GUIDELINES AND BEST PRACTISES FOR THE UTILIZATION OF TENDON MONITORING TECHNOLOGY IN HARD ROCK MINES

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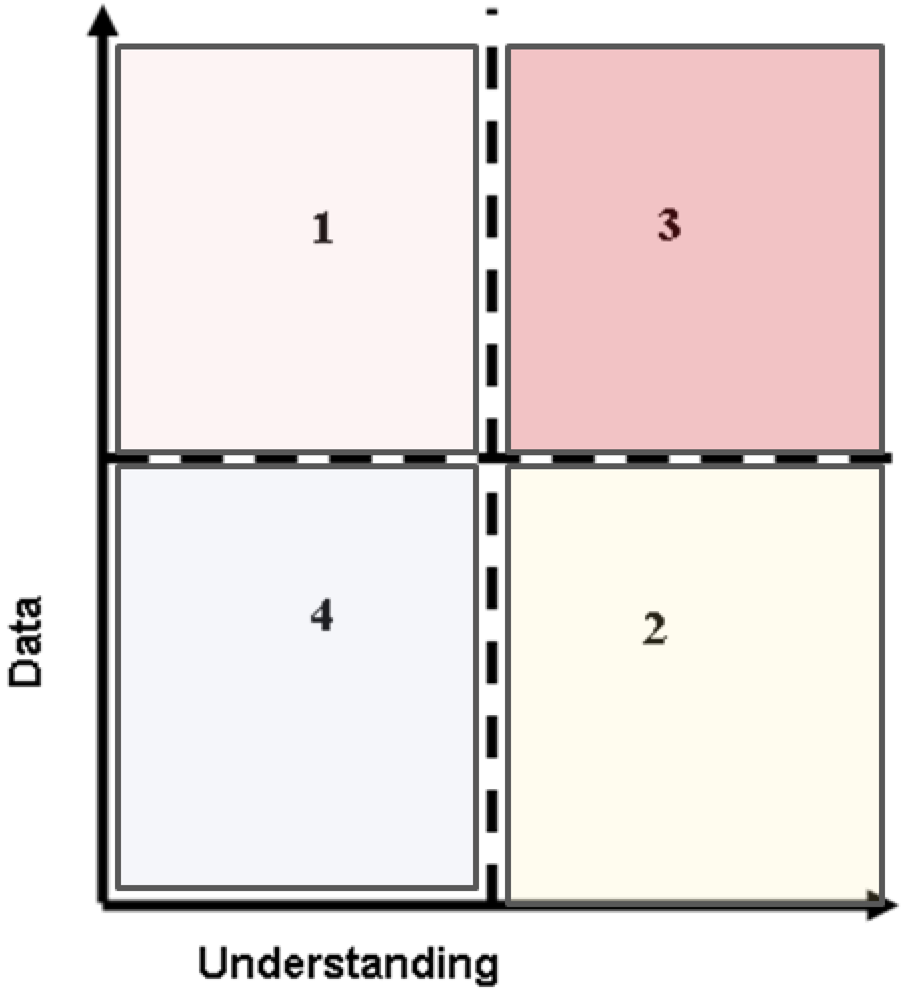
WE CAN ALL AGREE!

Doyle (1892) in the book "A Scandal in Bohemia", the fictional detective Sherlock Holmes advises Dr Watson that:
"It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts."

An Inconvenient Observation

In a rock mechanics context the need for geotechnical data was articulated by Hoek (1994). In a letter to the International Society of Rock Mechanics (ISRM) News Journal he provided a sobering commentary:

“I see almost no research effort being devoted to the generation of the basic input data which we need for our faster and better models and our improved design techniques. These tools are rapidly reaching the point of being severely data limited.”



- In region 1 there are good data but little understanding;
  - this is where statistics is the appropriate modelling tool.
- In region 3 one has both the data and the understanding;
  - models can be built, validated and used with conviction.
- Regions 2 and 4
  - data-limited problems
  - relevant data are unavailable or cannot easily be obtained.

MONITORING PHILOSOPHY 1

Bieniawski (1988) suggested that:
“…..geological and rock mechanics data must be collected in sufficient quantity and of high quality; data interpretation should be performed specifically for purposes of engineering design; and innovative design approaches should be used to bring about improvements in productivity and safety”.

Bolt rupture occurs at the end of a very complex and involved geotechnical process. Is a design approach based on bolt rupture realistic? **More importantly, from a liability standpoint is it prudent????** For ethical/legal reasons YieldPoint Inc. would never want to market a product that provided a BOOLEAN output related to rockbolt rupture.

The loading behavior of the rock bolt is intrinsically driven by the rock mass. Once the rock mass begins to fail the effectiveness/accuracy of existing design tools begins to degrade. Therefore it is extraordinarily difficult to interpret why a sub-population of bolts might fail, whether that represents a hazard, and what action should be taken. This lack of understanding could make MIGS II the most expensive project that RTC has ever proposed for its partners.

MONITORING PHILOSOPHY 2

At YP the focus is completely on improving Rock Bolt Design.

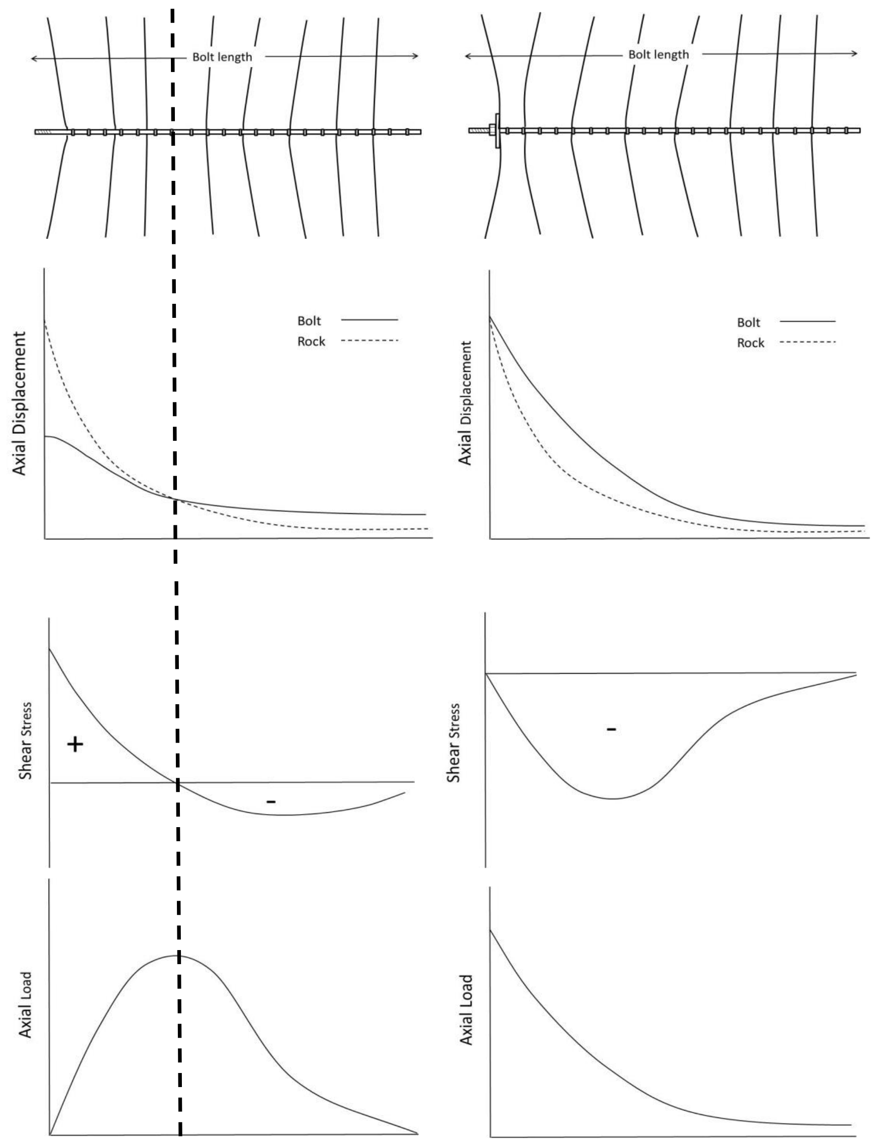
RULE #1. Must have numerical models and associated understanding in place before even considering instrumentation. START THE FEEDBACK ENGINE (NB. *it's a rotary engine*)

RULE #2 Data limited approach: Generate "rich" data that can provide feedback for computational design tools. Analyze patterns in space and time , focus on comparative studies (data limited approach)

- Relate mining events to increases in rock bolt load.
- Relate different bolt types to different rates of load increase
- Promote understanding that critical design parameter for rock bolts is stiffness.

From an operational perspective the objective is to assess the *reserve capacity* of the rock bolt system and hence whether there is requirement for proactive rehabilitation. HOW MUCH GAS IS LEFT IN THE TANK?

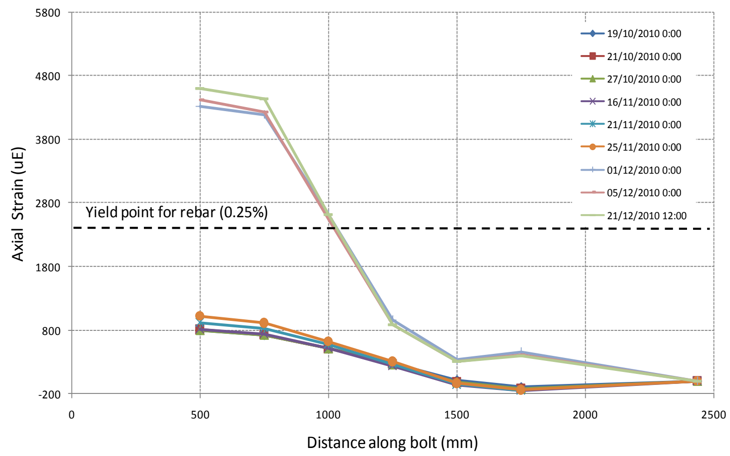
MODE 1. Axial Loading



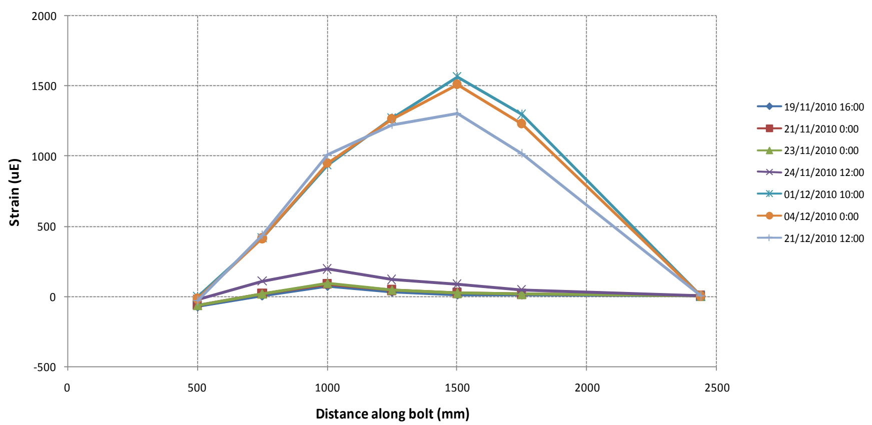
Freeman (1978) to explain data obtained from the Kielder experiment(UK)

These bolt may have completely different strain profiles

RESIN REBAR 100975102

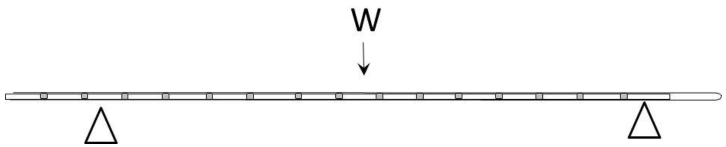


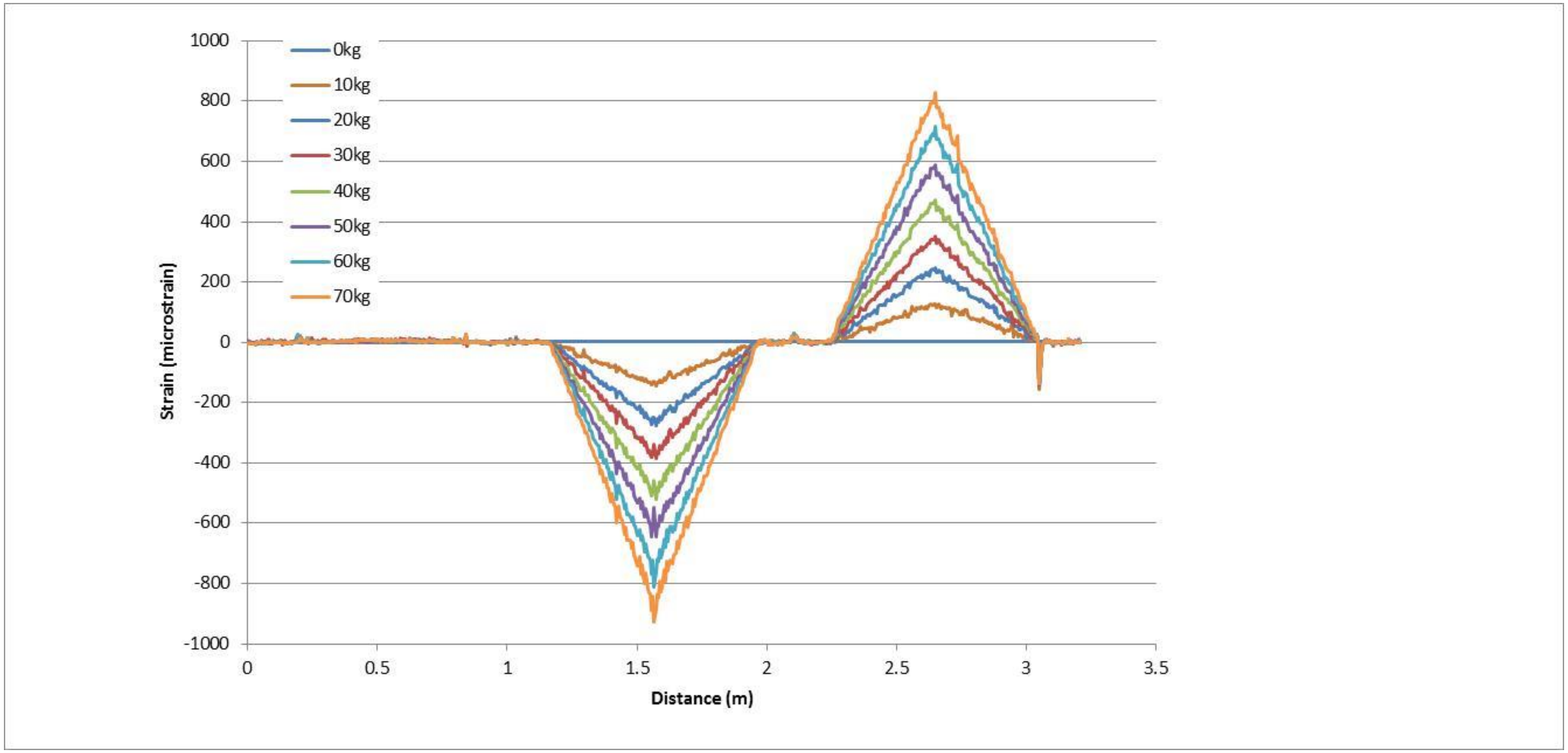
RESIN REBAR 101175001



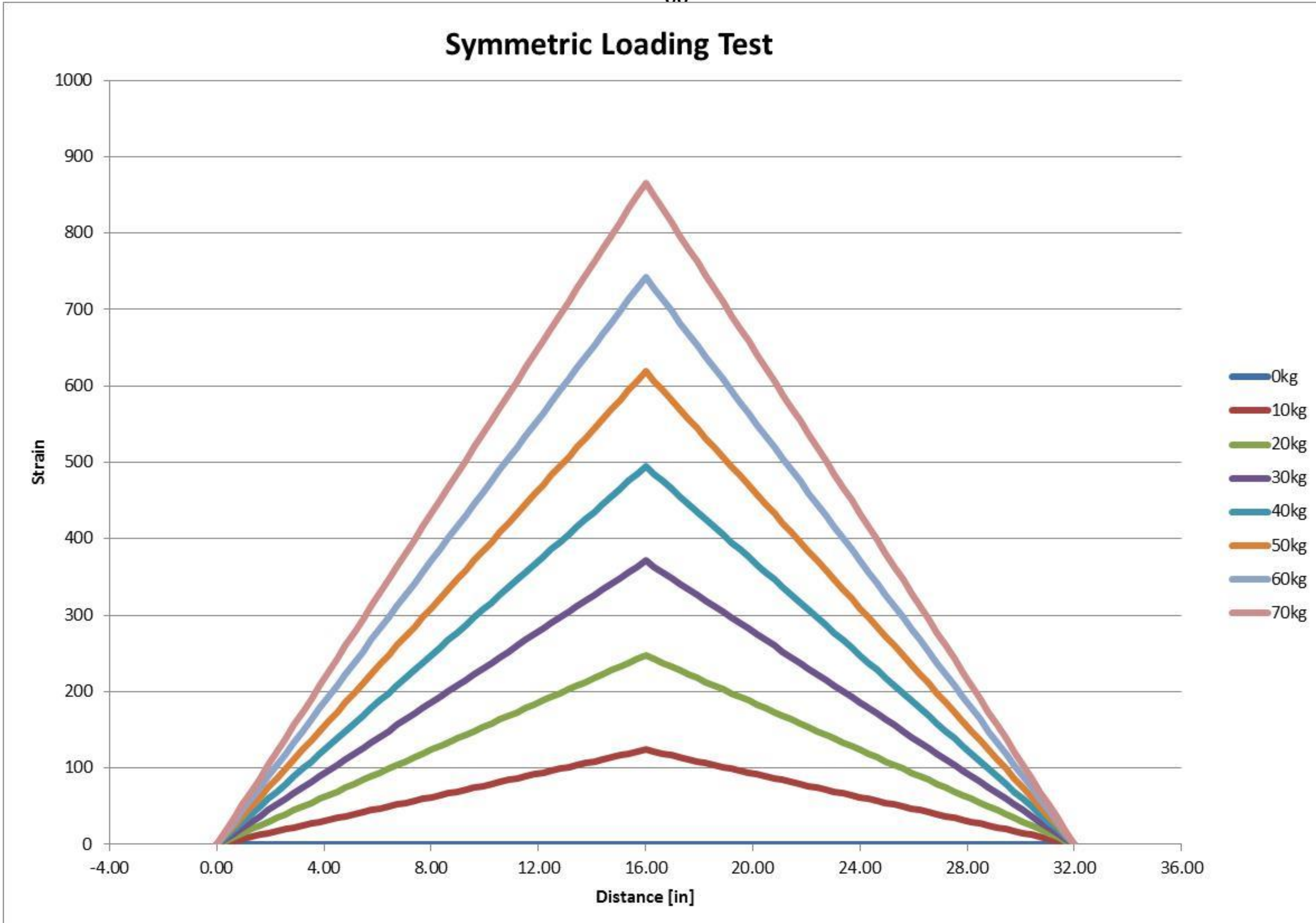
In reality it is found that loads quickly transfer onto the rebar's bolt plate depending upon the proximity of the deformation to the collar.

2. How about Bending??



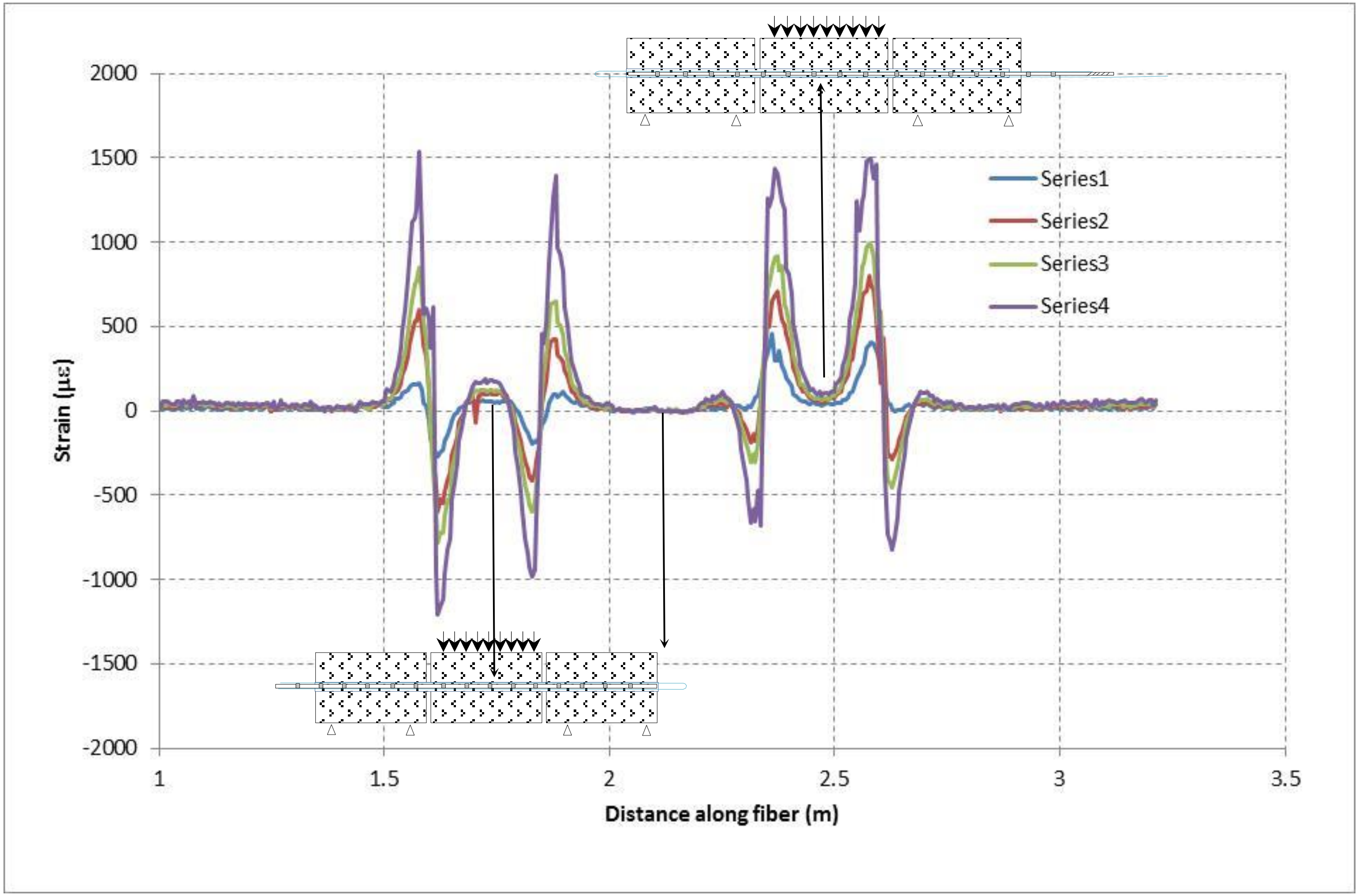


W

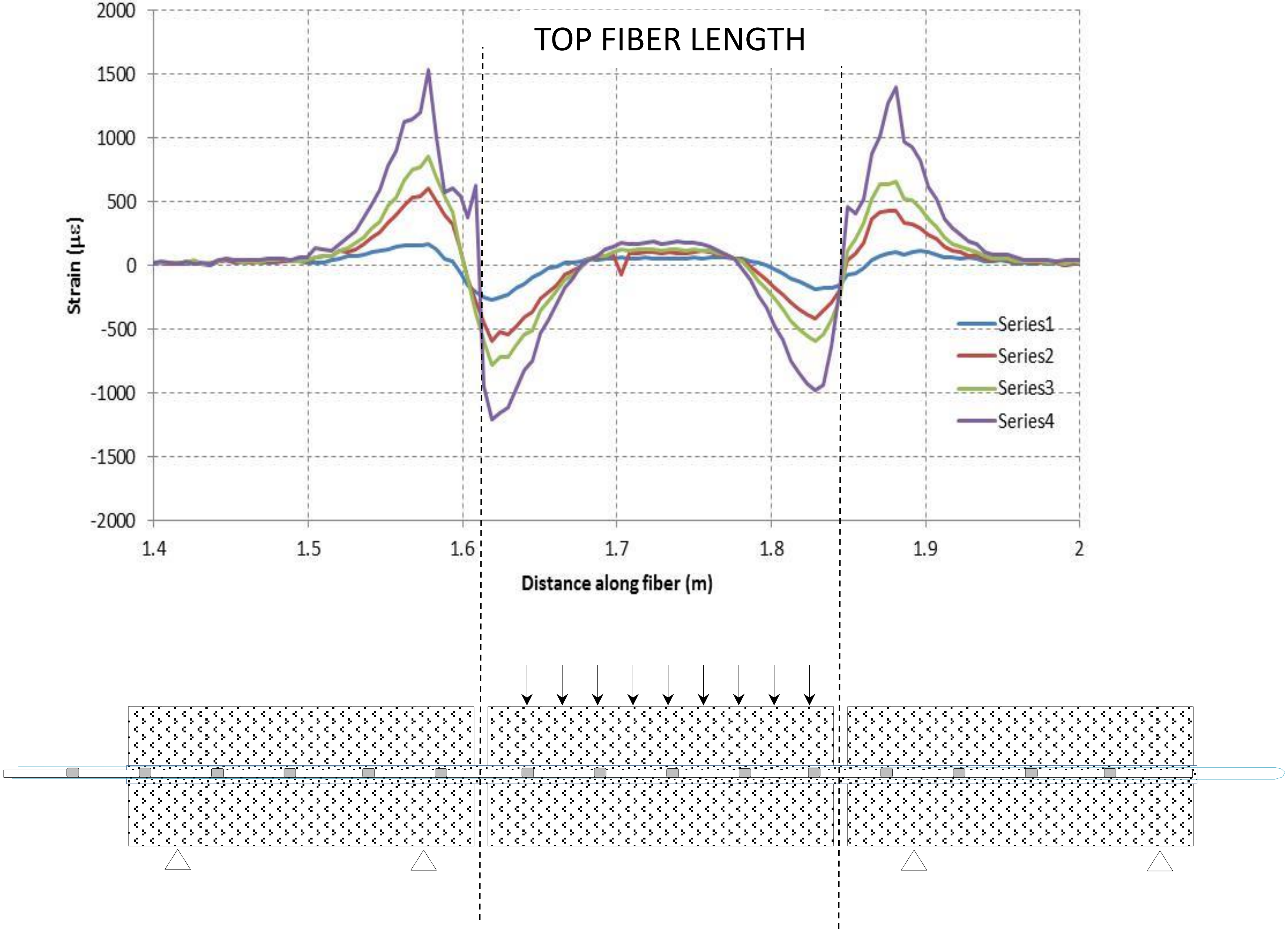


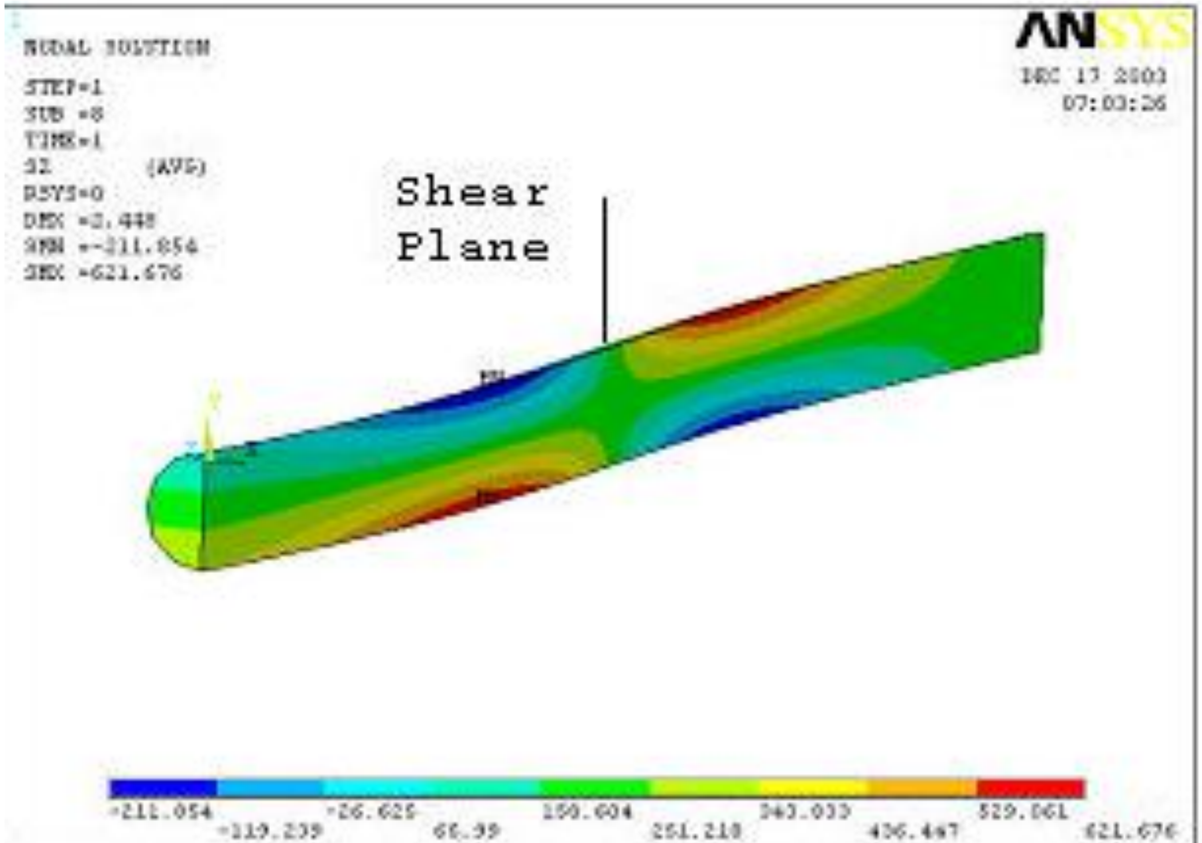
Symmetric Loading Test
Strain
1000
900
800
700
600
500
400
300
200
100
0
-4.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
36.00
Distance [in]
0kg
10kg
20kg
30kg
40kg
50kg
60kg
70kg

Mode 3: Shear

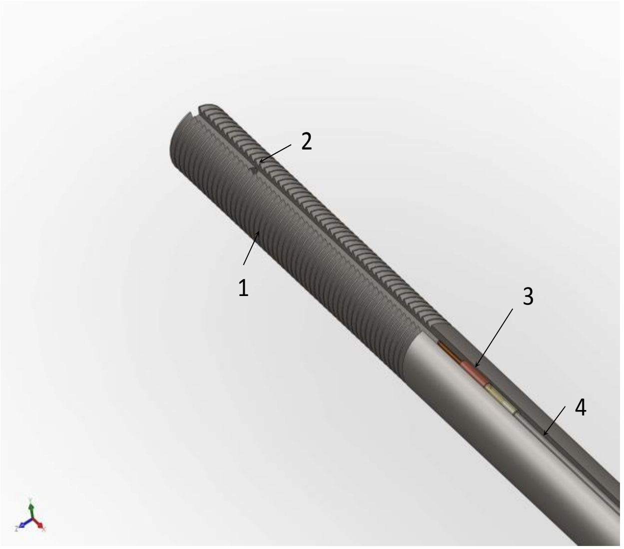


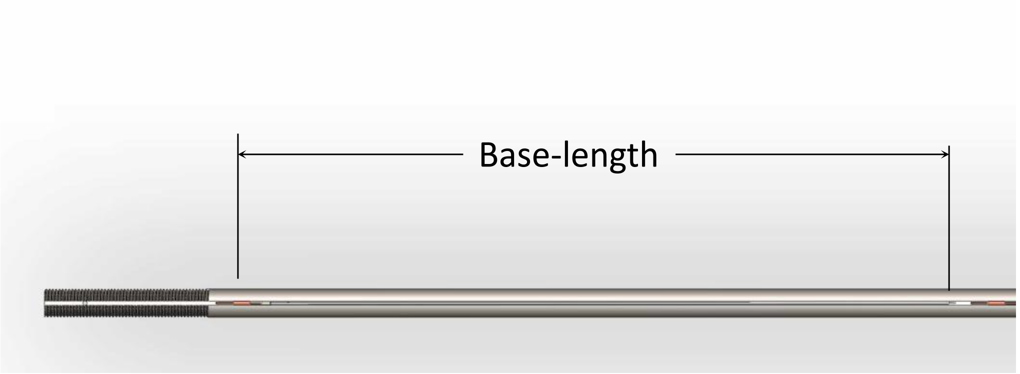
Strain (με)
2000
1500
1000
500
0
-500
-1000
-1500
-2000
1
1.5
2
2.5
3
3.5
Distance along fiber (m)
Series1
Series2
Series3
Series4


TOP FIBER LENGTH
2000
1500
1000
500
0
-500
-1000
-1500
-2000
Strain (με)
1.4
1.5
1.6
1.7
1.8
1.9
2
Distance along fiber (m)
Series1
Series2
Series3
Series4


ANSYS
NODAL SOLUTION
STEP=1
SUB =8
TIME=1
S2 (AVG)
DSYS=0
DMX =2.448
SMN =-211.054
SMX =621.676
DEC 17 2003
07:03:26
Shear
Plane
-211.054
-119.239
-26.625
66.99
160.604
251.218
343.033
436.447
529.061
621.676

d-REBAR Design

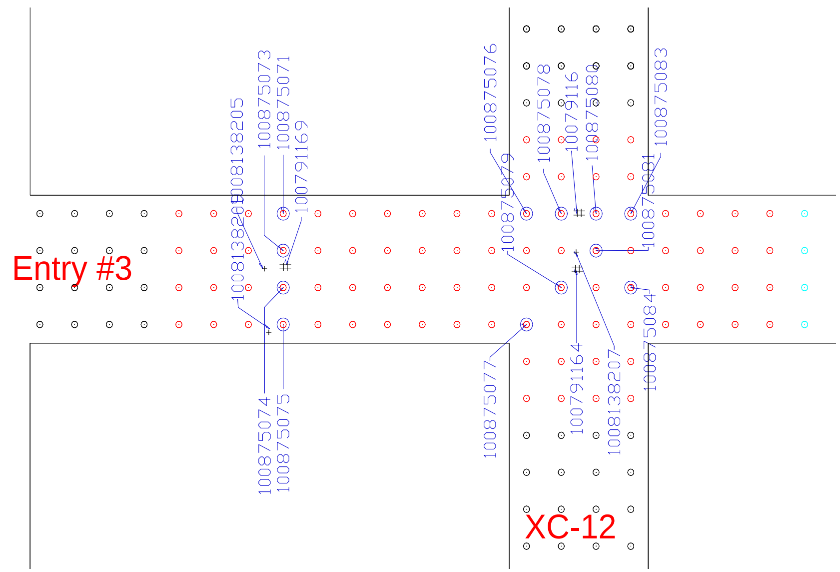




Provisional patent obtained September 2011

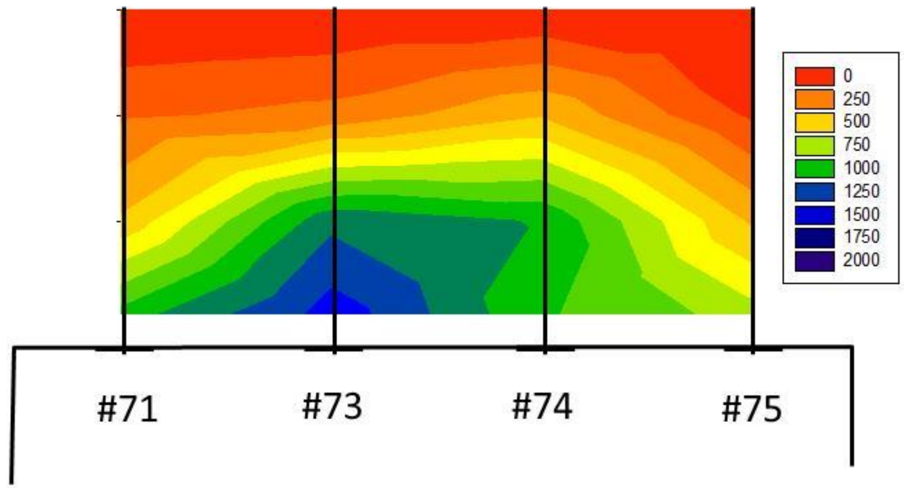
YieldPoint
Sensing the future

d⁶REBAR Case Study – Mine A

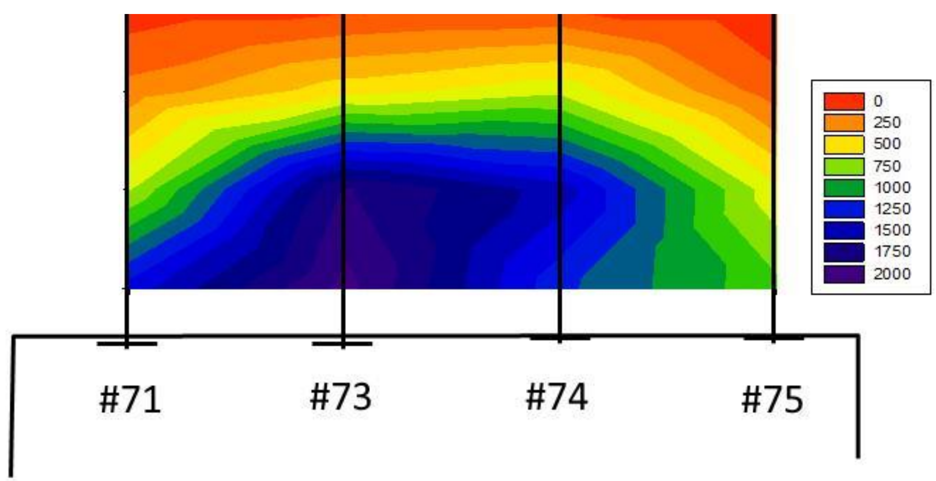


d^6REBAR Case Study –Strain Distribution $153\mu\varepsilon$=10kN

First Reading: 08/29/2010

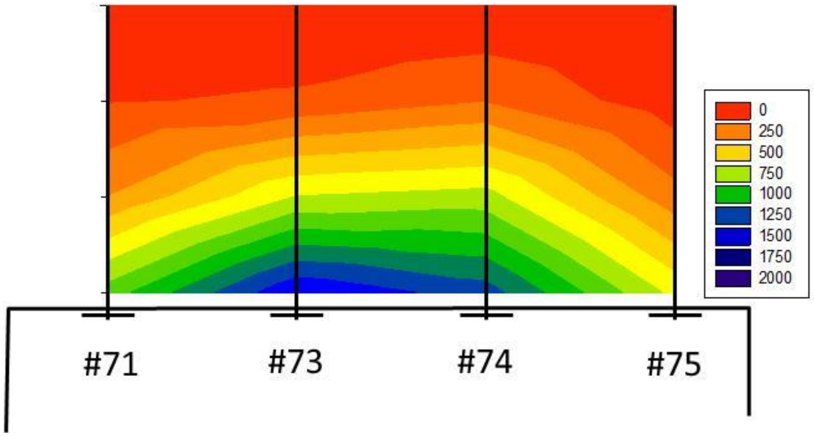


07/02/2011

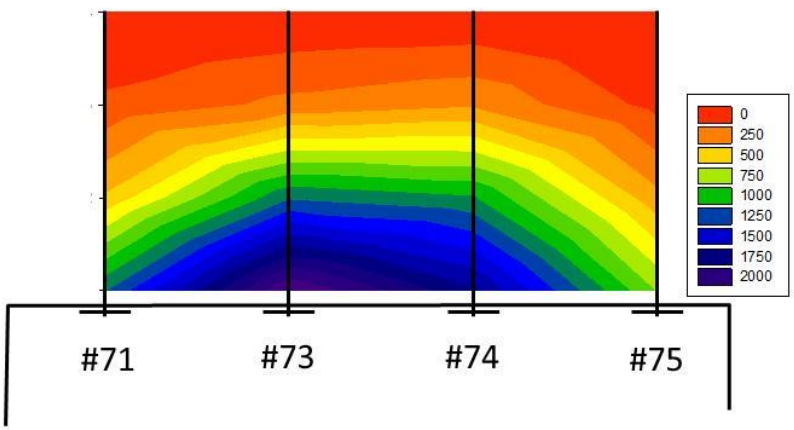


d^6REBAR Case Study –Displacement Distribution

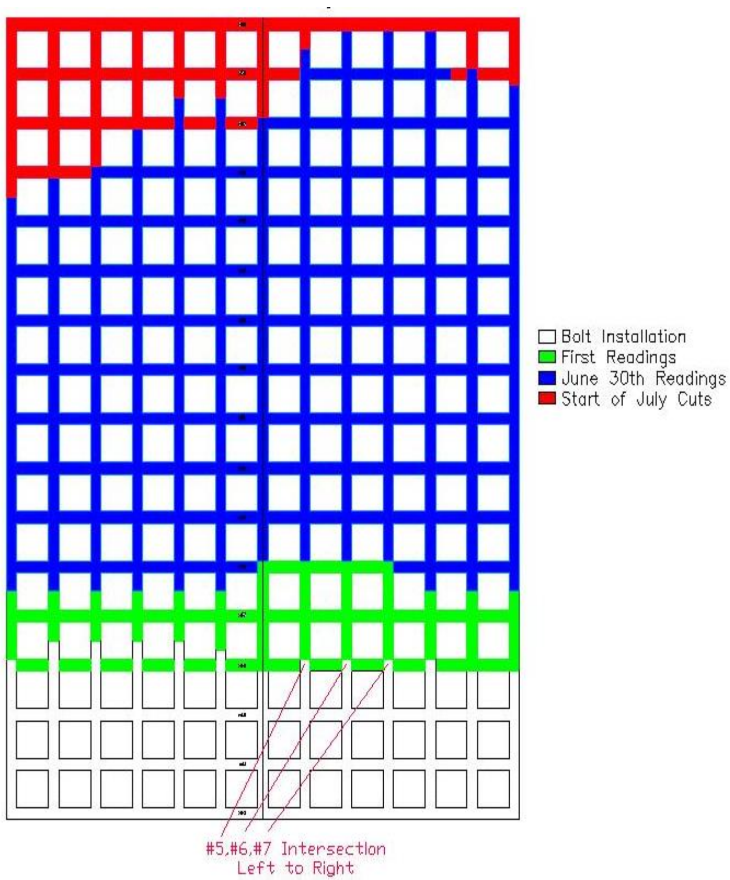
First Reading: 08/29/2010

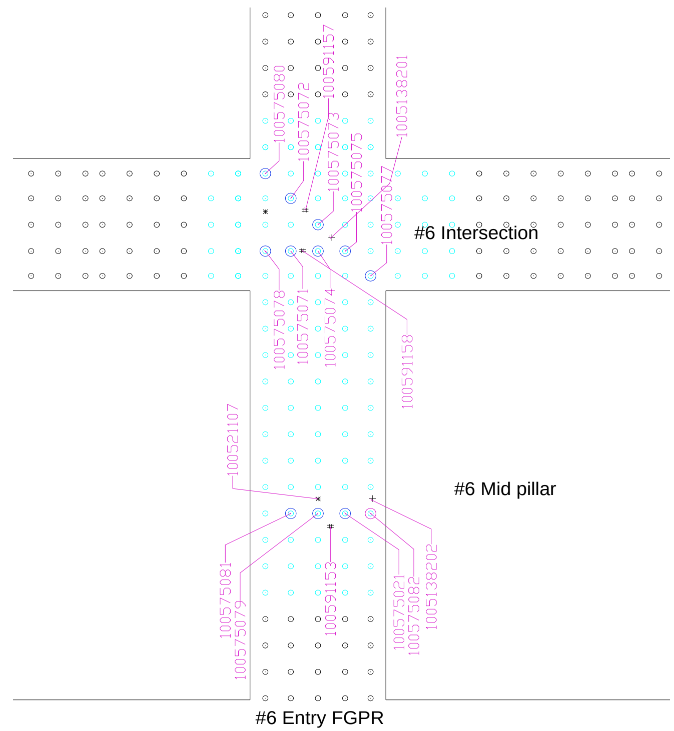


02/07/2011

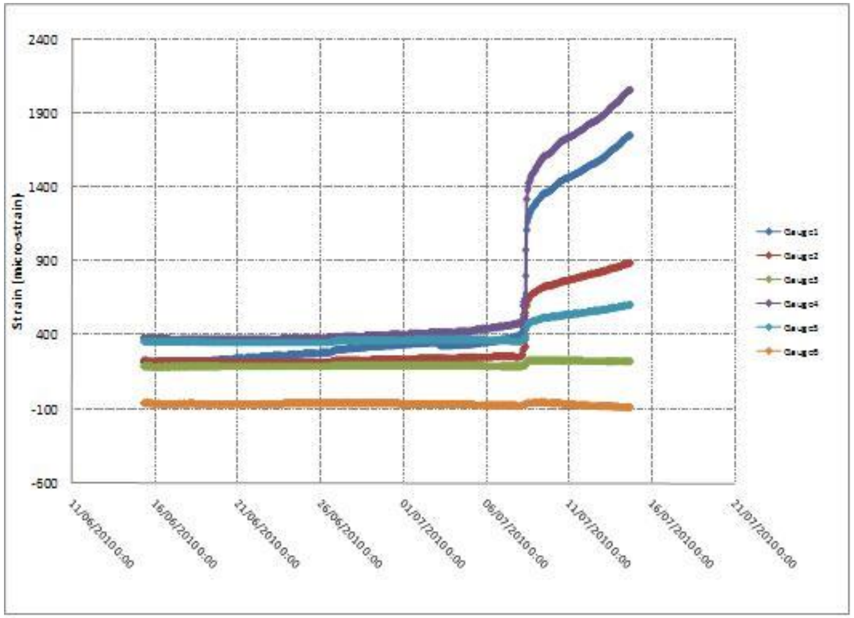


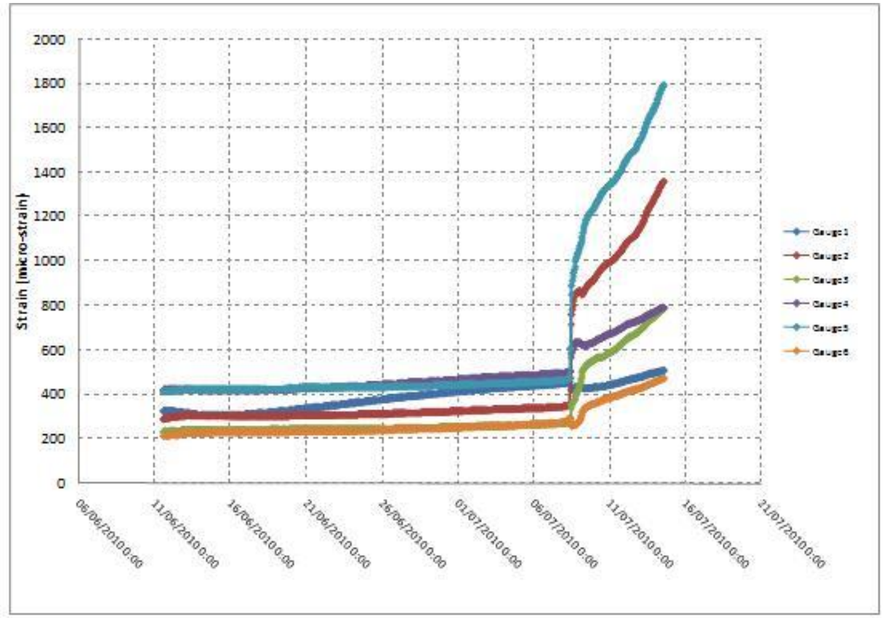
d^6REBAR Case Study – Mine B

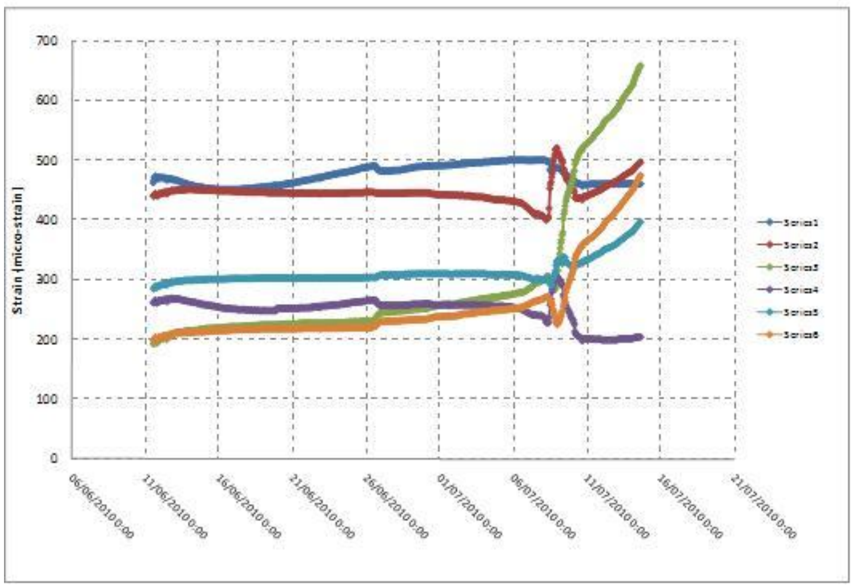


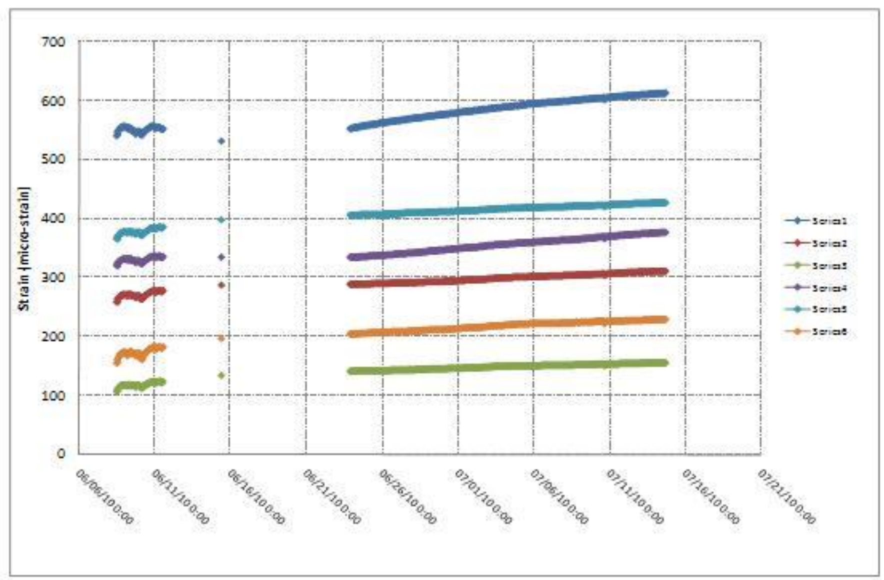


FGP d^6REBAR Results - Intersection

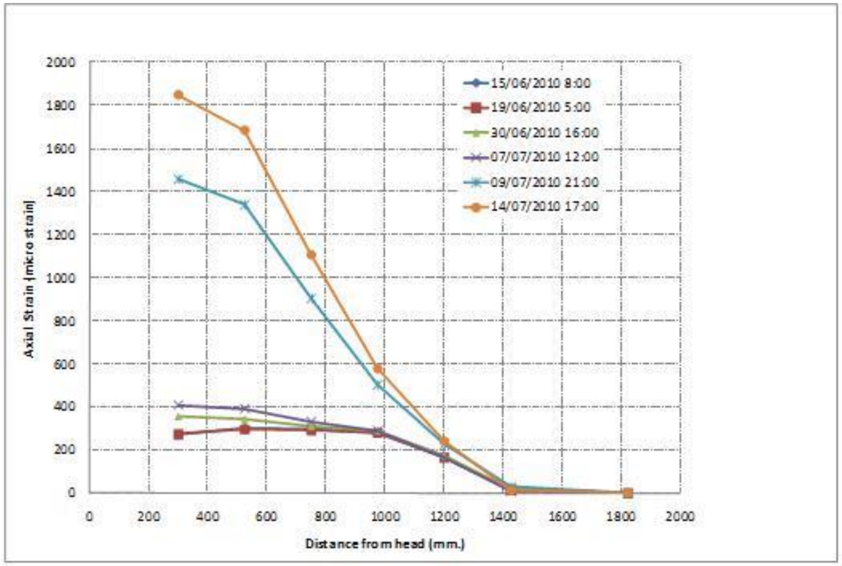


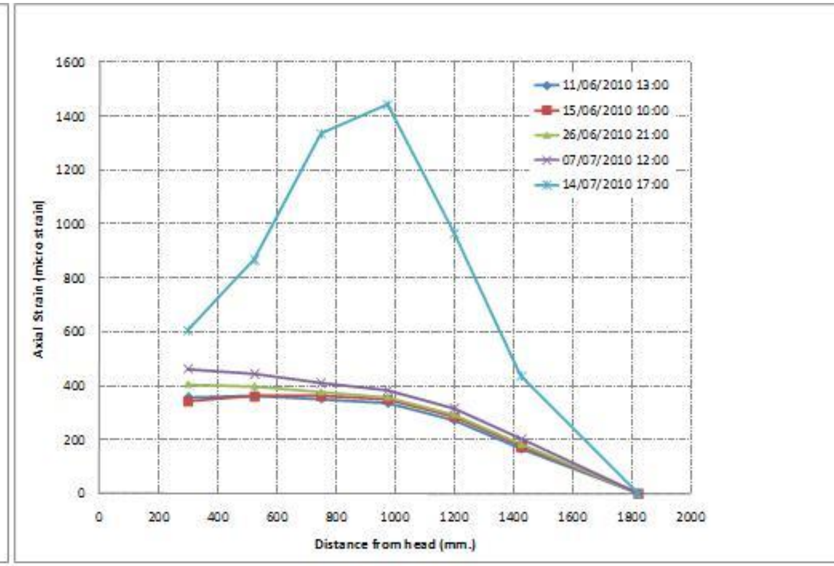


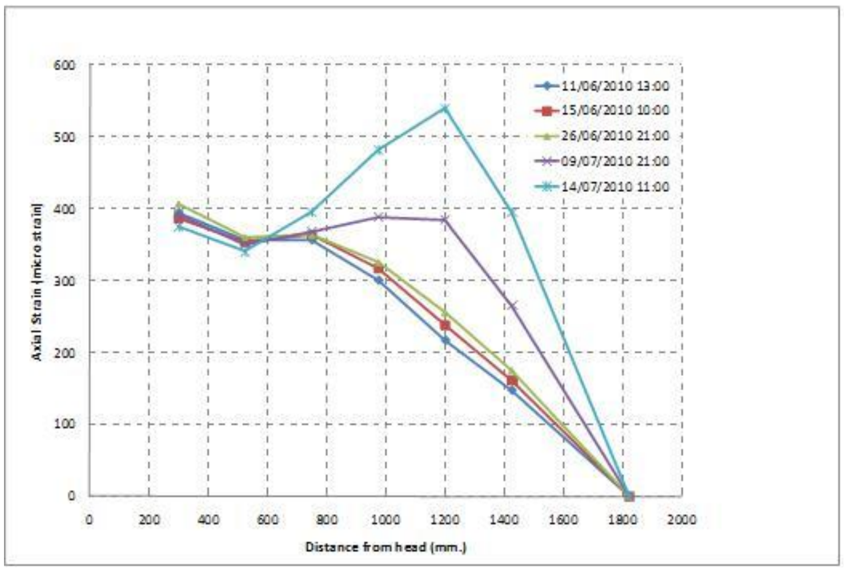


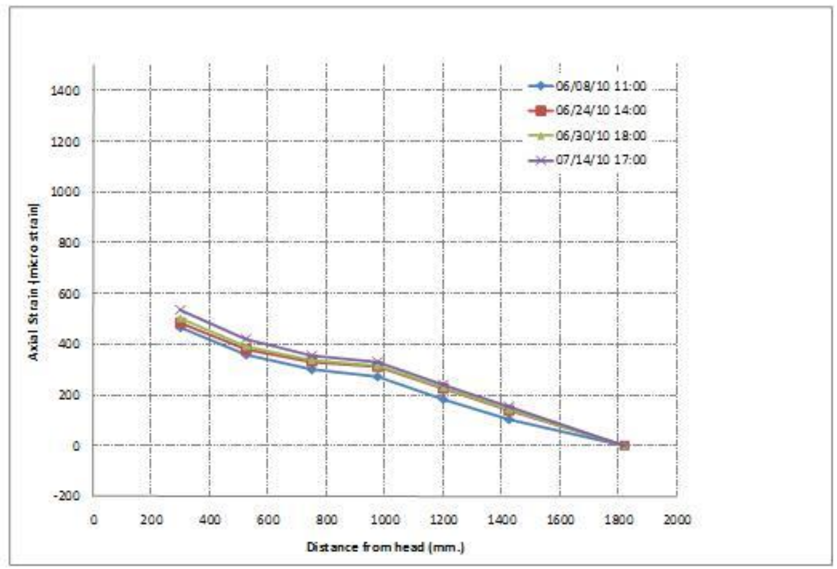


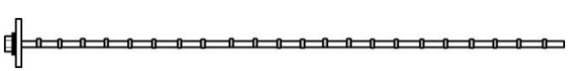
FGP d^6REBAR Result - Intersection

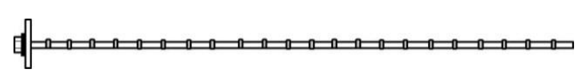




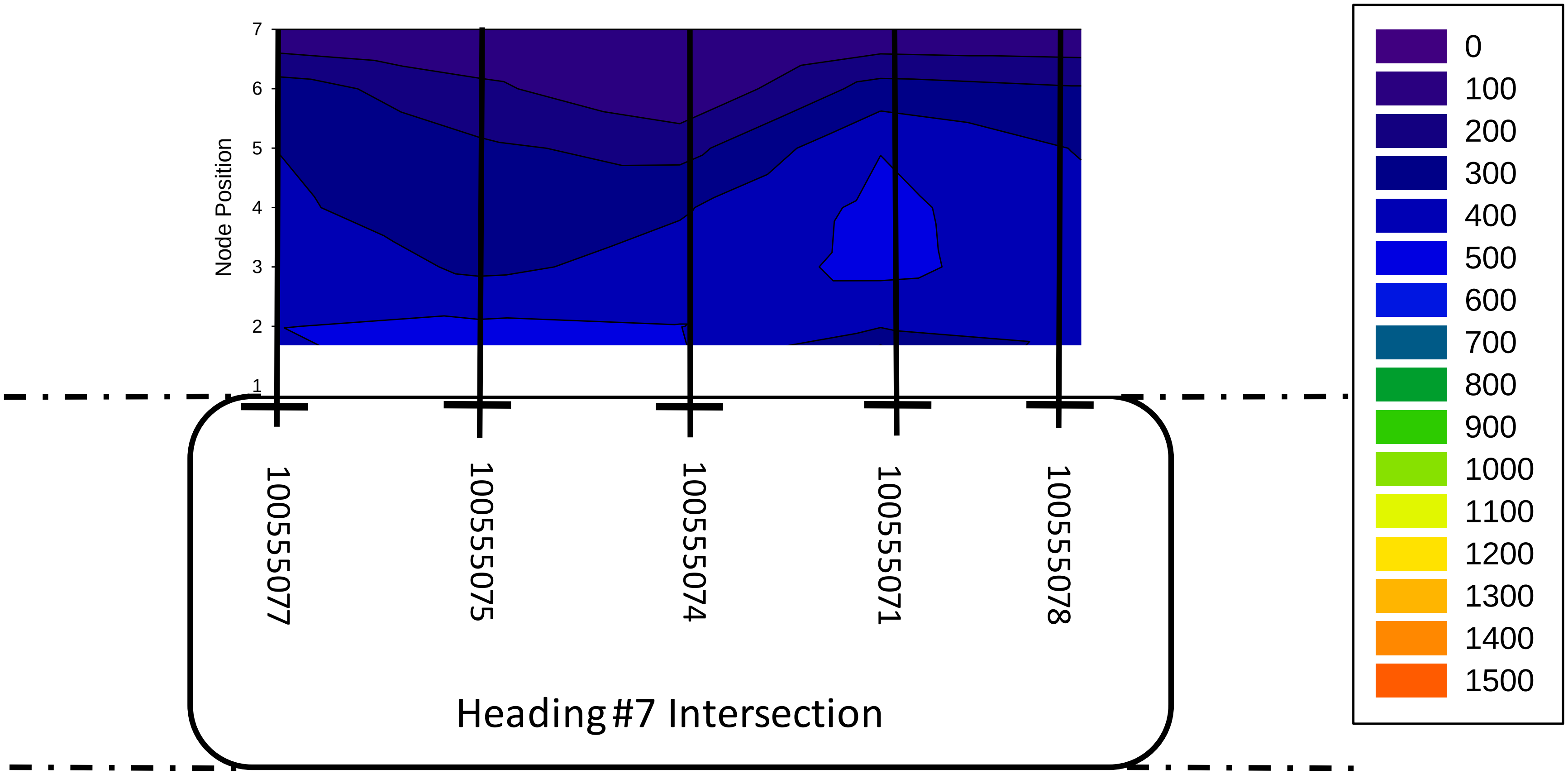




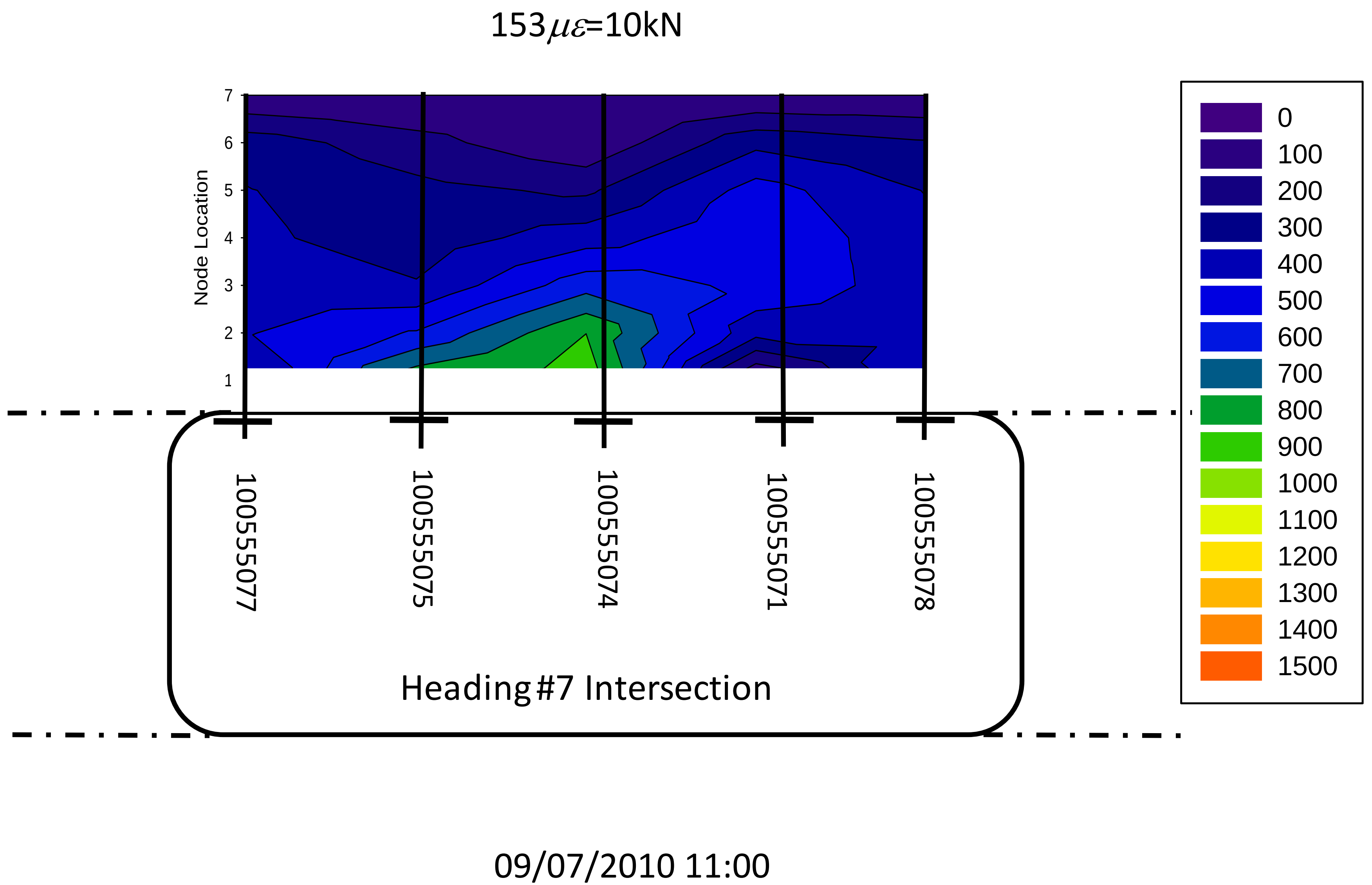




$153\mu\varepsilon$=10kN

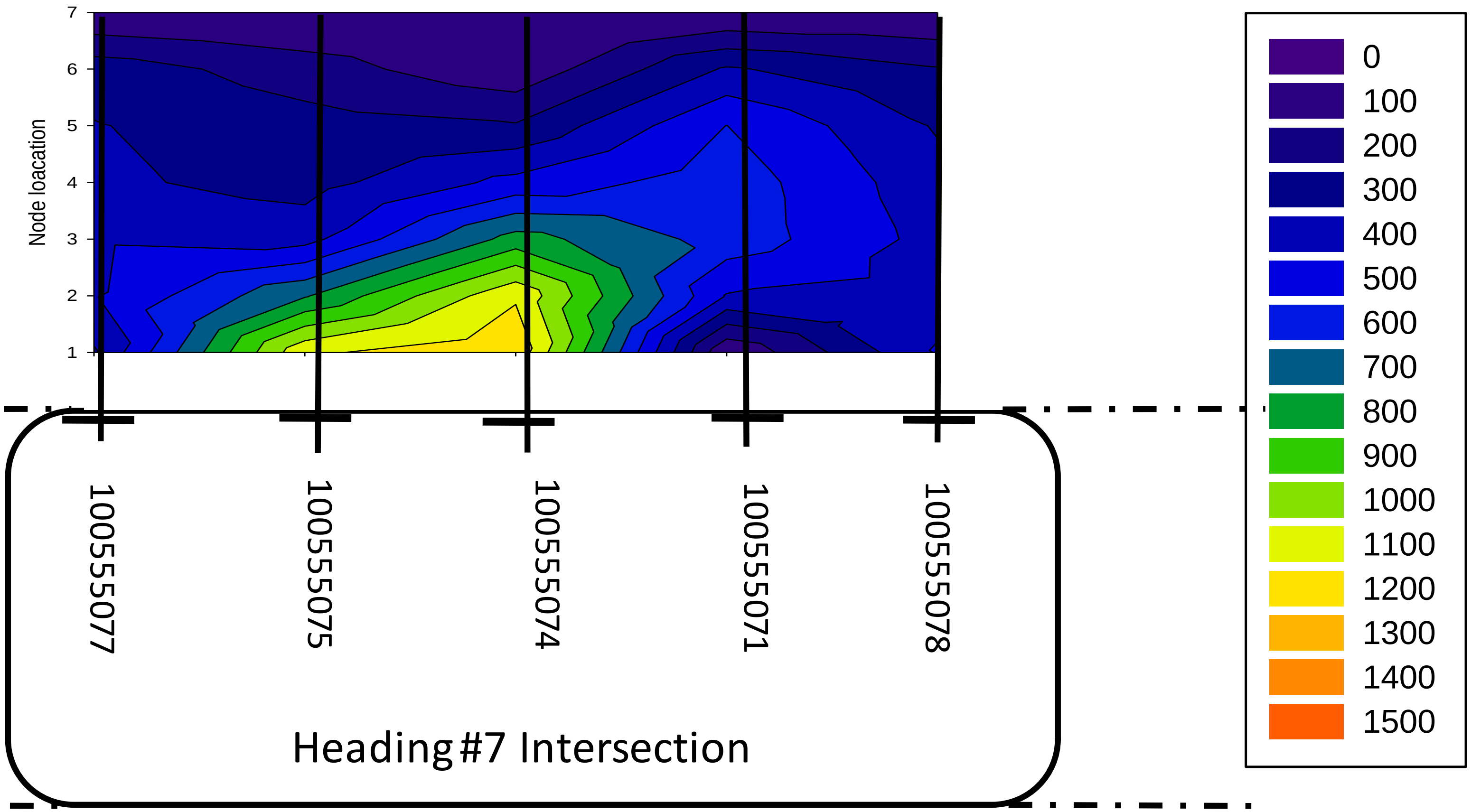


08/06/2010 (Initial readings) - 3days after installation



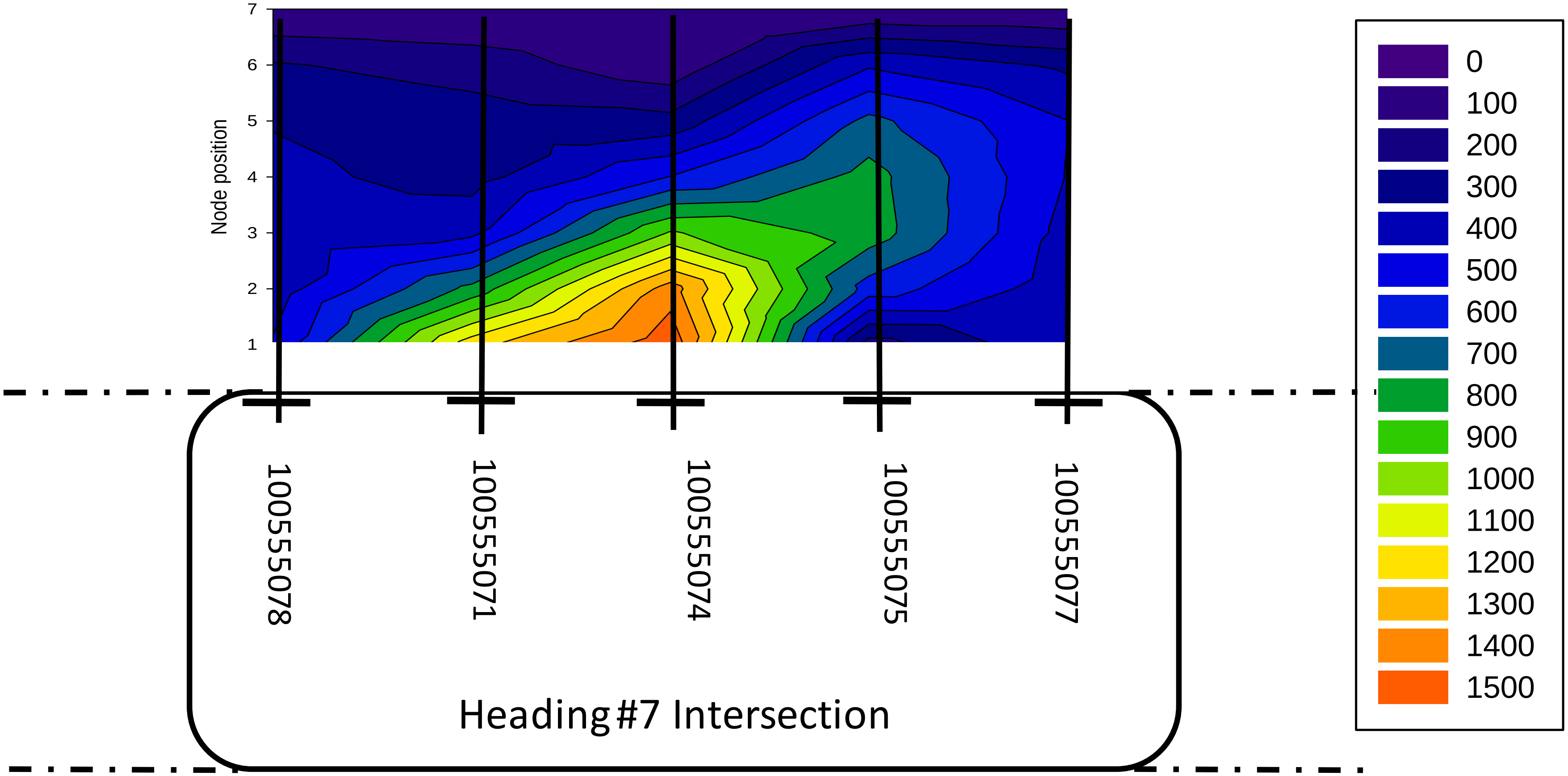
153$\mu\varepsilon$=10kN
Node Location
7
6
5
4
3
2
1
1005555077
1005555075
1005555074
1005555071
1005555078
Heading #7 Intersection
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
09/07/2010 11:00

$153\mu\varepsilon$=10kN

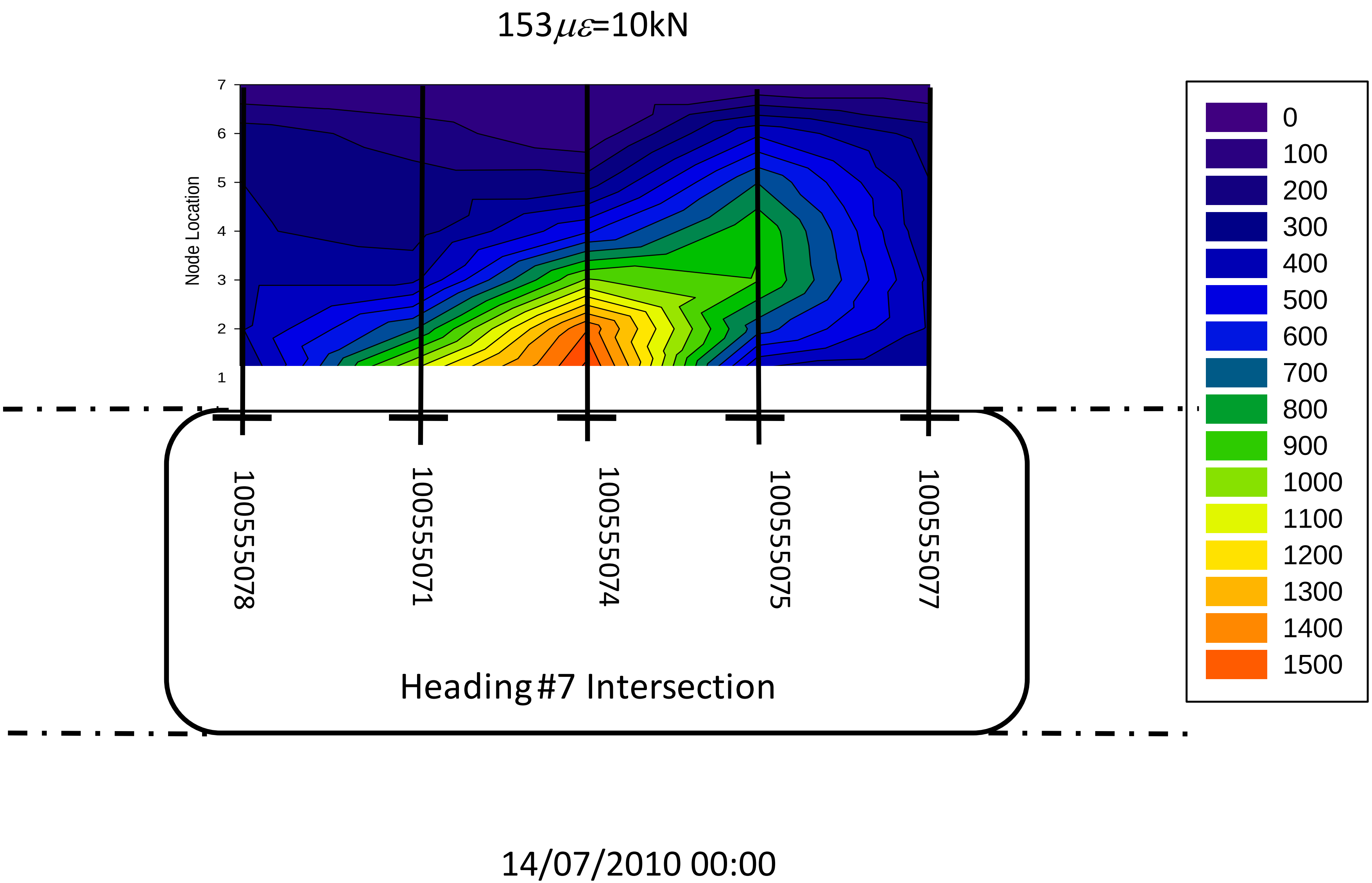


09/07/2010 13:00

153$\mu\varepsilon$=10kN

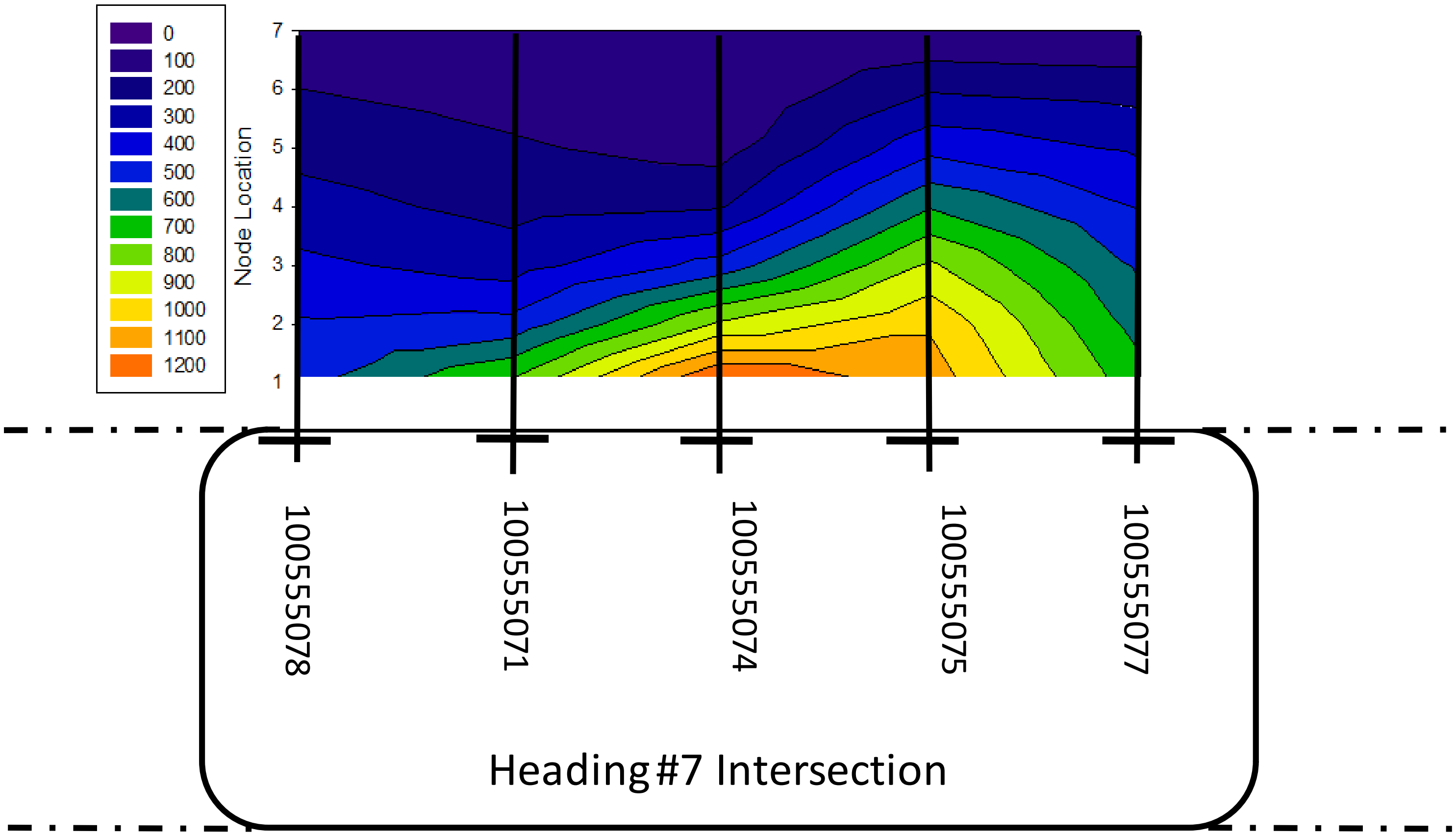


09/07/2010 17:00

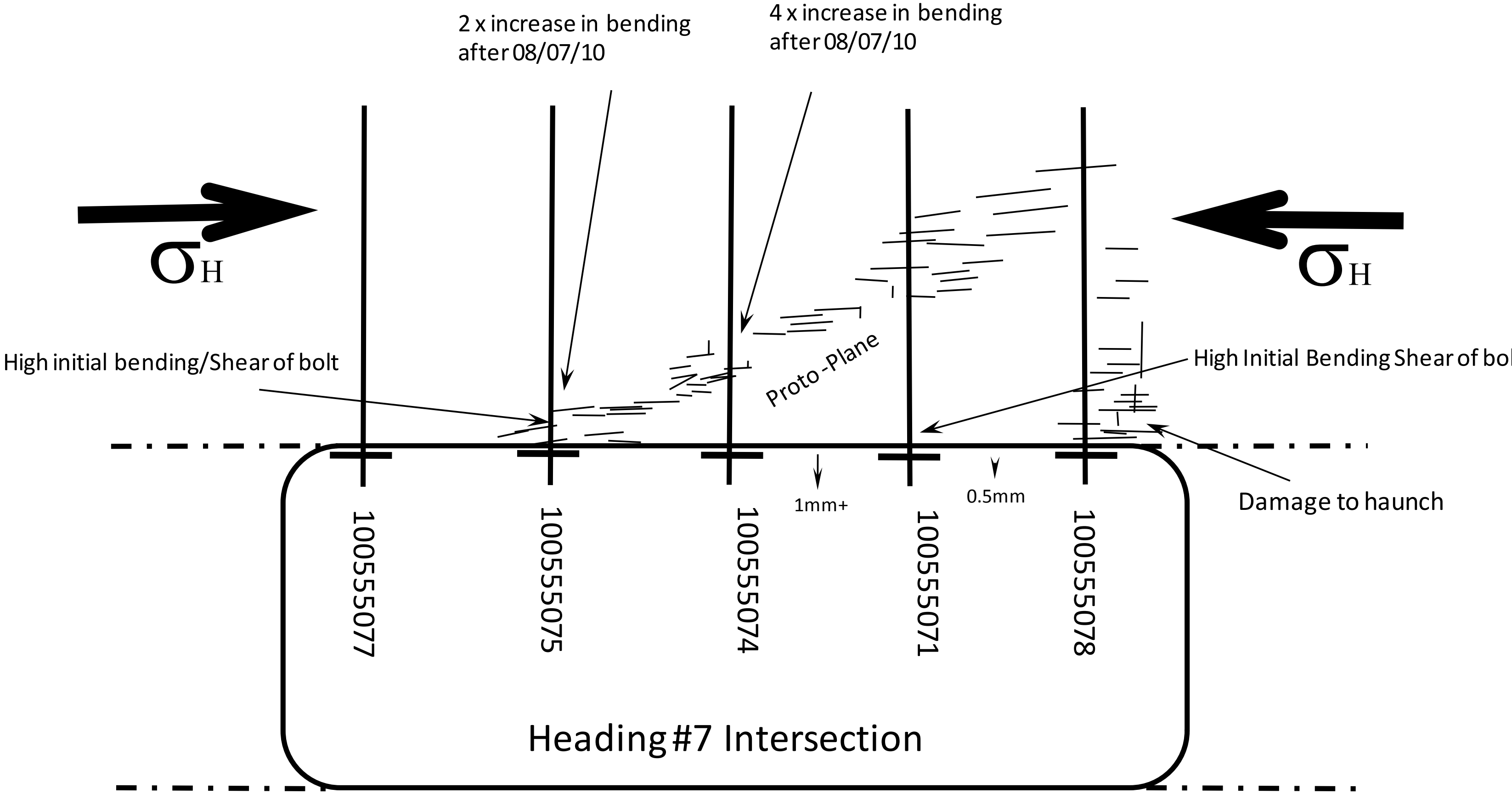


153$\mu\varepsilon$=10kN
Node Location
7
6
5
4
3
2
1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
100555078
100555071
100555074
100555075
100555077
Heading #7 Intersection
14/07/2010 00:00

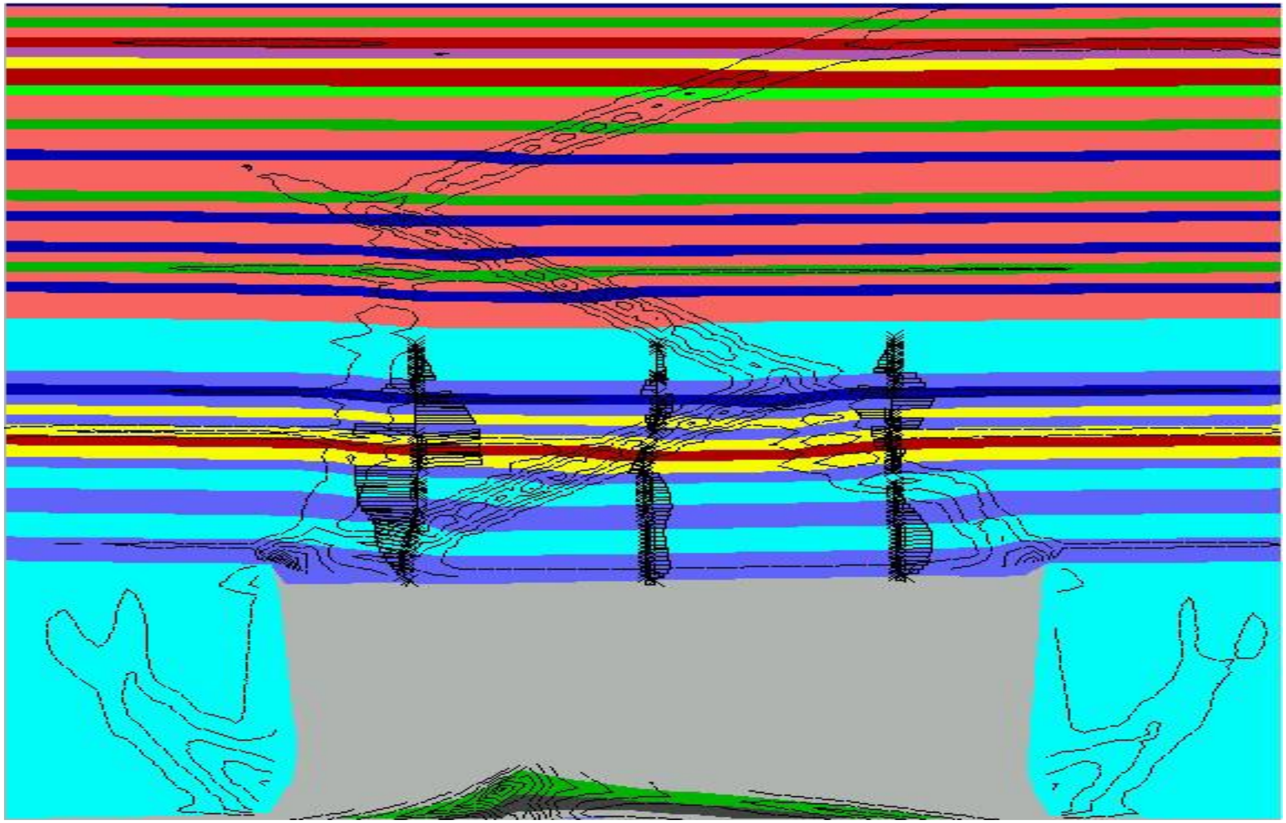
Bolt elongation (μm)



14/07/2010 00:00

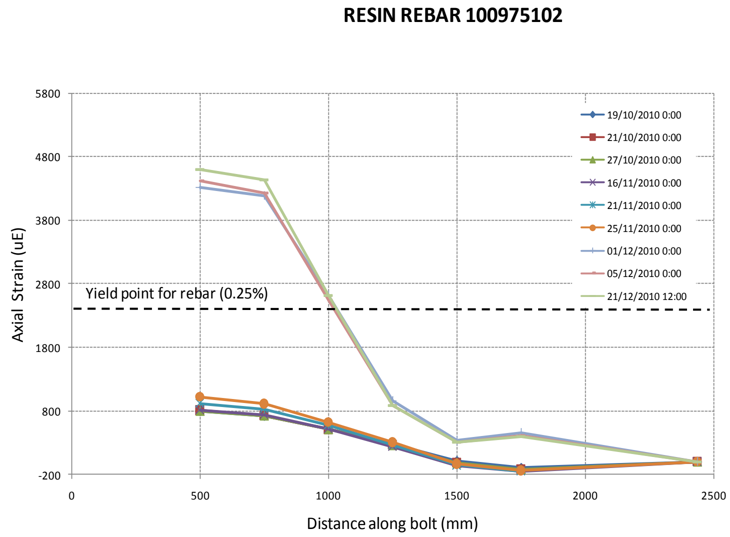


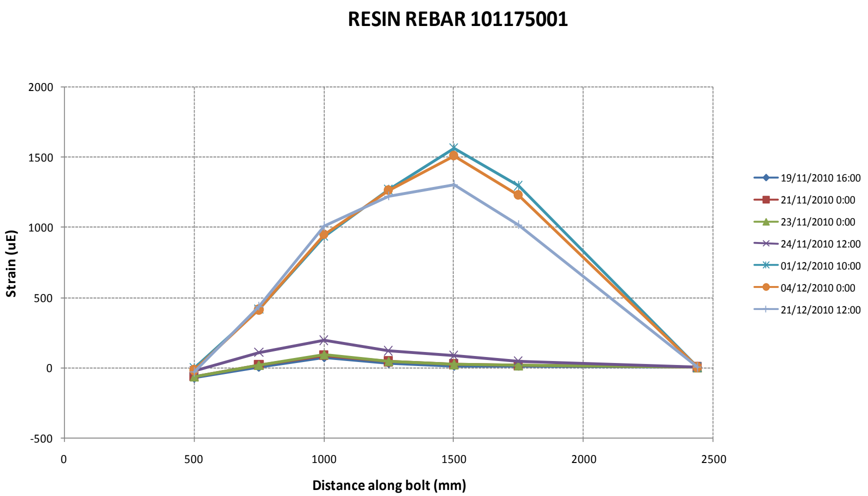
The intersection did not require rehabilitation .

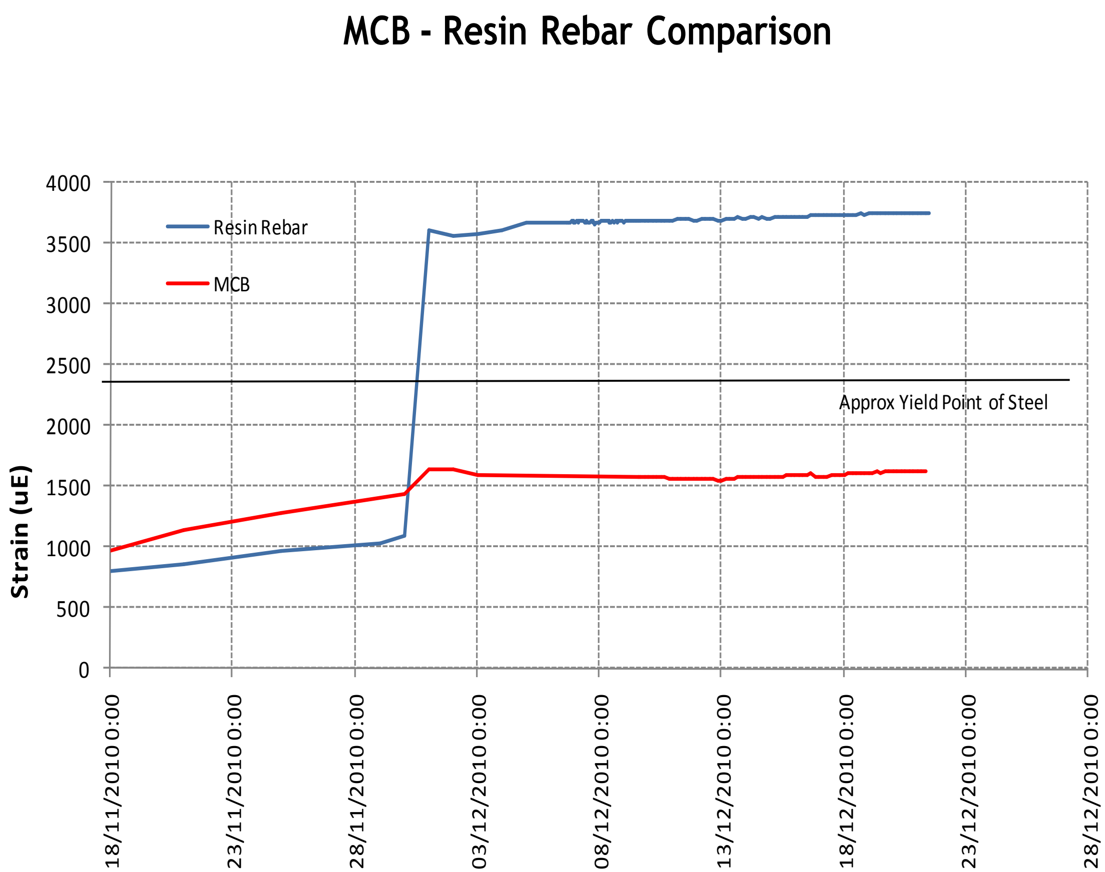


Independently conducted FLAC modeling [17]. The model uses strain softening behavior of failed rock to simulate “shear bands” similar to those hypothesized by the instrumentation results.

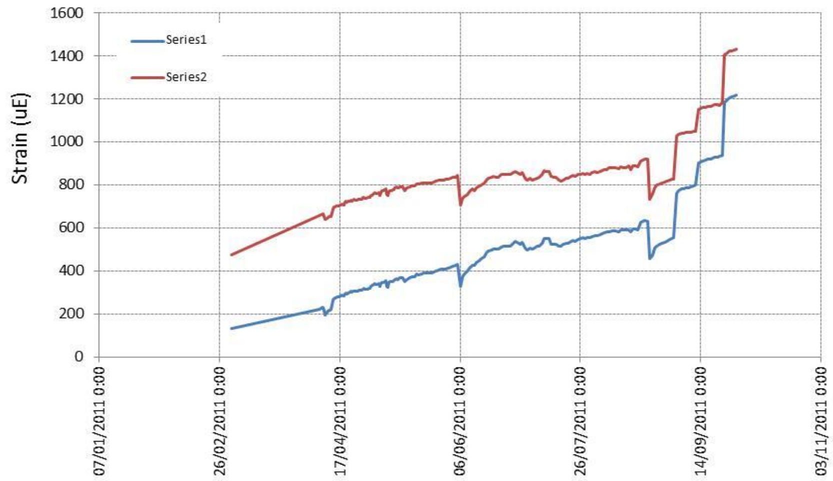
HARD ROCK MINES






MCB - Resin Rebar Comparison
Resin Rebar
MCB
Approx Yield Point of Steel
Strain (uE)
4000
3500
3000
2500
2000
1500
1000
500
0
18/11/2010 0:00
23/11/2010 0:00
28/11/2010 0:00
03/12/2010 0:00
08/12/2010 0:00
13/12/2010 0:00
18/12/2010 0:00
23/12/2010 0:00
28/12/2010 0:00

110135004



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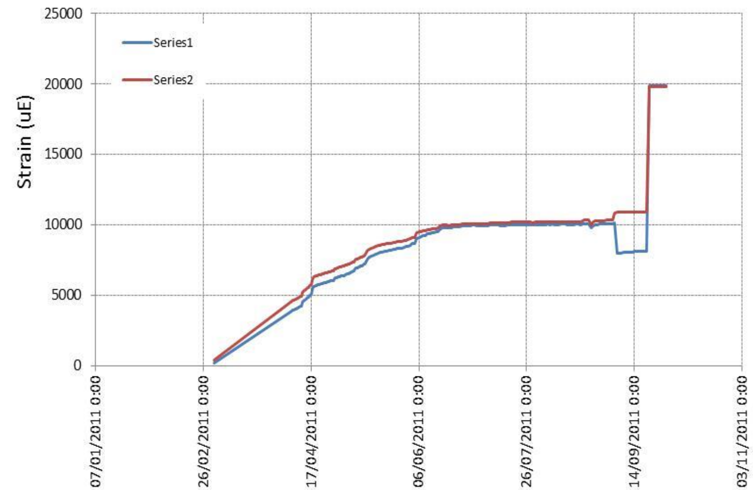

WIRELESS DATA TRANSMISSION

ROCK TENDON MONITORING

Keyword; Monitoring

Today monitoring implies bring data to the desktop.

Leaky feeder WIRELESS NODES: $2000ea

For this price we need to transmit “RICH” data

CONCLUSIONS

Personally the response to our Proposal has provided a philosphical crisis

We have presented our position and we obviously realize that we have not been able to address the specific demands of the RFP.

We have made some preliminary investigations of suitable technology but we do not have a “silver bullet” costing $3.

YieldPoint is not a single “widget company”. We want to bring technologies that can demonstrably provide insight into rock bolt design.