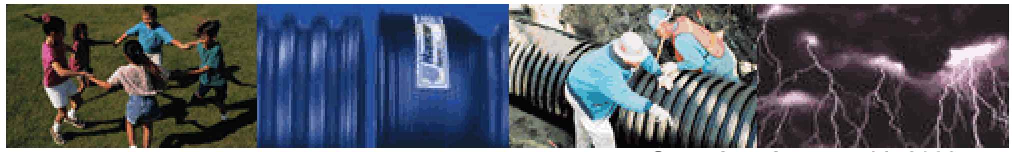
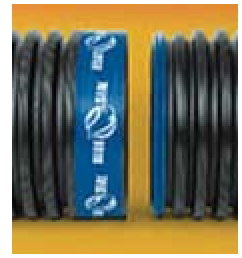


Saturday, January 11, 2003



Hancor Design Aids Section

2-7 SAMPLE CALCULATIONS

A 15-inch Sure-Lok® pipe is proposed as a culvert. AASHTO H25 loads are anticipated and minimum cover will be one foot (0.3m). Groundwater is below the pipe invert. Backfill material will be the native soil which, in this situation, is categorized as a Class III (SM) material. Density of this material is 120 pcf. Minimum compaction will be 90% standard Proctor density.

Determine whether this will be a successful installation based on wall stress, deflection, buckling, bending stress, and bending strain.

Wall thrust

Because this installation involves both live (vehicular) and dead (soil) loads, two wall thrust analyses must be made. The first analysis accounts for both the dead loads and live loads and employs the short term material properties throughout the procedure. The second analysis accounts for only the dead load and employs the long term material properties throughout. The more limiting of the two analyses governs.

Analysis 1 (dead and live loads; short term material properties)

Equation 2-6

$$T_{cr} = (F_y)(A)(\phi_p)$$

Where:

T_{cr} = critical wall thrust, lbs/linear inch of pipe

F_y = tensile strength, 3000 psi for short term conditions

A = section area, 0.230 in^2/inch of pipe (Table 2-1)

ϕ_p = capacity modification factor for pipe, 1.0

Substituting: $T_{cr} = (3000)(0.230)(1.0)$

= 690 lb/in

To check whether the calculated wall thrust is in excess of this value, use Equation 2-7.

Equation 2-7

$$T = 1.3(1.5W_A + 1.67P_LC_L + P_w)\left(\frac{OD}{2}\right)$$

Where:

T = calculated wall thrust, lb/in

W_A = soil arch load, psi (Equation 2-4)

= $(P_{sp})(VAF)$

$$P_{sp} = \frac{(\gamma_s)\left(H + 0.11\frac{OD}{12}\right)}{144}$$

P_{sp} = geostatic load, psi

γ_s = soil density, 120 pcf

H = burial depth, 1.0 ft

OD = outside diameter, 17.7 in. (Table 2-1)

$$P_{sp} = \frac{(120)\left(1.0 + 0.11\frac{17.7}{12}\right)}{144}$$

= 1 psi

$$VAF = 0.76 - 0.71\left(\frac{S_h - 1.17}{S_h + 2.92}\right)$$

Where:

VAF = vertical arching factor

S_h = hoop stiffness factor

$$S_h = \frac{\phi_s M_s R}{EA}$$

ϕ_s = capacity modification factor for soil, 0.9

M_S = secant constrained soil modulus, 670 psi (Table 2-4)

R = effective radius of pipe, in.

= ID/2+c

= 8.008 in

ID = inside diameter of pipe, 15 in. (Table 2-1)

c = distance from inside diameter to neutral axis, 0.508 in. (Table 2-1)

E = short term modulus of elasticity of polyethylene, 110,000 psi

$$S_h = \frac{(0.9)(670)(8.008)}{(110{,}000)(0.230)}$$

= 0.19

$$VAF = 0.76 - 0.71\left(\frac{0.19 - 1.17}{0.19 + 2.92}\right)$$

= 0.98

W_A = $(P_{sp})(VAF)$

= (1.0)(0.98)

= 0.98 psi

P_l = live load transferred to pipe, 15.63 psi (Table 2-7)

C_l = live load distribution coefficient

= the lesser of

$$\frac{L_w}{OD} \text{ or } 1.0$$

L_w = live load distribution width at the crown, 31 in. (Table 2-7)

P_w = hydrostatic water pressure at the springline of pipe, 0 psi, (Equation 2-5); provided groundwater is at the pipe springline or lower, it can be ignored

Substituting:

$$T = 1.3[1.5(0.98) + 1.67(15.63)(1.0) + 0]\left(\frac{17.7}{2}\right)$$

= 317 lb/in ($T<T_{cr}$; wall stress is well within limit)

Analysis 2 (dead load only; long term material properties)

Equation 2-6

$$T_{cr} = (F_y)(A)(\phi_p)$$

Where:

T_{cr} = critical wall thrust, lbs/linear inch of pipe

F_y = tensile strength, 900 psi for long term conditions

A = section area, 0.230 in^2/inch of pipe (Table 2-1)

ϕ_p = capacity modification factor for pipe, 1.0

Substituting:

$$T_{cr} = (900)(0.230)(1.0)$$

= 207 lb/in

To check whether the calculated wall thrust is in excess of this value, use Equation 2-7, recalling that live load is not included.

Equation 2-7

$$T = 1.3(1.5W_A + 1.67P_lC_l + P_w)\left(\frac{OD}{2}\right)$$

Where:

T = calculated wall thrust, lb/in

W_A = soil arch load, psi (Equation 2-4)

= $(P_{sp})(VAF)$

P_{sp} = geostatic load, psi

$$P_{sp} = \frac{(\gamma_s)\left(H + 0.11\frac{OD}{12}\right)}{144}$$

γ_s = soil density, 120 pcf

H = burial depth, 1.0 ft

OD = outside diameter, 17.7 in. (Table 2-1)

$$P_{sp} = \frac{(120)\left(1.0 + 0.11\frac{17.7}{12}\right)}{144}$$

= 1 psi

$$VAF = 0.76 - 0.71\left(\frac{S_h - 1.17}{S_h + 2.92}\right)$$

Where:

VAF = vertical arching factor

S_h = hoop stiffness factor

$$S_h = \frac{\phi_s M_s R}{EA}$$

ϕ_s = capacity modification factor for soil, 0.9

M_S = secant constrained soil modulus, 670 psi (Table 2-4)

R = effective radius of pipe, in.

= ID/2+c

= 8.008 in

ID = inside diameter of pipe, 15 in. (Table 2-1)

c = distance from inside diameter to neutral axis, 0.508 in. (Table 2-1)

E = long term modulus of elasticity of polyethylene, 22,000 psi

$$S_h = \frac{(0.9)(670)(8.008)}{(22000)(0.230)}$$

= 0.95

$$VAF = 0.76 - 0.71\left(\frac{0.95 - 1.17}{0.95 + 2.92}\right)$$

= 0.80

W_A = (P_{sp})(VAF)

= (1.0)(0.80)

= 0.80 psi

P_w = hydrostatic water pressure at the springline of pipe, 0 psi, (Equation 2-5); provided groundwater is at the pipe springline or lower, it can be ignored

Substituting:

$$T = 1.3[1.5(0.80) + 0]\left(\frac{17.7}{2}\right)$$

= 13.8 psi ($T<T_{cr}$; wall stress is well within limit)

Of the two analyses, neither violates their respective critical wall stress value; the wall thrust is within acceptable limits.

Deflection

Equation 2-8

$$\Delta y = \frac{K[(D_L)(W_c) + W_L]}{(0.149)(PS) + (0.061)(E')}$$

Where:

Δy = deflection, in.

K = bedding constant, dimensionless; assume 0.1

D_L = deflection lag factor, dimensionless; typically 1.0

W_C = soil column load on pipe, lb/linear inch of pipe (Equation 2-1)

$$W_c = \frac{(H)(\gamma_s)(OD)}{144}$$

$$W_c = \frac{(1.0)(120)(17.7)}{144}$$

= 15 lb/linear inch of pipe

W_L = live load, lb/linear inch of pipe

= (OD)(live load transferred to pipe from Table 2-7)

= (17.7 in.)(15.63 psi)

= 277 lb/linear inch of pipe

PS = pipe stiffness (Table 2-1)

= 42 psi

E' = modulus of soil reaction, psi (Table 2-3)

= 1000 psi, based on a Class III material compacted to 90% SPD

Substituting:

$$\Delta y = \frac{0.1[(1.0)(15) + 277]}{(0.149)(42) + (0.061)(1000)}$$

= 0.43 in.

= 2.9% (design OK; deflection is well within 7.5% limit)

Buckling

Equation 2-9

$$P_{cr} = \frac{0.772}{SF}\left[\frac{(E')(PS)}{1-\nu^2}\right]^{1/2}$$

Where:

P_{cr} = critical buckling pressure, psi

ν = Poisson ratio, dimensionless; 0.4 for polyethylene

SF = safety factor, 2.0

Substituting:

$$P_{cr} = \frac{0.772}{2}\left[\frac{(1000)(42)}{1-0.4^2}\right]^{1/2}$$

= 86 psi

To check whether the actual buckling pressure is in excess of this value, use Equation 2-10.

Equation 2-10

$$P_v = \frac{(R_w)(H)(\gamma_s)}{144} + \frac{(\gamma_w)(H_w)}{144} + \frac{W_L}{OD}$$

Where:

P_v = actual buckling pressure, psi

R_w = water buoyancy factor, dimensionless

= $1 - 0.33\ (H_w/H)$

γ_w = unit weight of water, 62.4 pcf

H_w = height of groundwater above top of pipe, ft.

= zero in this situation

Substituting:

$$P_v = \frac{(1.0)(1.0)(120)}{144} + \frac{(62.4)(0)}{144} + \frac{277}{17.7}$$

= 16.5 psi (design OK; actual buckling pressure is less than allowable)

Bending Strain

Equation 2-11

$$\text{Stress, } \sigma_b = \frac{(2)(D_f)(E)(\Delta y)(y_0)(SF)}{D_m^{\ 2}}$$

Where:

σ_b = bending stress, psi

D_f = shape factor, dimensionless (Table 2-6)

= 5.3 for SM material compacted to 90% SPD and PS of 42 psi

E = modulus of elasticity of polyethylene, 22,000 psi

y_o = distance from centroid of pipe wall to the furthest surface of pipe, in.

= the greater of $\frac{OD - D_m}{2}$ or $\frac{D_m - ID}{2}$

= 0.842 in.

SF = safety factor, 1.5

D_m = mean pipe diameter, in.

= ID + 2c

= 16.016 in.

c = distance from inside diameter to neutral axis, in. (Table 2-1)

= 0.508 in.

Substituting:

$$\sigma_b = \frac{(2)(5.3)(22{,}000)(0.43)(0.842)(1.5)}{16.016^2}$$

= 494 psi (design OK; actual stress is less than allowable 900 psi)

Bending Stress

Equation 2-12

$$\text{Strain}, \varepsilon_b = \frac{(2)(D_f)(\Delta y)(y_0)(SF)}{D_m^{\ 2}}$$

Where:

ε_b = bending strain, in./in.

Substituting:

$$\varepsilon_b = \frac{(2)(5.3)(0.43)(0.842)(1.5)}{16.016^2}$$

= 0.022 in/in

= 2.2% (design OK; actual strain is less than allowable 5%)

Conclusion

This is a suitable application for 15-inch Sure-Lok® pipe. All criteria are well within allowable values.

Featured Products

BLUE SEAL | Sure-Lok | LandMax | Hi-Q | EnviroChamber | TerraFiber

Home • About Hancor • Ordering
Contact Us • Monthly Drawing • Hot News