Deflection of a Flexible Pipe using the Modified Iowa Formula

This application calculates the defletion of a buried horizontal pipe using the Modified Iowa Formula.

Reference
Buried Pipe Design, Third Edition, Moser, A. P.

Pipe Properties

Pipe diameter $d_{nom} := 15\ \text{inch}$

Dimension ratio $DR := 35$

Pipe outside diameter (av) $d_{OD} := 15.3\ \text{inch}$ $B_c := d_{OD}$

Pipe inside diameter $d_{ID} := 14.426\ \text{inch}$

Pipe wall thickness and dimension ratio $t := 0.447\ \text{inch}$ $DR_{min} := d_{OD}/t = 34.228$

$m1 := \frac{B_c}{2} = 7.650\ \text{in}$

Modulus of elasticity $E := 400000\ \text{psi}$

Effective length of conduit $L := 3\ \text{ft}$ $n := \frac{L}{2} = 1.500\ \text{ft}$

Design deflection limit $x_{max} := 0.05$

Service Conditions

Design traffic load $P := 16000\ \text{lbf}$

Deflection lag factor $D_L := 1.5$

Trench width at top of pipe $B_d := 3.5\ \text{ft}$

Height of soil cover at top of pipe $H := 1.85\ \text{ft}$

Impact factor

$$F := \begin{cases} 1.5 & H > 0\ ft \text{ and } H \le 1\ ft \\ 1.35 & H > 1\ ft \text{ and } H \le 2\ ft \\ 1.15 & H > 2\ ft \text{ and } H \le 3\ ft \\ 3 & \text{otherwise} \end{cases}$$

$F = 1.350$

Bedding constant

$K_b := 0.1$

Trench Backfill Soil Properties

Modulus of soil reaction for trench side fill (Table 3.4, fine grained soil)

$E_{SR} := 400\ lbf \cdot inch^{-2}$

Unit weight of trench backfill soil

$\gamma_s := 120\ lbf \cdot ft^{-3}$

Soil type

trench_soil := "Wet sand"

Rankine ratio times friction coefficient (Table 2.1)

$$K := \begin{cases} 0.33 \cdot 0.5 & \text{trench\_soil} = \text{"Partially compacted damp topsoil"} \\ 0.37 \cdot 0.4 & \text{trench\_soil} = \text{"Saturated topsoil"} \\ 0.33 \cdot 0.44 & \text{trench\_soil} = \text{"Partially compacted damp clay"} \\ 0.37 \cdot 0.3 & \text{trench\_soil} = \text{"Saturated clay"} \\ 0.33 \cdot 0.5 & \text{trench\_soil} = \text{"Dry sand"} \\ 0.33 \cdot 0.5 & \text{trench\_soil} = \text{"Wet sand"} \end{cases}$$

$K = 0.165$

Soil Load

Soil load coefficient (Marton theory)

$$C_d := \frac{1 - e^{-2 \cdot K \cdot H / B_d}}{2 \cdot K} = 0.485$$

Soil load for flexible pipes

$W_c := C_d \cdot \gamma_s \cdot B_c \cdot B_d = 3.791 \times 10^3\ \frac{kg}{s^2}$ $\gamma_s = 120\ \frac{lbf}{ft^3}$

Unit soil load

$$w_c := \frac{W_c}{B_c} = 9.754 \times 10^3\ Pa$$

Superimposed Wheel Load

Wheel load coefficient

$$C_s := 1 - \frac{2}{\pi}\cdot\left(\arcsin\left(H\cdot\sqrt{\frac{m1^2 + n^2 + H^2}{\left(m1^2 + H^2\right)\cdot\left(n^2 + H^2\right)}}\right) - \frac{m1\cdot n\cdot H}{\sqrt{m1^2 + n^2 + H^2}}\cdot\left(\frac{1}{m1^2 + H^2} + \frac{1}{n^2 + H^2}\right)\right) = 0.331$$

Wheel load

$$W_{sc} := \frac{C_s\cdot P\cdot F}{L} = 2385.967\ \frac{lbf}{ft}$$

Unit wheel load

$$w_{sc} := \frac{W_{sc}}{B_c} = 12.995\ \frac{lbf}{in^2}$$

Total Load and Deflection

Total load

$$w := w_c + w_{sc} = 14.410\ psi$$

Pipe wall deflection (modified Iowa formula)

$$\Delta x_{pc} := \frac{D_L\cdot K_b\cdot w_c + K_b\cdot w_{sc}}{\frac{2\cdot E}{3\cdot\left(DR_{min} - 1\right)^3} + 0.061\cdot E_{SR}} = 0.048$$

Check deflection does not exceed limit

$$check := \begin{cases} \text{"All good"} & \Delta x_{pc} < x_{max} \\ \text{"Not good"} & \text{otherwise} \end{cases}$$

check = "All good"