To: Jed Friesen – PREDL Systems Silverbell
From: Alonso Vidal, P.E.
Date: November 12, 2018
Subject: PREDL Manhole static stability under partial excavation.

Background

As requested by PREDL we are covering in this document the following:

1. Local buckling due to transverse loading on annular cross section.
2. Differential lateral soil loading due to differential backfill on one site of the manhole versus the other. Maximum depth of differential loading at which the risers will not fail

   PREDL make reference to Clark County's (Nevada) concerns that differential lateral soil loading has been a problem in the past where another utility excavates next to the manhole to install a new duct bank, pipe, etc.

Content/Review

1) Item number one in of the requested analysis is included in the Manhole Design Table used by PREDL which is based on ASTM F 1759 – 97 (Reapproved 2004) Standard Practice for Design of High-Density Polyethylene (HDPE) Manholes for Subsurface Applications, sections 7.1.2.3 Axial Buckling and 7.1.2.9 Interaction of Axial and Radial Buckling. Input data is shown in Table 1with the results on Table 2.

Table 1 PVC material information

Description	value
PVC Pipe ID (in)	60.000
Wall Thickness (in)	1.208
I of Wall (in^4 /in)	0.147
Material Modulus (psi)	400000.000
Poisson Ratio	0.380
Tensile Strength (psi)	1000.000
Comp. strength (psi)	4000.000
axial strain limit	0.035
ring strain limit	0.050

Other	
Critical R.T,Dry (lbs/in)	2721.393
Critical Axial Strain at axial buckling	**0.025**
H20 wheel load (lbs)	16000

Table 2 Buckling calculations (ASTM F 1759 – 97)

		Ring Buckling			**Axial Buckling**		
Manhole Depth	**PVC Length**	**Critical. Ring Trust**	**Ring Trust stress**	**Safety Factor**	**Axial Strain**	**Critical Axial Strain at axial buckling**	**Safety Factor**
ft	ft	lbf/in	lbf/in		in/in	in/in	
4.00	1.00	1080.10	48.71	22	0.00018	0.025	139
5.00	2.00	1107.36	68.20	16	0.00019	0.025	133
6.00	3.00	1134.87	87.68	13	0.00020	0.025	124
7.00	4.00	1162.60	107.17	11	0.00021	0.025	115
8.00	5.00	1190.53	126.65	9	0.00023	0.025	105
9.00	6.00	1218.61	146.14	8	0.00026	0.025	95
10.00	7.00	1246.81	165.62	8	0.00029	0.025	86
11.00	8.00	1275.10	185.11	7	0.00032	0.025	78
12.00	9.00	1303.43	204.59	6	0.00035	0.025	70
13.00	10.00	1331.76	224.08	6	0.00039	0.025	63
14.00	11.00	1360.07	243.56	6	0.00044	0.025	57
15.00	12.00	1388.30	263.05	5	0.00048	0.025	51
16.00	13.00	1416.41	282.53	5	0.00053	0.025	46
17.00	14.00	1444.37	302.02	5	0.00059	0.025	42
18.00	15.00	1472.13	321.50	5	0.00065	0.025	38
19.00	16.00	1499.64	340.99	4	0.00071	0.025	35
20.00	17.00	1526.88	360.47	4	0.00077	0.025	32

2) The partial excavation of a manhole structure can produce failures in different modes, potentially some are:

    a. Buckling by crushing from the lid weight and other loads.
    b. Buckling by the same lid on a slender long raiser.
    c. Excessive bending or rupture by differential later soil loading
    d. Overturning by differential lateral soil loading (point in question).

Case “a” is covered by the original MH design where is shown that the raiser is capable of carrying the lid without any confining earth pressure

Case “b” is an unlikely failure mode given that the structure needs to be an unsupported 50 feet tall 60” raiser manhole to become a slender feature.

Case “C” is considered a potential scenario but given the elastoplastic properties of PVC a failure which should precede Case “D”

Case “D” is considered a potential scenario where the manhole raiser will overturn because of the differential loading of soil. The raiser should behave as a short column with a slenderness factor of 4, note that 10 or greater is consider slender. Moreover, this seem to be the case in question by PREDL and Clark County. The analysis follows

Consideration and Assumptions

- Manhole PVC pipe ID 60 inch.
- Manhole height: 20 ft
- Manhole Rise: Rigid shaft subject to earth pressure.
- Active State occurs on backfill side. Manhole riser wall move away from the soil.
- Passive State occurs on excavation side. Manhole riser wall move toward the soil.
- K_a: Coefficient of active earth pressure.
- K_p: Coefficient of passive earth pressure.
- Factor of Safety: 1.2.
- Overturning assumed to occur at excavation depth when Active Moment > Passive Moment. Moment at point a.

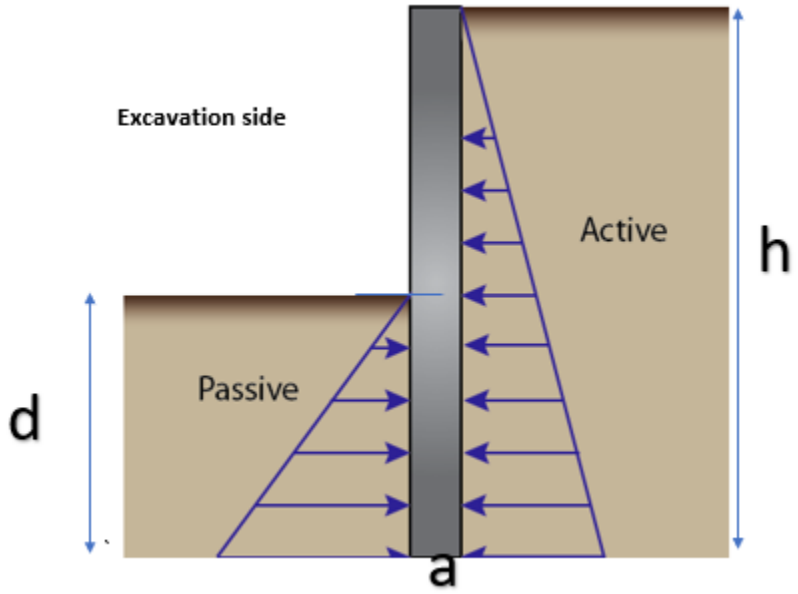
Soil Parameters	
ɣ Soil unit weight	120 lb./sf
K_a	0.333
K_p	3.0
Soil. friction angle	30°

$P_a = 0.5 * \gamma * K_a * h * h\beta$

$P_p = 0.5 * \gamma * K_p * d * d$

$\Sigma M_a = P_a * h/3 - P_p * d/3 = 0$

P_a	7,920 Lb
P_p	$180*(d)^2$
Ma	52,800 lb-ft
Mp	$60*(d)^3$
d	9.58 ft
Excavation depth at equilibrium	10.42 ft
Factor of Safety	1.2
Allowable Excavation depth	8.7 ft



Conclusions

The buckling potential, as calculated with the Standard Practice for Design of High-Density Polyethylene (HDPE) Manholes for Subsurface Applications is very low, as shown by the safety factor in the table.

The failure mode for a partial excavation is considered to be an overtopping event with the equilibrium point or maximum depth of differential loading at which the risers will not fail equal to 10.42 feet for 20 feet 60” manhole. Use 8.7 feet to have a 1.2 safety factor.