CAAP Quarterly Report

Date of Report: November 30, 2020

Prepared for: *U.S. DOT Pipeline and Hazardous Materials Safety Administration*

Contract Number: 693JK32050007CAAP

Project Title: Distributed Strain Sensing for Pipeline Safety Against Fault Moving and Landslide

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For quarterly period ending: Nov 30 2020

Business and Activity Section

(a) Contract Activity

No modification.

(b) Status Update of Past Quarter Activities

The research team conducted (i) literature review, (ii) laboratory experiments, and (iii) preparation of the numerical modeling task.

(c) Cost share activity

The research tem had several online meetings and email exchanges with Dr. David Xu of PG&E.

(d) Task 1 Design

1. Background and Objectives in the 1st Quarter

This task aims to develop fiber optic installation detail drawings based on UCB's experience and PG&E requirements. The development includes specifications of fiber optic material, installation methods, and repair strategies. One of the critical design criteria is to find a fiber optic cable attachment method that does not affect the cathodic protection. We have identified one possible solution using an adhesive coating tape (Tapecoat H35). It is a 35 mil tape designed to protect above ground, buried, or submerged metal surfaces from corrosion and electrolysis. It is used for coating pipe, pipe joints, fittings, couplings and other metal surfaces. Its multipolymer alloy film backing has been formulated to provide the strength that allows it to be pulled tightly around fittings and other irregular shapes with minimal pull back. It is resistant to UV rays, thermal expansion, impact, abrasion and can be applied over a wide range of ambient temperatures.

We have conducted the first trial of this attachment method in November 2020 with support from the East Bay Municipal Utility District (EBMUD). Fiber optic cables were attached to a HDPE pipeline of 20 inch diameter and 50 feet length using an adhesive coating tape, as shown in Fig. 1. The instrumented pipeline was lifted at two sides to create bending strain along the pipeline by self-weight. The strain profiles were measured using a distributed strain sensing interrogator. Finite element analysis was conducted to examine the performance of the attachment.

Figure 1 Testing of Tape attachment method

2. Results and Discussions

Figure 2 shows some examples of the strain profile measurement along the pipe length. Tensile strains are developing at the bottom (f1 and f2), whereas compressive strains (negative) are developing at the top (f4 and f5). As expected, for a given FO cable, the strain values are at their maximum at the center location of the pipeline where the bending strain (or curvature) is the largest. Some creep behavior is observed, which is typical of a HDPE pipe under load. Also, the direct sunlight exposure led to an increase in temperature and hence thermal expansion. Some tensile strain, which increases with time, is observed at the cables attached at the sides of the pipe (i.e., neutral axis) (f3).

The measured bending strain and axial strain profiles were used to evaluate the vertical displacement profiles and longitudinal displacement profiles. The results given in Figure 3 show that the pipeline displaced about 0.4 m vertical downward and stretched 0.4 m in the longitudinal direction.

A 3D finite element analysis of the problem was conducted using COMSOL. The finite element model is shown in Figure 4. Figure 5 shows the deformed model with contours of strains in 3 directions (ε_{xx}, ε_{yy}, ε_{zz}) and vertical displacement (w). The computed strain profiles along the locations close to where the fiber optic cables were attached are shown in Figure 6. The computed strain profiles are similar to the measured strains shown in Figure 2. The computed vertical displacement at the center portion of the pipeline of 0.4 m is similar to what was measured and estimated from the fiber optic data (Figure 3 left figure).

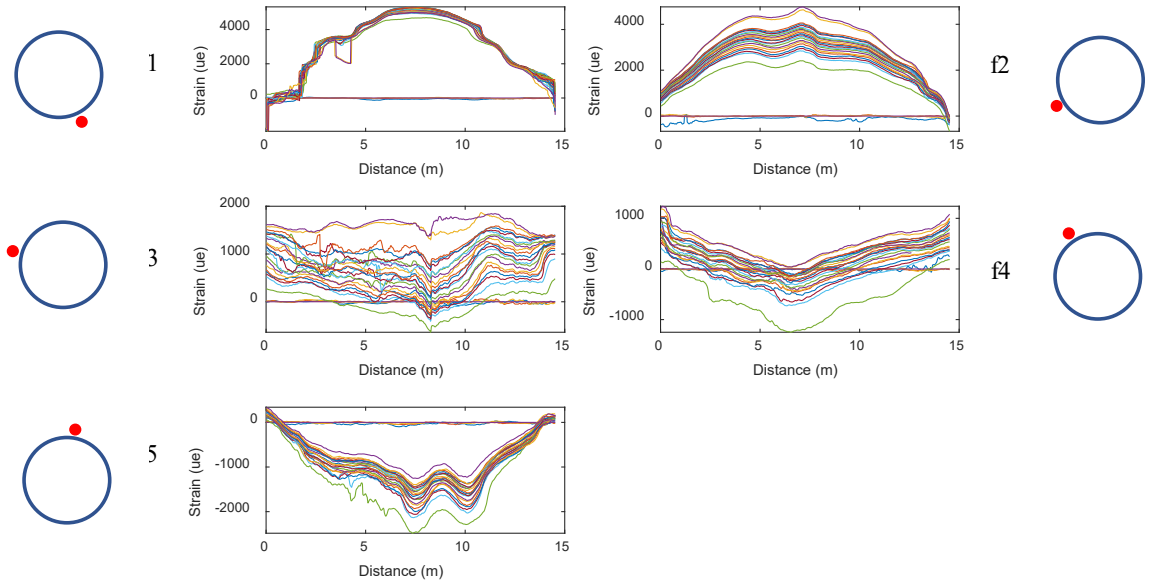

Figure 2 – An example of distributed strain profiles measured by a distributed strain sensor interrogator.

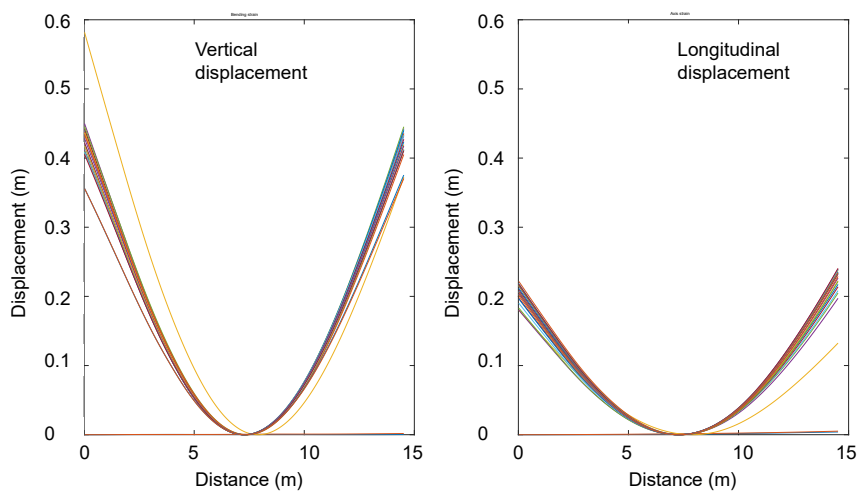

Figure 3 Estimated displacements from the DFOS data

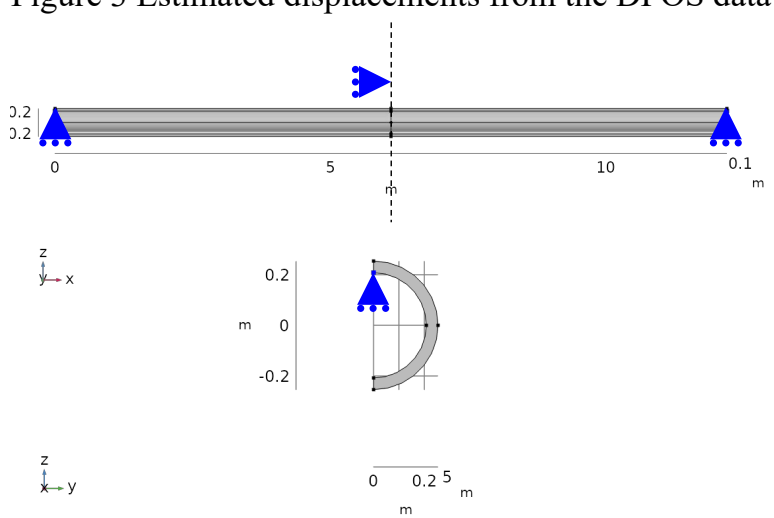

Figure 4 3D finite element model of the problem

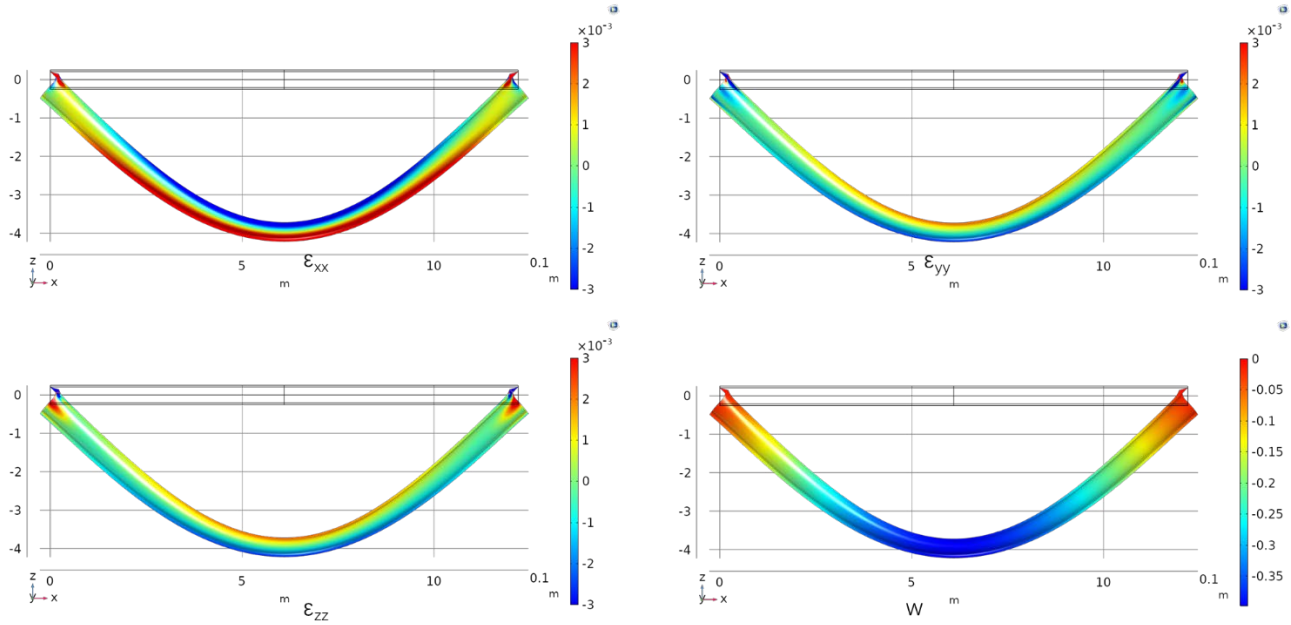

Figure 5 Deformation shape and strain/displacement contours

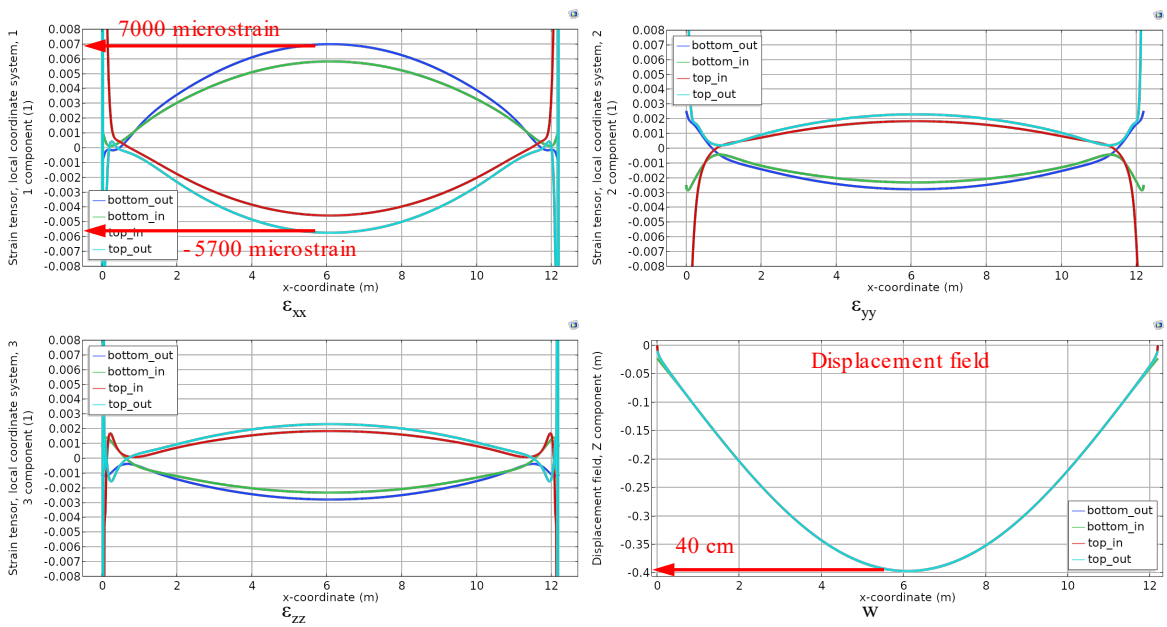

Figure 6 Computed longitudinal strain profiles at locations near the fiber optic cables were installed.

3. Future work

The results from the first experiment are promising as part of Task 1 Design. Our next step is to conduct similar experiments on steel pipelines as part of Task 2 Experiments at the UC Berkeley laboratory. We are also planning to participate in a large-scale steel pipe bending experiment conducted by another collaborating company along with guidance from PG&E. This test, which will be performed in Houston, is scheduled for mid-December 2020.

Direct coupling of the fiber optic cable to the pipeline may provide only moderately different results from measuring the strain in the soil near the pipeline by itself. We will first examine this in our numerical modeling task (Task 5). In this case, the cost of each installation type can be evaluated for the most cost-effective and beneficial use of the technology.