HydroFoamer Bend Calculation Methodology

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Overview

This model predicts axial displacement at couplers adjacent to GRP pipe bends encased in PU or PIR foam. It calculates the deformation from internal thrust at the bend apex, resolved through resistance via foam compression, shear against the trench, and tensile wrap at the coupler neck. Field validation from the Adamselv project and A-frame tests confirms model behaviour.

Assumptions

- Curved bend geometry using industry standard-derived segment radii and arc lengths (sheet renamed Bend Geometry).
- Square foam block cross-section around pipe.
- Elastic response from PU or PIR foam (Young's modulus E, Poisson's ratio ν).
- Activation deformation occurs early, then stabilizes.

Step-by-Step Calculations

1. Internal Pressure

$$P = \gamma \cdot H$$

2. Thrust Force at Bend

$$F = P \cdot A_p \cdot 2 \cdot \sin\left(\frac{\alpha}{2}\right), \quad A_p = \pi \left(\frac{D}{2}\right)^2$$

3. Stiffness Components

Compression:

$$k_C = \frac{E \cdot A_C}{L_C}$$

Shear (floor and crown):

$$G = \frac{E}{2(1+\nu)}, \quad k_S = \frac{G \cdot A_S}{L_S}$$

Tension (coupler wrap):

$$A_T = A_{\text{block}} - A_{\text{pipe}}, \quad k_T = \frac{E \cdot A_T}{L_T}$$

4. Total System Stiffness

$$k_{\text{total}} = k_C + k_{S,\text{floor}} + k_{S,\text{crown}} + k_T$$

5. Elastic Displacement

$$\delta_{\text{elastic}} = \frac{F}{k_{\text{total}}}$$

6. Activation Offset

$$\delta_{\text{activation}} \approx 0.1 \text{ mm} \quad \text{(empirical: A-frame \& Adamselv)}$$

7. Total Coupler Displacement

$$\delta_{\text{total}} = 2L \left(1 - \sqrt{1 - \left(\frac{\delta_z}{2L}\right)^2}\right) + \delta_{\text{activation}}$$

8. Angular Deflection

$$\theta = \arcsin\left(\frac{\delta_{\text{coupler}}}{2L}\right)$$

9. Stress and Safety Factor

$$\sigma = \frac{F}{A_C}, \quad \text{SF} = \frac{\sigma_{\text{creep limit}}}{\sigma}$$

Conclusion

This model replicates observed field behaviour from the Statkraft Adamselv project 2016–2019. The 0.1 mm activation offset aligns with the Multiconsult Mathcad calculations (2016), the initial A-frame, sub-size thrust force simulation tests (2016), and Adamselv test data as published by NTNU (2019). All strain remains below the 2% limit, and predicted coupler movement is within safe elastic bounds even under 400 m head and 90° bends. Conservative safety factors (often >10×) demonstrate robustness for GRP anchoring in foamed trench environments.