Numerical Model for the Response of Unbonded FREI at Low Temperatures

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Wednesday, June 27
Outline

▸ Introduction

▸ Objectives

▸ Experimental Testing

▸ Numerical Model

▸ Conclusion
Introduction
FREI

- Fiber-Reinforced Elastomeric Isolators (FREI)
Unbonded FREI

- Rollover mechanism
  - Appropriate aspect ratio required (width : total height)
Force-Displacement Curve

- **Rollover Starts**
- **Rollover Continues**
- **Full Rollover**

**Force** vs **Lateral Displacement**

- **Softening Behaviour**
- **Stiffening Behaviour**
Objective

- Evaluate U-FREI at low temperature through experimental testing
  - Effective lateral stiffness & energy dissipated
- Develop a numerical model to describe the response of U-FREI at low temperatures
Experimental Testing

- U-FREI Conditioned at Low Temperature

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Duration (Days)</th>
<th>AASHTO Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C (68°F)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>-18°C (0°F)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>-26°C (-15°F)</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>-37°C (-35°F)</td>
<td>1</td>
<td>4/5</td>
</tr>
<tr>
<td></td>
<td>14</td>
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<tr>
<td></td>
<td>28</td>
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</table>
Test Setup

- Lateral Actuator
- Vertical Actuator
- Loading Beam
- Specimen, Insert & Chamber
- Three-axis Load Cells
- Pedestal
- Vertical Actuator
- Reaction Frame
Test at 20°C (68°F)
Hysteresis Loop

![Hysteresis Loop Diagram](image)

- **Normalized Lateral Force (F/GA)**
- **Normalized Lateral Displacement (u/tr)**

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Effect of Temperature (1 Day Conditioning)
Effect of Duration (-37°C)
Numerical Model

- Non-linear Elastic Spring Model
- Takeda Bilinear Plastic Model
- Takeda-Elastic Model
Numerical Model

▶ Low temperature
  ◦ Function of Temperature or Duration in form of “y = mx + b”

\[
P_{Temperature} = a_{T0} + a_{T1}T \quad -18^\circ C \geq T \geq -37^\circ C
\]

\[
P_{Duration} = a_{D0} + a_{D1}D \quad 1 \text{ Day} \leq D \leq 28 \text{ Days}
\]

▶ “a” coefficients
  ◦ Determined once through simultaneous least squares linear regression
Sample Hysteresis Loop

Normalized Lateral Force \((F/GA)\)

Normalized Lateral Displacement \((u/t_r)\)

Experimental

Model

1 Day \(-37^\circ C\)
Sample Hysteresis Loops

Room Temperature

Normalized Lateral Force (F/GA)

Normalized Lateral Displacement (u/tr)

1 Day | −37°C

28 Day | −37°C
Acknowledgments

- Centre for Effective Design of Structures (CEDS)
- Ontario Ministry of Research and Innovation (MRI)
- Natural Sciences and Engineering Research Council of Canada (NSERC)
Thank you!

- Numerical Model for the Response of Unbonded Fiber-Reinforced Elastomeric Isolators at Low Temperatures

- Model is a function of
  - Temperature
    \[ P_{Temperature} = a_{T0} + a_{T1}T \quad -18^\circ C \geq T \geq -37^\circ C \]
  - Duration
    \[ P_{Duration} = a_{D0} + a_{D1}D \quad 1 \text{ Day} \leq D \leq 28 \text{ Days} \]