Review of Proposed Design Approaches for Liners Installed in Partially Deteriorated Host Pipes

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Overview

- Shortcomings of ASTM F1216
- Brief Summary of Gumbel's Model
- Points of Strong Agreement
- Other Possible Forms for a Design Model
- Recommendations

Shortcomings of ASTM F1216

- Using enhancement factor K
- Ovality factor C *(works pretty good)*
- Annular gap not included
- Other types of imperfections can not be considered *(such as longitudinal or wavy intrusions)*
- Uncertainty in extending a short-term model to predict long-term response

Brief Summary of Gumbel's Model

- Eliminates the need for enhancement factor K by using a solution based on constrained buckling behavior
- Accounts for the coupled effect of gap and ovality *(finite element solution)*
- Gives multiple approaches for the format of the design approach *(chart, equation, combined chart and equation, and automated using software)*
- Some testing to account for long-term behavior is suggested

Points of Strong Agreement

- K should not be part of ASTM F1216
- Gap should be part of ASTM F1216
- Coupled effects for the most common defects (at least gap and ovality) is needed

Other Possible Forms of Design Approach

OPTION 1

$$P_{cr} = c_{ovality} \cdot c_{gap} \cdot c_{\text{int}\,rusion} \cdot c_{\#\ lobes} \cdot c_{other} \cdot \frac{E_{long-term}}{E_{short-term}} \cdot P_{glock}$$

- ADVANTAGES
  - easy to understand
  - easy to include effect of other defects if needed
- DISADVANTAGES
  - hard to account for parameter coupling if more than two correction factors used

Researchers: Falter ('96), El Sawy and Moore ('97), McAlpine ('96)

Other Possible Forms of Design Approach

OPTION 2

$$P_{cr} = c \cdot \frac{E_{long-term}}{1 - \nu^2} \cdot \left(\frac{D}{t}\right)^m$$

- ADVANTAGES
  - Easier to account for couplings between imperfections (gap, ovality, . . .)
  - Can write evaluate constants using software
- DISADVANTAGES
  - Harder to see the direct influence of a given imperfection

Researchers: Boot ('98), Gumbel ('01), Zhu ('00)

Other Possible Forms of Design Approach

OPTION 3

$$P_{cr} = E_{long-term} \cdot 0.455 \cdot k^{2/5} \cdot c_{gap} \cdot \frac{t^{11/5}}{p^{2/5} \cdot R^{9/5}}$$

- ADVANTAGE
  - Fully closed-form analytical solution
  - Accounts for both gap and ovality
  - Works for other pipe shapes: egg shaped, horseshoe shaped
- DISADVANTAGES
  - Probably won't be as accurate as a FEA based solution

Researchers: Thepot ('01)

Other Possible Forms of Design Approach

OPTION 4

DESIGN GRAPHS

- ADVANTAGE
  - People like graphs
  - Can be used in conjunction with the other types of models
- DISADVANTAGES
  - Hard to include couplings between multiple imperfections

Recommendations

- Decide on the list of imperfections / parameters to include in the standard (gap, ovality, intrusions, . . .)
- Develop recommended, minimum and maximum values for these parameters for various rehabilitation products
- Decide between one-lobe and two-lobe buckling
- Decide whether or not different design models are needed for CIPP and thermoplastic close-fit liners (and other systems)

Recommendations

- Evaluate the leading models in the literature for low DR, medium DR, and high DR designs using at least two different imperfection sets for each of these designs *(this side-by-side comparison will show us the predictive capabilities of the various models)*

- Evaluate the performance of these models and upgrade the standard accordingly

Conclusion

The design approach presented by Gumbel offers a clear improvement over ASTM F1216 by correctly modeling the effect of host pipe constraint and annular gap.