

Monitoring the Ground in order to Optimize Support: Ground Support Elements Equipped with Optical Frequency Domain Reflectometry Technology

Bradley Forbes

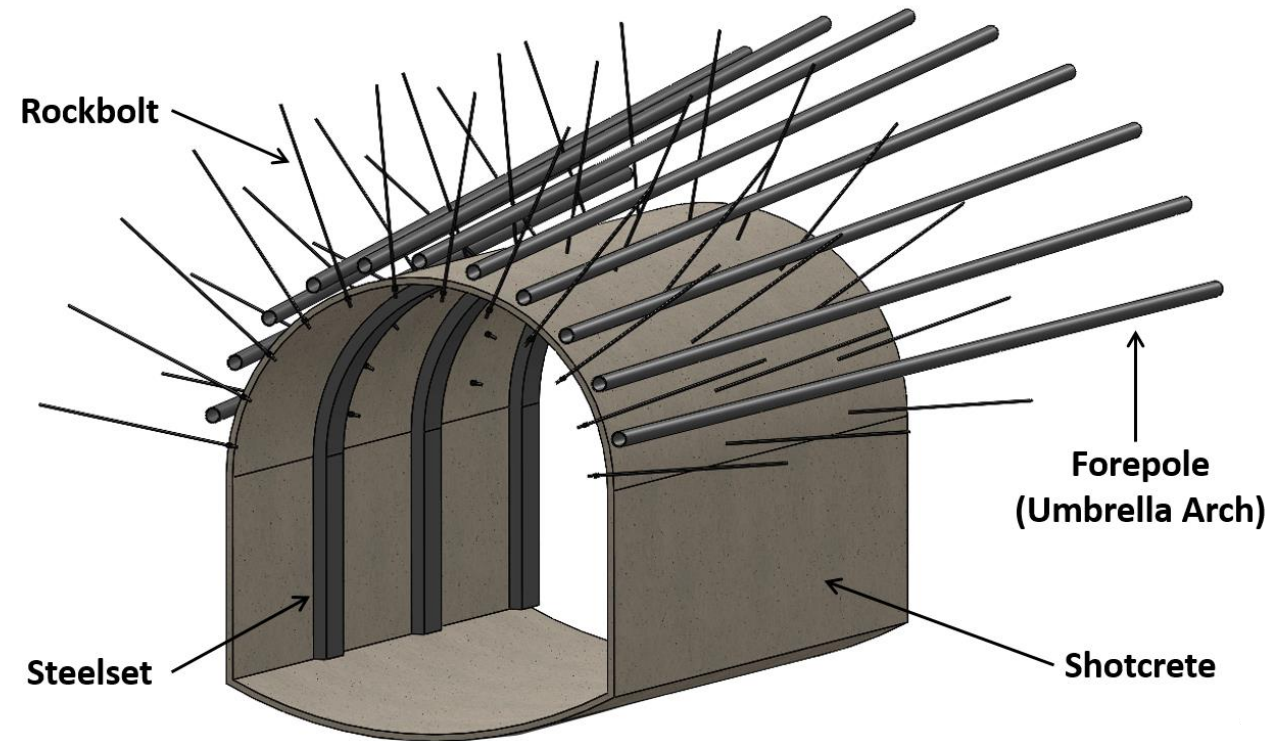
Geomechanics Group, Queen's University

Nicholas Vlachopoulos, Royal Military College of Canada

Mark S. Diederichs, Queen's University

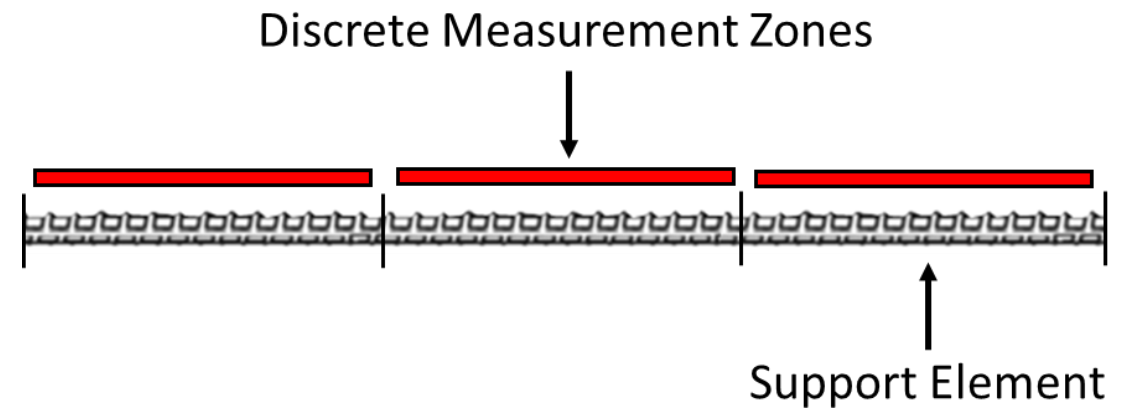
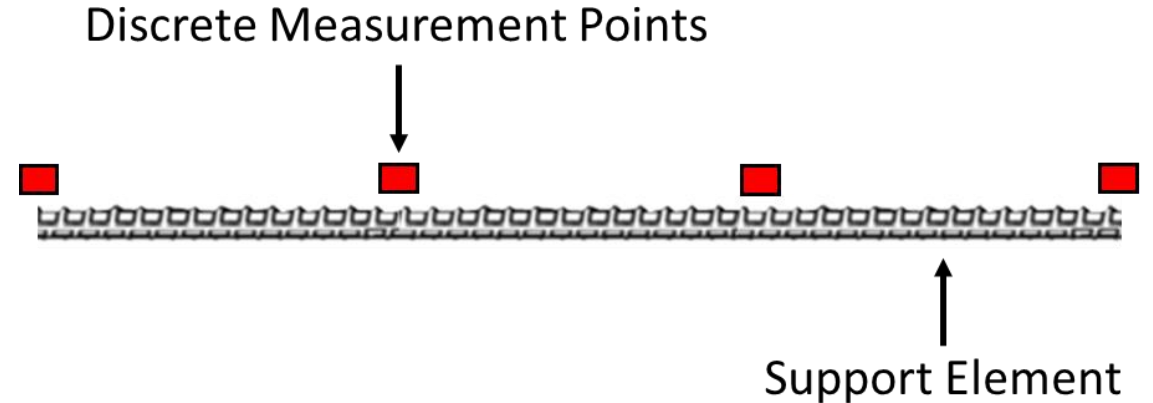
Temporary Support in Underground Excavations

- Support systems are often composed of many individual support elements
- Installed in order to maintain excavation stability and maintain project specific guidelines
- This research has focused specifically on:
 - Rock bolting (i.e. fully grouted rebar)
 - Forepole support (i.e. umbrella arch)



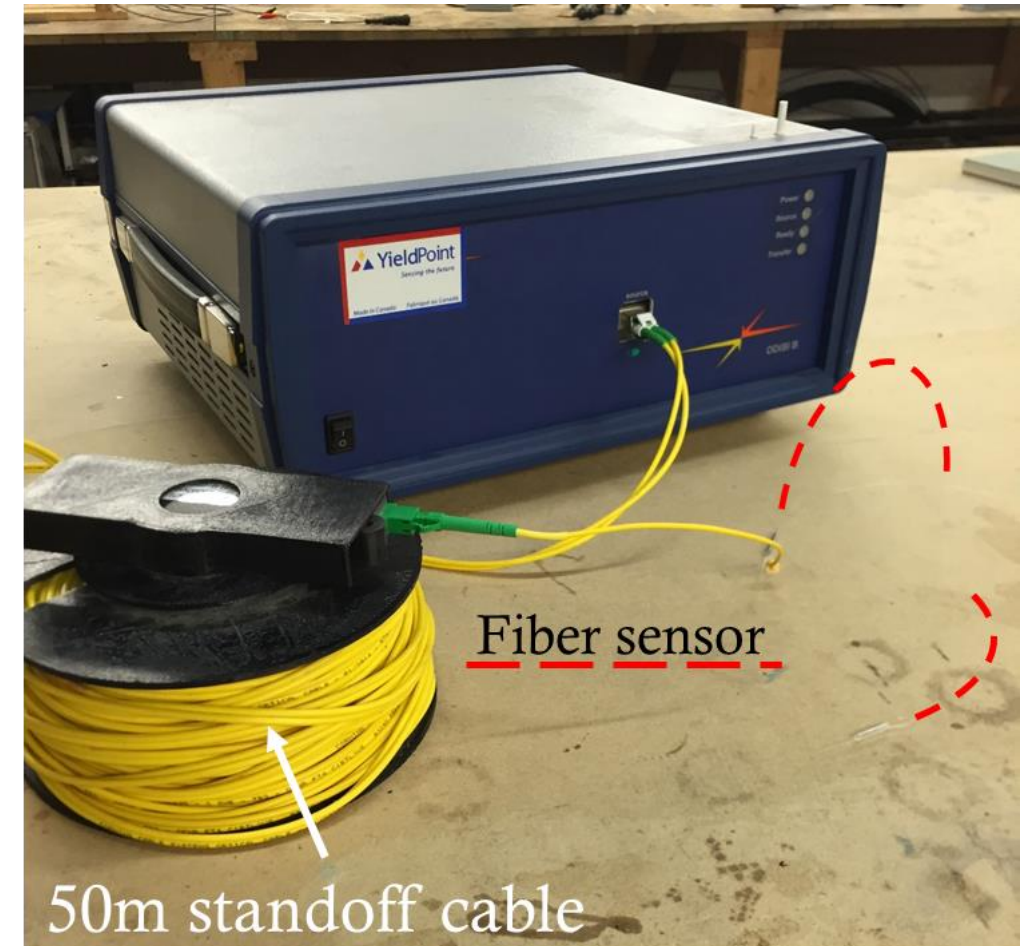
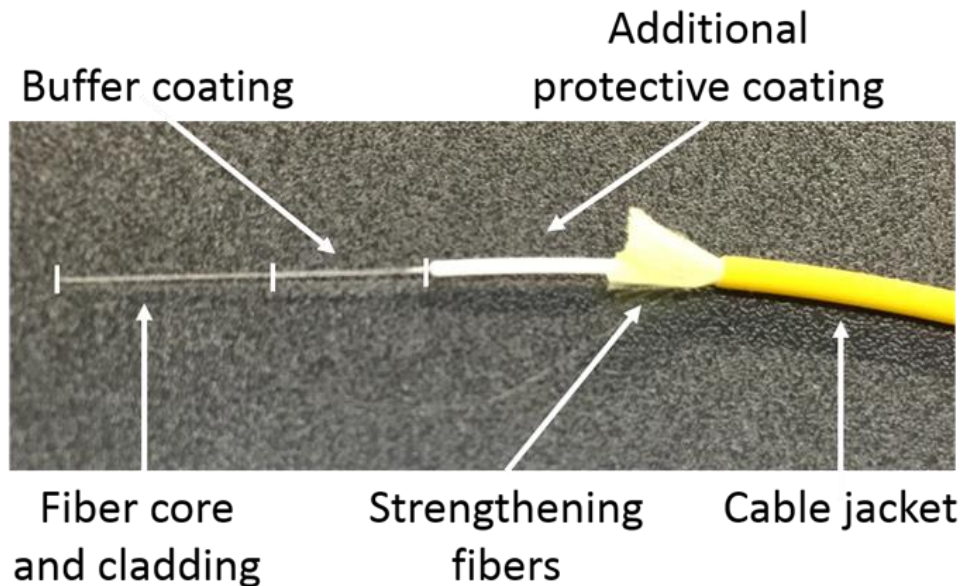
Discrete Versus Continuous Monitoring

- Support may not be loaded in a continuous fashion *in situ*
- Limited by costs and manufacturing difficulties
- The ability to capture localized loading is contingent on the positioning and number of discrete gauges
- Discrete sensing is prone to misinterpretation and possible omission of loading features



Distributed Optical Sensing (DOS)

- One, low cost, single mode optical fiber is used as the transducer and lead
- Strain is captured at a 1.25mm spatial resolution along the optical sensor



Previous Research: DOS Rock Bolts

Optical analyzer protection unit



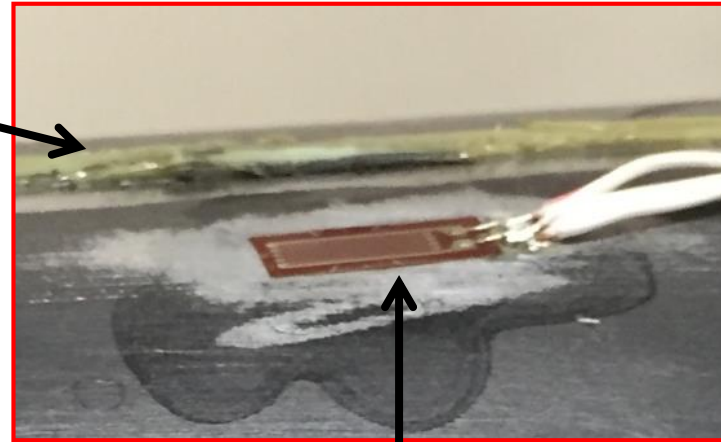
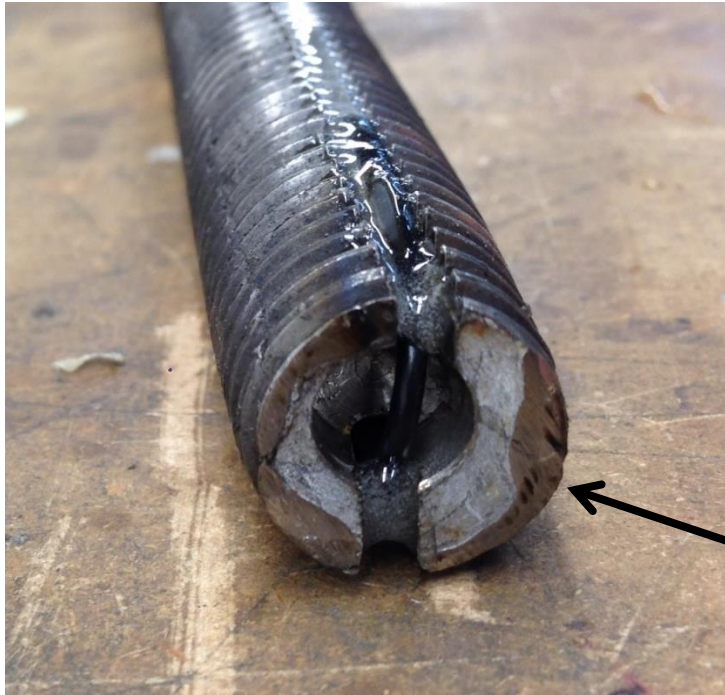
- Fully grouted rebar specimens successfully instrumented with DOS
- Optical technique proved suitable for underground application



DOS instrumented bolt installed in the roof of a coal mine

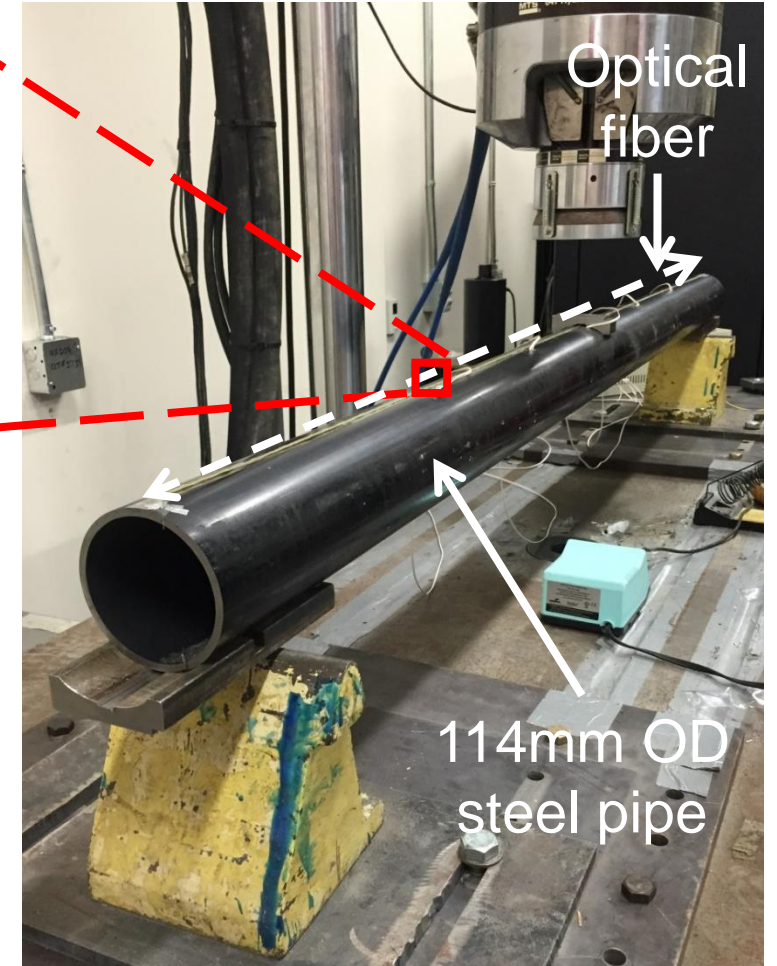
DOS Development with Support

Surface mounted
optical fiber

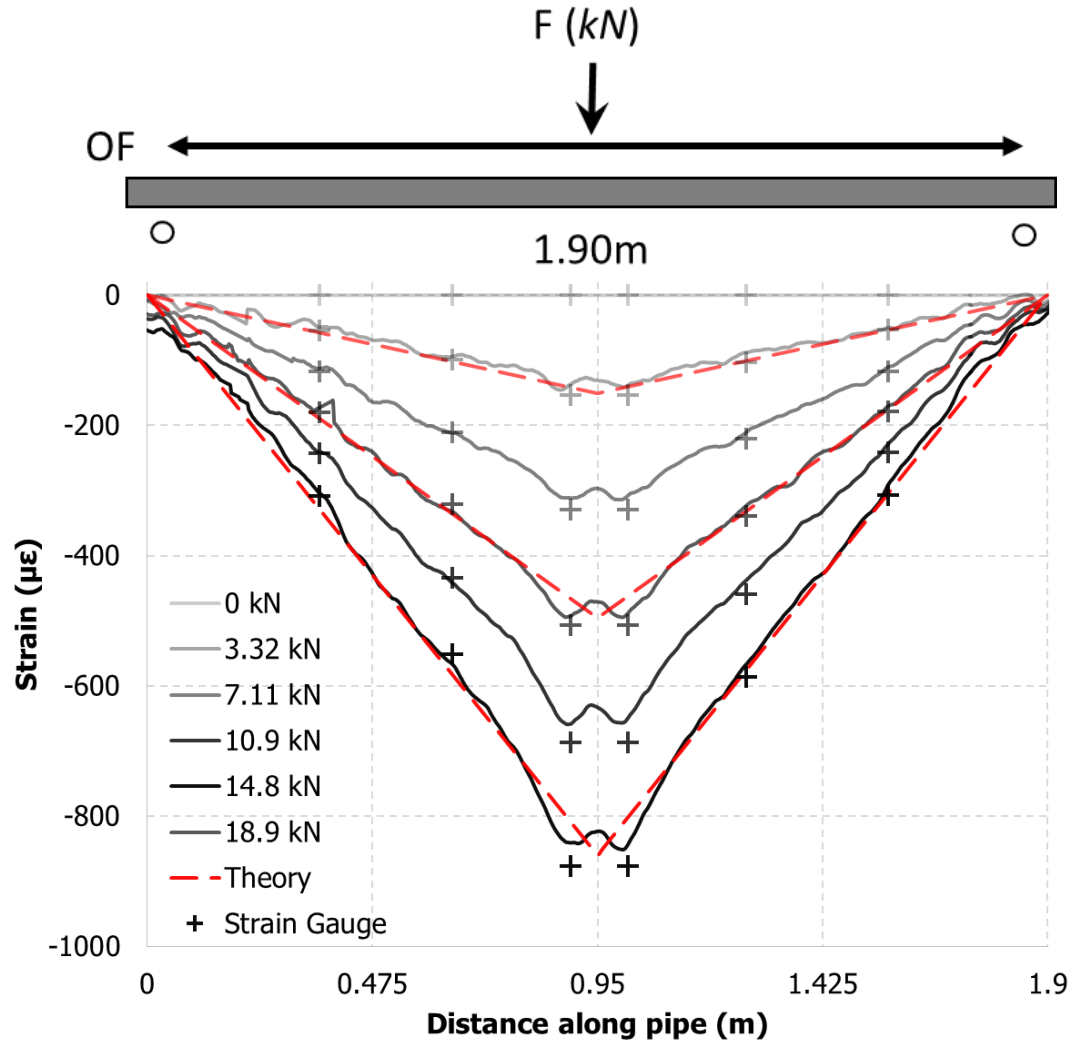


Strain gauge
(verification of DOS)

Optical fiber embedded
and encapsulated with
machined grooves

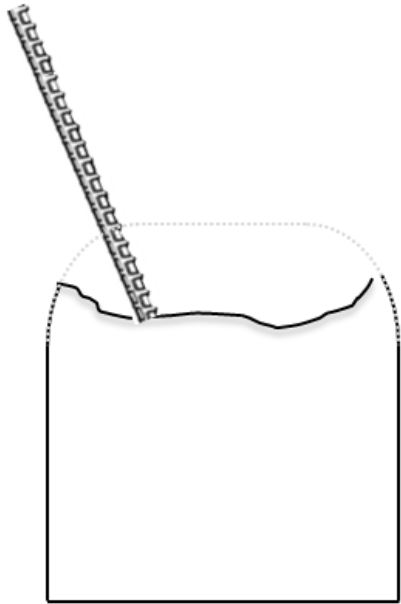


DOS Forepole Support: Symmetric Bending

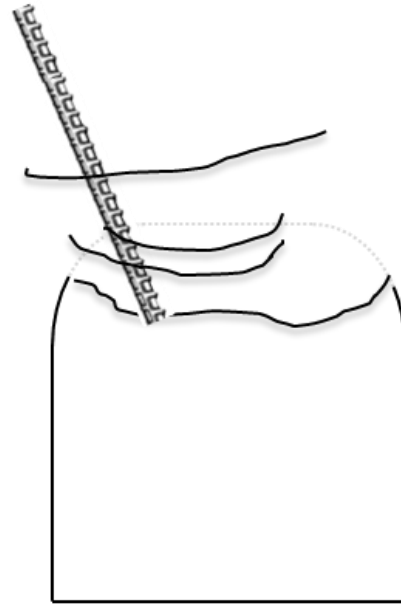


- Strain profile captured along the entire length of a forepole element
- DOS profile comparable with theory and discrete strain gauges
- 4 inch OD pipe found to deflect in an elliptical manner at smaller support spans
- Sub-centimeter spatial resolution requires no interpolation or “guessing” between measurement points

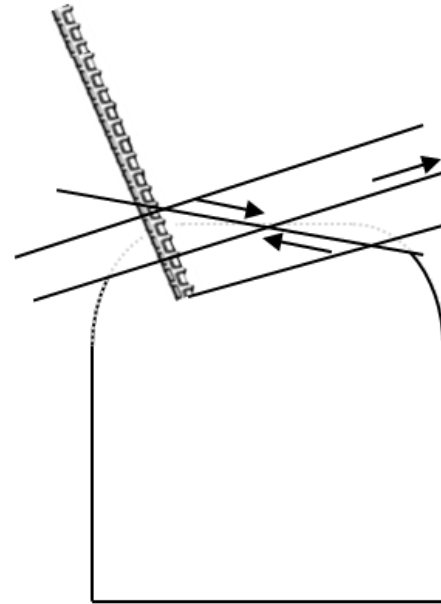
Is Continuous Monitoring Necessary?



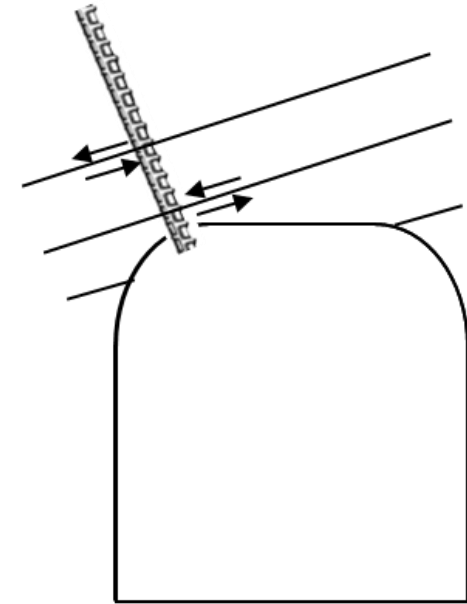
(1)



(2)

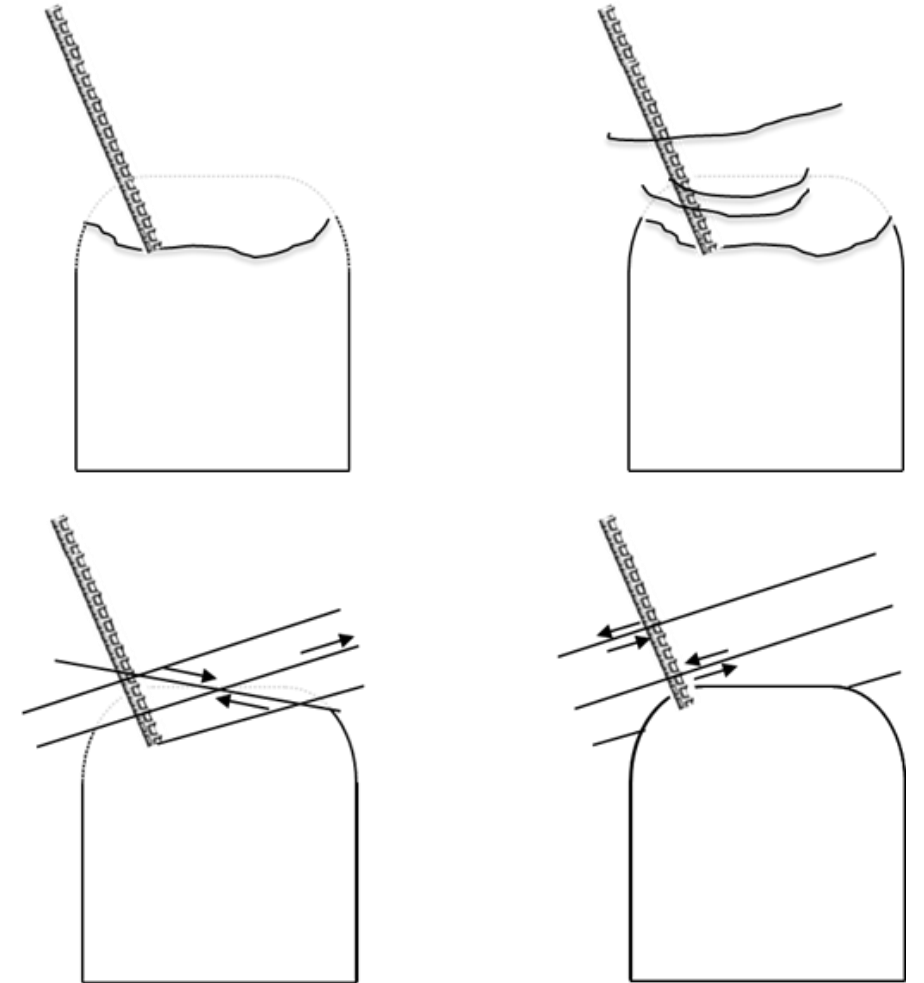
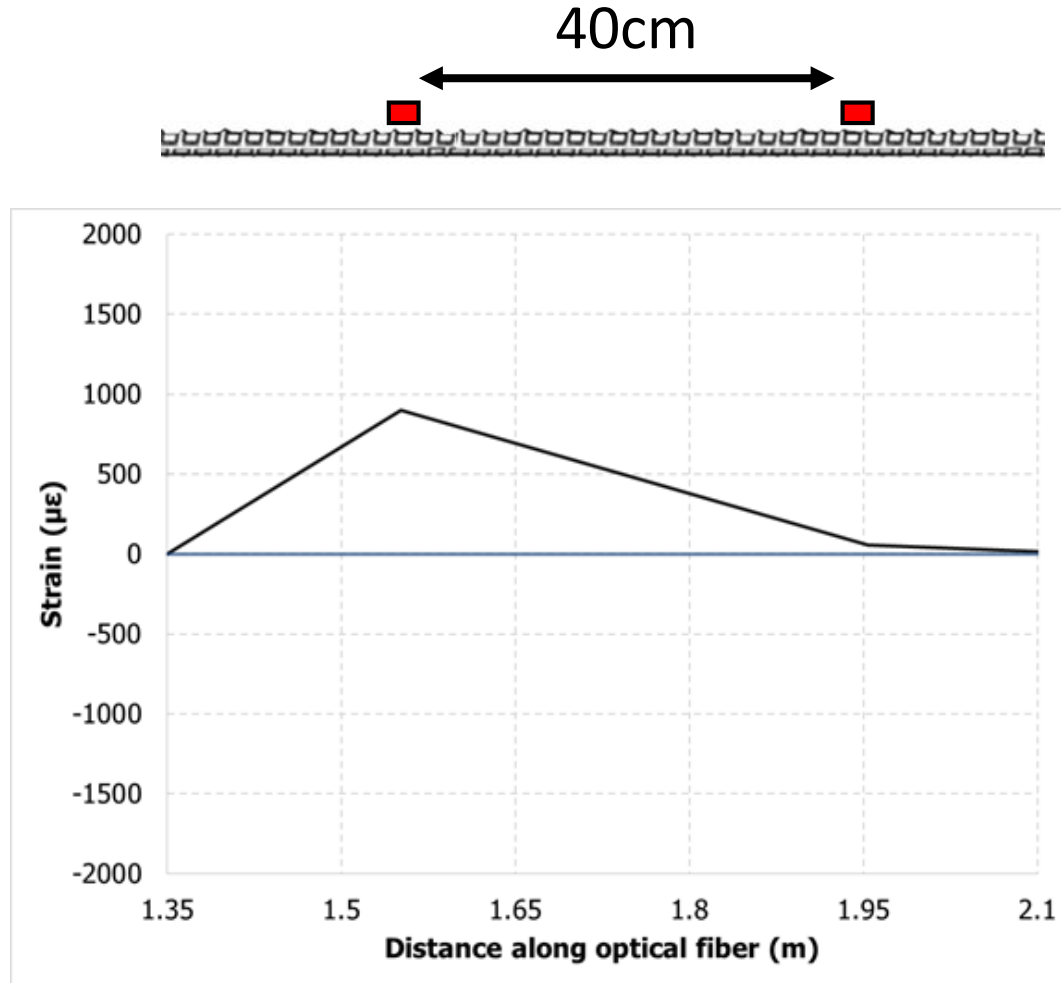


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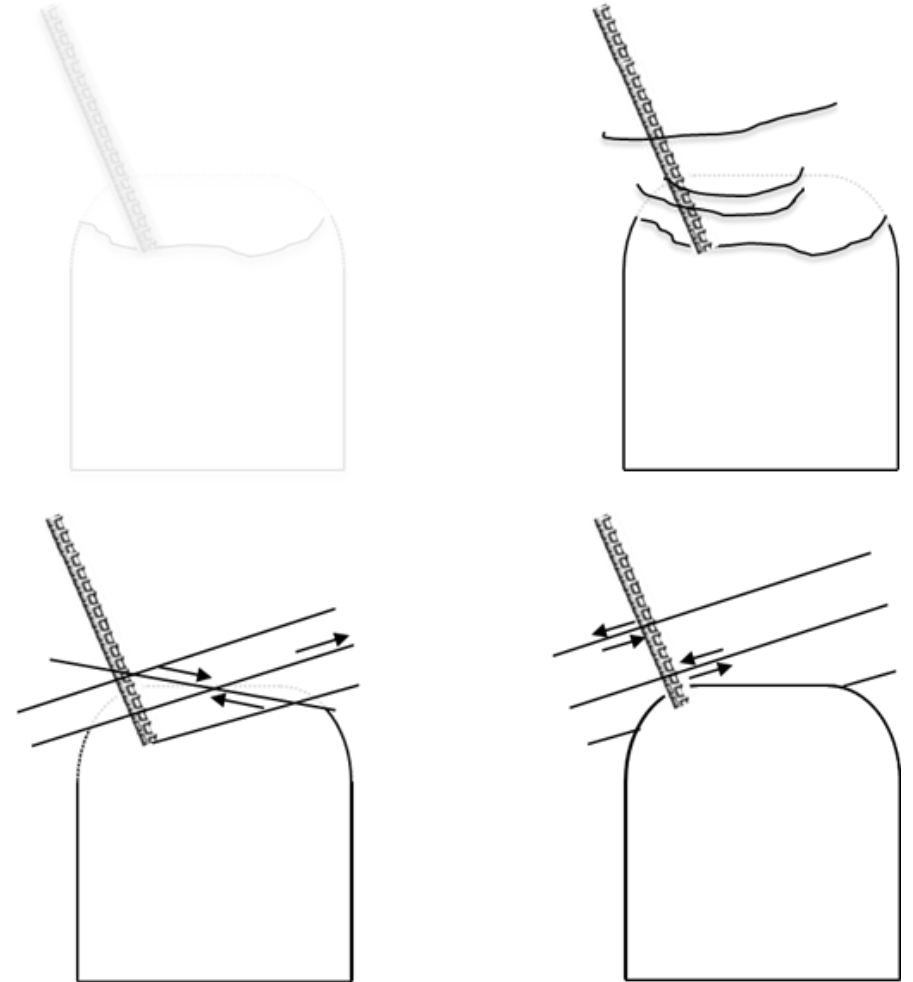
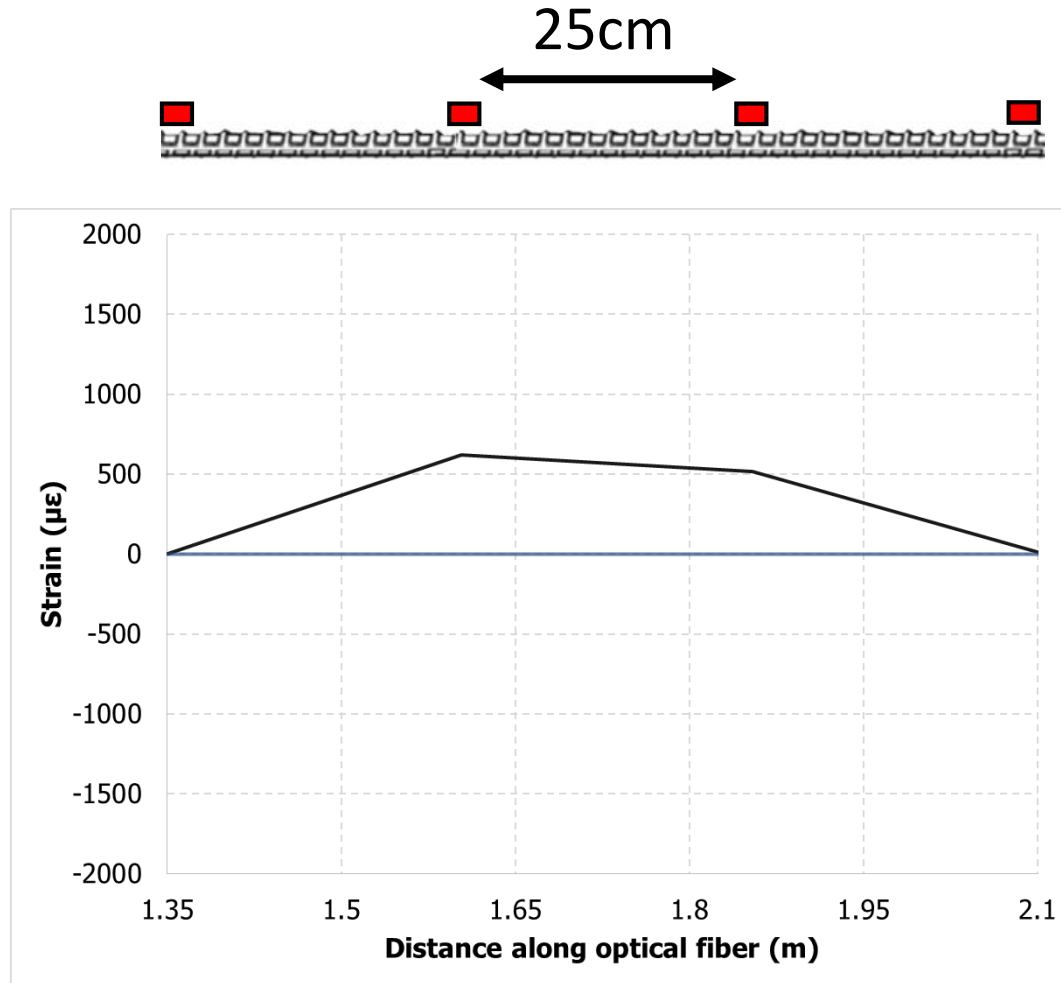


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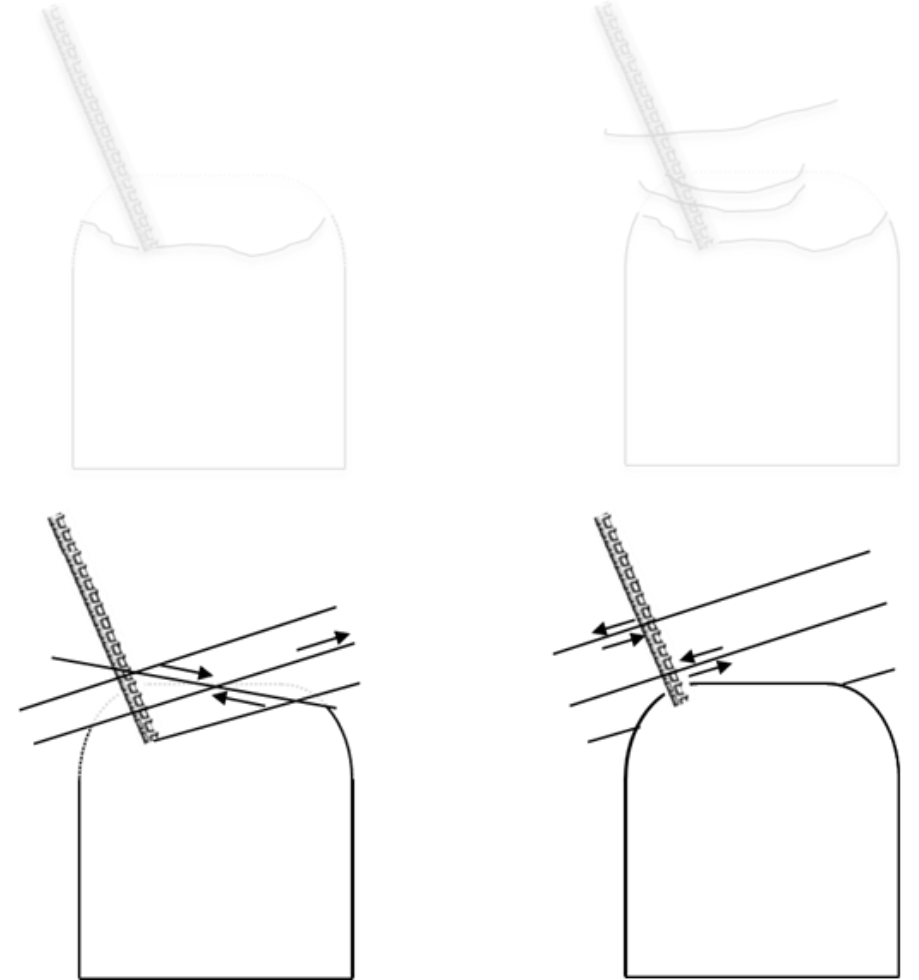
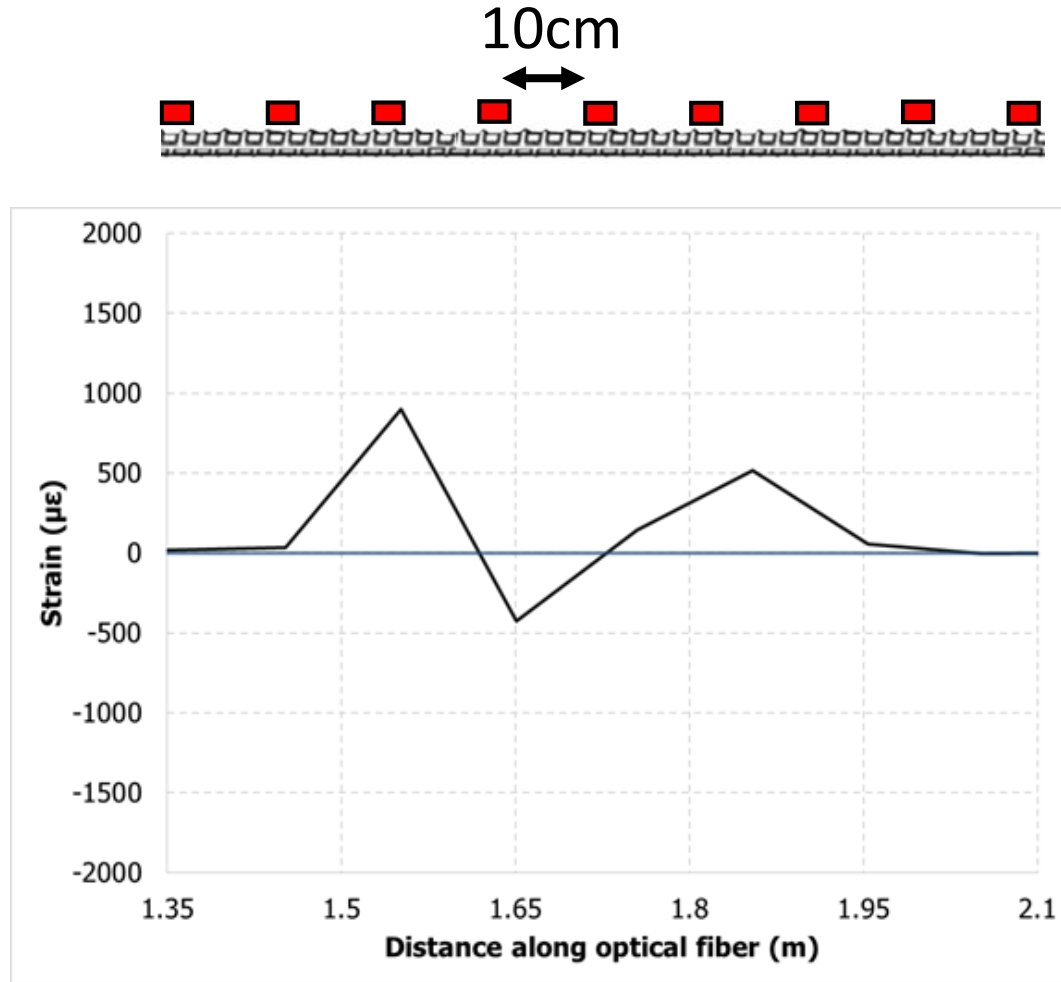
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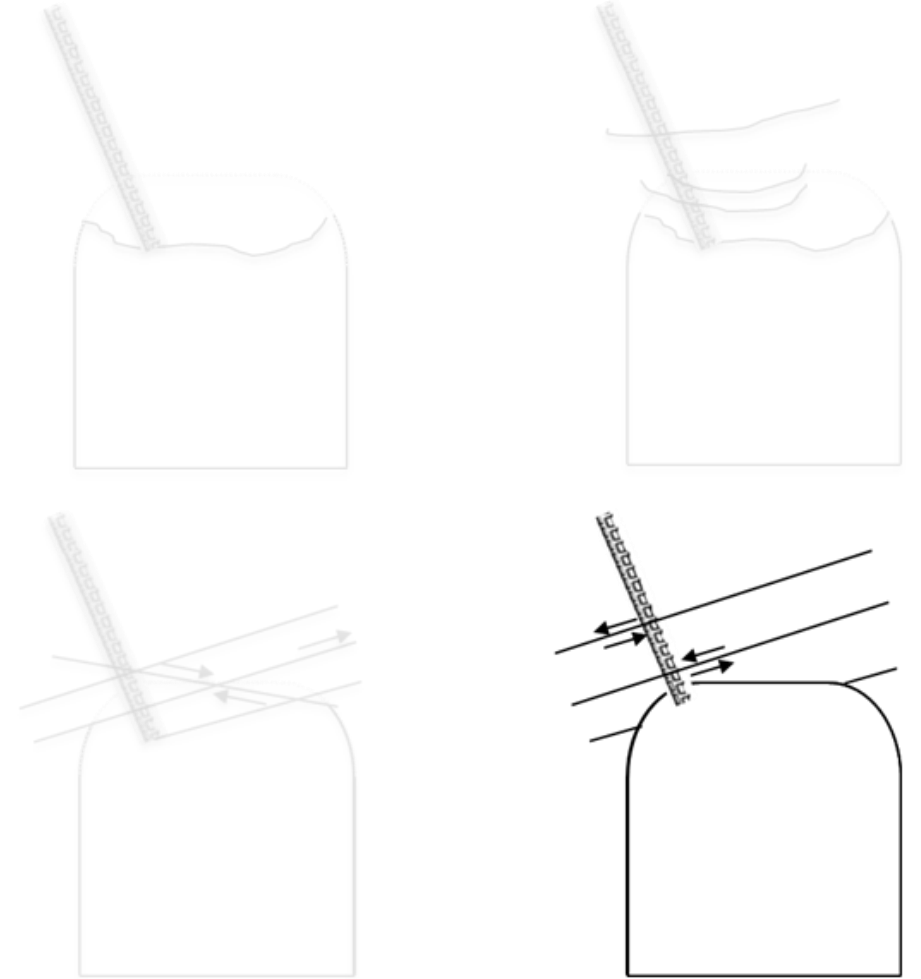
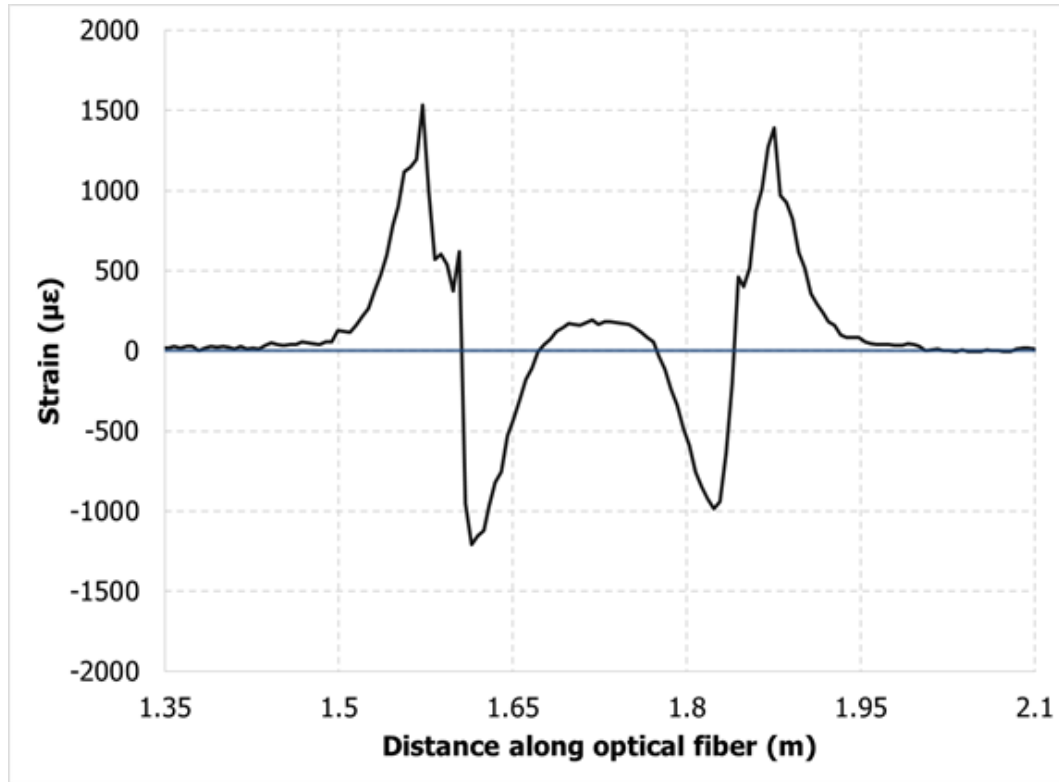


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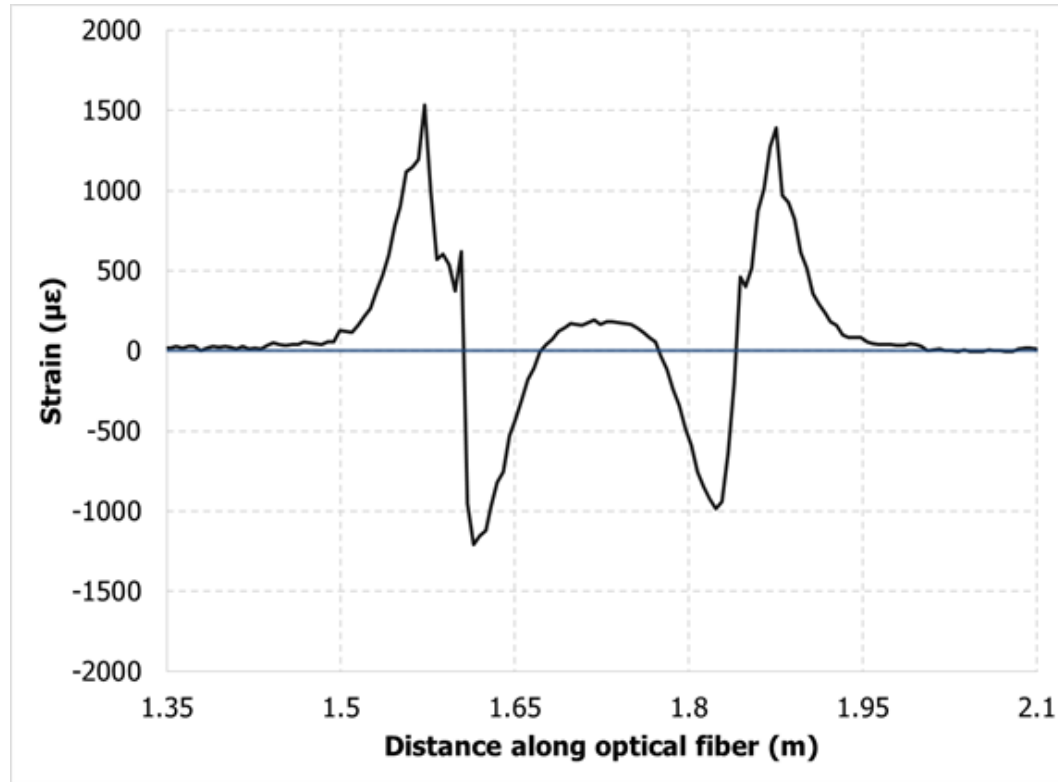
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1.25mm

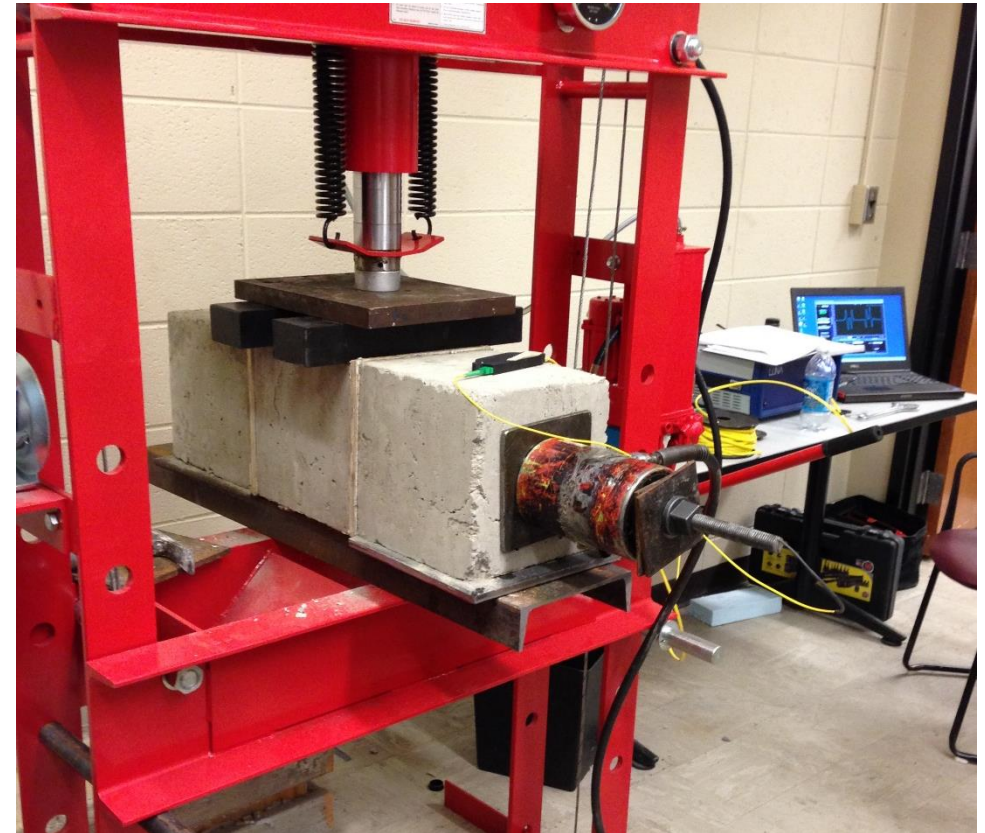


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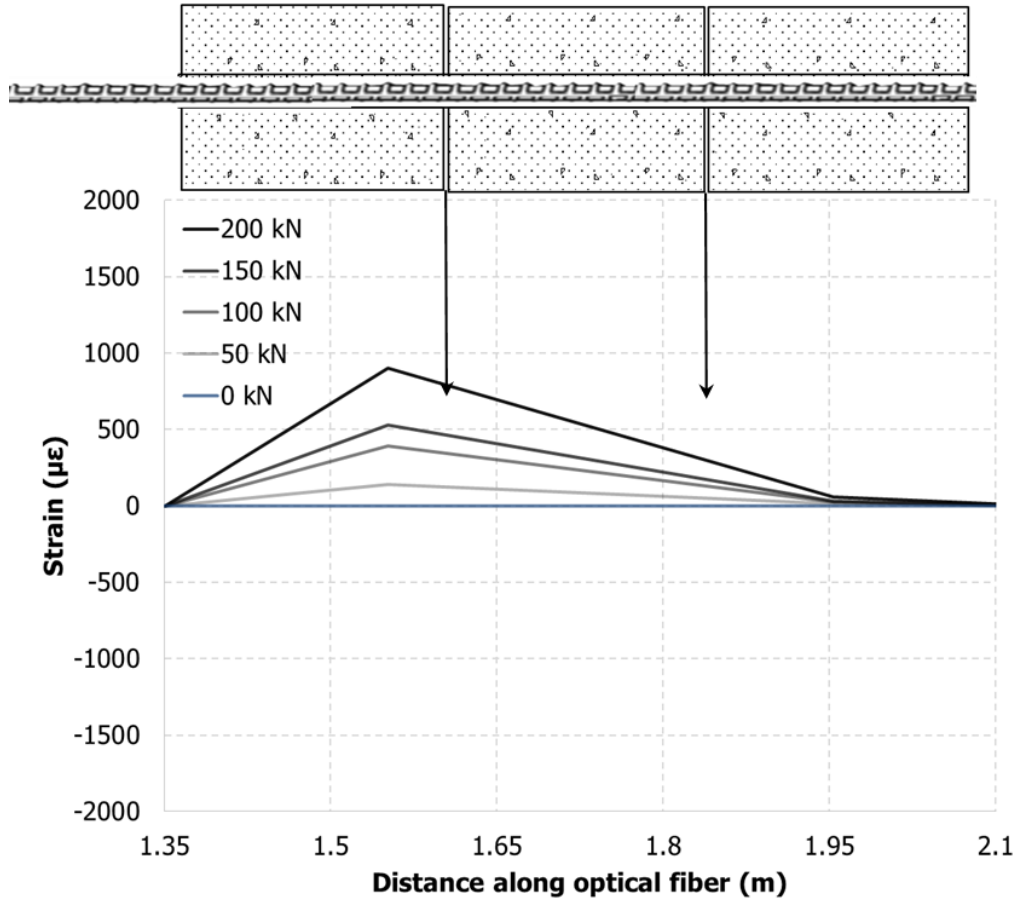


Double Shear Test

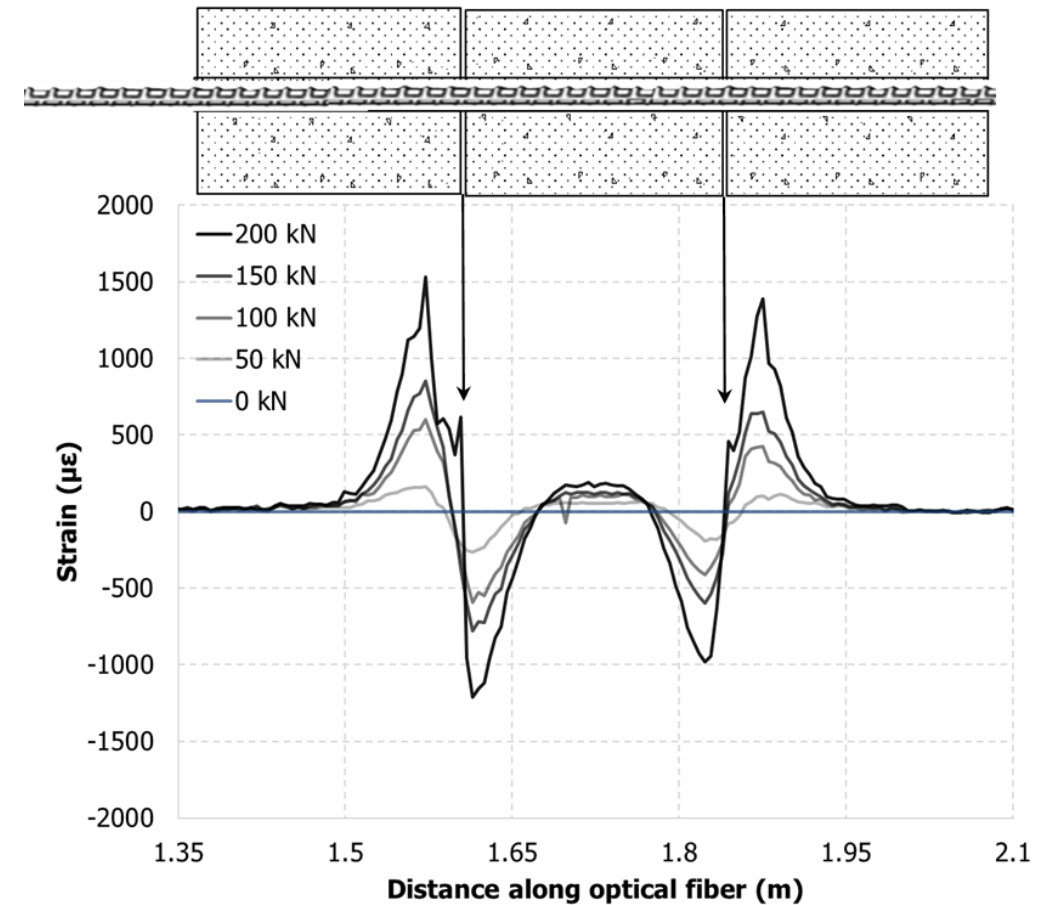


Is Continuous Monitoring Necessary?

40cm

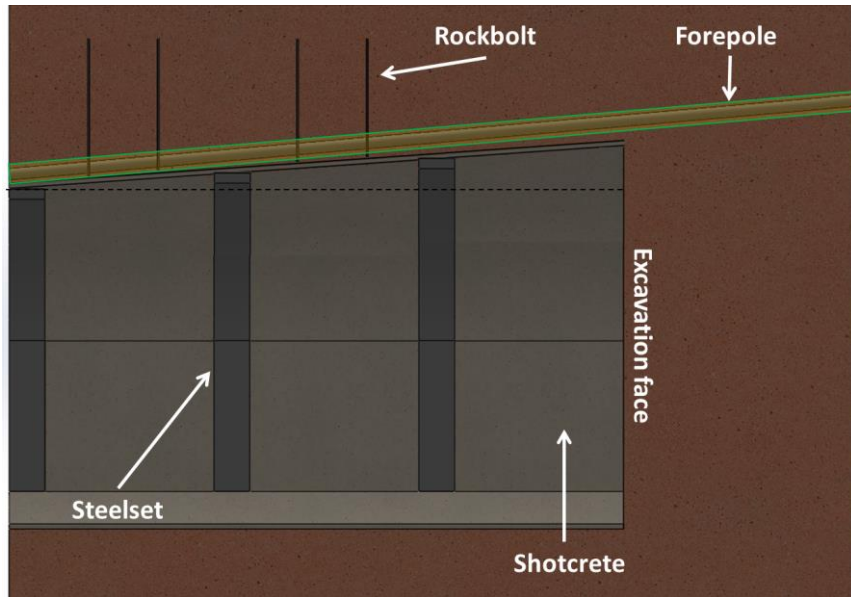


1.25mm



Development of a “Stand-Alone” Shape Sensor

- Forepole support extends longitudinally ahead of the excavation face
- Sensor can be used to “forecast” future ground conditions



Acknowledgments

