CONTROLLING CRACKING AT THE ENDS OF PRETENSIONED CONCRETE BRIDGE BULB TEE GIRDERS

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THE UNIVERSITY of WISCONSIN MADISON

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PRE-TENSIONED BRIDGE GIRDERS

Advantages:

- ✓ Durability
  - Crack free
- ✓ Structural Efficiency
  - span / depth up to 30
  - spans up to 200 ft
- ✓ Faster construction
  - Wider flanges
  - Fewer girders

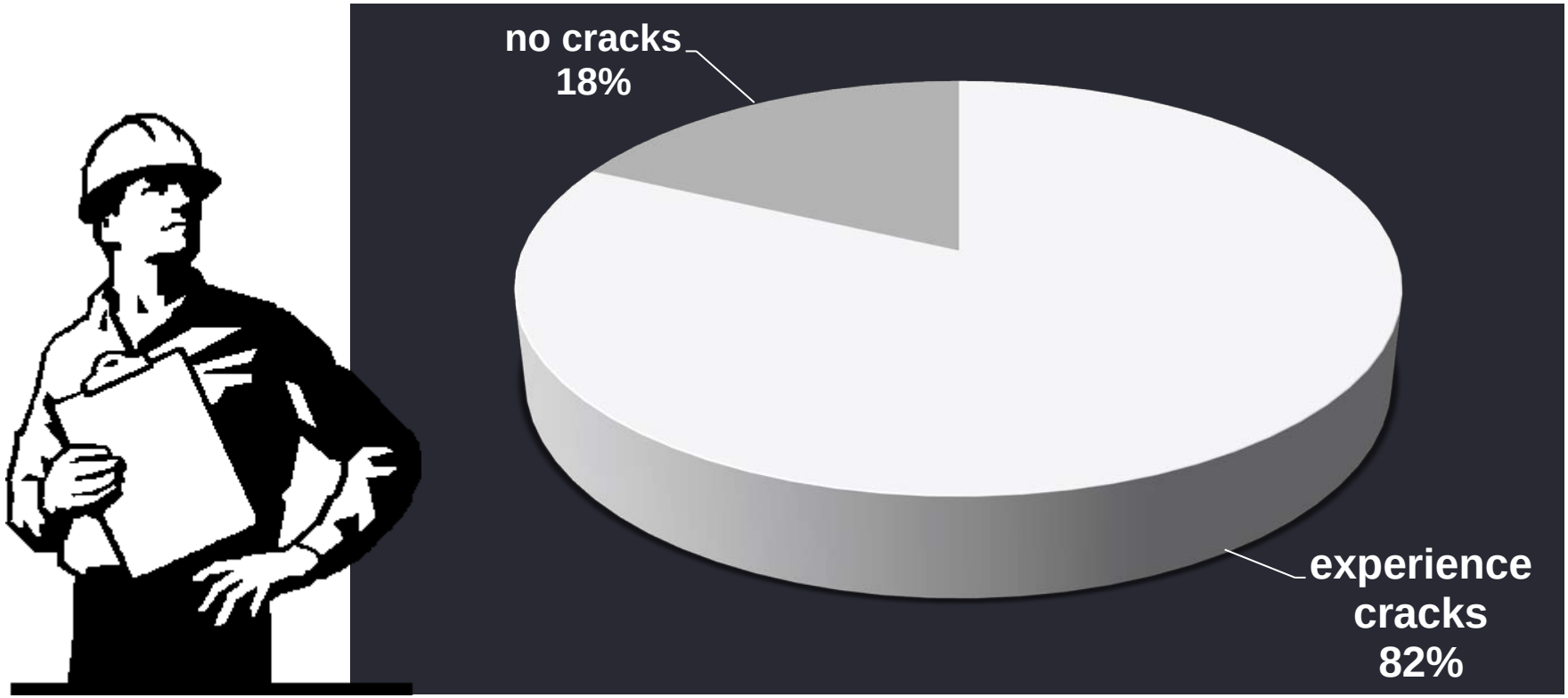
RESEARCH PROBLEM

Problem:

- Cracks may form at plant
  - Corrosion
  - Higher maintenance and life cycle cost
  - Structural damage
  - Limits the use

RESEARCH PROBLEM

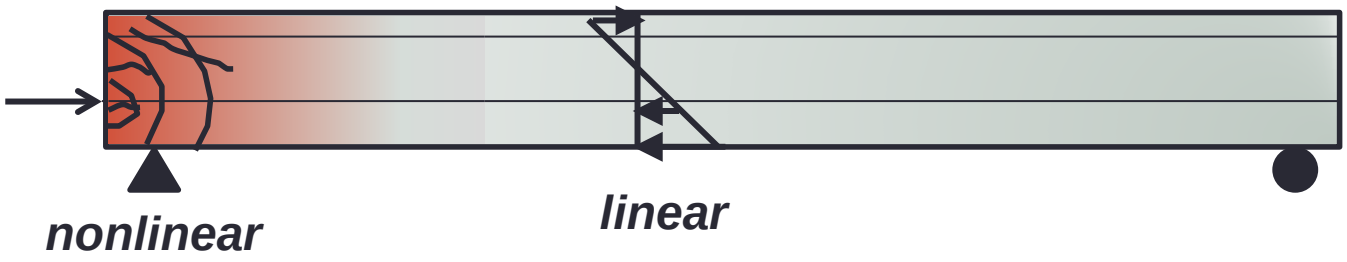
- Survey among DOTs, precasters, consultants, researchers



Tadros, M. K.; Badie, S. S.and Tuan C. Y. *Evaluation and Repair Procedures for Precast/Prestressed Concrete Girders with Longitudinal Cracking in the Web.* Washington, D.C.: TRB, NCHRP 2010.

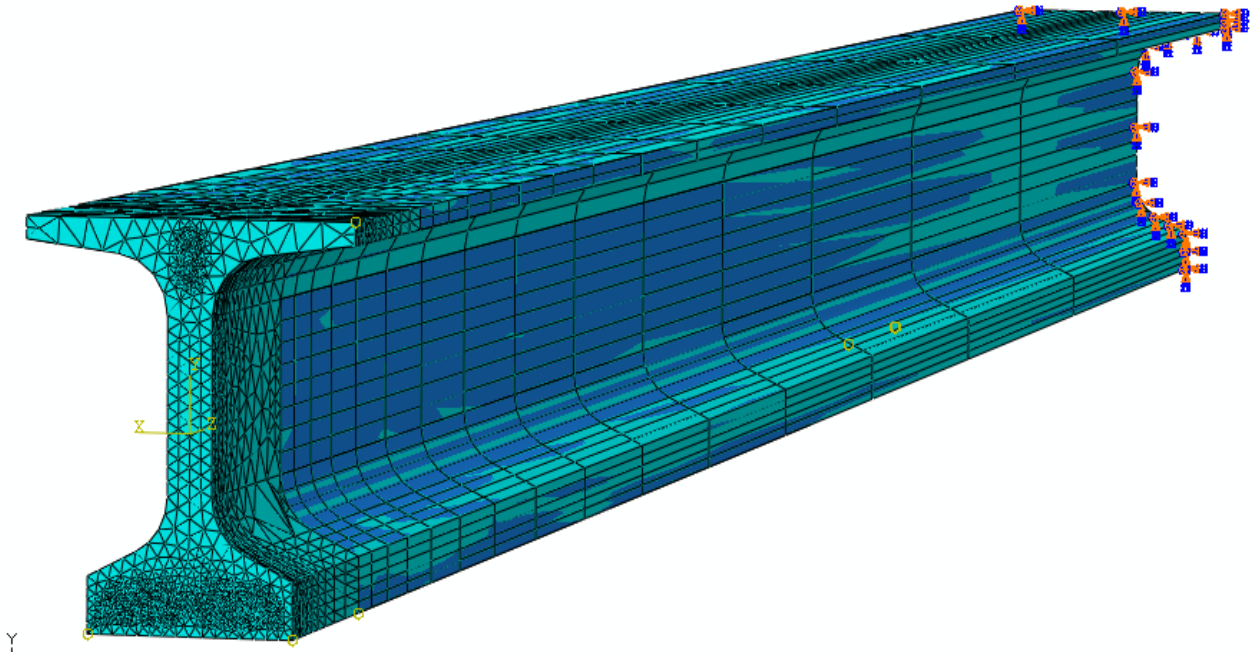
END REGION BEHAVIOR

- Crack formation
- Proximity to the load (prestress transfer)



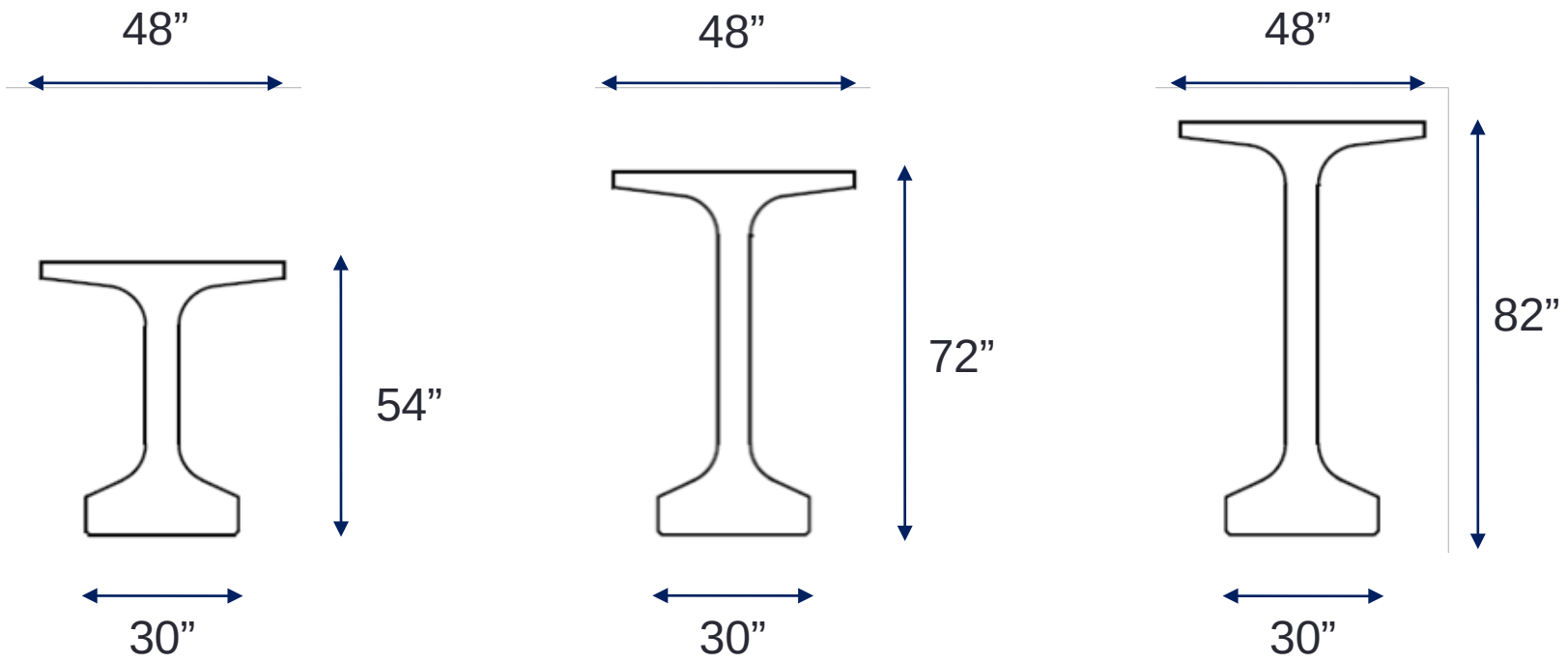
NONLINEAR ANALYSIS

- Analysis using Nonlinear Finite Element Analysis
- Experiments to verify simulations



GIRDERS STUDIED

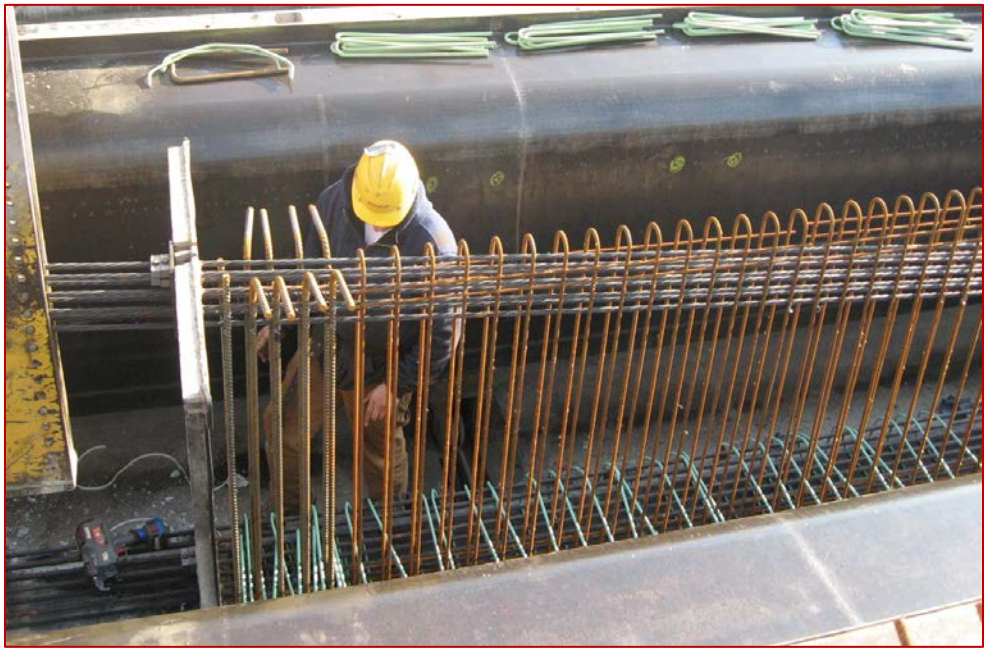
- Standard Wisconsin Bulb Tee Girders



54W **72W** **82W**

GIRDER END DETAILS

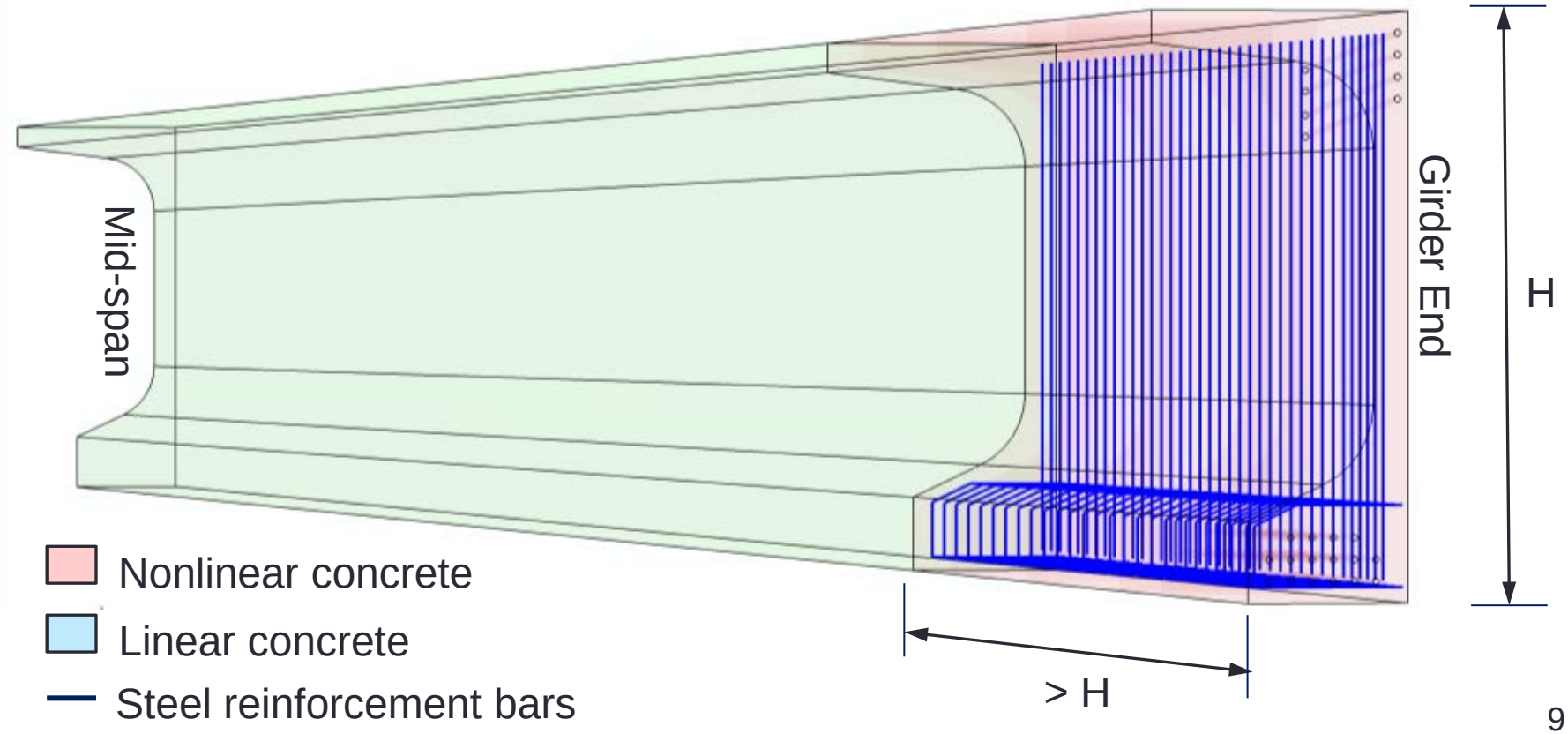
Steel prestressing strands



Steel reinforcing bars

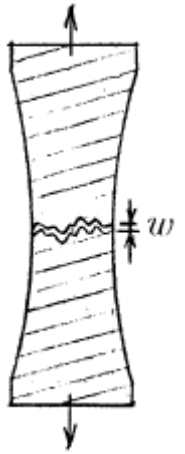
FEA MODEL - OVERVIEW

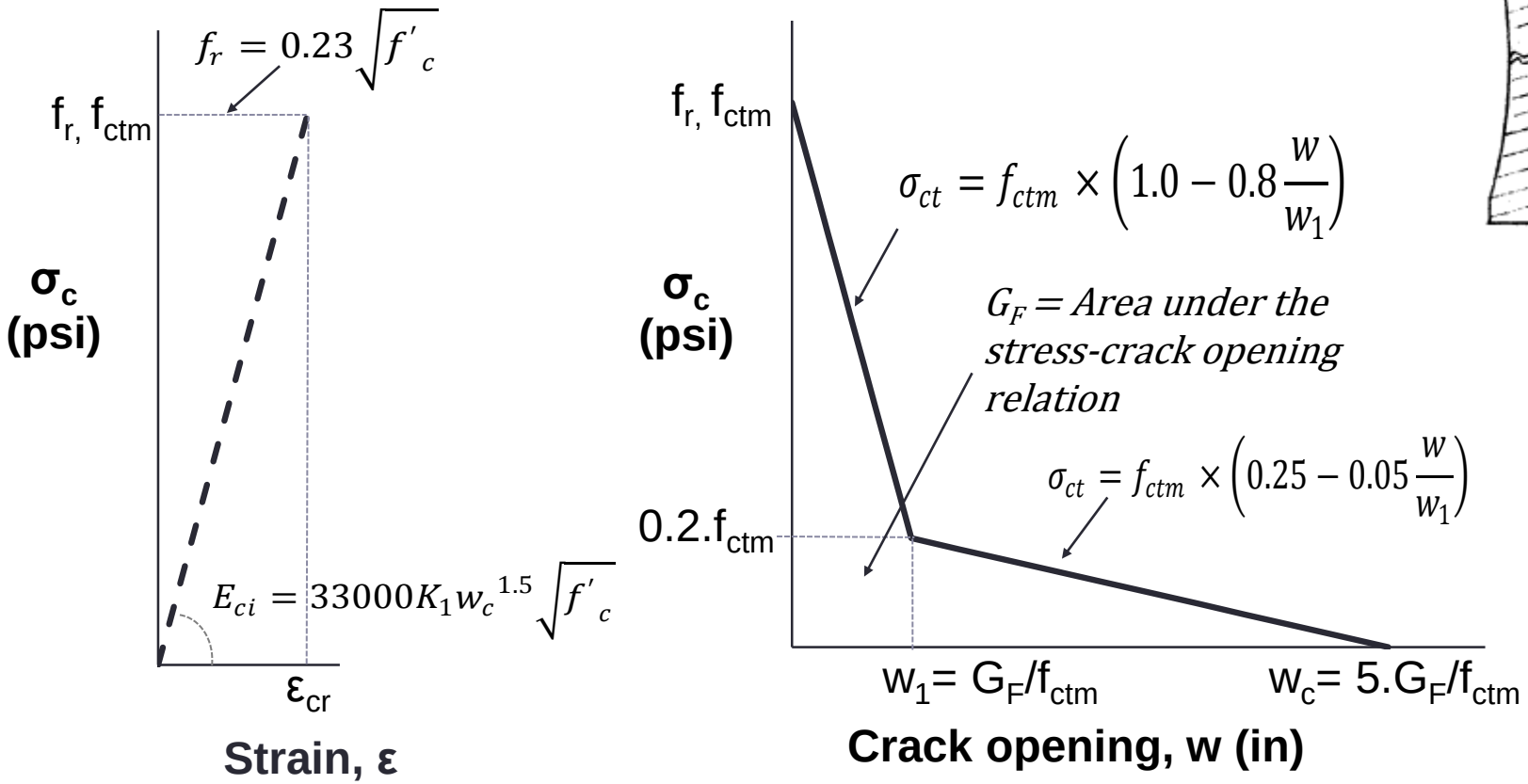
- Computational Efficiency
  - Symmetry
  - Nonlinearity limited to girder end



FEA MODEL – MATERIAL PROPERTIES

- CONCRETE PROPERTIES: in tension





HOW ACCURATE IS THE FEM?

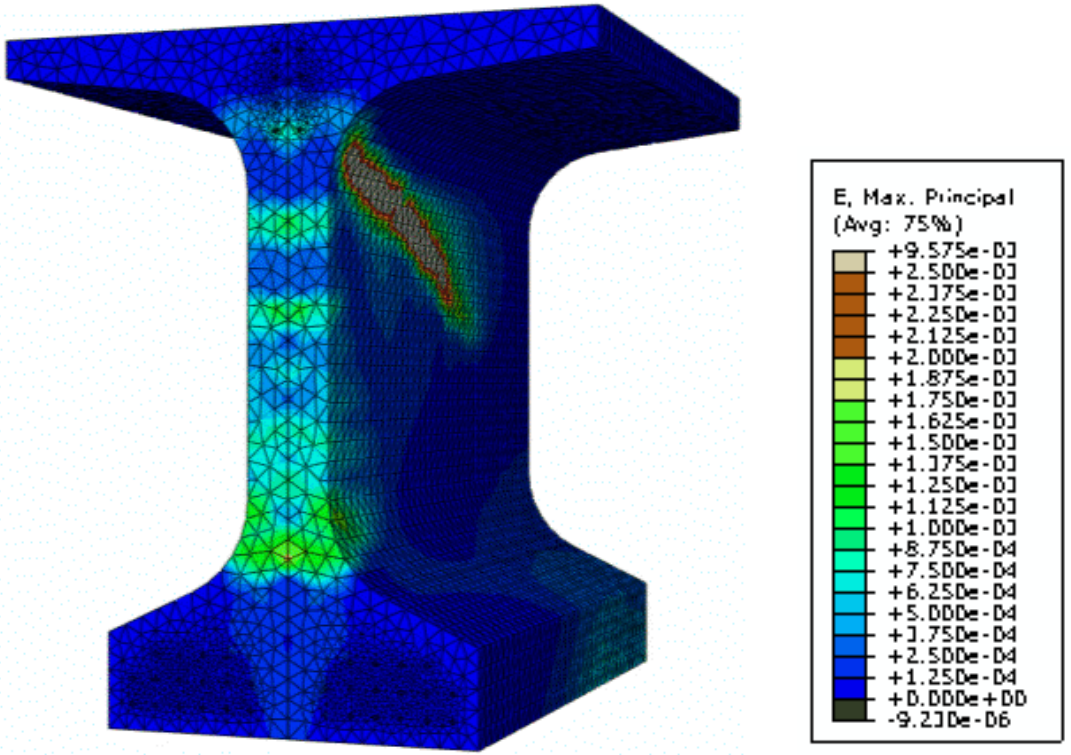
Embedded Gages in concrete

Surface Gages on rebar and strands

Measurements were taken at precast plants during de-tensioning

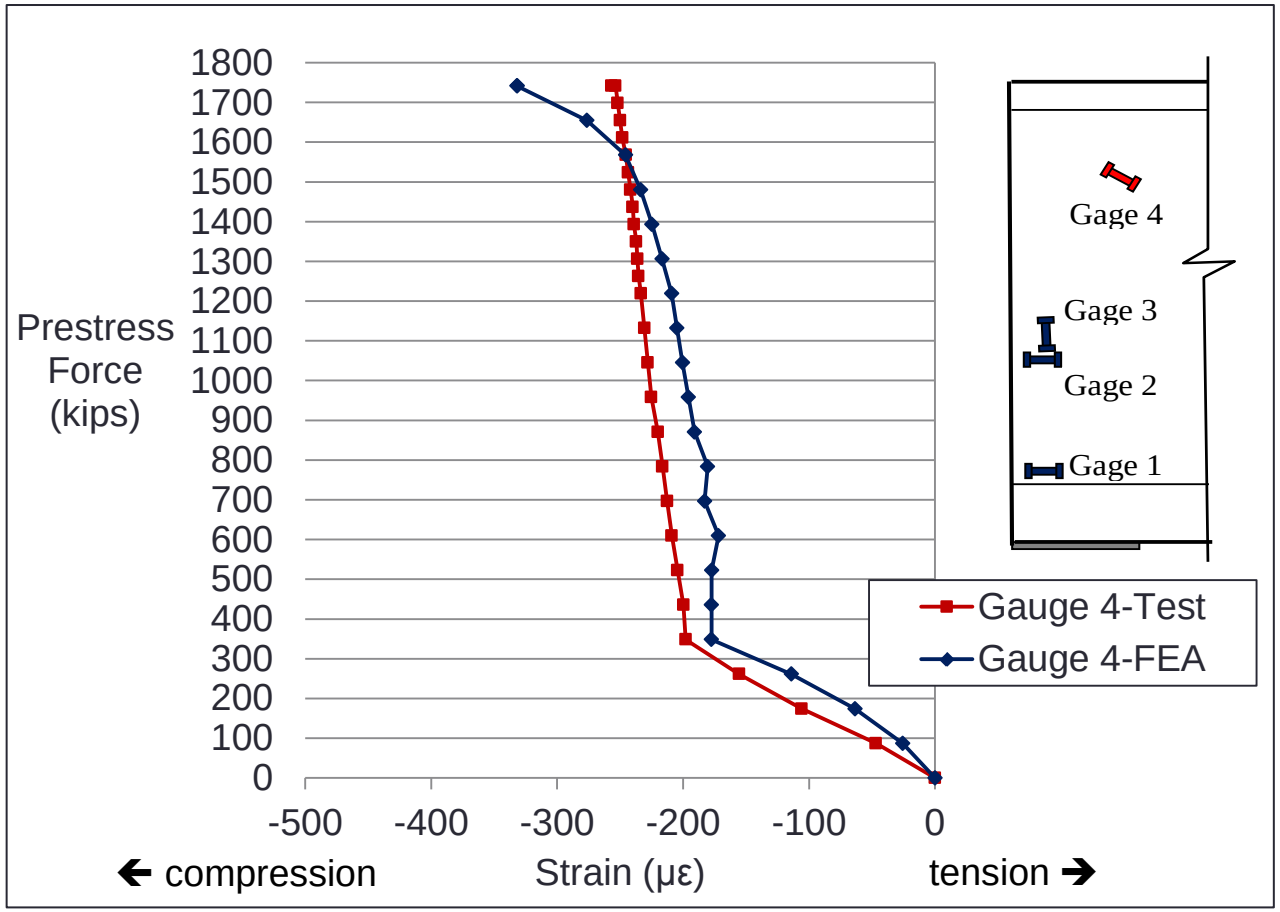
VERIFICATION BY EXPERIMENTS

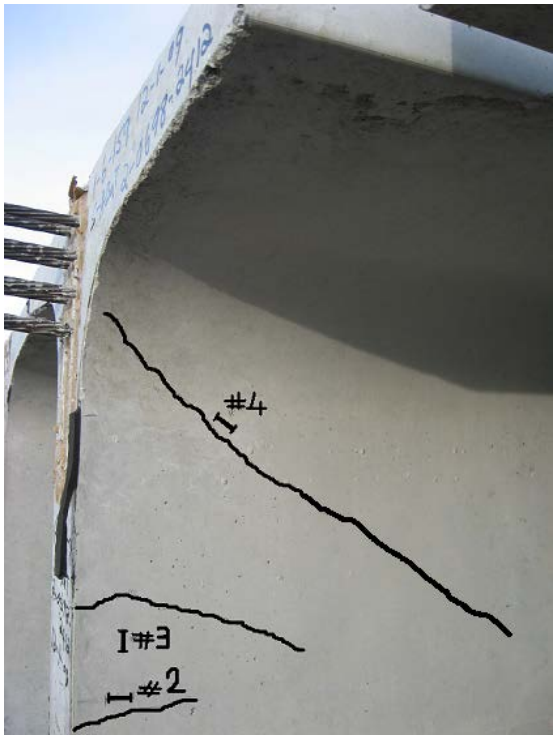
- QUALITATIVE COMPARISON – Principal Tensile Strains



VERIFICATION BY EXPERIMENTS

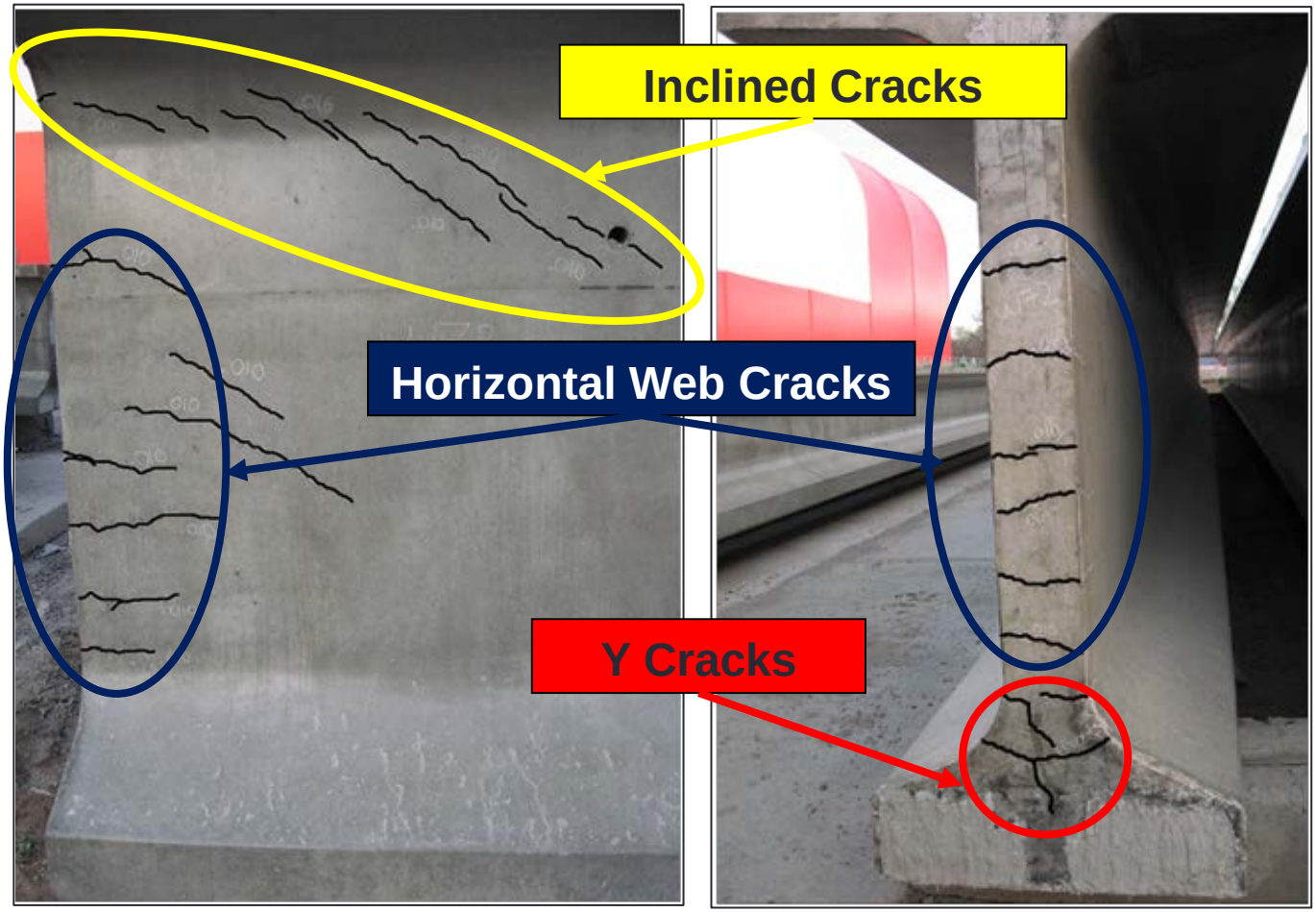
- QUANTITATIVE COMPARISON – Strain Change





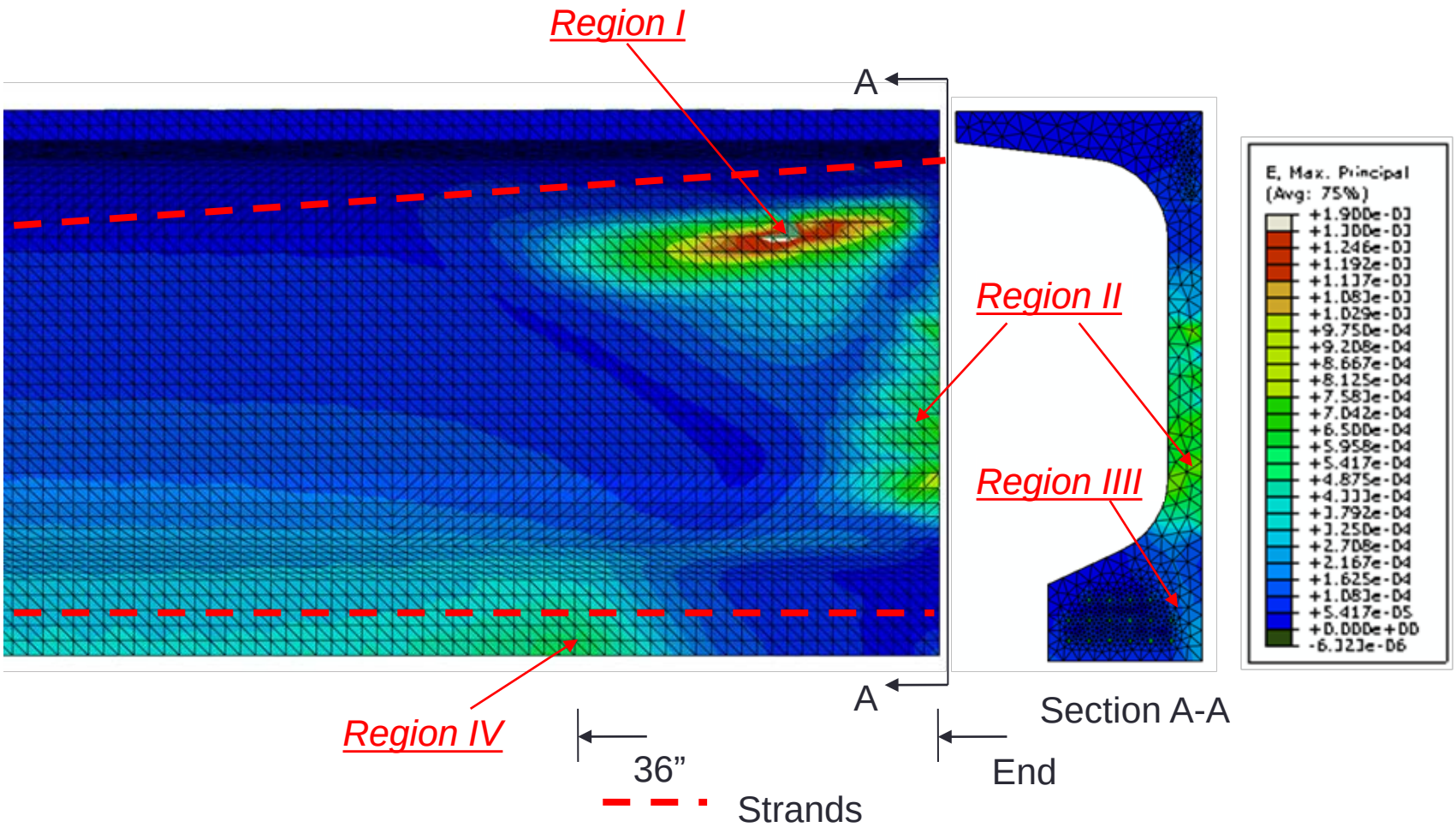
TYPICAL CRACKING

- CRACK CLASSIFICATION



FEA RESULTS

- CONCRETE RESPONSE



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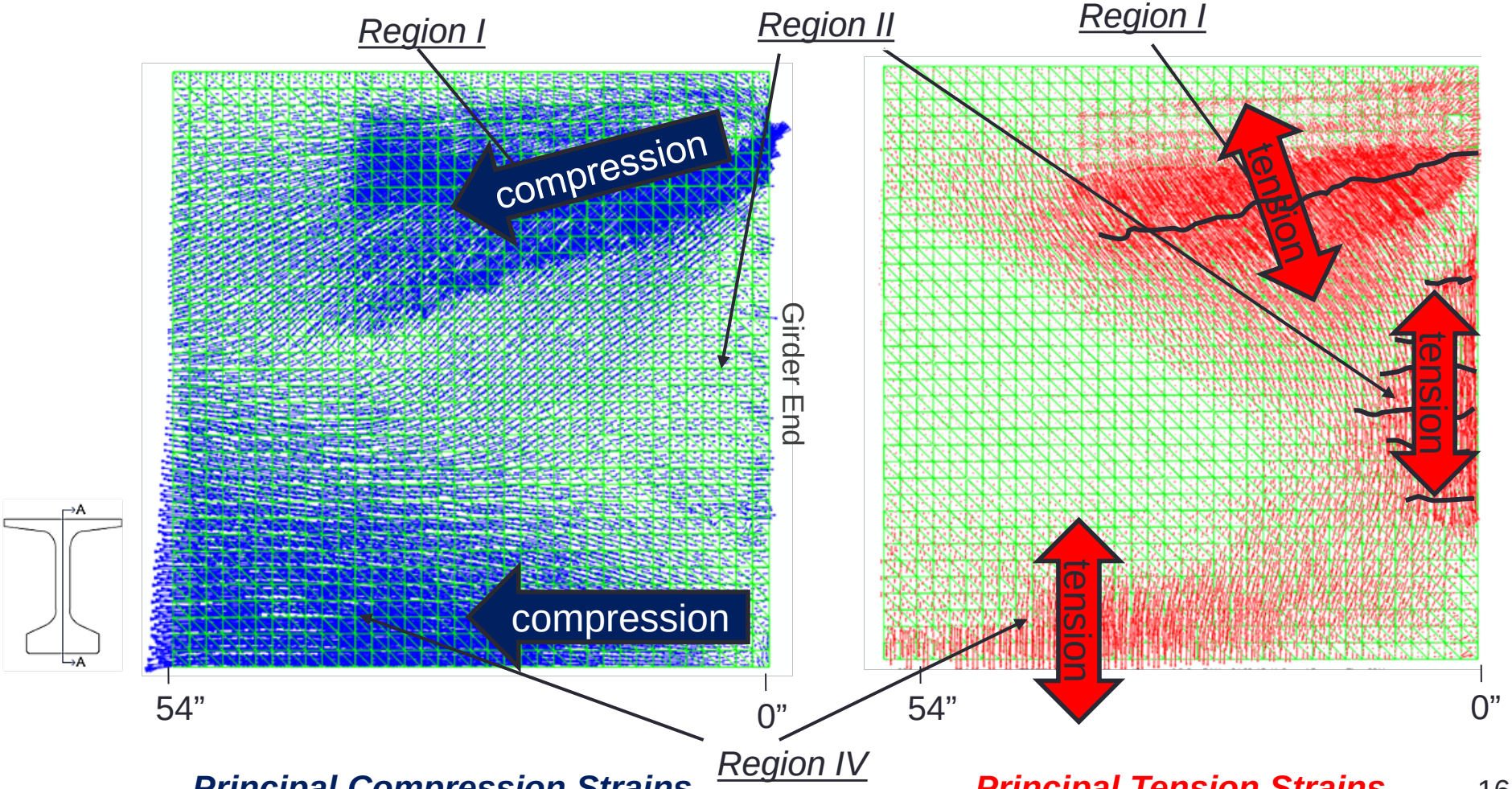

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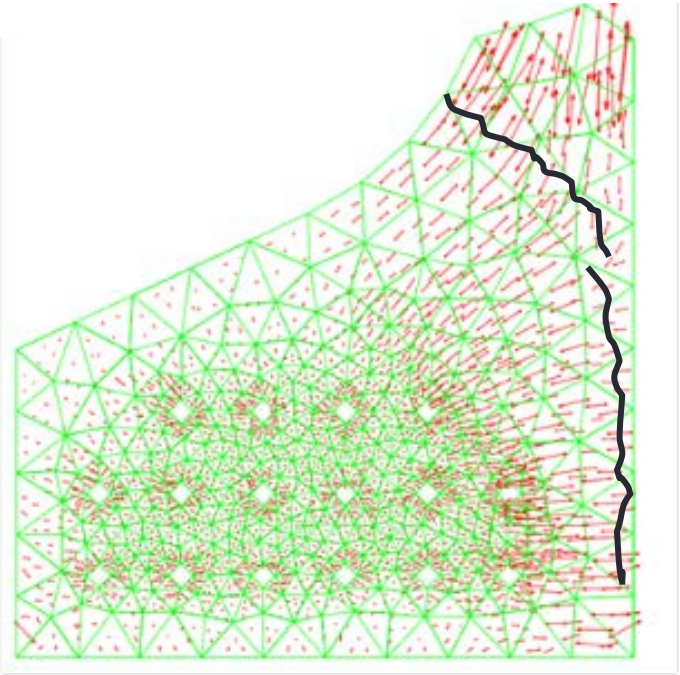
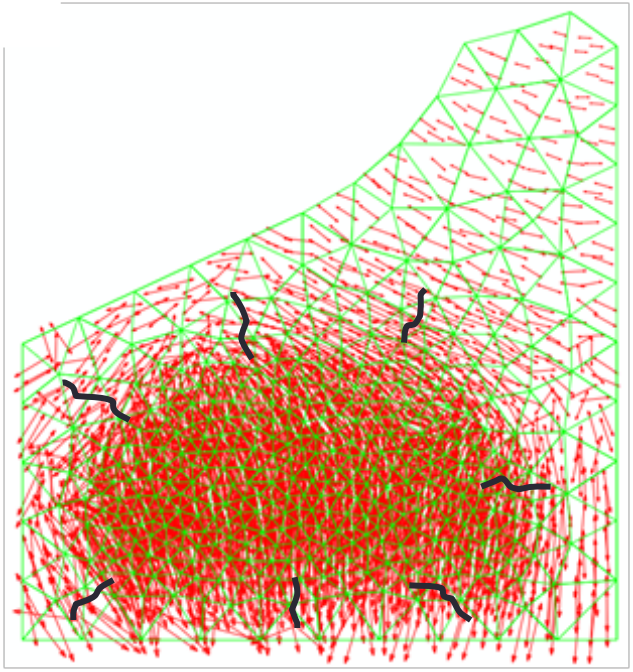


at the end



at transfer length

Principal Tension Strains

HOW CAN WE CONTROL CRACKING?

Rebar pattern

Strand de-bonding

Strand release order

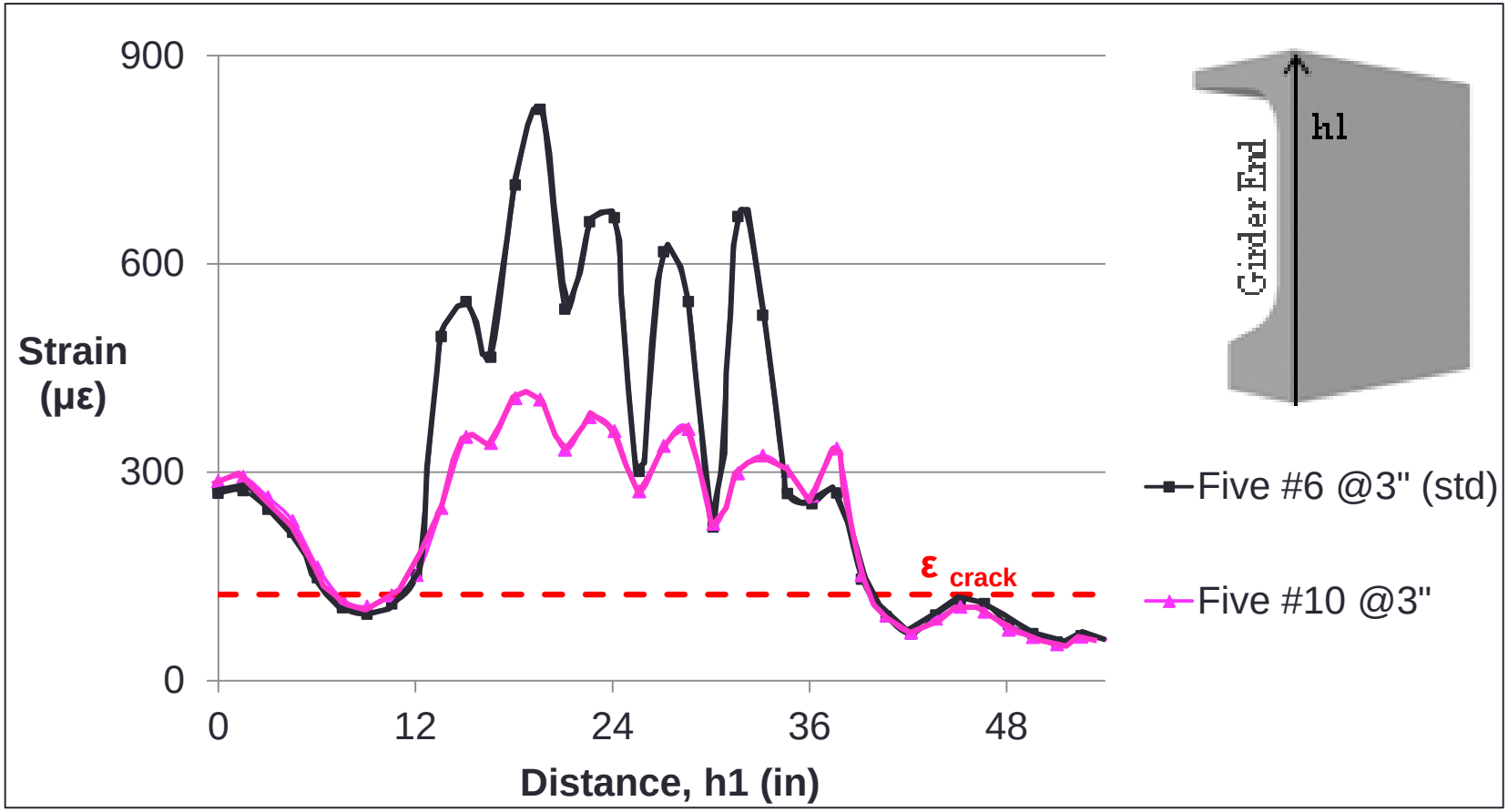
Harped strand pattern

Location of lifting

CRACK CONTROL BY REINFORCEMENT BARS

TARGET CRACKS

CRACK CONTROL BY REINFORCEMENT BARS



Even #10 bars cannot prevent cracking (only 50% reduction)

HOW CAN WE CONTROL CRACKING?

Rebar pattern

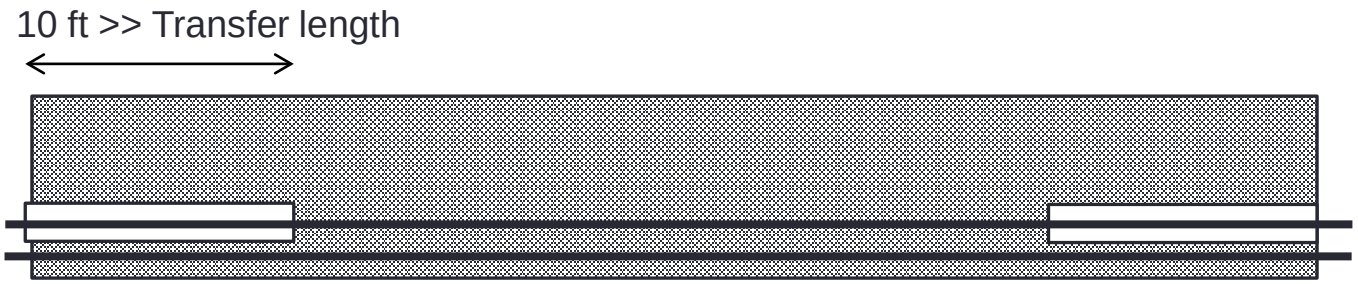
Strand de-bonding

Strand release order

Harped strand pattern

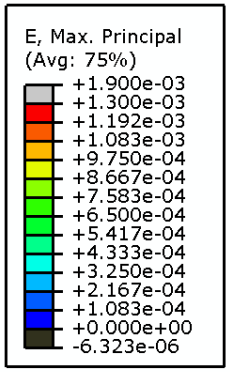
Location of lifting

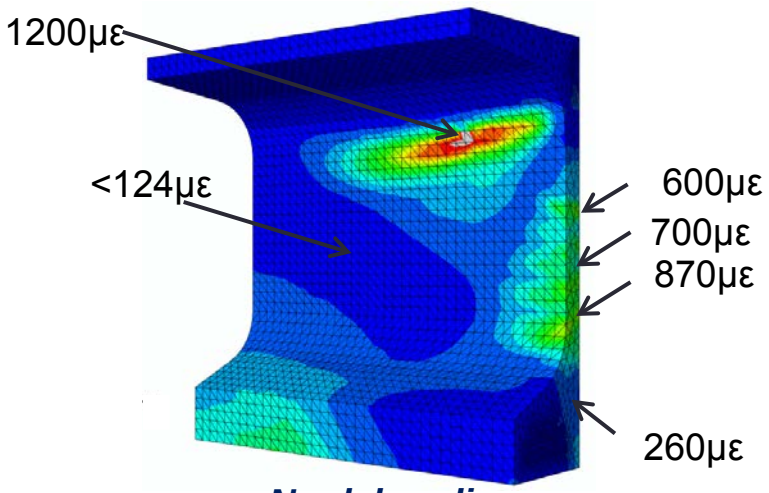
CRACK CONTROL BY PARTIAL STRAND DEBONDING



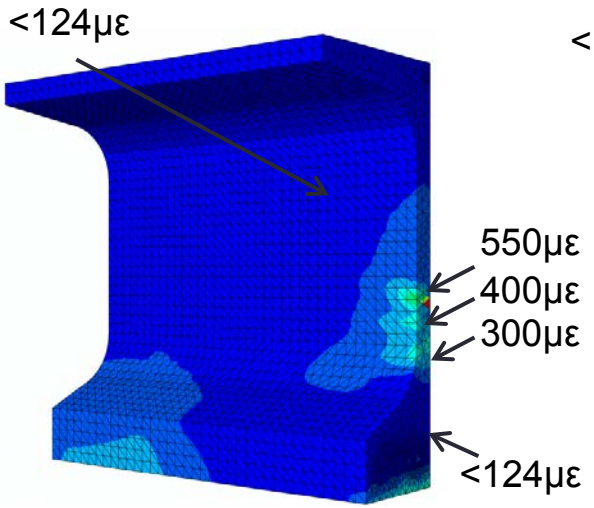
- ***AASHTO limits debonding to 25% of total strands***
- ***AASHTO does not provide specific guidance for debonded strand pattern***

CRACK CONTROL BY PARTIAL STRAND DEBONDING

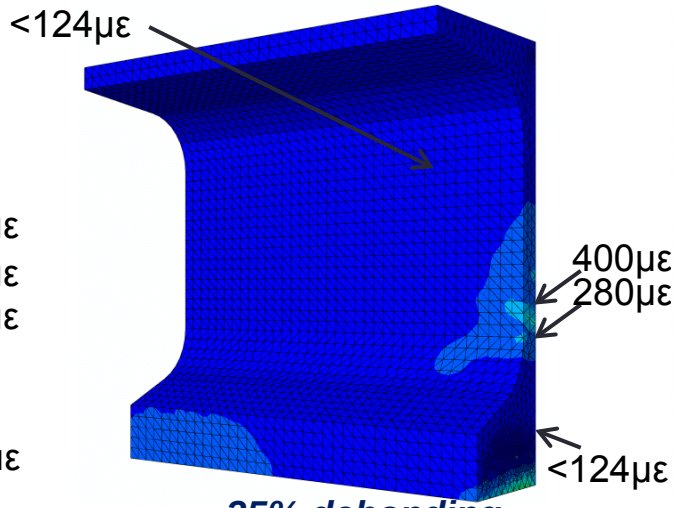




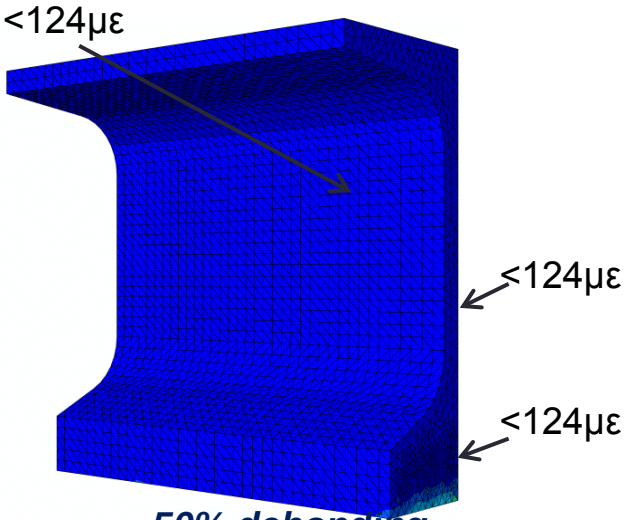
No debonding



25% debonding



35% debonding

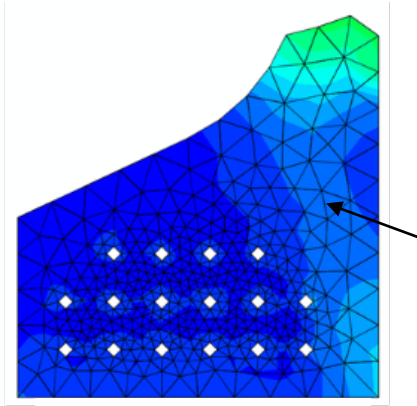


50% debonding

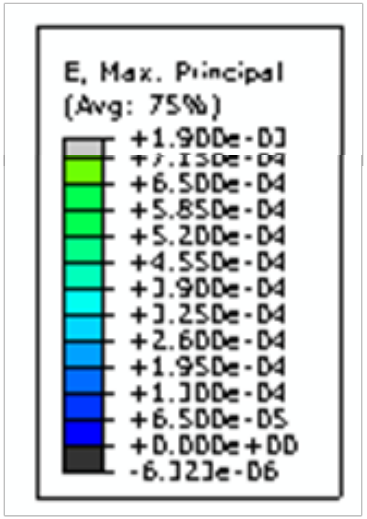
Inclined and Y cracking can be eliminated

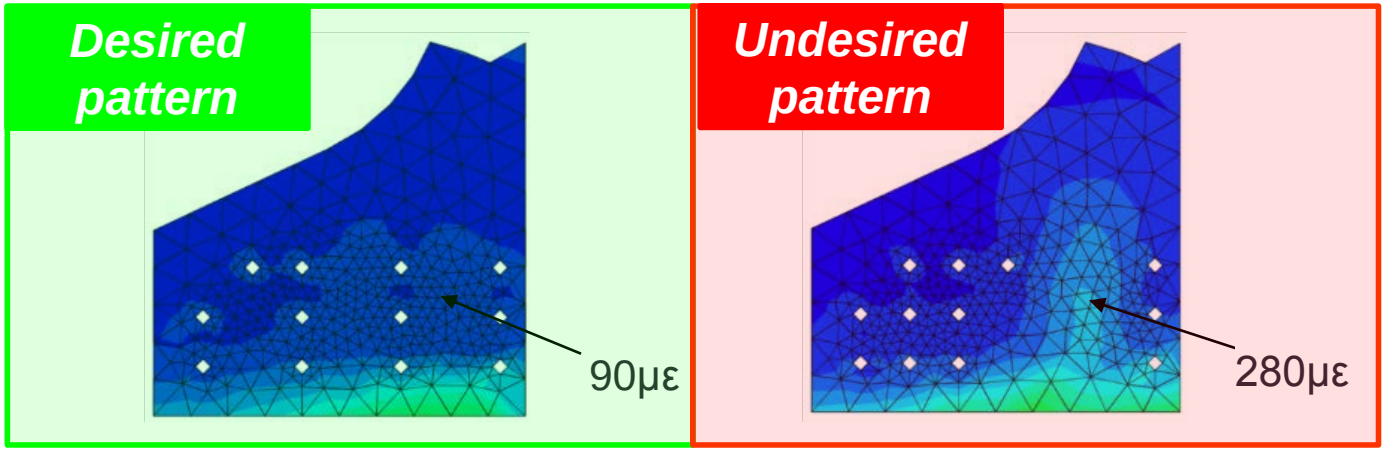
CRACK CONTROL BY PARTIAL STRAND DEBONDING

- DEBONDING PATTERN FOR Y CRACKS



0% debonding

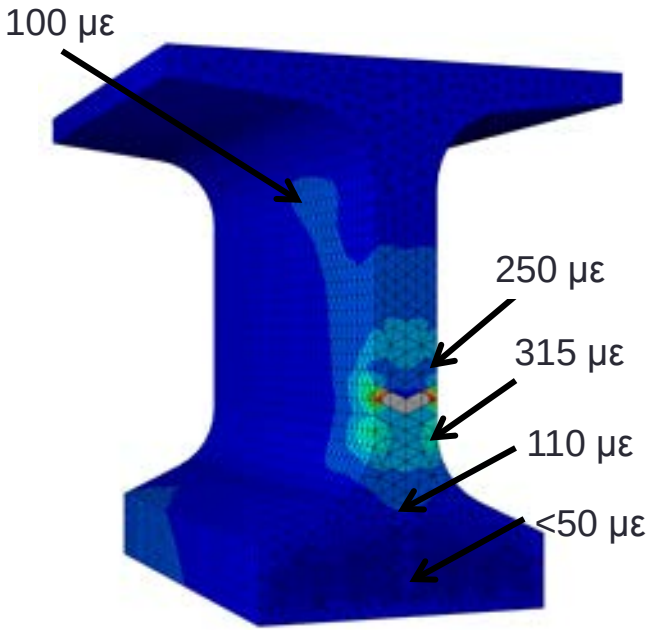




35% debonding

CRACK CONTROL BY PARTIAL STRAND DEBONDING

- IMPLEMENTATION



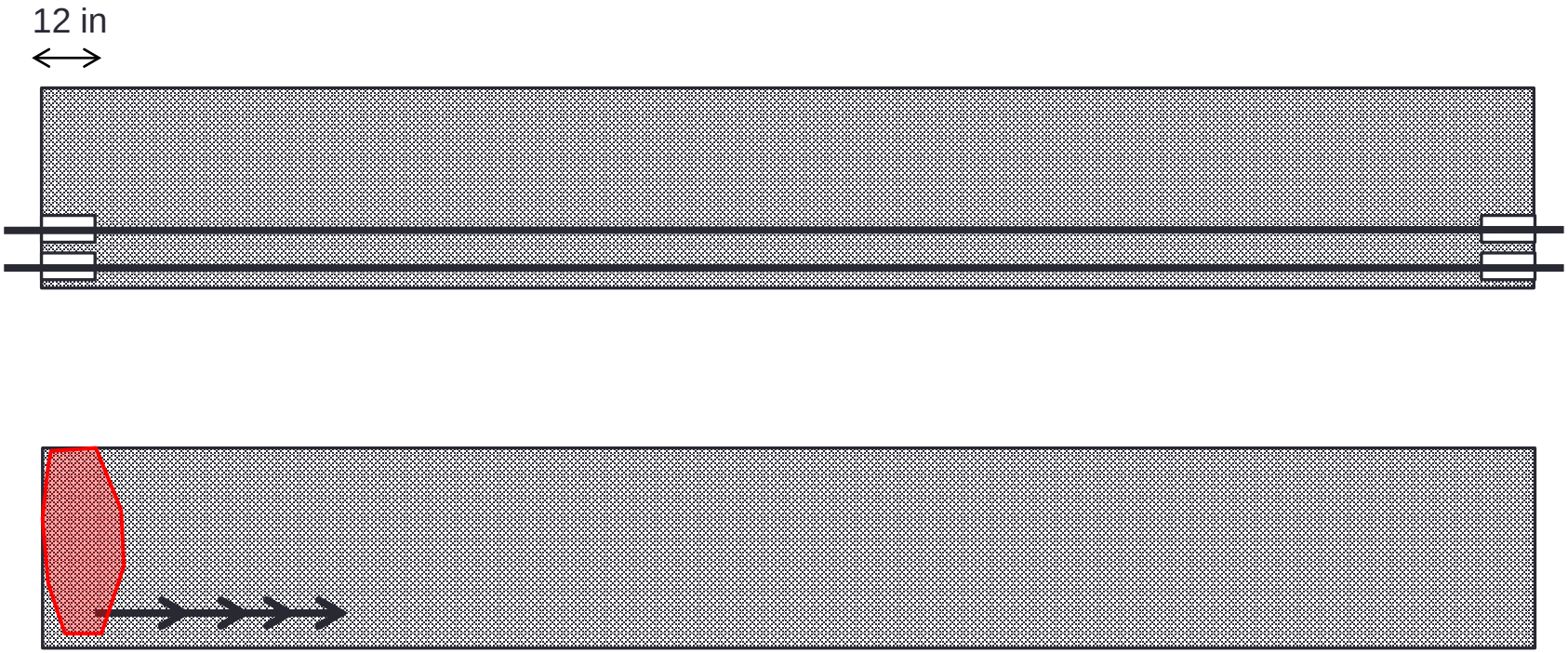
42% debonding

0% debonding

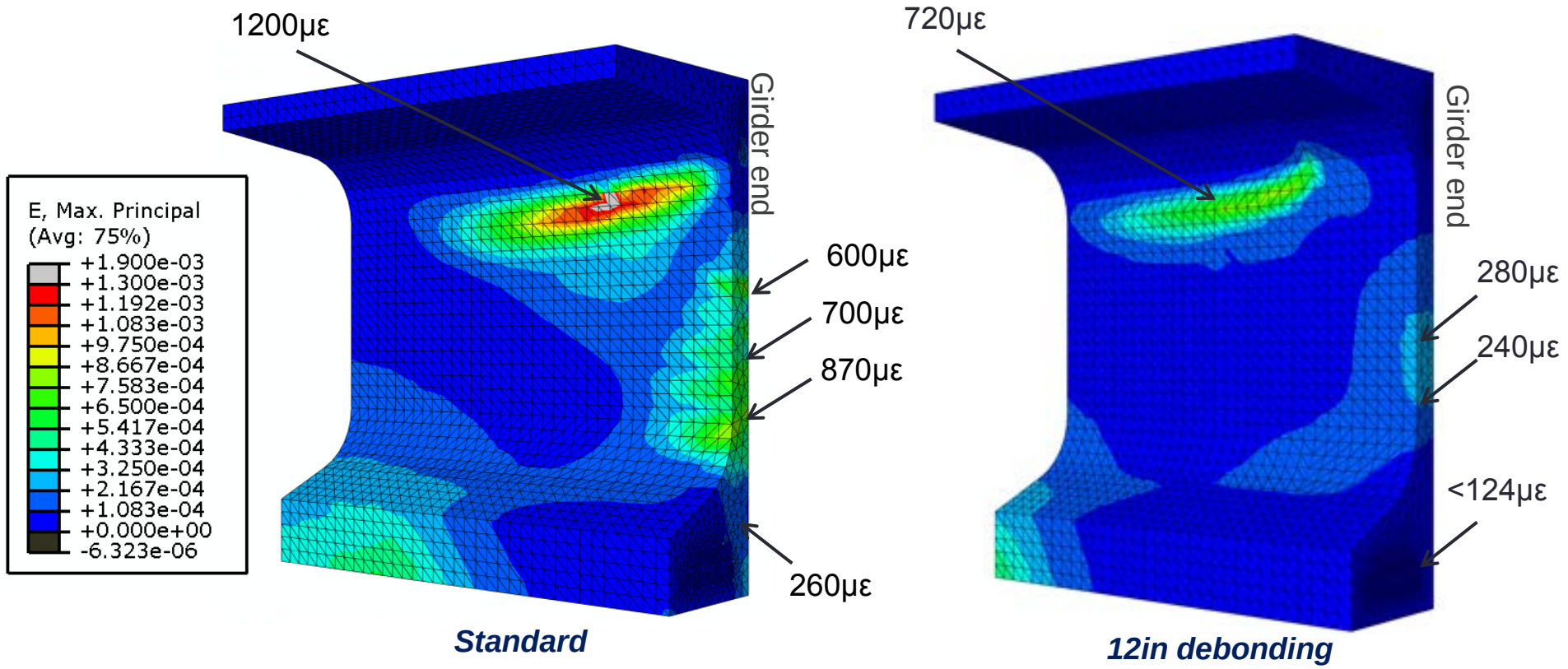
- ***Strands should be distributed: Adjacent columns should not be debonded***
- ***Interior strands should remain bonded***

CRACK CONTROL BY 12in STRAND DEBONDING

- Larger area to resist tension



CRACK CONTROL BY 12in STRAND DEBONDING



Standard ***12in debonding***

Comparable to 35% debonding, web cracks can be limited
Y cracks can be eliminated

HOW CAN WE CONTROL CRACKING?

Rebar pattern

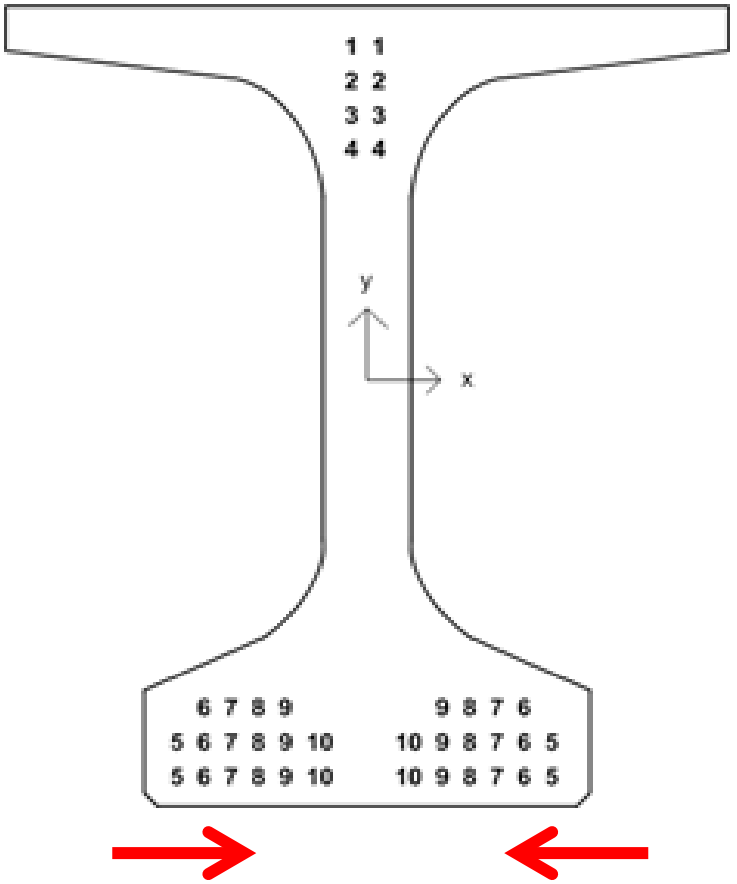
Strand de-bonding

Strand release order

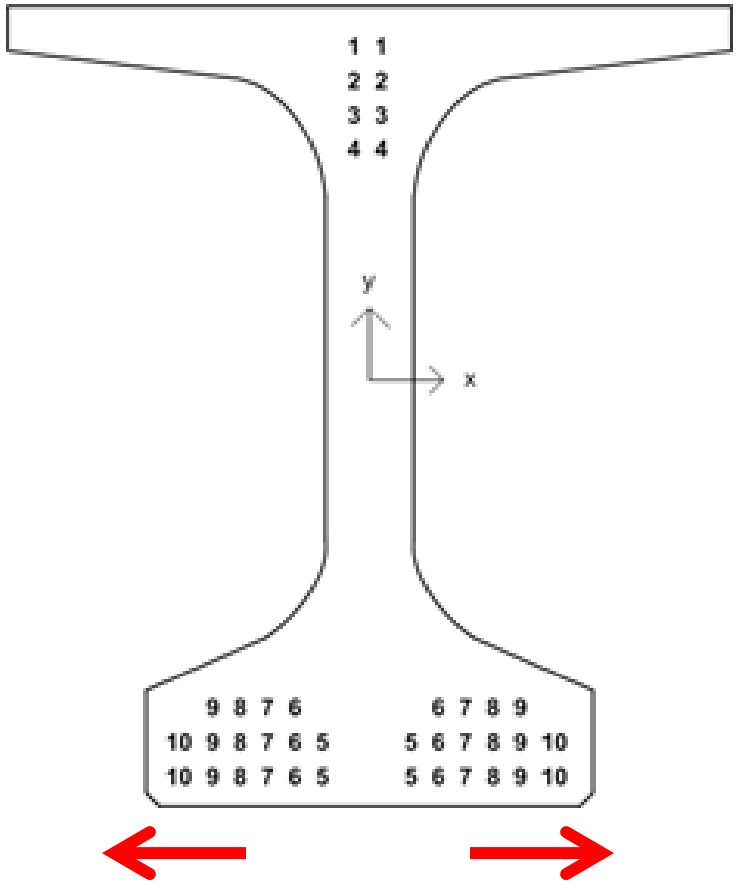
Harped strand pattern

Location of lifting

CRACK CONTROL BY STRAND CUTTING ORDER



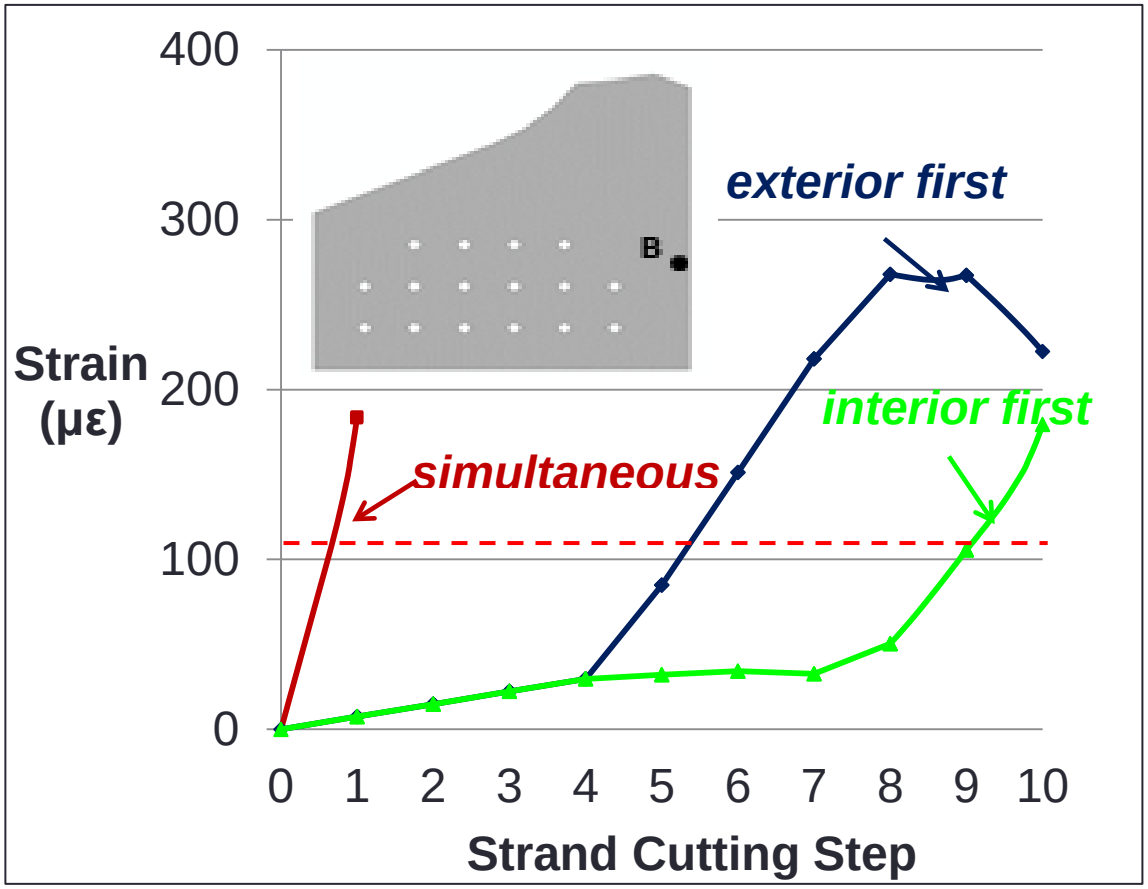
Exterior strands first



Interior strands first

CRACK CONTROL BY STRAND CUTTING ORDER

- Increase in strains during de-tensioning



Smaller strains if internal strands are cut first or all cut simultaneously

HOW CAN WE CONTROL CRACKING?

Rebar pattern

Strand de-bonding

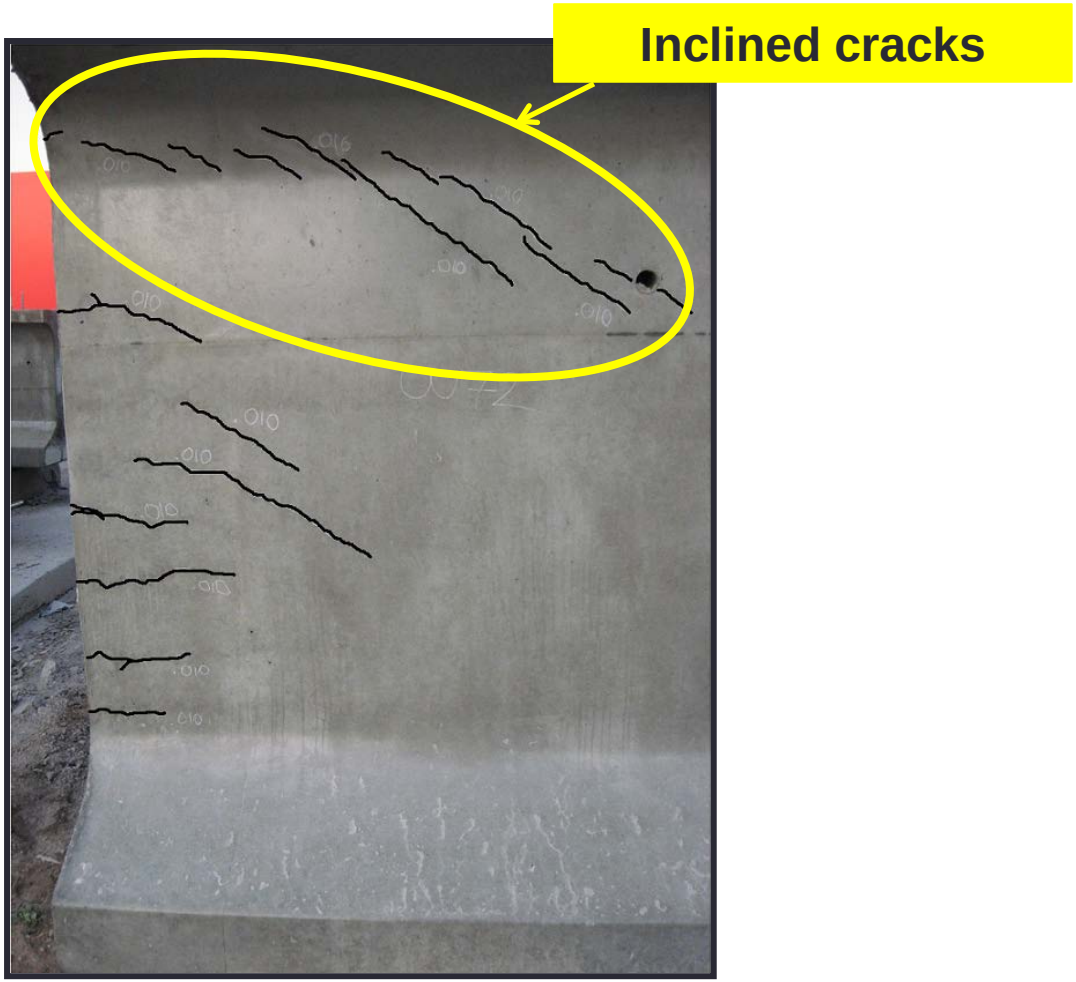
Strand release order

Harped strand pattern

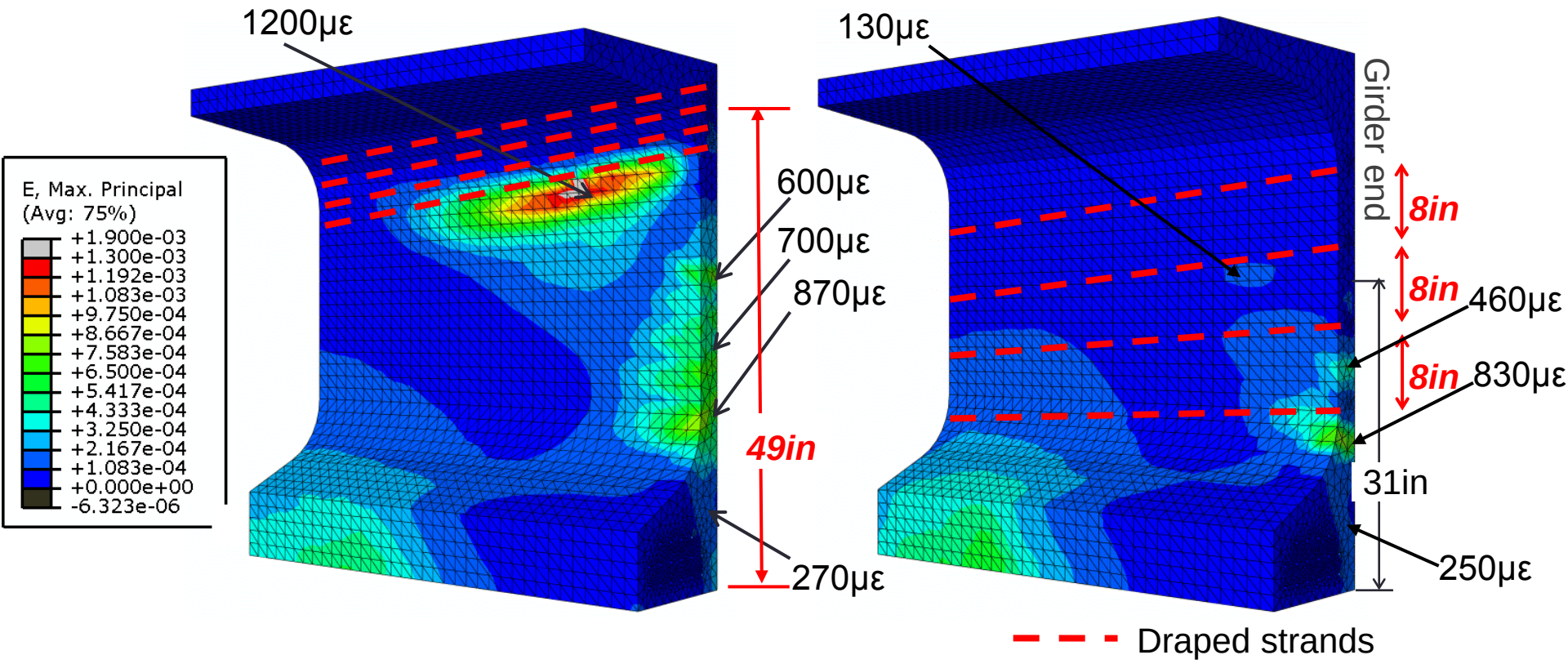
Location of lifting

CRACK CONTROL BY DRAPED STRANDS

- TARGET CRACKS



CRACK CONTROL BY DRAPED STRANDS



Lowering and spreading draped strands can eliminate inclined cracking but… by compromising girder efficiency

HOW CAN WE CONTROL CRACKING?

Rebar pattern

Strand de-bonding

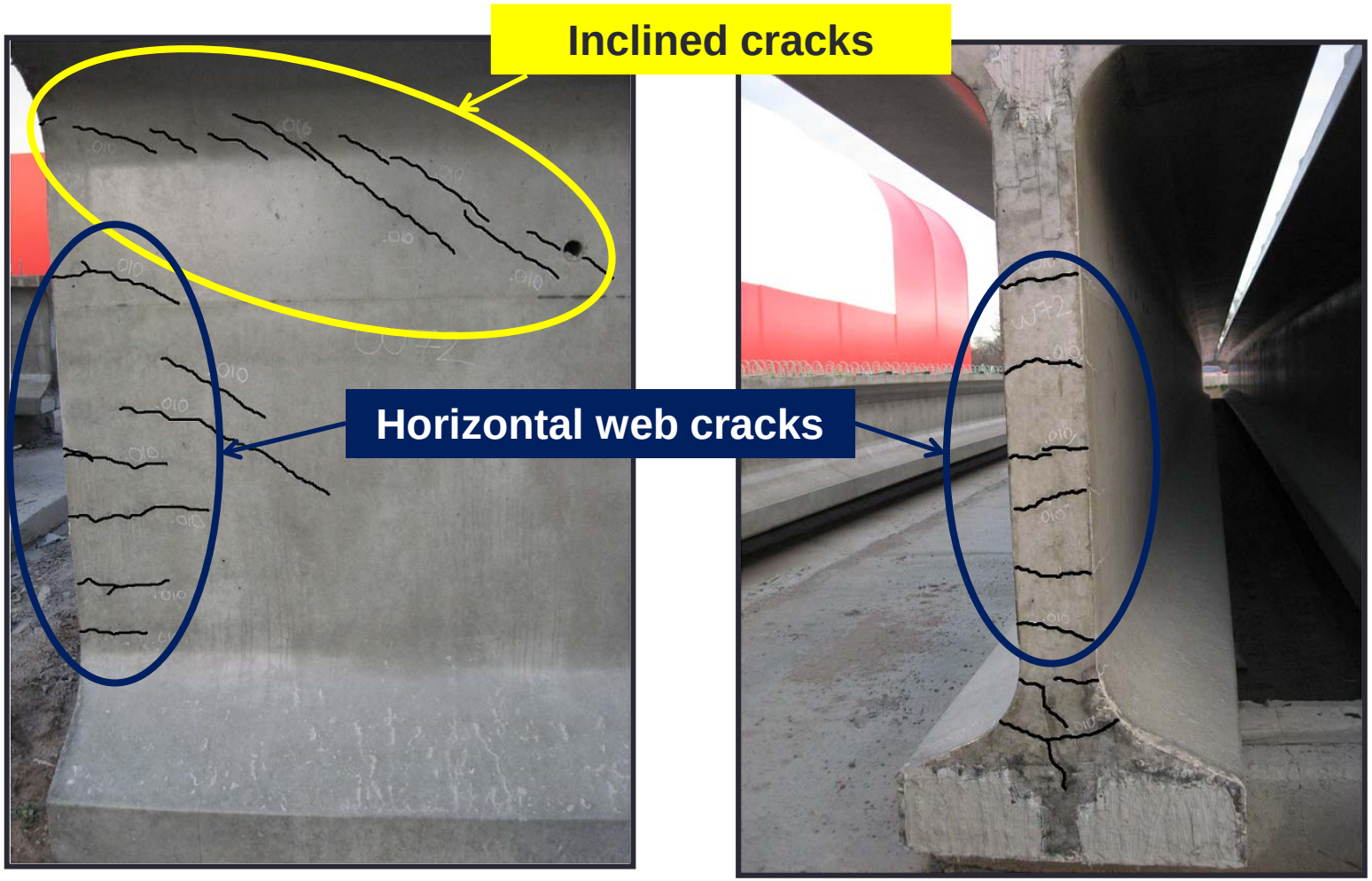
Strand release order

Harped strand pattern

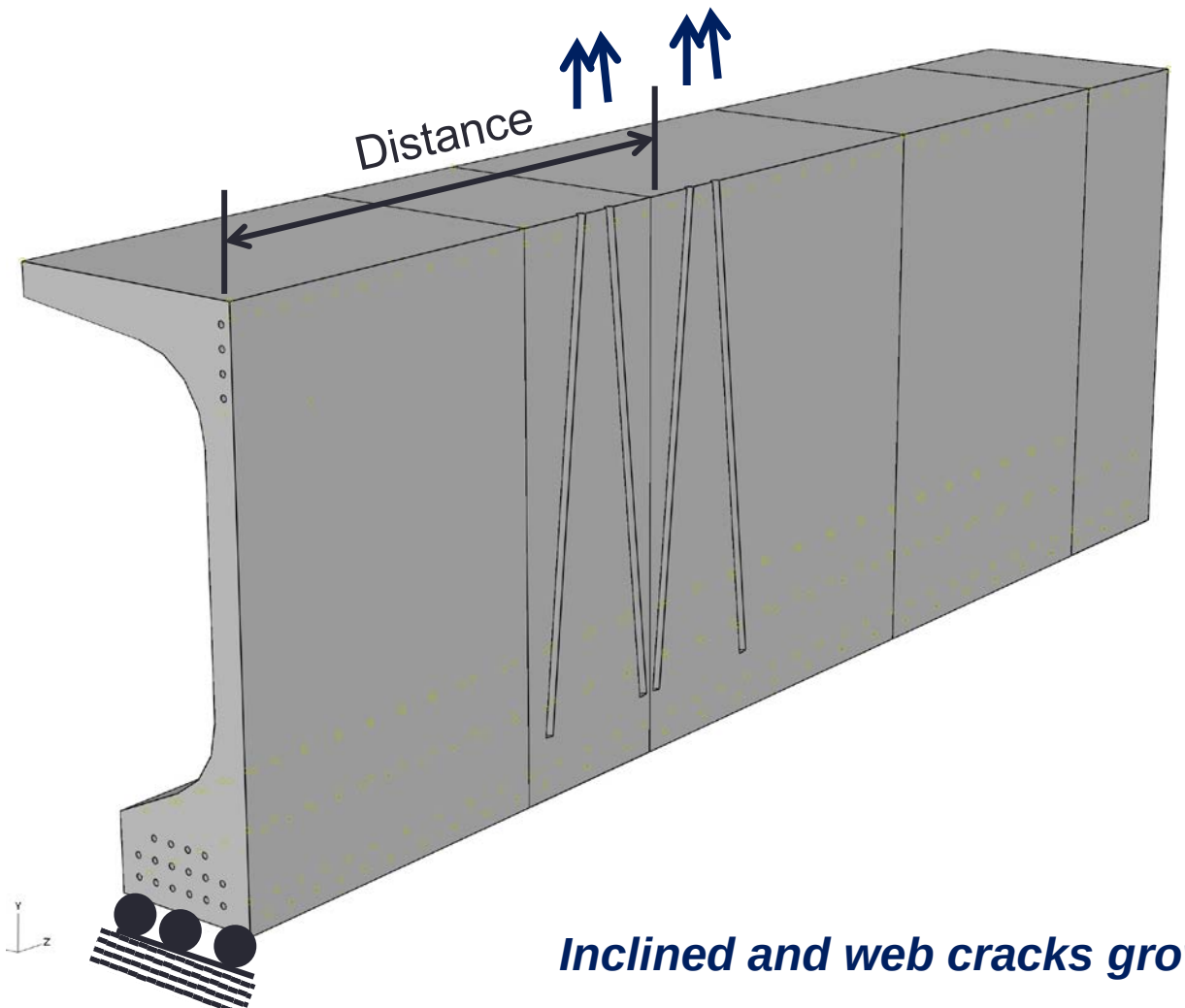
Location of lifting

CRACK CONTROL BY LIFTING LOCATION

- TARGET CRACKS



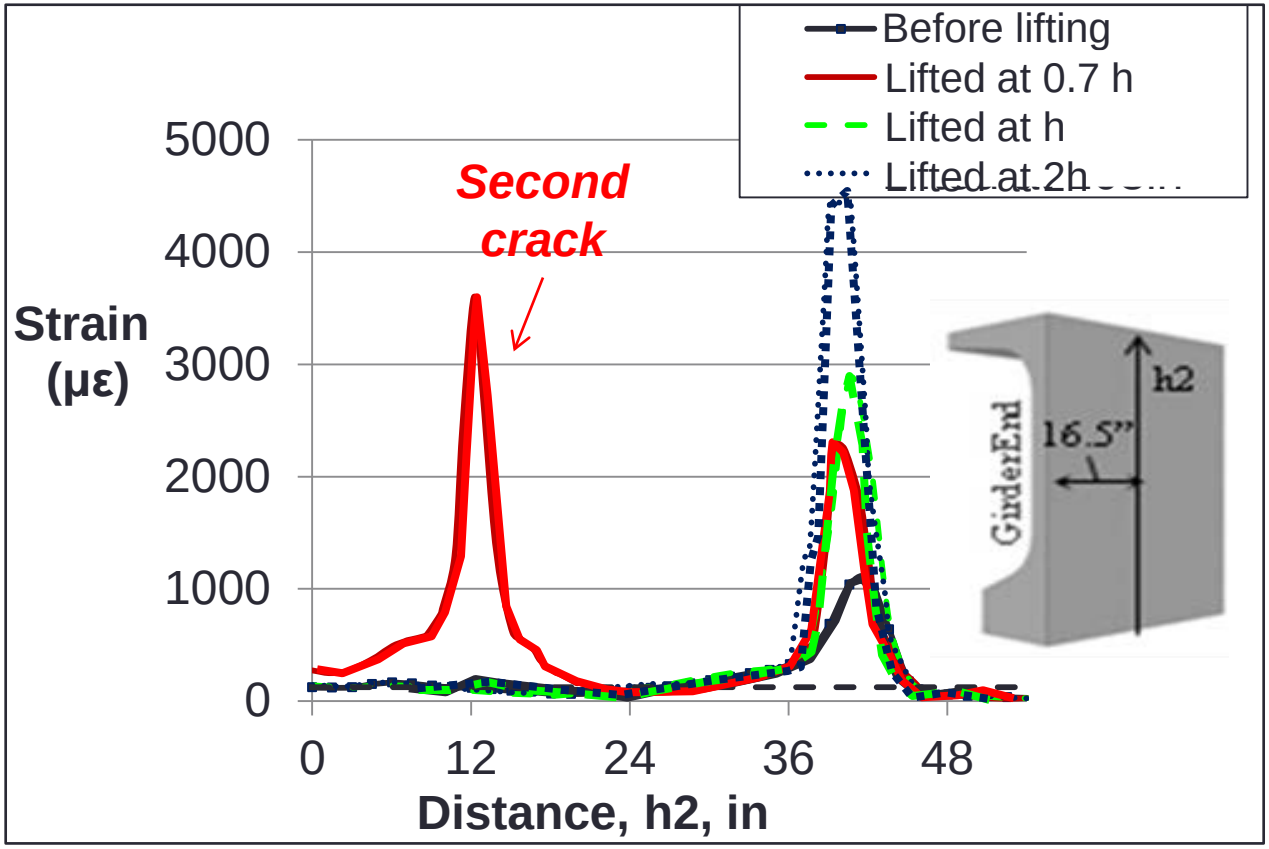
CRACK CONTROL BY LIFTING LOCATION



Inclined and web cracks grow significantly

CRACK CONTROL BY LIFTING LOCATION

- LIFTING LOCATION



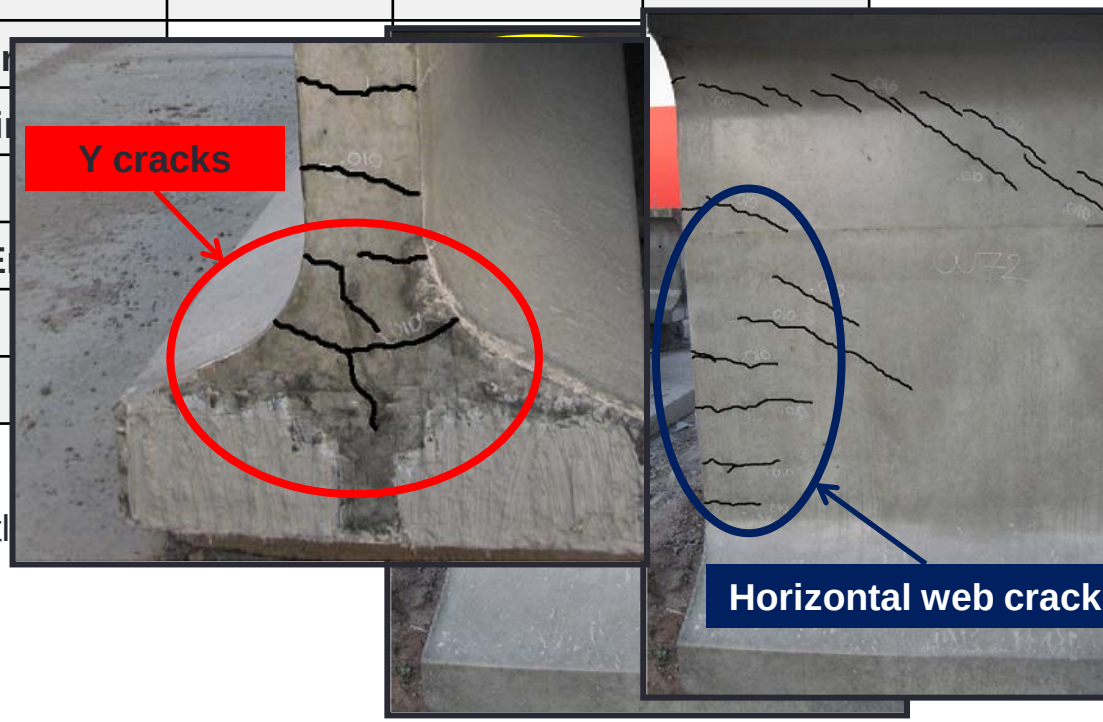
Girders should be lifted as close to the end as possible
Lift locations should not be in nonlinear region

KEY FINDINGS

Control Method			Inclined Cracks	Web Cracks	Y Cracks
1	Increase in	The closest two bars to girder			
2	Area of:	Bars further away from the gi			
4	Debonding Some Strands at the End				
5	Debonding All Strands for 12in from the E				
6	Change in Strand Cutting Order				
9	Lowered & Spread Draped Strands				

HIGH = can eliminate cracking

MODERATE = can reduce strains significantl



Acknowledgements

Thank you
Questions?