figure 2b: Cable displacement (stretch) versus time

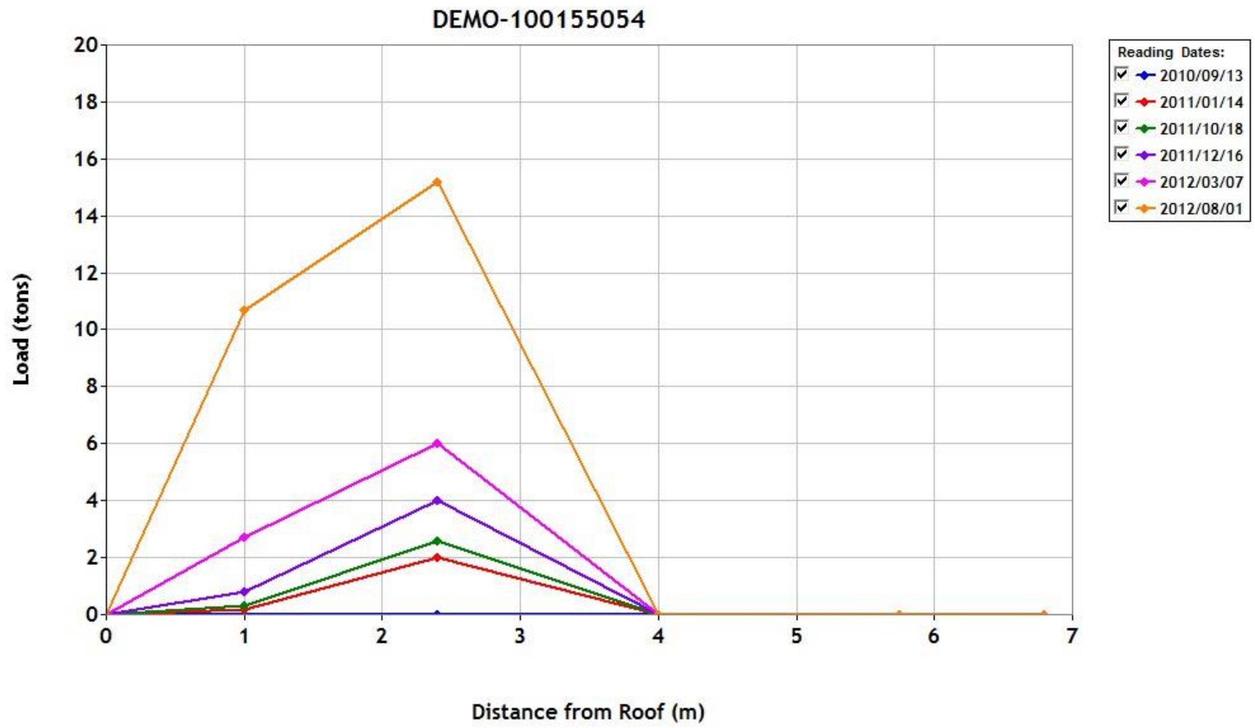


Figure 2c: Load versus distance along cable

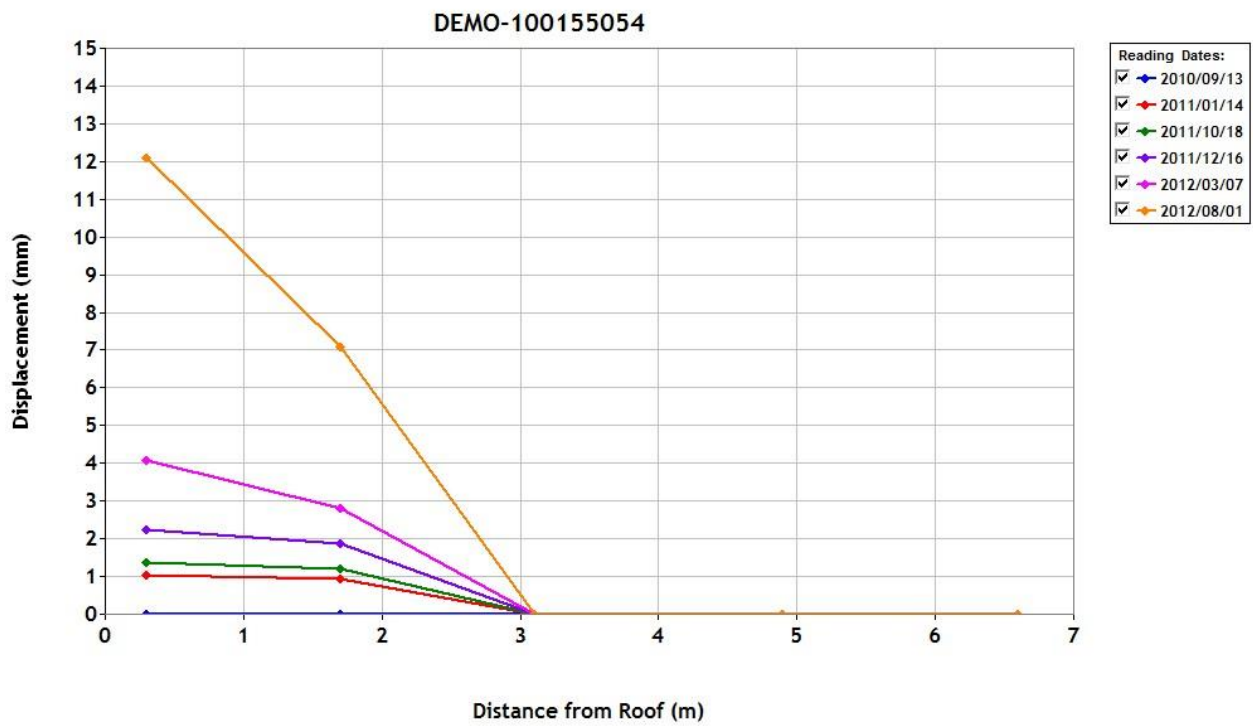


Figure 2d: Cable displacement (stretch) versus distance along cable.

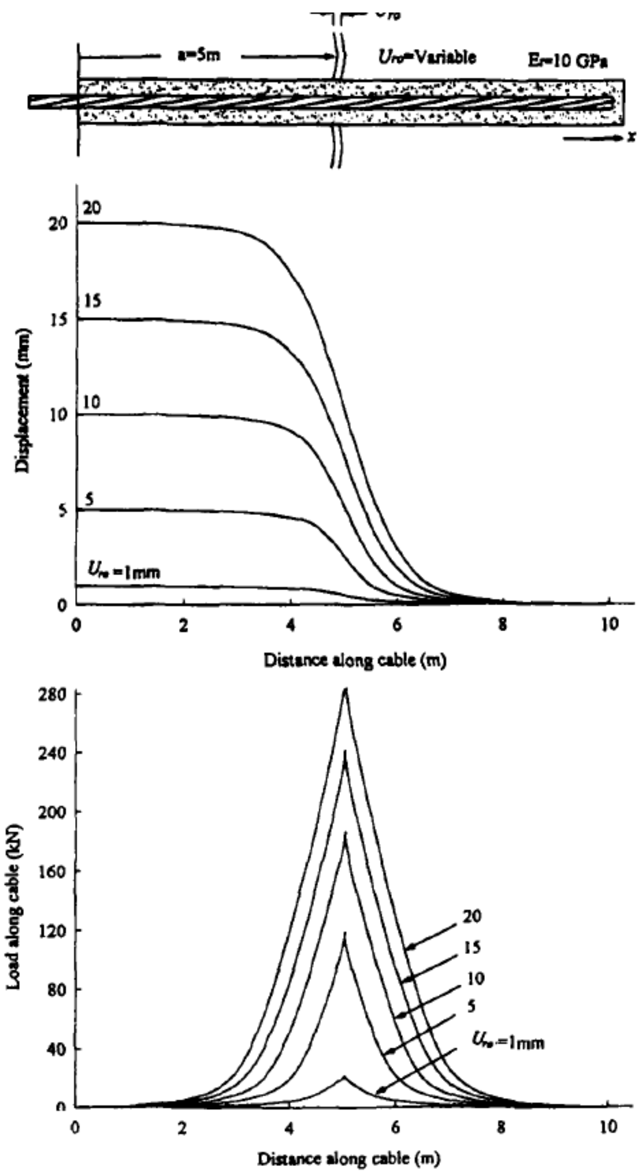
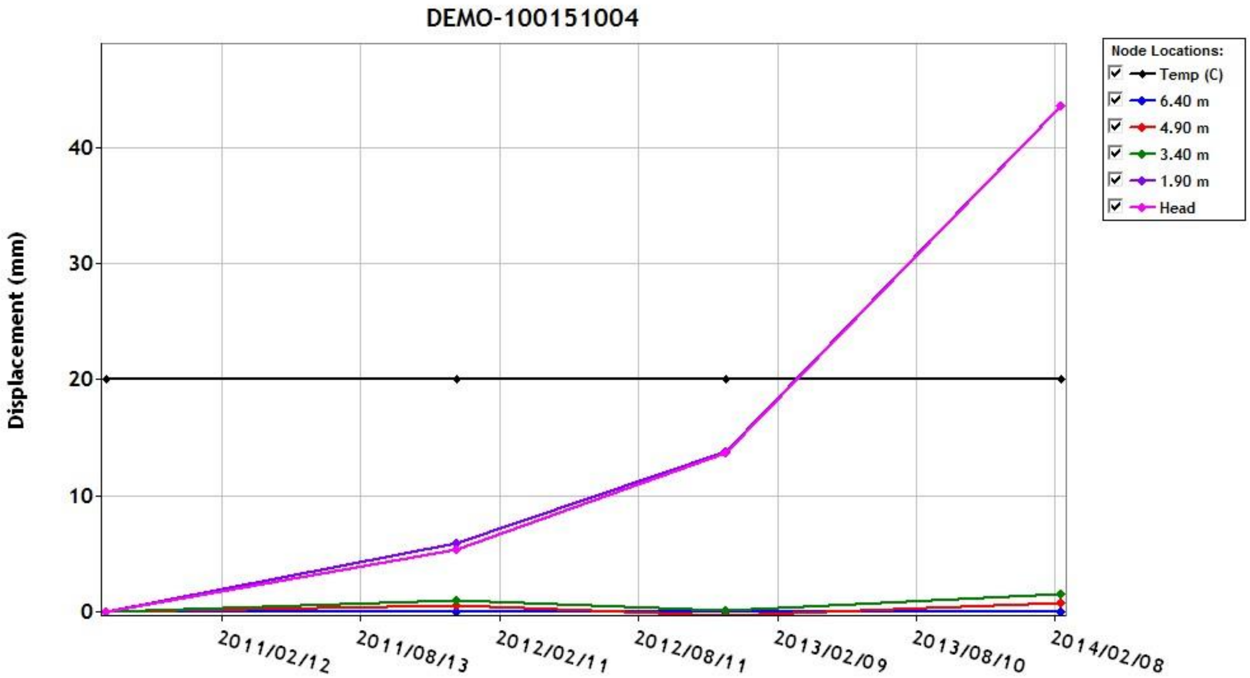


Figure 3: Displacement and load distribution for a bolt loaded rock movement localized at a single crack (from Hyett et al. paper)

Recent d_MPBX movement

The pattern of the deformation between 1.9m and 3.5m has continued. But the magnitude has now increased from 13.8mm over 43mm (i.e. 3x). Whereas previously the cable was loaded to 15 tonnes now it has certainly surpassed the yield point of the steel. When this occurs the load capacity of the cable has been fully exhausted and the cable can offer no additional restraint. Basically it is just going along for the ride and may well have ruptured (at least several wires). Additional loading due to a dynamic event or burst may cause problems.

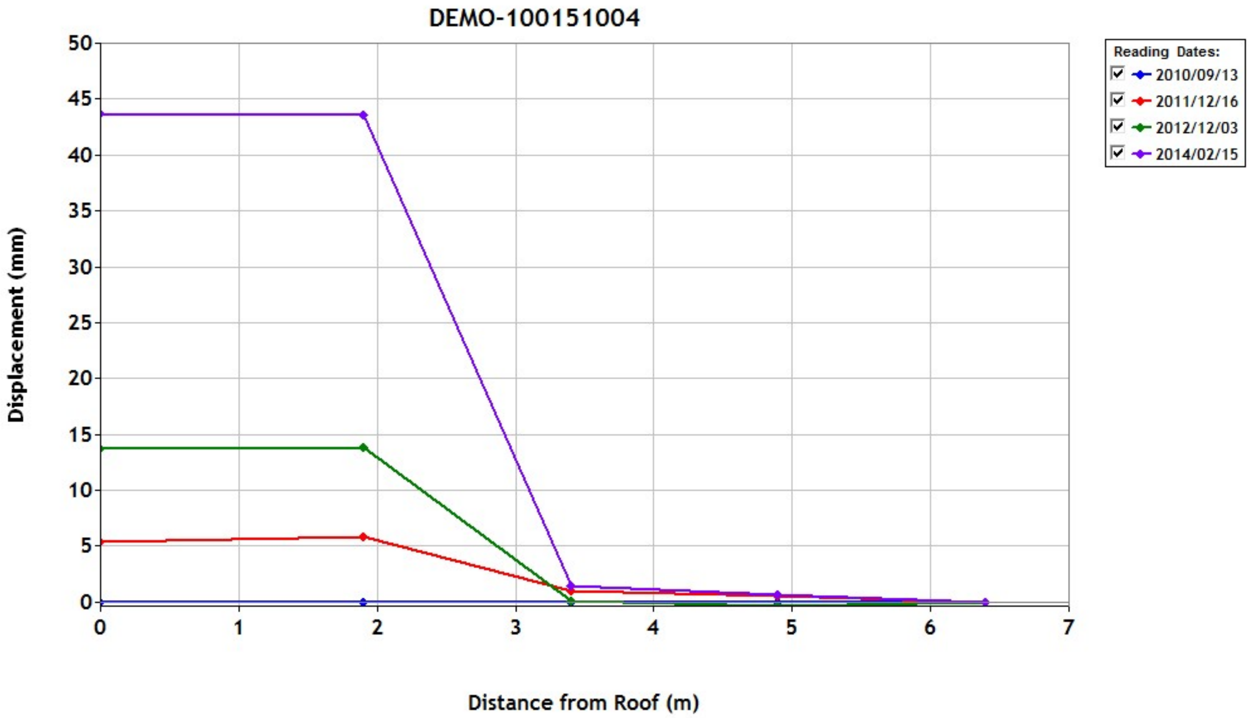


IDEAS:

For localized deformation event as observed here the cable can accommodate about 20-25mm of ground movement before the cable reaches yield. For a more distributed pattern of deformation the amount of deformation will be higher. Using plain non plated cables is a good approach in this ground.

If this situation was observed repeatedly and evidence existed that the cables were highly loaded behind the primary support then an option to debond (or partially debond using SPIRAL WRAP) the cables through this region (2m -> 3m) might be considered. However, any action related to debonding cables would need to be thoroughly justified.

Finally, as the data-logger that you have collected indicates, it is extremely important to collect the data in real time so that we can see the effects of individual blasts.


DEMO-100151004
Displacement (mm)
Distance from Roof (m)
0
5
10
15
20
25
30
35
40
45
50
0
1
2
3
4
5
6
7
Reading Dates:
2010/09/13
2011/12/16
2012/12/03
2014/02/15