Structural Design Calculations to measure percentage deflection in accordance with BS EN 1295 – *Structural design of pipelines under various conditions of loading*.

Project: Main Road, Anytown

Ovalization Design Calculation:

$$\frac{\Delta}{D} = \frac{K_x\,[(D_L P_e)+P_s]}{(8EI/D^3) + (0{,}061E')}$$

Where:

Δ = Deflection

D (Outside Diameter of pipe ribs) = 1286mmØ

K_x (Deflection Coefficient) = 0.083 (for Class S1 bedding and surround material)

D_L (Deflection Lag Factor) = 1

P_e (Vertical Soil Pressure) = 17.64 kN/m^2*

P_s (Surcharge Pressure) = 81 kN/m^2 (0.9m depth of cover with 'Main Road' wheel load**)

EI/D^3 = 4.3kN/m^2 (**Long-Term** Stiffness of 1200mmØ Pipe)

E' (Overall Soil Modulus Reaction) = E'_2 C_L

E'_2 (Bed & Surround soil modulus at 85% compaction) = 7MN/m^2

E'_3 (Native soil modulus) = 5MN/m^2 (firm to stiff clay)

*(19.6kN/m^3 x 0.9 (min depth of cover in metres)) as per clause 6.3 BS EN 1295-1

** BS 9295:2010 Table A.1 Surcharge pressures, Ps (kN/m^2)

Calculation of C_L – Soil modulus adjustment factor

$$C_L = \frac{0.985 + (0.544 B_d/B_c)}{[1.985-0.456(B_d/B_c)]\,(E'_2/E'_3) - [1 - (B_d/B_c)]}$$

B_c = 1286 (mm)

B_d = 1586 (mm)

C_L = 0.74

Therefore E' (Overall soil modulus) = 5.21

Ovalization design calculation is therefore:

$$\frac{\Delta}{D} = \frac{0.083\,[(1 \times 17.64) + 81]}{(8 \times 4.3) + [0.061 \times 5210]}$$

= 0.0232

Deflection = 0.0232 x D

= 0.0232 x 1.286m = 0.0299m = 29.9mm

Percentage Deflection of ID = (0.0299/1.200) x 100 = 2.49%

Maximum Permissible Deflection is ≤6.0%, therefore a value of 2.49% is well within this range.

Permissible Deflection is derived from the 'Spangler' calculation methods referred to in BSEN 1295 (p.10 B.1.12), these methods being the basis of the standard. The range of 'permissible deflection' defined by Spangler is between 5 and 7.5%. In the UK, the Highways Agency use the 5% figure, but the more widely adopted figure used by all of the water companies is 6%.

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Buckling Design Calculation (with side support)

$$FS = \frac{1}{\{(Pe/Pcrl) + (Ps+Pv)/Pcrs\}}$$

Where:

Pcrl = 0.6.(El.I/D³)^0.33.(E')^0.67

Pcrs = 0.6.(Es.I/D³)^0.33.(E')^0.67

D (Outside Diameter of pipe ribs) = 1286mmØ

Pe (Vertical Soil Pressure) = 17.64*

Pv (Transient Vacuum Pressure) = 0

Ps (Surcharge Pressure) = 81kN/m^2 (0.9m depth of cover with 'Main Road' wheel load**)

Es.I/D^3 = 5.0kN/m^2 (Short-Term Stiffness of 1200mmØ Pipe)

El.I/D^3 = 4.3kN/m^2 (Long-Term Stiffness of 1200mmØ Pipe)

E' (Overall Soil Modulus Reaction) = E'2 CL

*(19.6kN/m^3 x 0.9 (min depth of cover in metres)) as per clause 6.3 BS EN 1295-1
** BS 9295:2010 Table A.1 Surcharge pressures, Ps (kN/m^2)

FS = 3.17 which is >2 therefore OK

Factor of Safety against Buckling (without soil support)*

$$FS = \frac{Pcra}{(Pe + Pv)}$$

Where

Pcra = 24 Es.I/D³

FS = 6.8 which is >1.5 therefore OK

* Calculation only required where cover depth < 1.5m as per clause 6.2.3 (b) BS EN 1295-1