Line 5 Straits

Engineering Assessment

East Leg and Anchor EP-17-1

PRIVILEGED AND CONFIDENTIAL

21 June 2020

ENBRIDGE

SUMMARY:

This Engineering Assessment (EA) was conducted following the discovery of a damaged support anchor identified as EP-17-1 on the East Leg of Line 5. Enbridge has completed detailed modelling and fitness for service assessments in order to confirm and demonstrate that the East Leg pipeline is safe for continued operation. The longitudinal loading experienced by the anchor and resulting stress transferred to the pipeline is between 60 – 77 times lower than engineering design limits of the pipeline critical strength. Further, direct field examination of the pipe shows only minor coating damage and no metal disturbance caused by the movement of the anchor. Additionally, this assessment demonstrates that the damage to the support did not create a pipeline span or support safety concern. Finally, a recent ROV inspection has confirmed that there is no mechanical damage to the other screw anchors and other portions of the pipe.

PIPE CONDITION ASSESSMENT

ROV imagery as well as a diver survey was conducted at Span E-11 where anchor EP-17-1 is located. Photos of the condition of the anchor as found coupled with the diver assessment of the pipeline coating indicate very little load transfer between the screw anchor's saddle assembly and the pipeline. In addition, as the saddle of the anchor traversed towards the South, no coating holidays occurred due to contact in this area indicating that the shear stresses on the coating remained low throughout the event. The diver assessment indicates no visible deformations on the pipeline.

The maximum force on the support anchor would have been due to dragging it in the longitudinal direction (i.e. along the axis of the pipe). The limiting point on the anchor is the slip force of 2600 lbs friction load which occurs at the saddle component and is the interface between the anchor and the pipe. This dragging force equates to less than 0.054 ksi or less than 0.18% specified minimum yield strength (SMYS) of the pipe.

The support anchors are designed to provide stability to the pipeline where spans develop. By design, the anchor supports can de-couple or come apart at various connections in case unplanned forces act upon them. This de-coupling or de-connection occurs at forces far less than the force (700 – 900 kN or 157,366 – 202,328 lbs) needed to cause critical pipeline damage. The resultant movement and damage of the support anchor in this instance demonstrates this design behavior. In other words, an unplanned force that can displace or break apart the anchor is well below the force required to cause critical pipeline damage. For illustration purposes, the pipeline's resistance (represented as 180,000 lbs) to pulling force relative to the force imparted on the East Leg support is shown in Figure 1 below alongside some pulling force comparators. As shown, the design of the Straits crossing is highly resistant to this type of event.

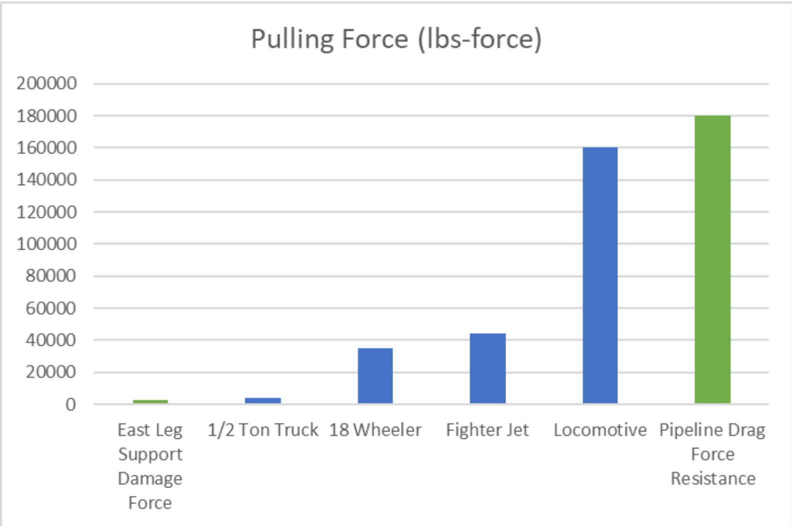

Figure 1: Comparison of Drag Force that Occurred at the Anchor to Sample Scenarios

LINE 5 ANCHOR DESIGN

The primary purpose of the anchors is to manage forces associated with loads such as gravity, buoyancy and water current. These are "in-plane" lateral loads (perpendicular to pipe axis). The in-plane frame action of the anchor assembly with the high bending stiffness of the cross-beam provides higher stiffness and strength to support the pipe in lateral direction. In the out-of-plane direction (along the pipe axis), the anchor assembly deforms in a cantilever mode which provides much less stiffness and strength. In simpler terms, the anchor is designed to be stiffer or stronger when the forces are perpendicular to the pipe. When these forces are aligned to the pipe, the anchor will deflect easily as intended. Under out-of-plane loads applied to the cross-beam or one of the helical piles, the flexible bolted connection between the beam and the pipe limits the axial load transfer between them. The Neoprene pad between the pipe and saddle also limits the load transfer between the pipe and the anchor assembly in the longitudinal direction of the pipe.

Figure 2: Displaced Anchor looking West

ANCHOR ASSEMBLY LOAD DETERMINATION

Two load case scenarios are analyzed to verify the safety of the line when the anchor assembly is loaded in the out-of-plane direction by an external source.

In the first loading scenario, under horizontal out-of-plane load applied to one anchor pile, the anchor and pipe system remain connected until such time as the static friction between the Neoprene pad and pipe coating is exceeded. The assembly of the anchor involves increasing torque on the threaded rod sections until there is approximately 3/16" worth of compression in the 1 ½" thick 60 durometer Neoprene. This level of compression corresponds to just under 50 ft lbs of torque on each of the 4 threaded rod assemblies. The compressive force between the saddle assembly can then be calculated based on the 8" wide saddle as 13,000 lbs. The static friction coefficient is conservatively estimated at 0.2 based on wet contact face between the Neoprene and the coal tar coating. The resulting required axial force at the pipe to cause initial slip is then calculated to be approximately 11.6 kN or 2600 lbs. Once axial movement is initiated, all preload stored between the three ½" Neoprene pads is lost as the upper spacer separates from the cross-beam as shown in Figure 2 above.

Secondly, the same analysis was repeated with no restraint on the pipe saddle to calculate the maximum load that fails the anchor pile after the anchor assembly is completely detached from the pipe. The maximum applied horizontal load in this scenario is 6.5 kN or 1461 lbs as determined through Finite Element Analysis where loading was increased until pile failure initiation was observed. Once the yield strength of the pile is reached, there is relatively little increase in load to continue deforming the anchor assembly. The loading condition shown in Figure 3 below has the loading of the cross-member where it meets the East helical screw pile. This loading condition matches the as found deformed shape of the assembly when viewed from above as shown in Figure 4 below. Also, the reduced stresses within the West helical screw pile in Figure 3 support this loading condition.

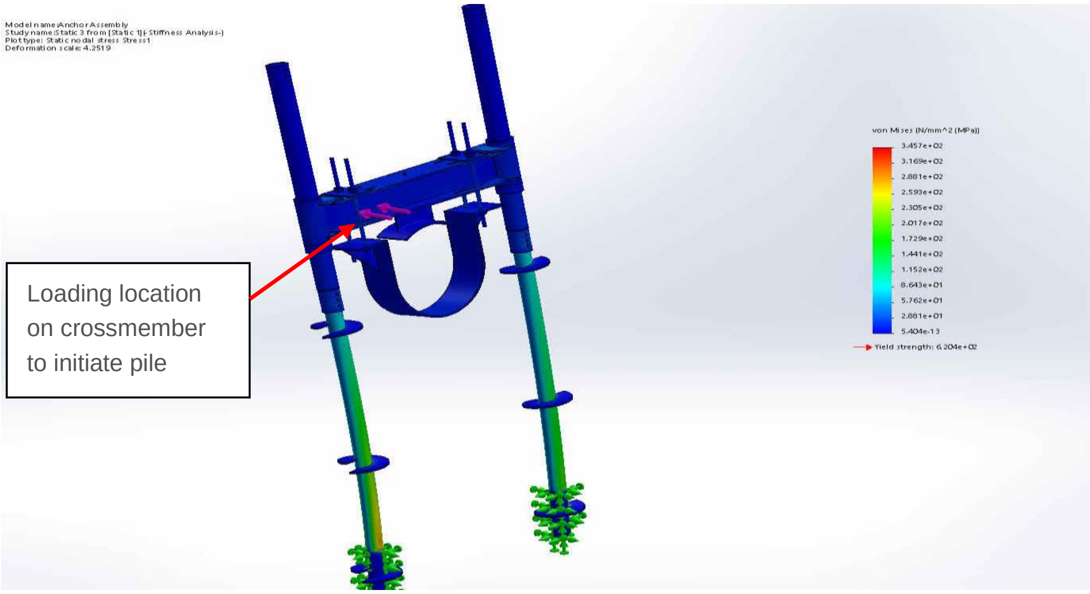

Figure 3: Required loading to yield the helical anchor

Figure 4: View from above showing the increased deflection within the East helical pile

PIPE SPAN SUPPORT CONDITION

The pipe is currently sitting on clay material nearby the damaged support anchor as shown in Figure 4 above and Figure 5, below. The clay touchdown serves as a support point and is 66 ft from the next anchor. This new pipe span of 66 ft is shorter than the remediation target of 75 ft, as stipulated within the requirements of the Line 5 Straits Easement Agreement. The 75 ft target provides a 2x safety factor. The 3rd Consent Decree additionally stipulates that locations identified beyond 65 ft span will require assessment and determination for remediation. The damaged anchor is incapable of carrying any measurable pipeline load due to the damaged and mis-aligned 1-inch threaded rods, as well as the gap between the top cross member and the pipeline as shown in Figure 5 below. This indicates that the maximum vertical load that can be imparted to the pipe is limited to the bending load of the failed 1" threaded rods and that the existing damaged anchor does not provide sufficient span management. As such, in order to meet the requirements of the Consent Decree, a replacement anchor will be scheduled for install in the near term once the required permit modifications are approved by both USACE and EGLE.

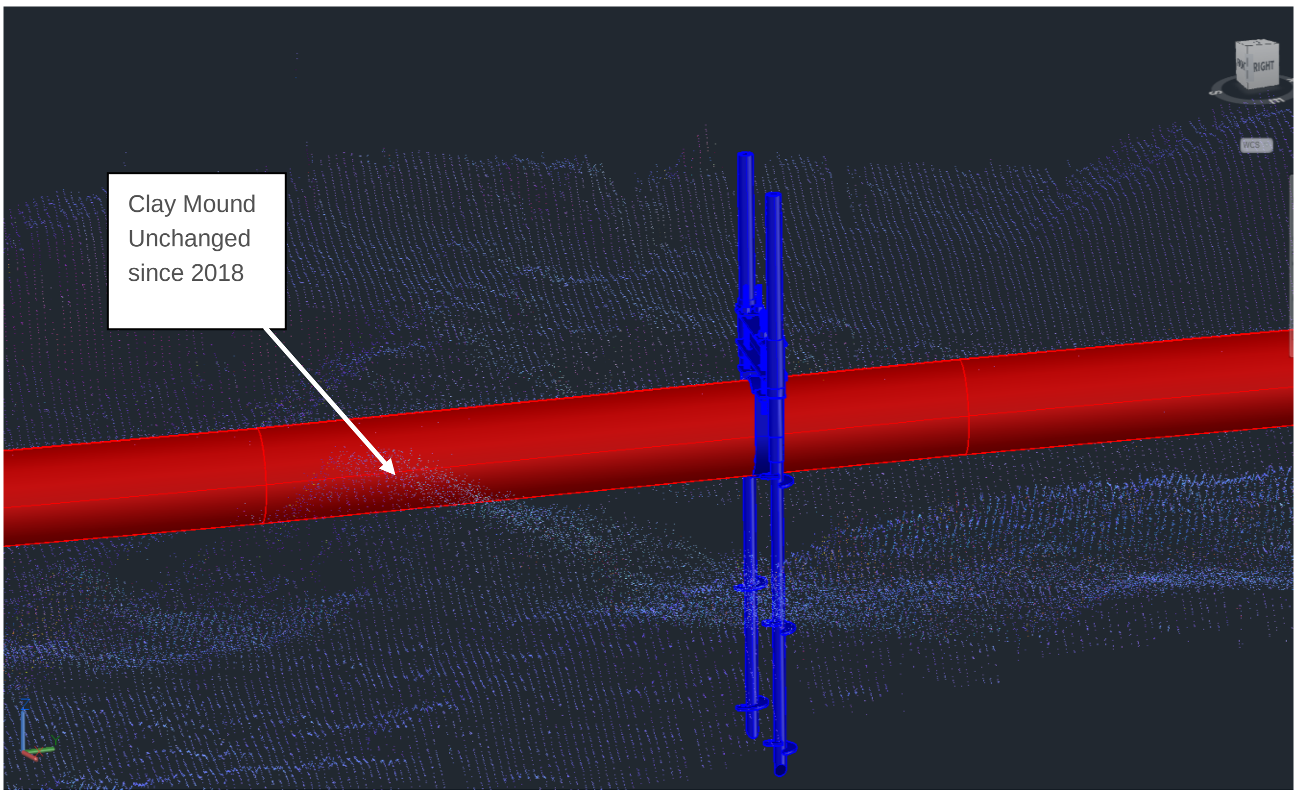

Figure 5: Multibeam bathymetry of EP-17-1 in relation to the adjacent clay mound.

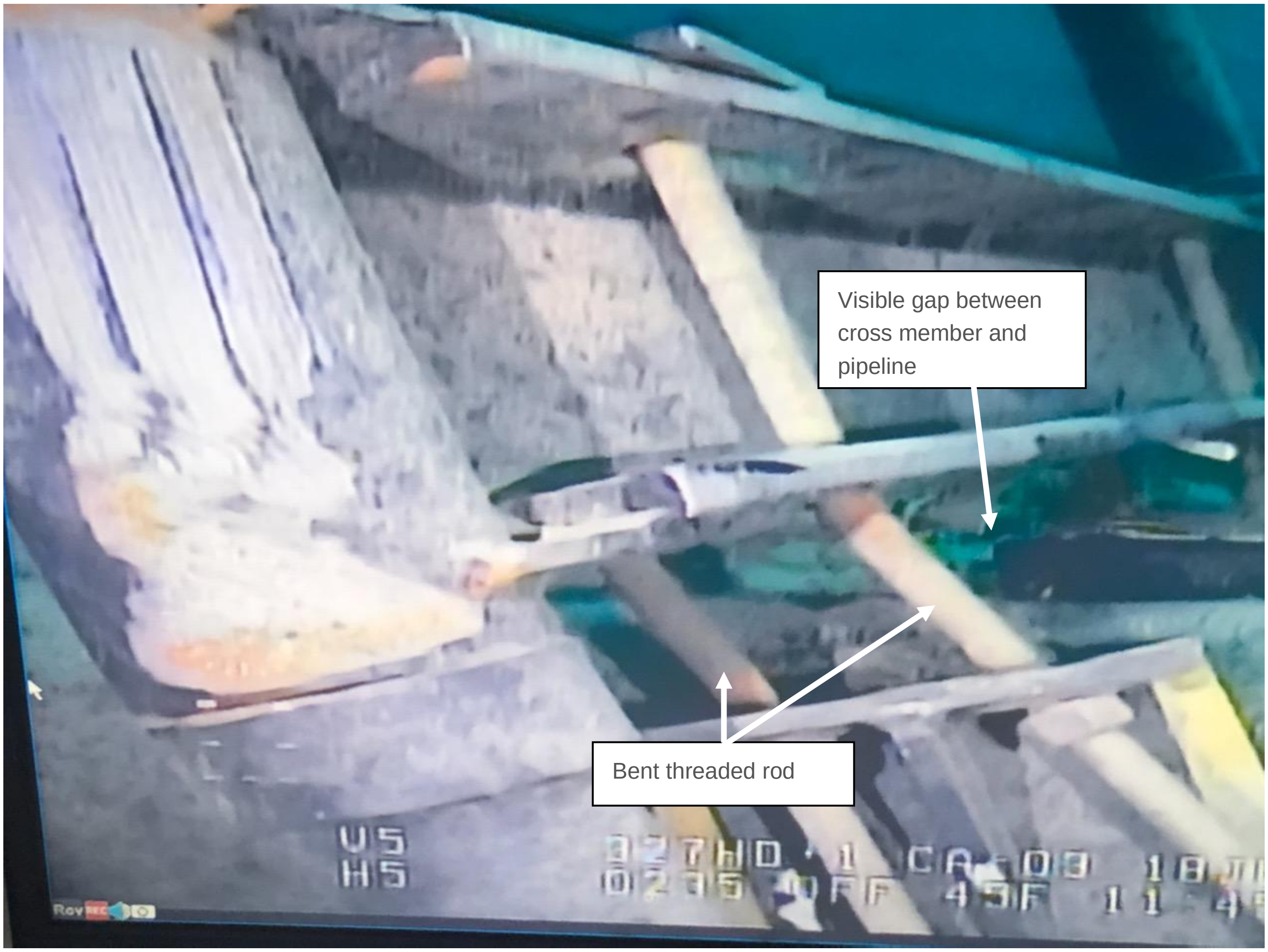

Figure 6: Damaged Threaded Rod Assemblies and Pipeline Gap to Cross Member

ADDITIONAL INSPECTIONS

The East Pipeline through the Straits was inspected to detect metal loss using BHGE Magnescan MFL4CAL on January 14, 2020. This tool provides simultaneous collection of metal loss inspection data as well as geometric inspection data. Vendor specifications indicated that metal loss as low as 12% of wall thickness, and geometric anomalies as small as 0.6% of diameter can be discerned.

The metal loss inspection reported zero metal loss anomalies and zero geometry features in this general area.

In addition, an ROV assessment of the east leg has been recently completed, confirming that there is no mechanical damage to any of the other screw anchors, or to the east leg pipeline and its coating.

CONCLUSION

The design of the Line 5 helical screw piles is fit for purpose to assure unplanned loading does not damage the pipe. This assessment of the unplanned load acting on the anchor assembly at anchor EP-17-1 has demonstrated no mechanical damage was caused to the pipeline, and ROV inspection has confirmed that there is no mechanical damage to the other screw anchors and other portions of the pipe.