Compressive Fields in Prestressed Concrete Monoblock Crosstie Rail Seats

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Motivation for Research

- Industry partners have stated on numerous occasions that rail seat positive cracks are not an issue in field, two possible reasons:
  - Crosstie is overdesigned at rail seat (design is over-conservative)
  - Load is being transferred differently than expected in analysis (analysis is over-conservative)
Motivation for Research (cont.)

• Russell Lutch’s thesis stated “deep beam behavior likely exists in the rail seat region”

• Talks with UIUC concrete structures experts have steered away from true deep beam behavior, but have supported the possibility of compressive field development in the rail seat region

• Proving this compressive field behavior could lead to smaller, cheaper, and more efficient crosstie designs
Introduction to Compressive Fields

• A compressive field is a region of a loaded material where the material is only in compression

• This type of behavior is well-documented and expected in many branches of engineering
  – As load flows through a structural system the load spreads, following the geometry

• For concrete, this behavior is seen in the design of corbels and spread footings
Comparison of International Standards Assumptions

Rail Seat Positive \( (M_{RS+}) \)

Center Negative \( (M_{C-}) \)

* Backcalculated from McQueen
UIC 713R Assumption

- **UIC 713R Rail Seat Positive Bending Moment (M_{RS+}) Calculation**
- Assumes compressive field acting at 45-degree angle from end of rail seat to neutral axis
- For 8’-6” long, 9” deep crosstie with 6” rail base,

\[
M_{RS+} = \frac{R}{4} \left( \frac{a}{2} - \frac{f}{2} - \frac{h}{2} \right)
= \frac{62.1 \text{ kip}}{4} \left( \frac{42”}{2} - \frac{6”}{2} - \frac{9”}{2} \right)
= 210 \text{ kip-in}
\]
Design Implications of Compressive Field

- Rail seat loading area makes a significant difference on bending moment analysis at that region.

- Bending moment analysis:
  - 348 kip-in
  - 279 kip-in
  - 210 kip-in
Experimental Plan

- Use vertically-oriented surface strain gauges to record compressive strains experienced by crosstie
  - Measure three points along rail seat section
  - Measure five points along neutral axis of crosstie
- Testing UIC 713R assumption
  - Entire rail seat region (42”) supported by wood
  - Loaded from 0-60 kips (Test 1-2) and 0-80 kips (Test 3-4) over 5” 50A Durometer pad
Instrumentation Layout

Compressive Field

N.A. 6 7 8 9 10
Hypothetical Results

Graph showing measured strain vs. position about RS centerline.
Preliminary Results (0 – 60 kips)

Hypothetical

Test 1

Test 2
Preliminary Results (0 – 80 kips)

Hypothetical

Test 3

Test 4
Preliminary Conclusions

- **Preliminary results are inconclusive**
  - Some gauges are experiencing compression, some tension
  - Strain magnitudes are lower than expected
  - Likely due to improper support
    - Steel plates may not be "bridging" gap between supports effectively enough to promote compressive field
    - Wood may be too stiff to promote load spreading
- **Some evidence is shown for compressive field formation**
  - Test 3 (80 kips) shows lower strains at gauges 7 – 9 (bottom row) than gauges 3 – 5 (top row)
  - This could indicate that a certain level of stress is required to initiate compressive field formation
  - However, 80 kip rail seat loads are highly uncommon
Future Work

- Test with softer support to ensure crosstie bottom is in full contact
  - Softer support may also initiate more load spreading
- Test on Static Load Testing Machine (SLTM)
  - Machine will allow uniform support under rail seat regions
- Perform finite element analysis and run parametric study varying applied load, loading area, and support conditions
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