

To: Jed Friesen, PREDL Systems.
 From: Alonso Vidal, P.E. Bowman Consulting
 Date: August 9, 2018
 Subject: 3ASC Phase 1 Submittal 27 Predl PVC Riser Test Manhole response

Background

In response to the request to confirm that thermal expansion/contraction of the PVC riser of the proposed manhole will not impact the drivable surface of the manhole.

Content/Review

Data:

Table 1 Thermal Coefficient - Engineering Toolbox

| Material | Expansion Coefficients | |
|-------------------------------------|---|---------------------------------------|
| | $10^{-6} \text{ in/in } ^\circ\text{F}$ | $10^{-6} \text{ m/m } ^\circ\text{C}$ |
| Aluminum | 12.8 | 23.1 |
| Carbon Steel | 6.5 | 11.7 |
| Cast Iron | 5.9 | 10.6 |
| Copper | 9.3 | 16.8 |
| Stainless Steel | 9.9 | 17.8 |
| ABS Acrylonitrile butadiene styrene | 35.0 | 63.0 |
| HDPE High density polyethylene | 67.0 | 120.0 |
| PE Polyethylene | 83.0 | 150.0 |
| CPVC Chlorinated polyvinyl chloride | 44.0 | 79.0 |
| PVC Polyvinyl chloride | 28.0 | 50.4 |

for a 108-inch (9-foot) diameter PVC riser (L), and assuming a 38°F temperature increase (ΔT) from 72°F to 110°F, and using the thermal coefficient of 0.000028 in/in °F (α), the thermal expansion experienced by the riser ($\Delta L = L * \alpha * \Delta T$) is 0.115-inches, see Table 2 below

Table 2 - Length Change from Temperature Expansion

| L | Temperature change | Coefficient | DL |
|----|--------------------|----------------|-------|
| Ft | Fahrenheit | In. per Degree | In |
| 1 | 38 | 0.000028 | 0.013 |
| 2 | 38 | 0.000028 | 0.026 |
| 3 | 38 | 0.000028 | 0.038 |
| 4 | 38 | 0.000028 | 0.051 |
| 5 | 38 | 0.000028 | 0.064 |
| 6 | 38 | 0.000028 | 0.077 |
| 7 | 38 | 0.000028 | 0.089 |
| 8 | 38 | 0.000028 | 0.102 |
| 9 | 38 | 0.000028 | 0.115 |
| 10 | 38 | 0.000028 | 0.128 |
| 11 | 38 | 0.000028 | 0.140 |
| 12 | 38 | 0.000028 | 0.153 |
| 13 | 38 | 0.000028 | 0.166 |
| 14 | 38 | 0.000028 | 0.179 |
| 15 | 38 | 0.000028 | 0.192 |
| 16 | 38 | 0.000028 | 0.204 |
| 17 | 38 | 0.000028 | 0.217 |
| 18 | 38 | 0.000028 | 0.230 |
| 19 | 38 | 0.000028 | 0.243 |
| 20 | 38 | 0.000028 | 0.255 |
| 21 | 38 | 0.000028 | 0.268 |
| 22 | 38 | 0.000028 | 0.281 |
| 23 | 38 | 0.000028 | 0.294 |
| 24 | 38 | 0.000028 | 0.306 |
| 25 | 38 | 0.000028 | 0.319 |

Conclusions

The length increase shown of 0.115 inches for a 9 feet pipe (the proposed manhole). This is acceptable given mitigating factors that some deformation will be translated to strain since it is loaded and the 38 degrees change in the whole raiser is a considerable change for a buried structure.