

d-CABLE - User Manual



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The *d*-CABLE

Principle of operation

The *d*-CABLE is based on a miniature borehole extensometer recessed inside a surrogate tubular king wire. The instrument will measure how a certain point on the cable bolt (node point) moved in moves or stretches response to loading (Fig. 1).

Up to 6 node points may be specified where the extensometer wires attach to the kingwire. Nodal points may be concentrated at locations where it is predicted that the cable will intersect a known geological structure. By convention, node 1 is closest to the instrumentation head and Node 6 is furthest away.

The translation of the six wires is measured by 6 displacement sensors at the head of the device. As the cable stretches each displacement sensor measures the relative displacement between the head and the nodal point ($u_1, u_2 \dots u_6$). The difference between adjacent nodal points can be used to calculate the strain of the cable,

$$\varepsilon_{12}(\%) = \frac{u_2 - u_1 \text{ (mm)}}{x_2 - x_1 \text{ (mm)}} \times 100$$

or

$$\varepsilon_{12} (\mu\varepsilon) = \frac{u_2 - u_1 \text{ (mm)}}{x_2 - x_1 \text{ (mm)}} \times 10^6$$

Where ε_{12} is the average strain between nodes 1 and 2. The corresponding load can be calculated by multiplying the strain ($\varepsilon_{12}(\mu\varepsilon)$) by the stiffness of the cable (30N/ $\mu\varepsilon$ or 300kN/%).

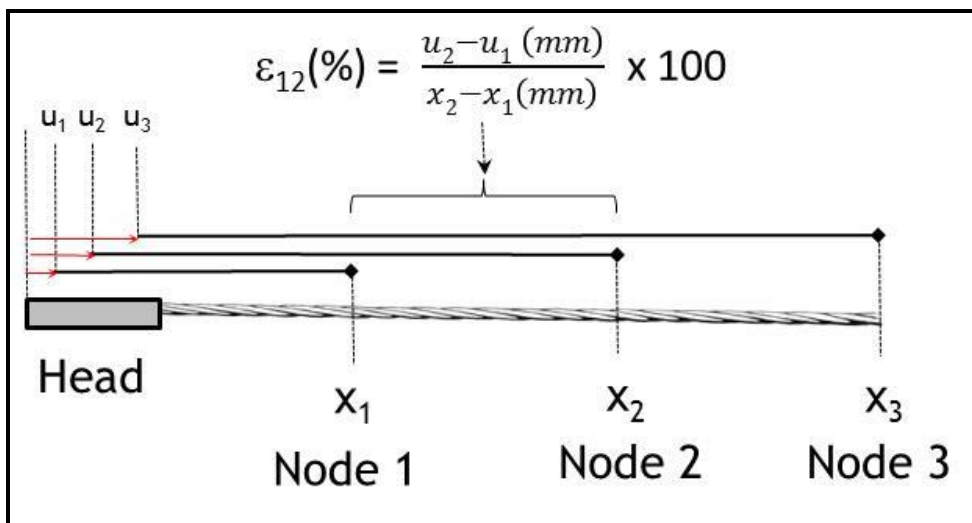


Figure 1. d-Cable: Principle of operation

Output signal

The output signal from the **d-CABLE** is a digital signal RS485 serial (9600,8, N,1) signal with the Serial Number, Sensor Type and data multiplexed on a single twisted pair. The reading comprises multiple values (one for each displacement sensor) directly in **millimeters** so that the user has a direct and immediate indication of cable deformation without having to enter the data in a spreadsheet.

NOTE: The YieldPoint manual readout unit (**d-READER**) outputs displacement directly in millimeters (resolution 0.01mm).

YieldPoint's d-Cable resolves the following issues found with the SMART cable design:

- (i) The voltage readings need to be processed in a spreadsheet prior to interpretation. This prevents instantaneous manual interpretation of deformation or load (i.e. Factor of Safety) and the use of local alarm systems.
- (ii) The potentiometer displacement transducers are inaccurate (linearity 5%FS) and are susceptible to water and blast damage.
- (iii) The analog voltage signal transmitted is not suitable for the harsh mining environment.

Manufacturing and Calibration

Very king wire is stretched to establish that the internal wiring is robust and that the wires are in the correct sequence.

Every **d-CABLE** is individually calibrated over the 125mm strope length of the displacement sensors. The calibration data sheets are shipped with every order. There is no need to apply calibration coefficients to the data.

Date of calibration: 10/21/2019

Sensor ID: 191071020

Sensor Type: d6CABLE

APPLIED DISP. (mm)	DISP-1 (mm)	DISP-2 (mm)	DISP-3 (mm)	DISP-4 (mm)	DISP-5 (mm)	DISP-6 (mm)
0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.33	8.35	8.35	8.34	8.31	8.32	8.33
16.66	16.68	16.67	16.67	16.64	16.65	16.67
25.00	25.00	25.02	25.00	24.97	24.97	24.98
50.00	50.00	50.00	50.00	49.99	50.00	50.01
75.00	74.99	74.99	75.00	75.00	74.99	75.00
100.00	99.99	99.99	99.98	99.99	100.00	100.00
125.00	124.98	124.98	124.98	124.98	124.98	124.98
CAL. SLOPE	0.9997	0.9997	0.9998	1	1	0.9999
CAL. OFFSET	0.0127	0.0146	0.0085	-0.0146	-0.0092	0.002

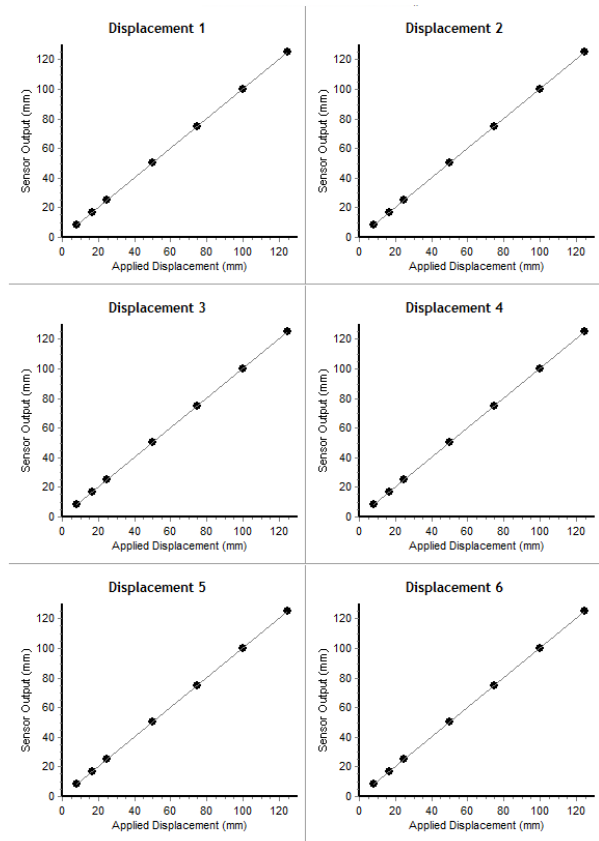
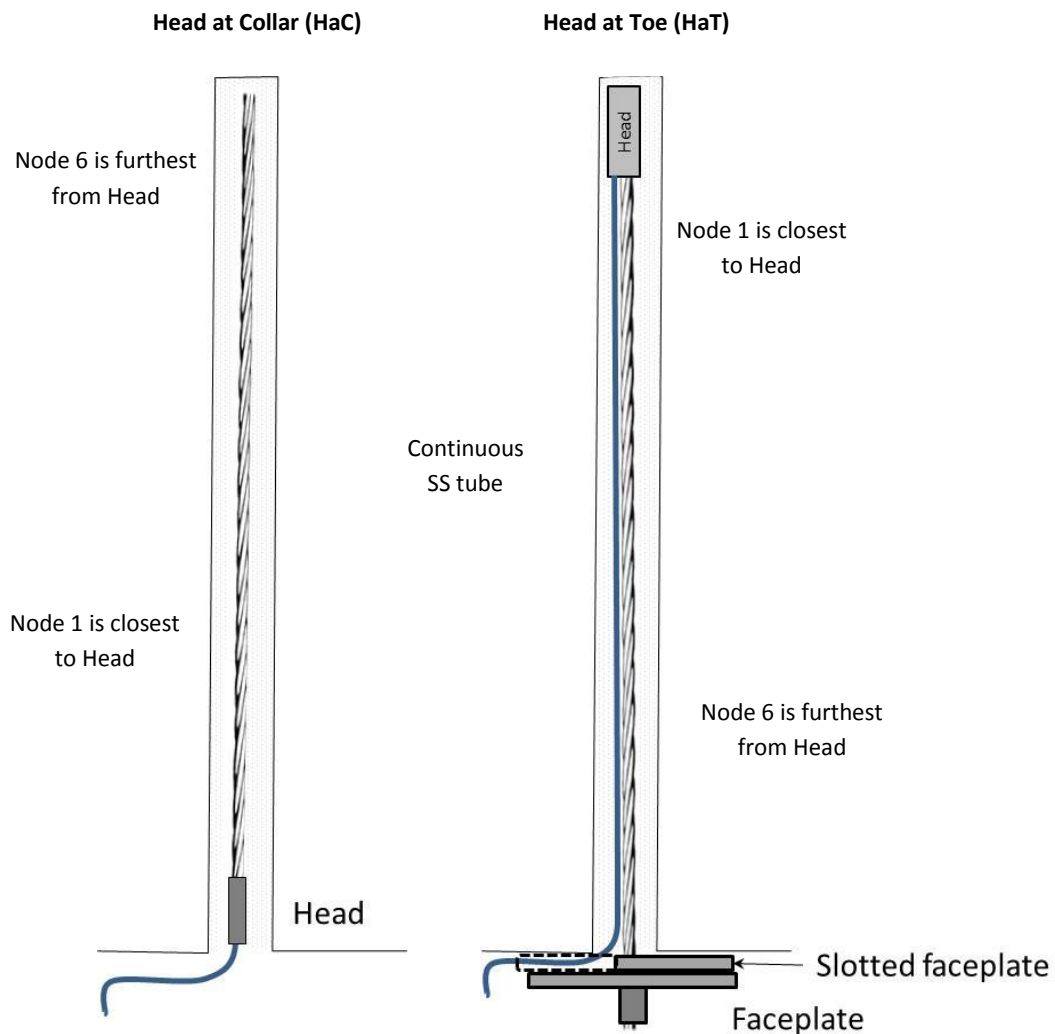


Figure 2: A typical calibration result

INSTALLATION OF THE d-CABLE

If there is no need to install a face-plate on the **d-CABLE** then it can be installed just as regular cable-bolt (HaC)

If a faceplate must be installed it is important to inform YieldPoint Inc. at the time the instrument is ordered. The most effective strategy for installing a faceplate is to recess the instrumentation head to the toe of the borehole (HaT) and retrieve the lead-wires through a continuous steel conduit. The steel conduit is attached to the cable with the BLACK cable ties which should not be removed during installation. A slotted plate is provided through which to run the conduit.



For customers using HaT configured cables, contact YieldPoint for information concerning the slotted faceplate.

Figure 3. The 3 possible options for installing a d-CABLE. Option 1 is not plated and Option 3 is the preferred option for a plated cable.

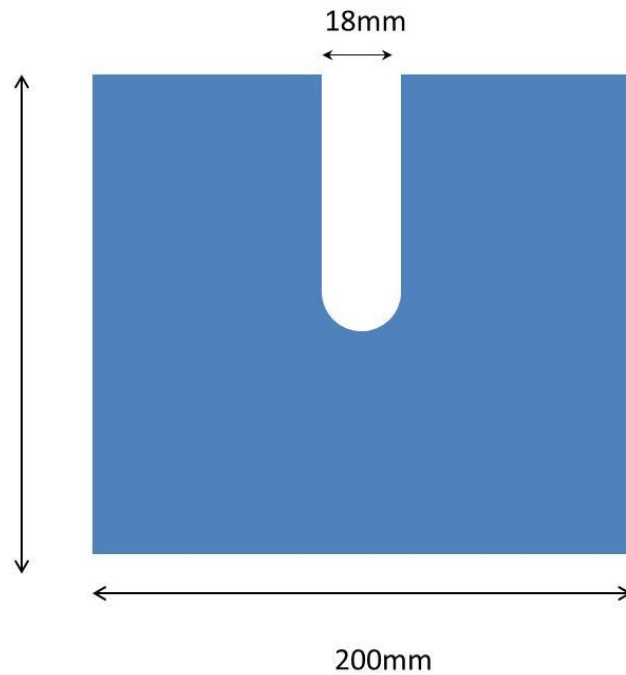


Plate thickness = 8-10mm

Figure 4. The 3 possible options for installing a **d-CABLE**. Option 1 is not plated and Option 3 is the preferred option for a plated cable.

Uncoiling the d-Cable.

1. Plug the cable into the **d-READER** and take a reading with the instrument coiled. The instrument will scroll through its anchors. The readings should be approx. 20mm.
2. Cut the smaller white cable ties to release the regular lead wire from the cable.
3. Holding the head of the cable carefully cut the large black cable ties beginning at the toe of the cable. This is most easily accomplished with the cable in an upright orientation. Remember: considerable energy is stored in a coiled cable so care must be taken.
4. Lay the cable straight and if necessary straighten the steel conduit. Do not cut the black cable ties.

IMPORTANT: For HaT cables The Yellow tape indicates the end-point of the instrumentation array.

Installing the cable in the borehole:

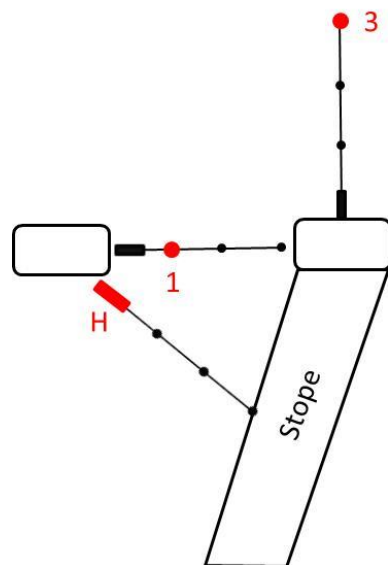
5. Blow all down-holes and in general make sure the holes are as clean as possible.
6. In poor ground insert a regular (non-instrumented) cable and grout hose to make sure the borehole is viable.
7. Cut a length of grout hole to the appropriate length for the **d-CABLE**. Remember to cut the end of the grout hose at a 60 degrees angle to make insertion easier.
8. Securely attach the grout hose to the instrumented end of **d-CABLE** with electrical tape (toe to collar grouting assumed). The angled end of the grout hose should be within 150mm of the capped CPVC tube at the instrument head.
9. Insert into the borehole carefully by pushing on the grout hose. Tape the grout hose to the **d-CABLE** at regular intervals during insertion.

Best Practises for grouting.

For mines regularly using cables bolts the d-cable should be installed with exactly the same procedures. Information on best practises for grouting can are here.

Selection of a reference Point.

Since bore extensometers measure displacement then the values need to be referenced to a point that is not moving, or that moves least. This should be considered before instrument installation.



The head or any nodal point can be set as the reference point. For HaC installations the reference point will usually be the most distal nodepoint.

DATA REDUCTION FOR THE d-CABLE

The **d-CABLE** is based on a miniature borehole extensometer manufactured into a surrogate tubular king-wire. A total of up to six wires are fixed to the king-wire at nodal locations x_1, x_2, \dots, x_6 . Node 1 is always closest to the head. The translation of the six wires is measured by 6 displacement sensors at the head of the device. As the cable stretches each displacement sensor measures the relative displacement between the head and the nodal point ($u_1, u_2 \dots u_6$). The difference between adjacent nodal points can be used to calculate the strain of the cable,

$$\varepsilon_{12}(\%) = \frac{u_2 - u_1 \text{ (mm)}}{x_2 - x_1 \text{ (mm)}} \times 100$$

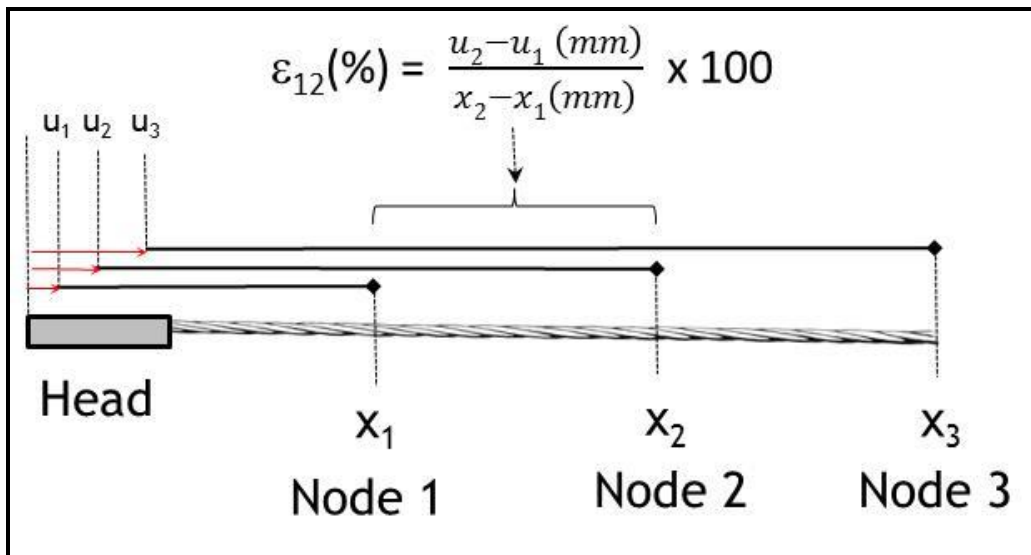
or

$$\varepsilon_{12} (\mu\varepsilon) = \frac{u_2 - u_1 \text{ (mm)}}{x_2 - x_1 \text{ (mm)}} \times 10^6$$

Where ε_{12} is the average strain between nodes 1 and 2. The corresponding load can be calculated by multiplying the strain ($\varepsilon_{12}(\mu\varepsilon)$) by the stiffness of the cable (30N/ $\mu\varepsilon$ or 300kN/%).

The nodal points can be concentrated at locations where it is predicted that the cable may intersect a known geological feature. The location of the nodal points is specified by the customer.

$$F(\text{kN}) = \varepsilon_{12} \times 30,000$$



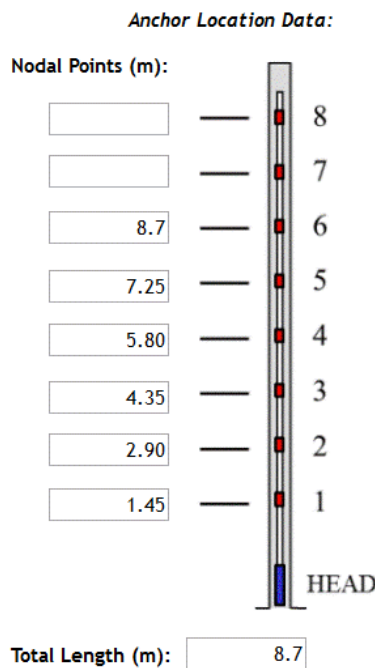
IMPORTANT: Sensor 1 is closest to the head.

The **d-CABLE** can be applied to any type of cable bolt: Plain Strand, Garford Bulb or de-bonded cable, and the data reduction math does not change. It is also applicable to cables that will be spun in resin and that will be twinned. The user can specify the number of displacement sensors to be arranged along the instrument in order to capture the elongation along the entire length of the cable but maybe with some higher coverage near one end or the other.

Visualization Using VantagePoint

Vantage point is a powerful visualization tool for displaying data from the **d-CABLE**.

The configuration of the **d-CABLE** is provided on the last page of the calibration sheet.



The nodal points can be input into the instrument page in VantagePoint.

Instrument ID	Name	Type	Level	Project	Location
160671031	test	dCable	12		EP-278-20W

Instrument ID:	160671031	Instrument type:	dCable
Channels:	7	Head at:	collar
Name:	test	Stiffness (kN/%):	240
Project:	<input type="text"/>	Capacity (kN):	260
Location:	<input type="text"/>	Length (m):	8.7
Coordinates:	east, north, depth:	Stroke Length (mm):	8
Azimuth:	12	Reference Anchor:	8
Dip:	12	Bulbed:	<input checked="" type="checkbox"/>
Level:	12	Plated:	<input type="checkbox"/>
Borehole:	12	Active:	<input checked="" type="checkbox"/>
Zero timestamp:	2016-01-01 16:53:07		
Install date:	2016-09-14 10:45:56		
Installed by:	<input type="text"/>		
Purpose:	test		
Notes:	test		

Borehole Toe

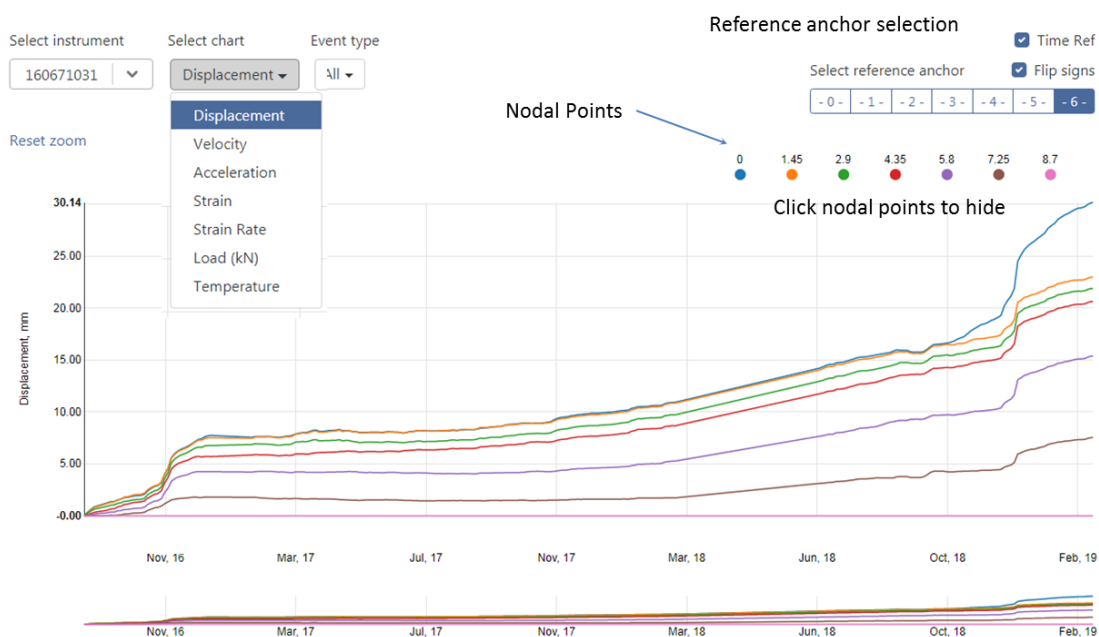
Borehole Collar

Additional information can also be added to the database.

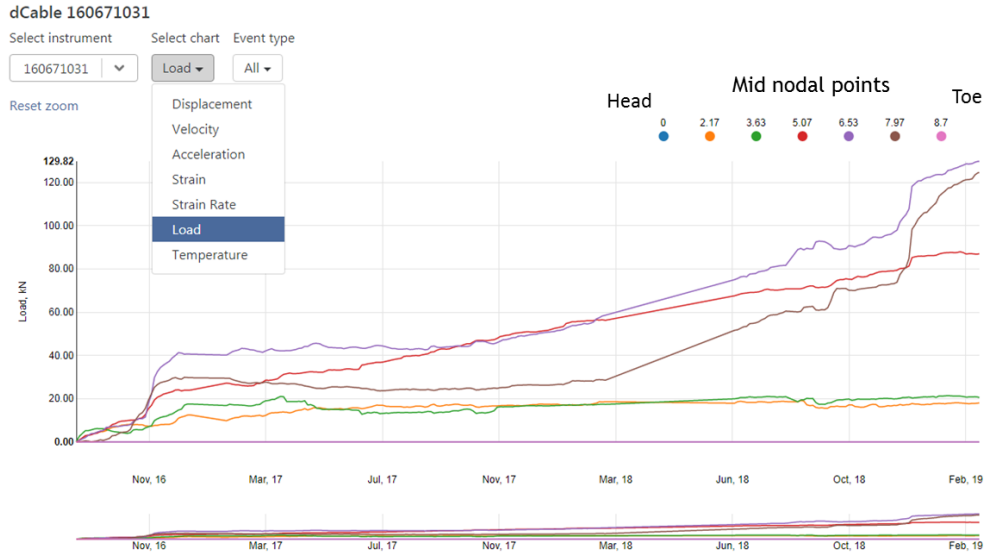
IMPORTANT: The nodal points must be entered before the temporal and spatial plots will render.

Temporal plots

Temporal plots can be selected for displacement, velocity (disp rate), strain and Load



A temporal plot for displacement

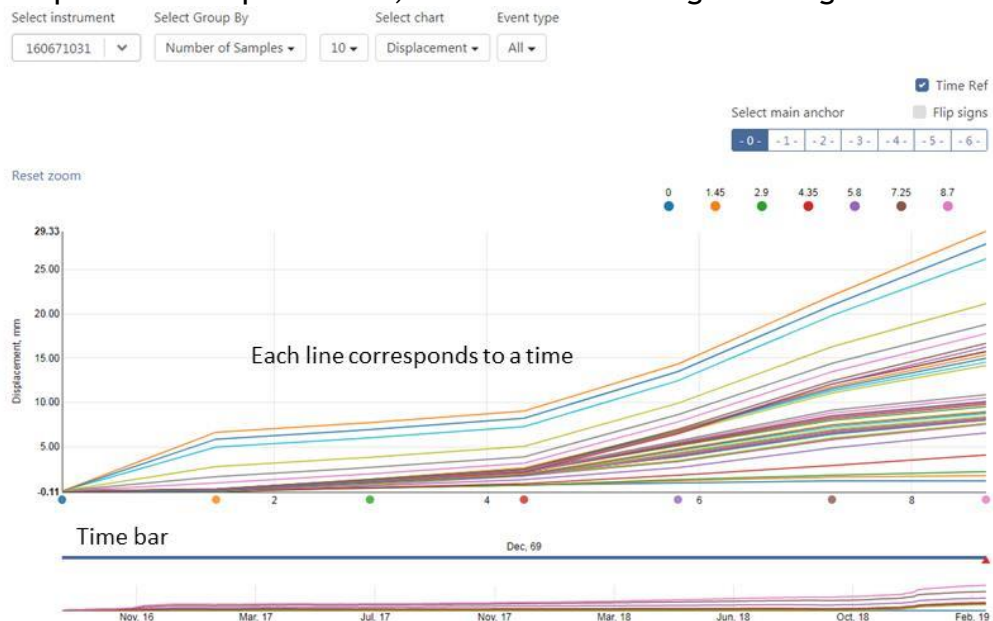


The corresponding temporal plot for strain

Temporal plots can be used to associate mining activity events (blasts and seismic events) with the development of instrument load.

Spatial Plots

For a multipoint instrument such as a d-Cable a spatial plot is used to represent the profile of displacement, strain or load along the length of the instrument.



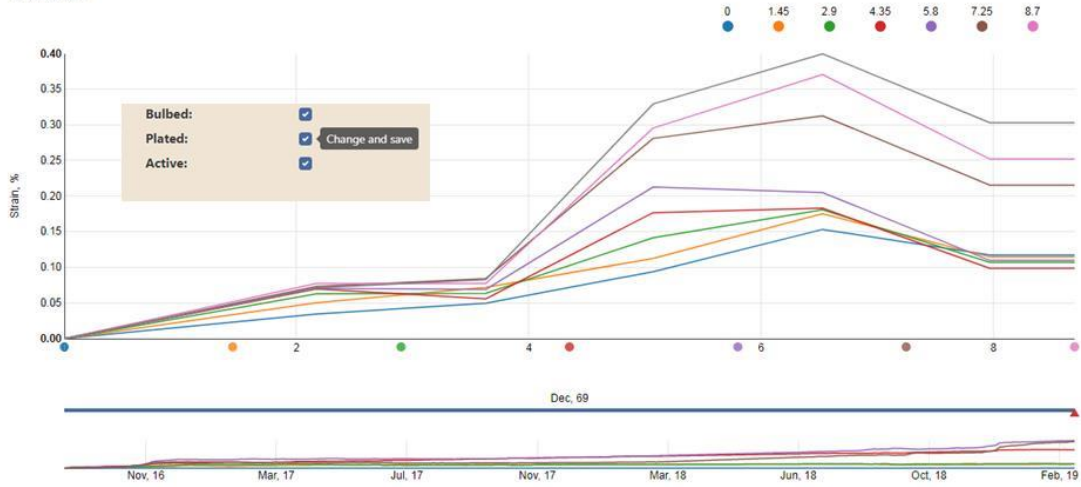
The displacement spatial plot

dCable 160671031

Select instrument Select Group By Select chart Event type

160671031 Number of Samples 10 Strain All

Reset zoom

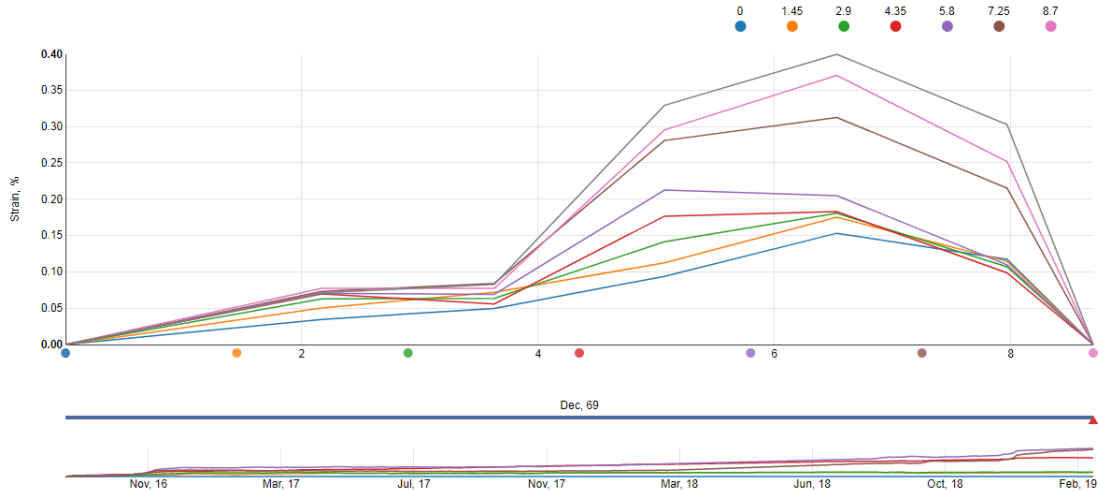


dCable 160671031

Select instrument Select Group By Select chart Event type

160671031 Number of Samples 10 Strain All

Reset zoom



The load spatial plot with (top) and without a faceplate.

When the graph is rendered the progressive changes are illustrated in sequence.

TYPICAL APPLICATIONS

d-CABLE have been widely used for many application in both civil and mining projects including:

- ▲ Slope monitoring.
- ▲ Monitoring cable reinforcement in tunnels and drifts
- ▲ Monitoring cable reinforcement in stopes and other large openings
- ▲ Monitoring cables in fill mats
- ▲ Monitoring ground anchors
- ▲ Monitoring strand reinforced concrete
- ▲ Monitoring tie-backs