Parametric Study of Factors Impacting End Zone Cracking in Pretensioned Concrete Bulb-Tee Girders

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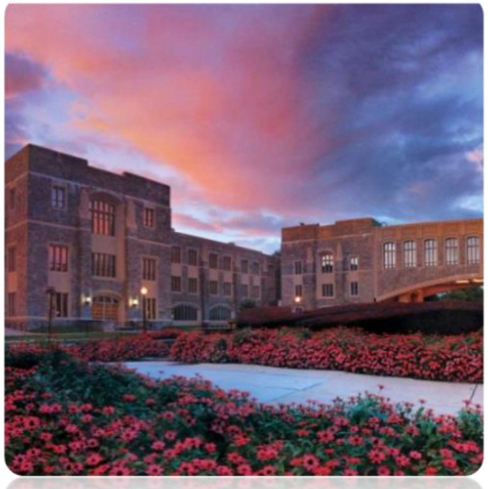
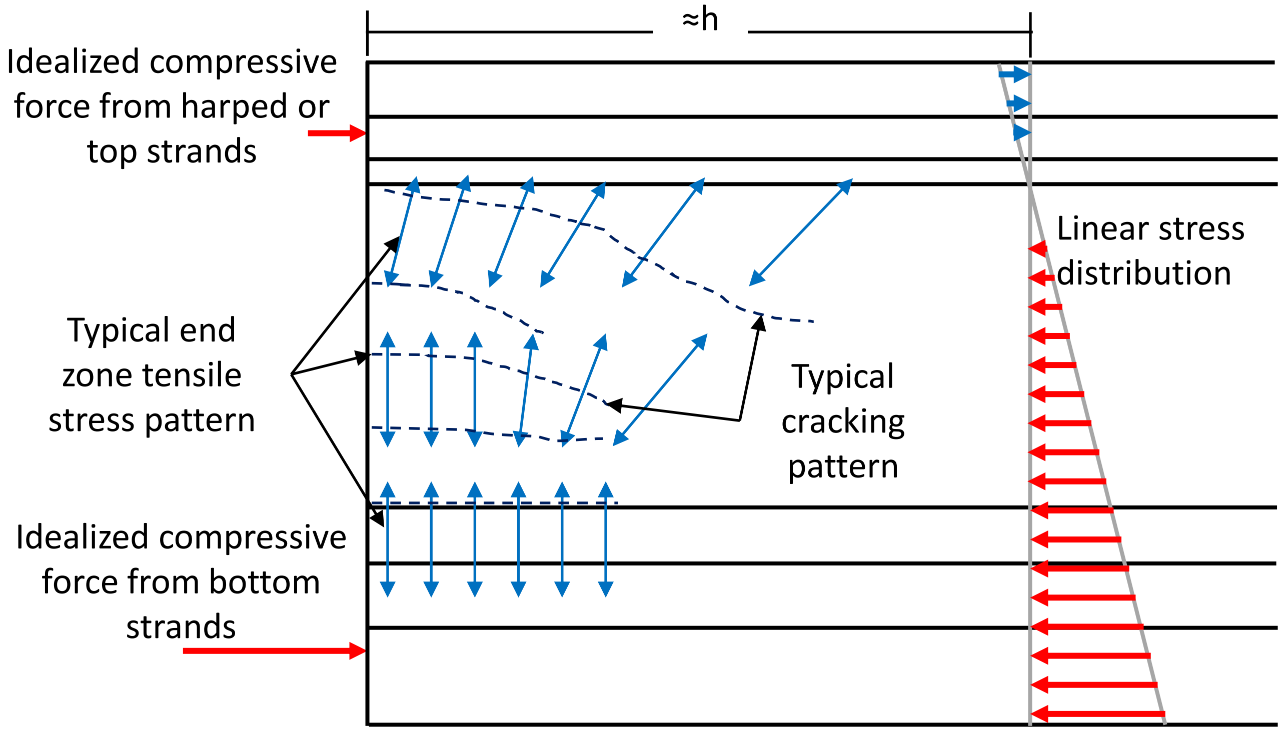


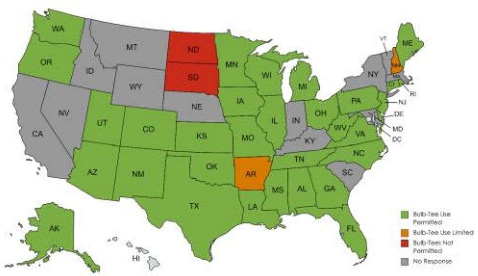
Background

Typical tensile stress and cracking patterns due to detensioning:

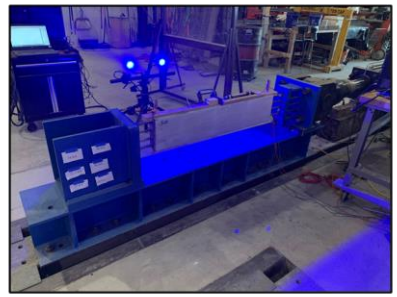


Research Approach

1. Analyze Current Practices
Literature review, DOT survey, Precast Plant Survey

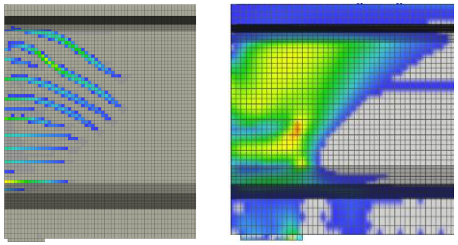


2. Specimen Tensile Testing
Specimens meant to mimic half of PCBT web cross-section



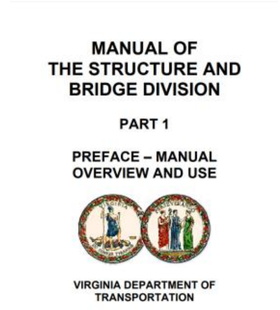
3. Large Scale PCBT Testing
Observe cracking performance in PCBTs with varying levels of reinforcement

4. Investigate Behavior ★
Analyze impact of various factors on end zone cracking using FEA



5. Validation
Optimized designs will be included in ongoing bridge projects

6. Finalize Design Guidelines


MANUAL OF
THE STRUCTURE AND
BRIDGE DIVISION

PART 1

PREFACE – MANUAL
OVERVIEW AND USE

VIRGINIA DEPARTMENT OF
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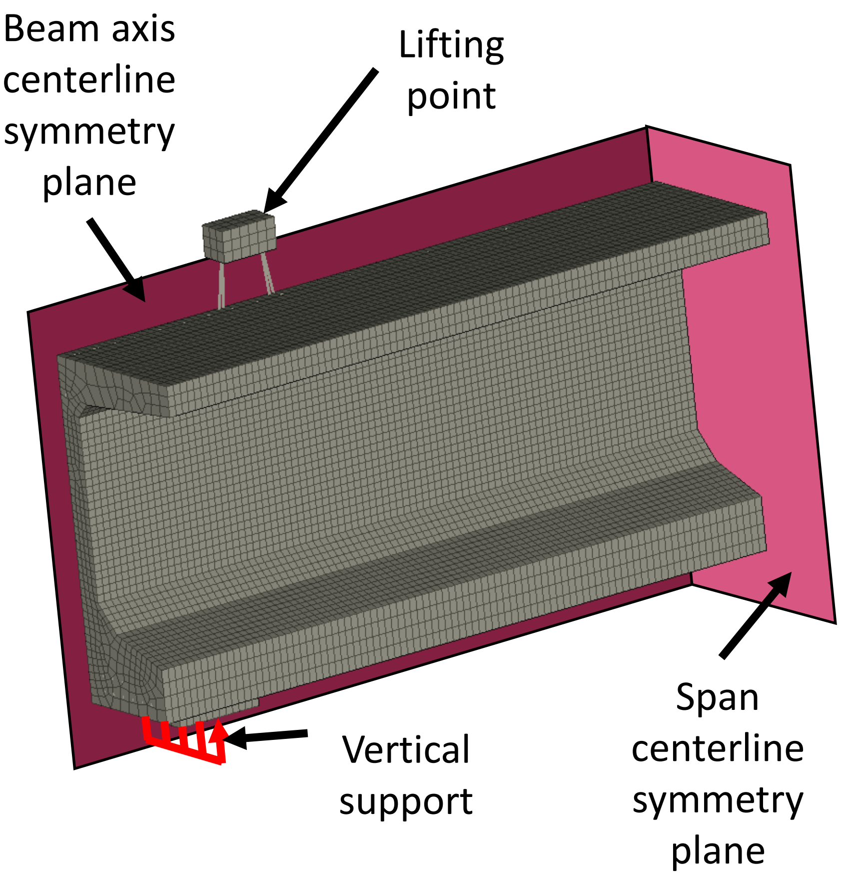
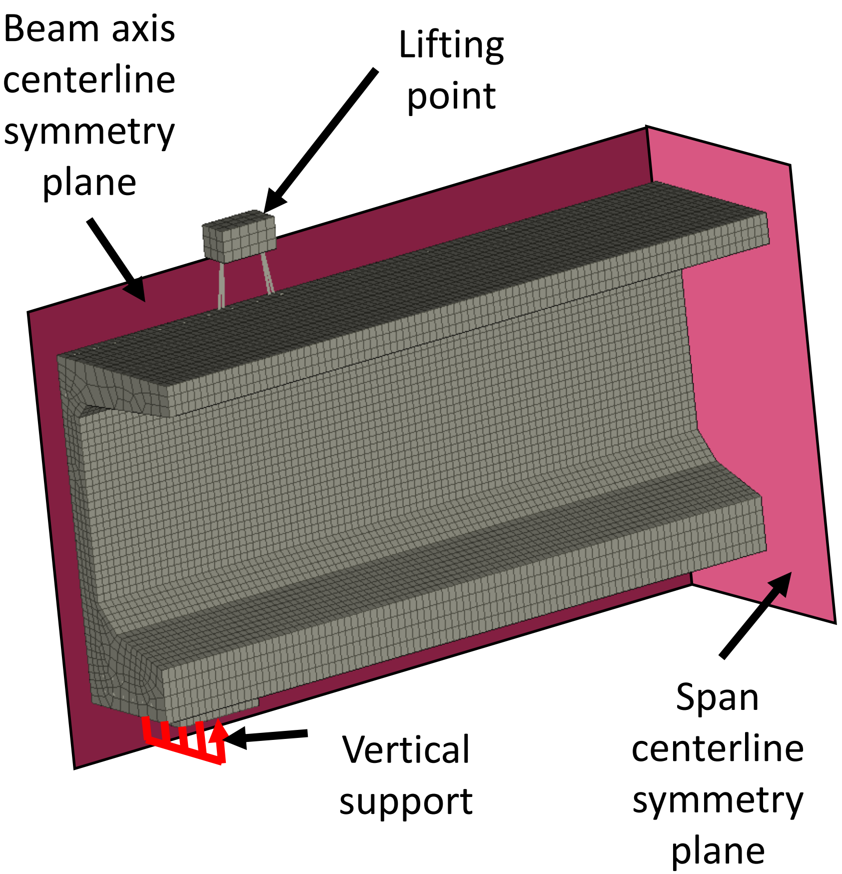
FE Model

- FEA conducted using ATENA
- Utilized symmetry constraints to model ¼ of each PCBT
- Solid elements for concrete
- Embedded truss elements with appropriate bond-slip laws for reinforcement
- Utilizes ACI (2022), fib (2010), and Bažant and Becq-Giraudon (2002) models to estimate various material properties



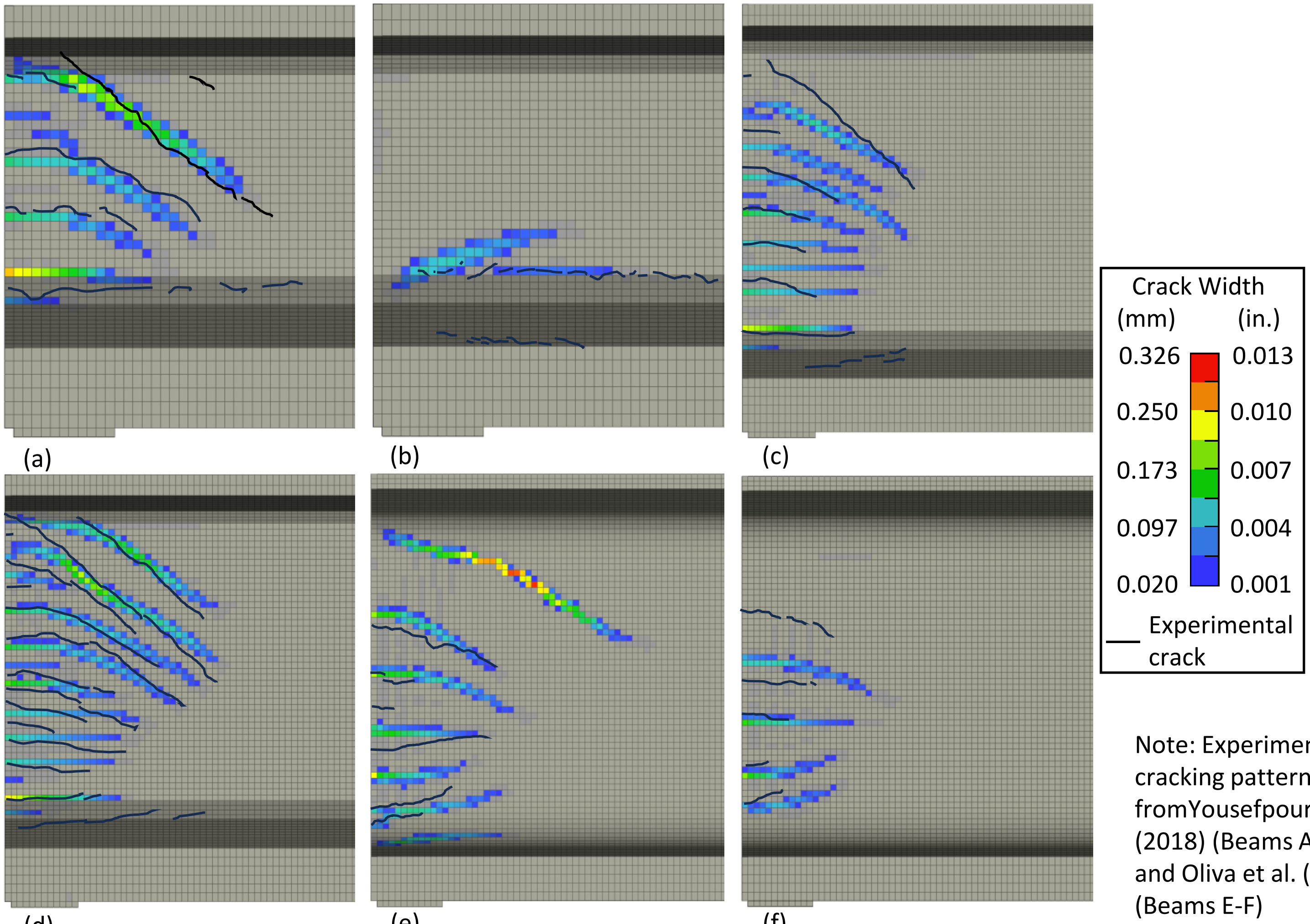
FE Model

- Prestressing and self weight applied over 10 load steps
- Includes change of support condition to capture crack opening upon lifting of the beam from precast bed



Model Validation

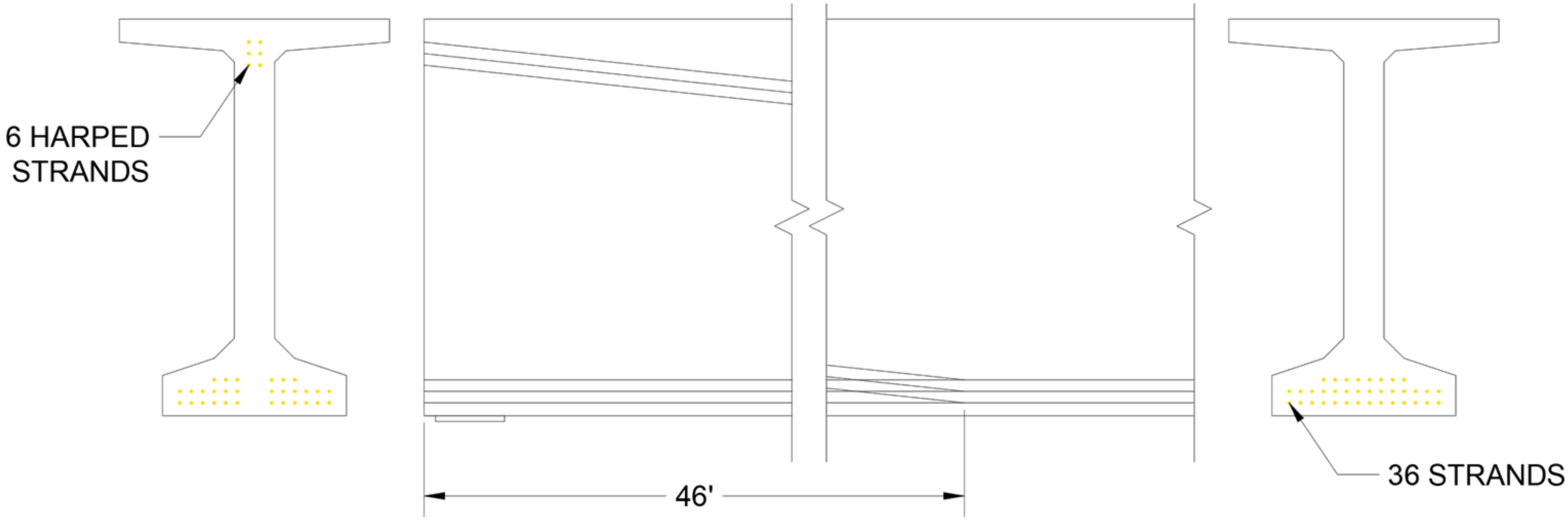
FEA to experimental cracking comparison



Note: Experimental cracking pattern fromYousefpour et al. (2018) (Beams A-D) and Oliva et al. (2016) (Beams E-F)

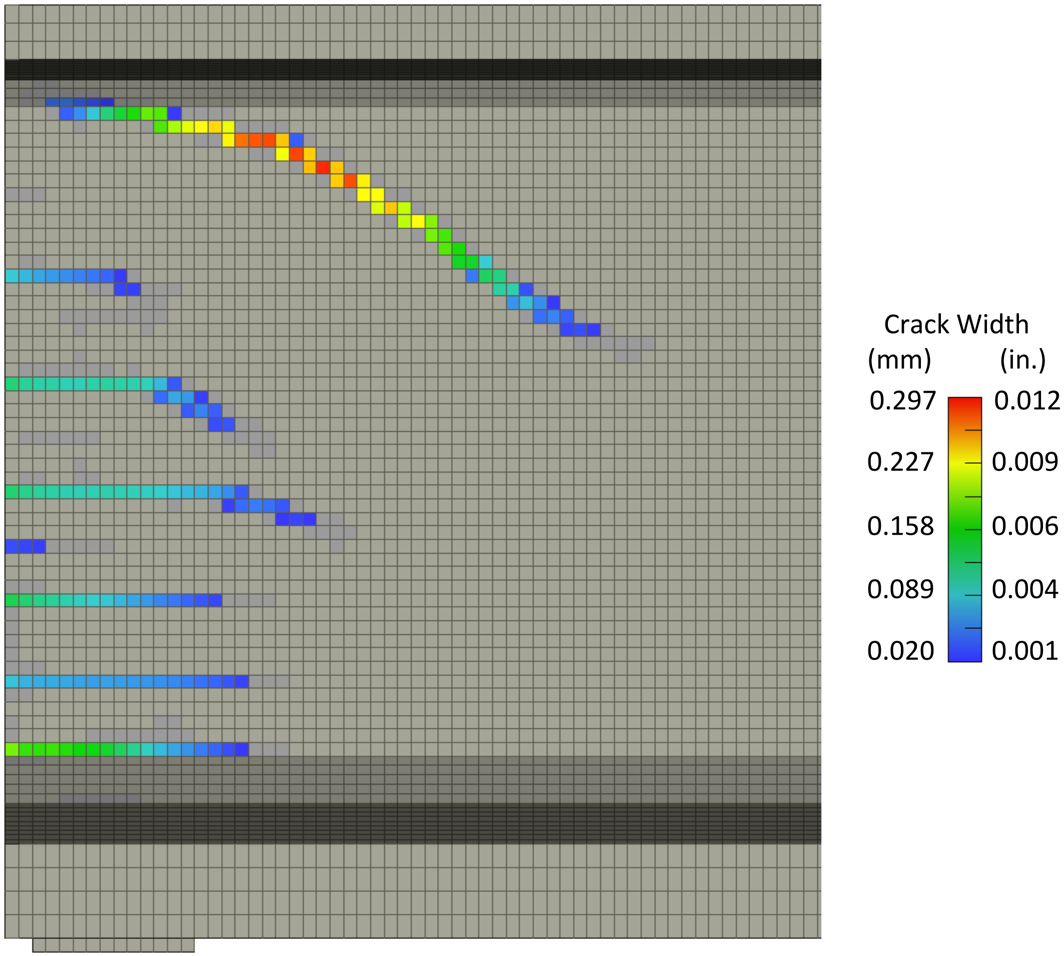
Baseline Beam for Parametric Study

- 114 ft span VDOT PCBT-69
- $f_c' = 8$ ksi, $f_{ci}' = 6.4$ ksi
- 8 in. composite deck
- 10 ft assumed beam spacing
- #5 stirrups
- End zone reinforcement designed per Crispino et al. (2008)



Baseline Beam Results

- Max crack width = 0.011 in.
- Average crack width = 0.004 in.
- Cracks narrower than the accuracy level of a typical crack microscope were filtered out

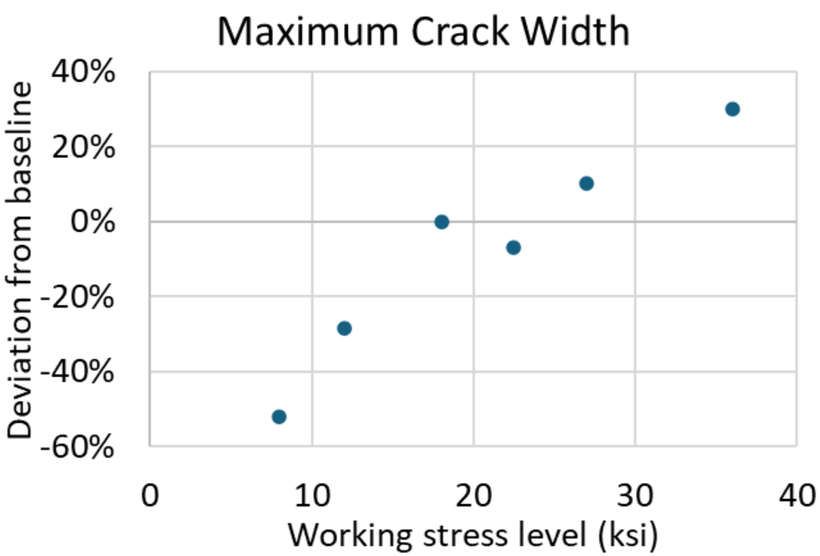


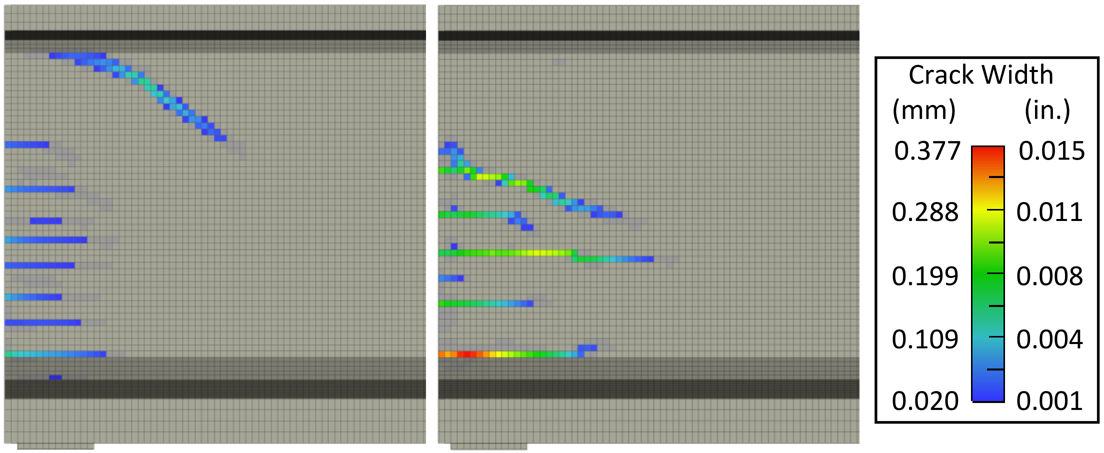
Parametric Study Parameters

- Largely, two ways to control end zone cracking:
  - **Modifying Capacity**
    - Reinforcement working stress level
    - Reinforcement location/layout
    - Reinforcement diameter
    - Concrete Material Properties
  - **Modifying Demand**
    - Changes in draping pattern
    - Removal of draped strands in favor of straight top strands
    - Strand debonding

Effect of Reinforcement Working Stress Level

- Designed using the Davis et al. (2005) strut-and-tie model
- Cracking pattern changes as working stress increases (around 27 ksi)



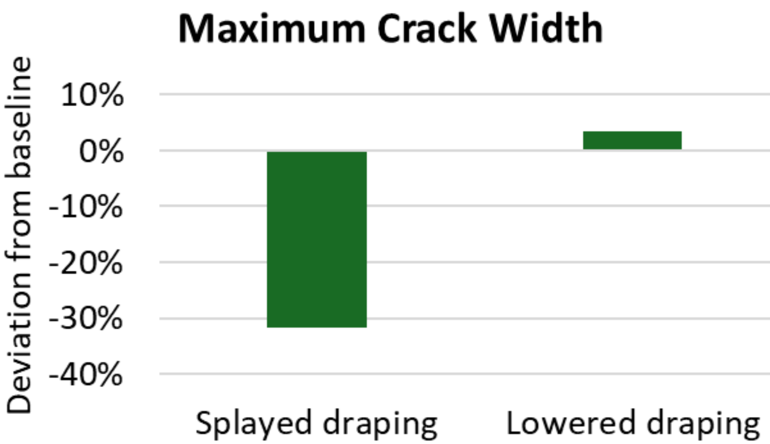


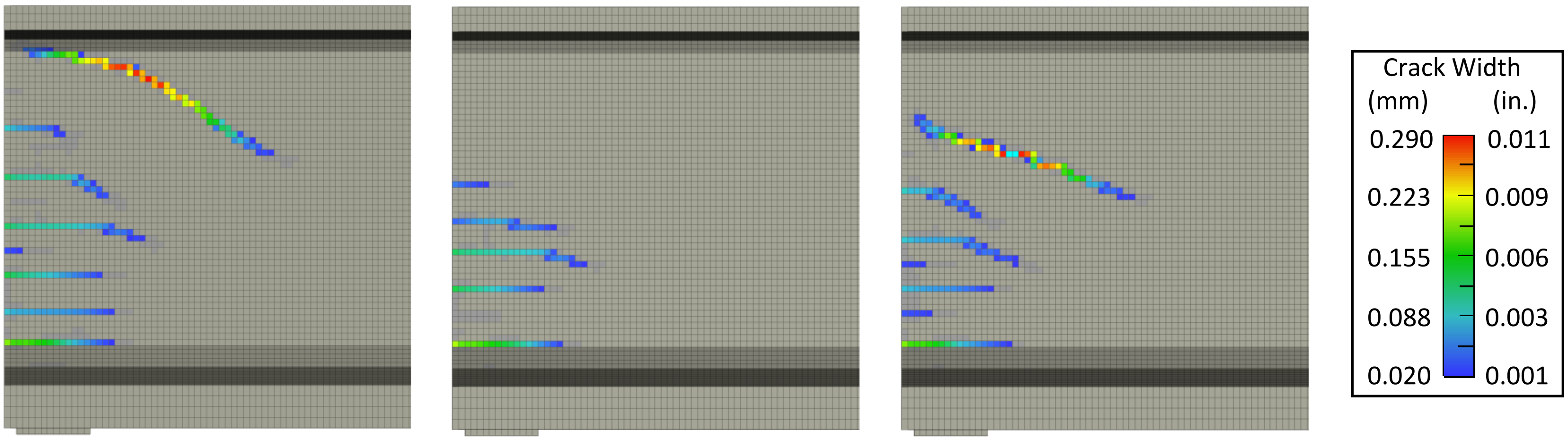
(a) 8 ksi

(a) 36 ksi

Effect of Modifying Draping Pattern

- Splayed draping:
  - Significant improvement
- Lowered draping:
  - Reduced number of cracks
  - Did not reduce intensity

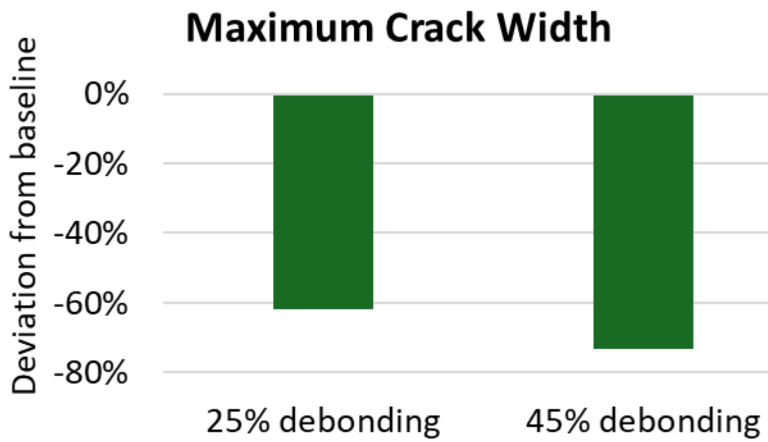


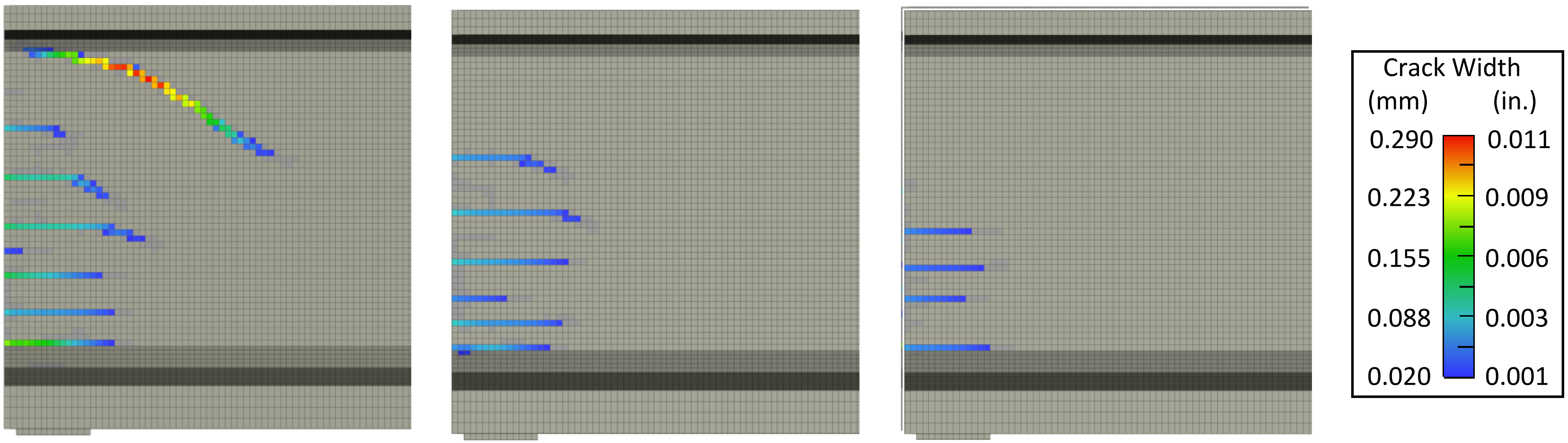


(a) Baseline (b) Splayed draping (c) Lowered draping

Effect of Strand Debonding

- 25% and 45% debonding considered
- Offered significant reduction in crack width by reducing demand

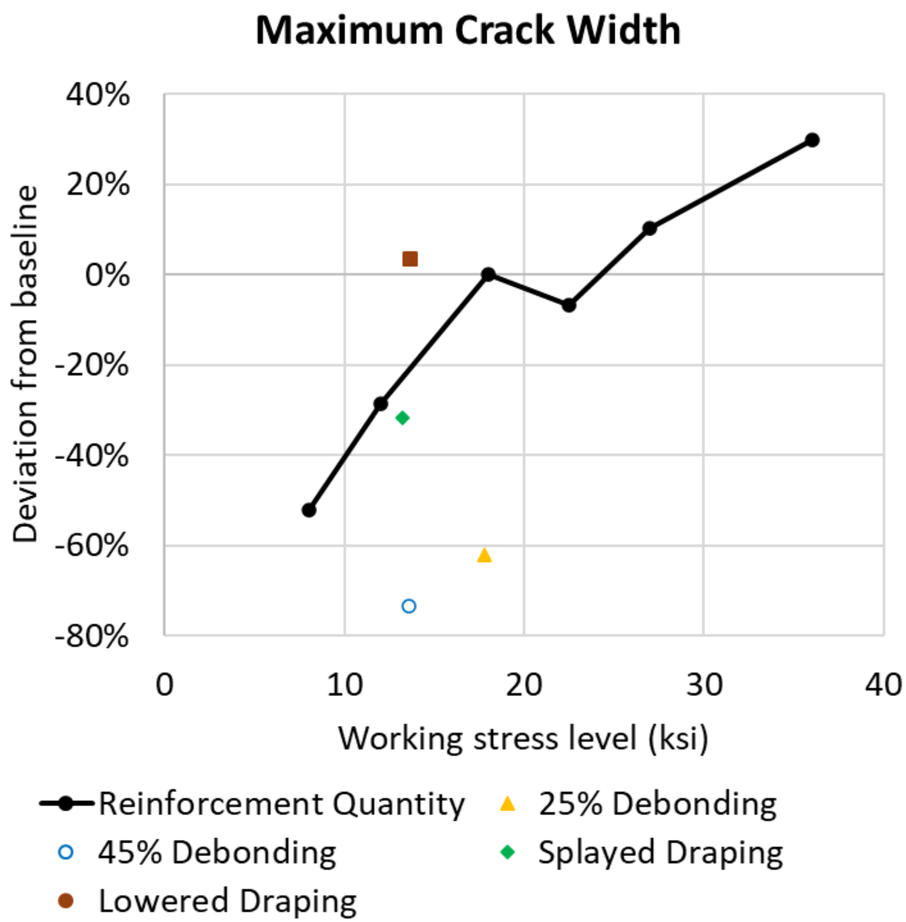




(a) Baseline (b) 25% debonding (c) 45% debonding

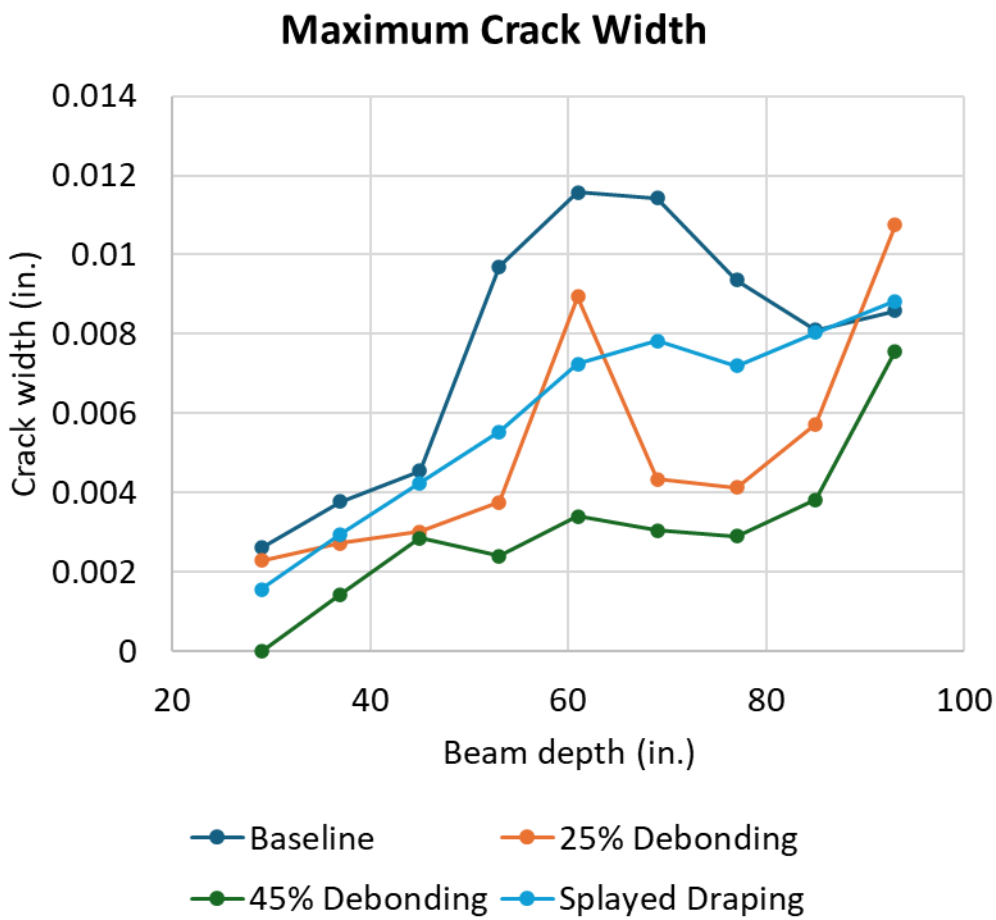
Comparison of Methods

- Current STM does not capture change in working stress for changes from traditional strand pattern
- Debonding provided superior crack control to splayed draping



Extension to Other Depth PCBTs

- On average:
  - Splayed draping = 22% improvement
  - 25% debonding = 31% improvement
  - 45% debonding = 61% improvement
- Significant reduction in number of cracks and average crack widths as well



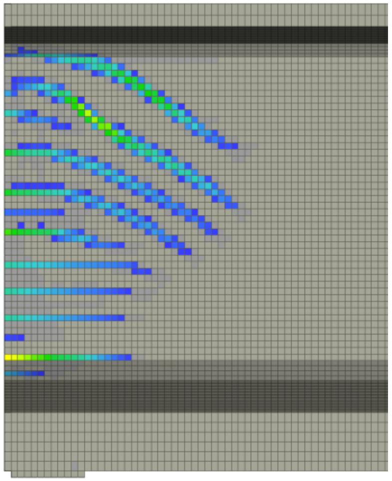
Conclusions and Future Work

Conclusions

- End zone cracking can be controlled through either demand or capacity approaches
- Both methods work to control cracking, but decreasing demand creates less congested designs

Future work

- Development of new design equations and models to predict end zone demand
- Large scale validation of findings



Questions?

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