FINITE ELEMENT ANALYSIS of WIDE FLANGE PRESTRESSED GIRDERS to UNDERSTAND and CONTROL END CRACKING

THE UNIVERSITY of WISCONSIN MADISON

Research Update
by

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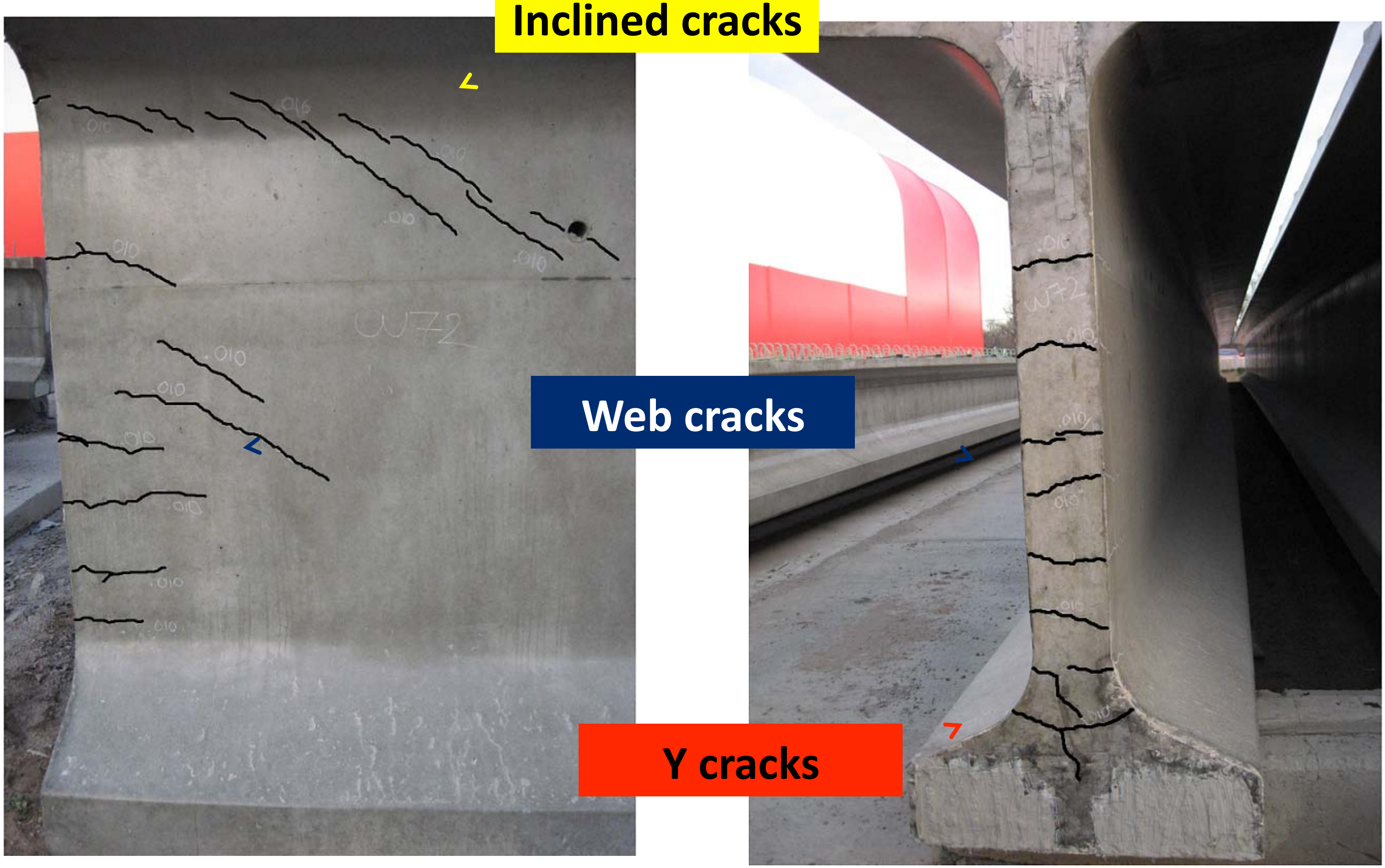
12-16-2010

AGENDA

- Problem and Objectives
- Verification of the Finite Element Model (FEM)
- Exploring Potential Solutions
- Recommendations

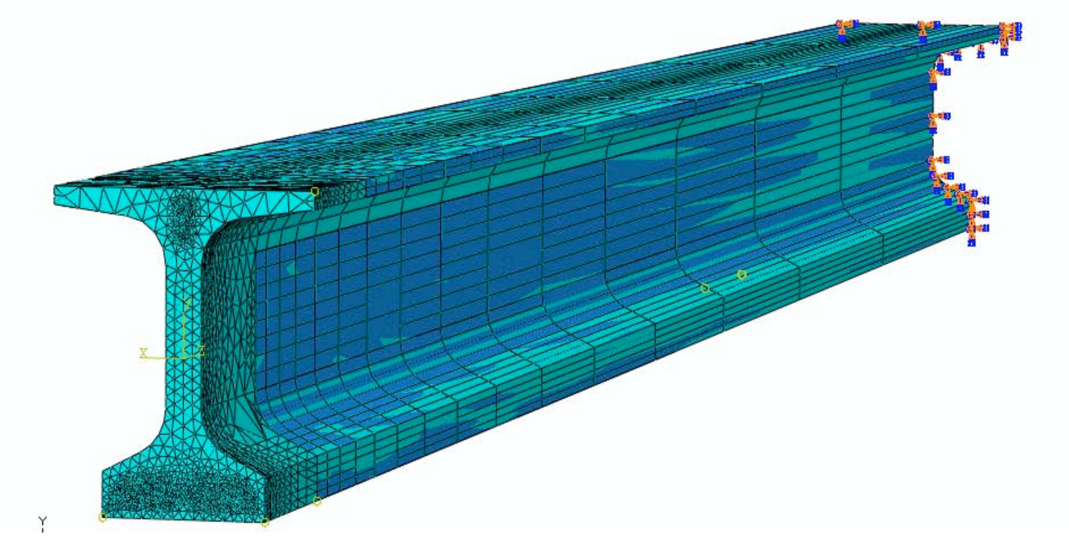
GIRDER END CRACKS



PROJECT GOALS

Through Finite Element Analysis:

- Investigate the stress pattern at the girder ends
- Understand causes of cracking
- Explore possible solutions to limit cracking

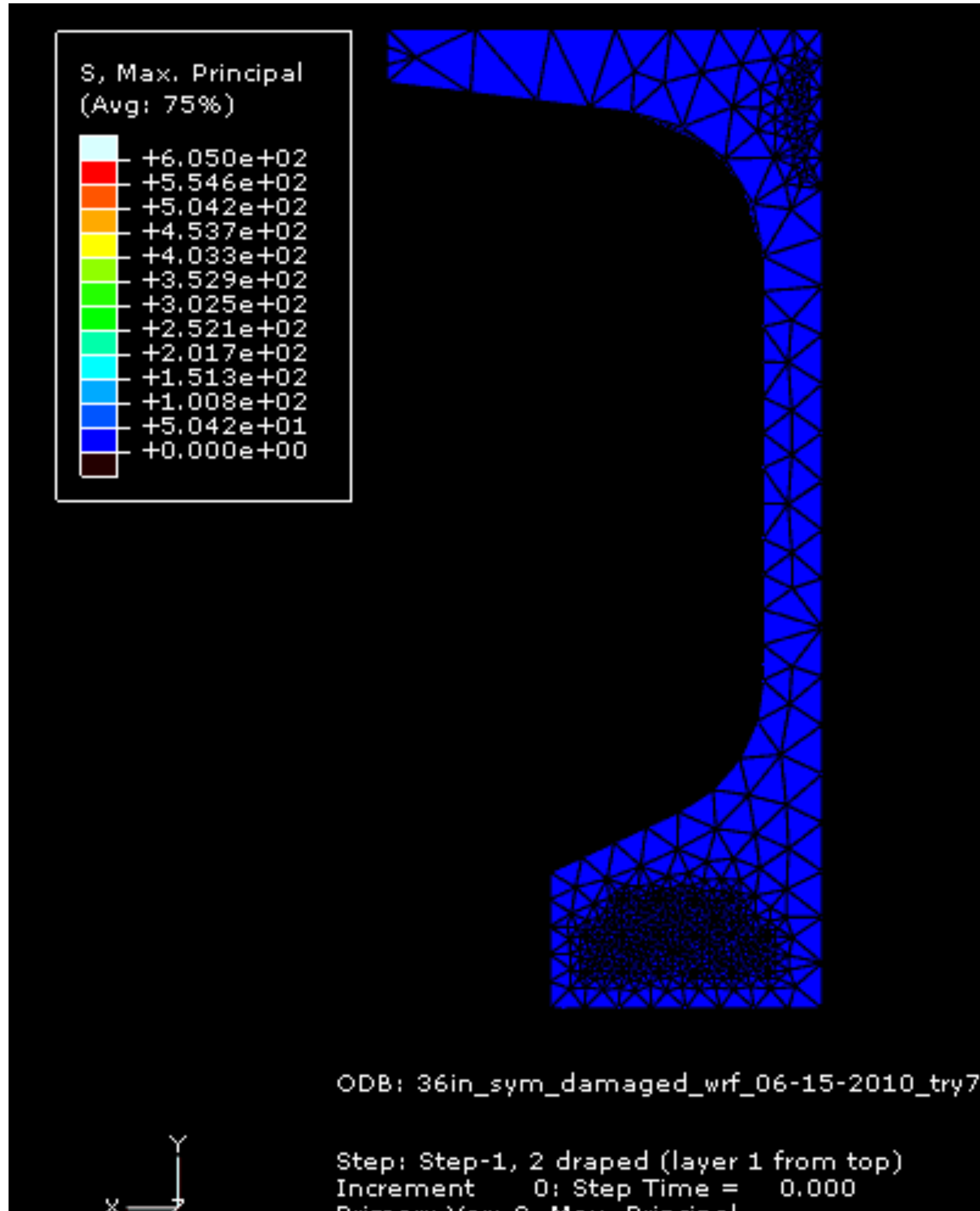


VERIFICATION of the FEM

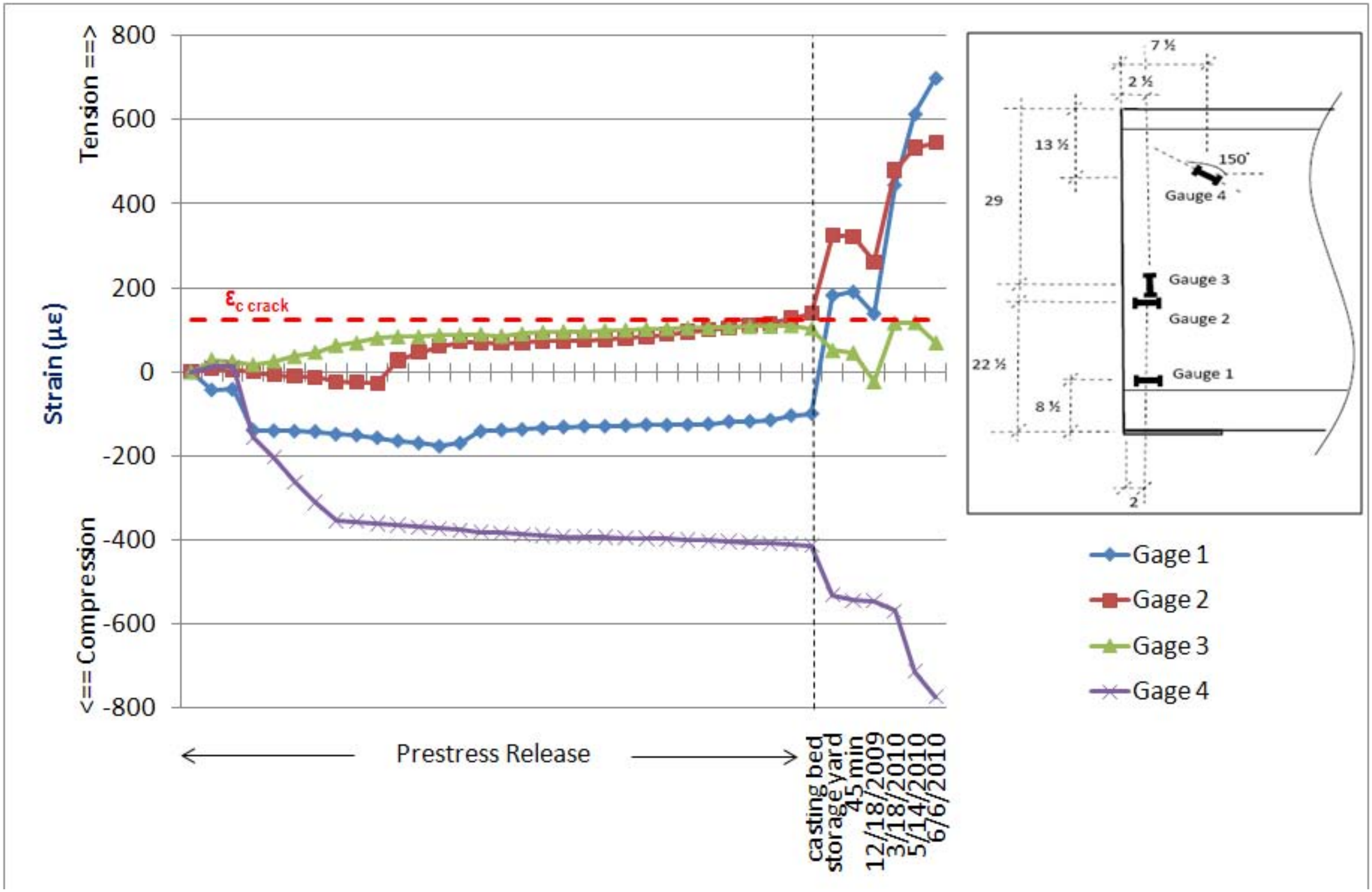
Test data available on Girders:

- Spancrete W54
- County W54
- Texas Tx70

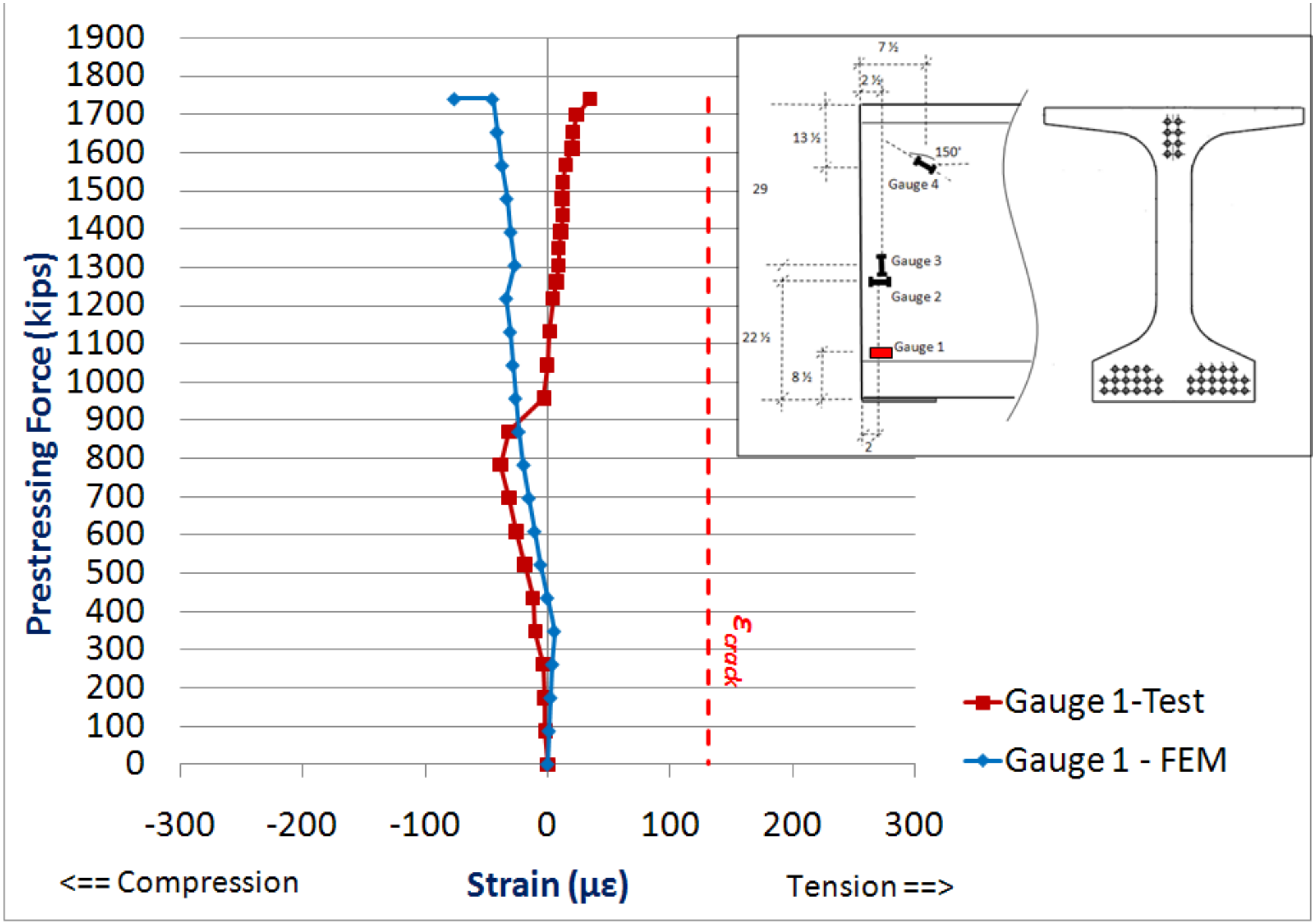
SPANCRETE W54 GIRDER - Cracks



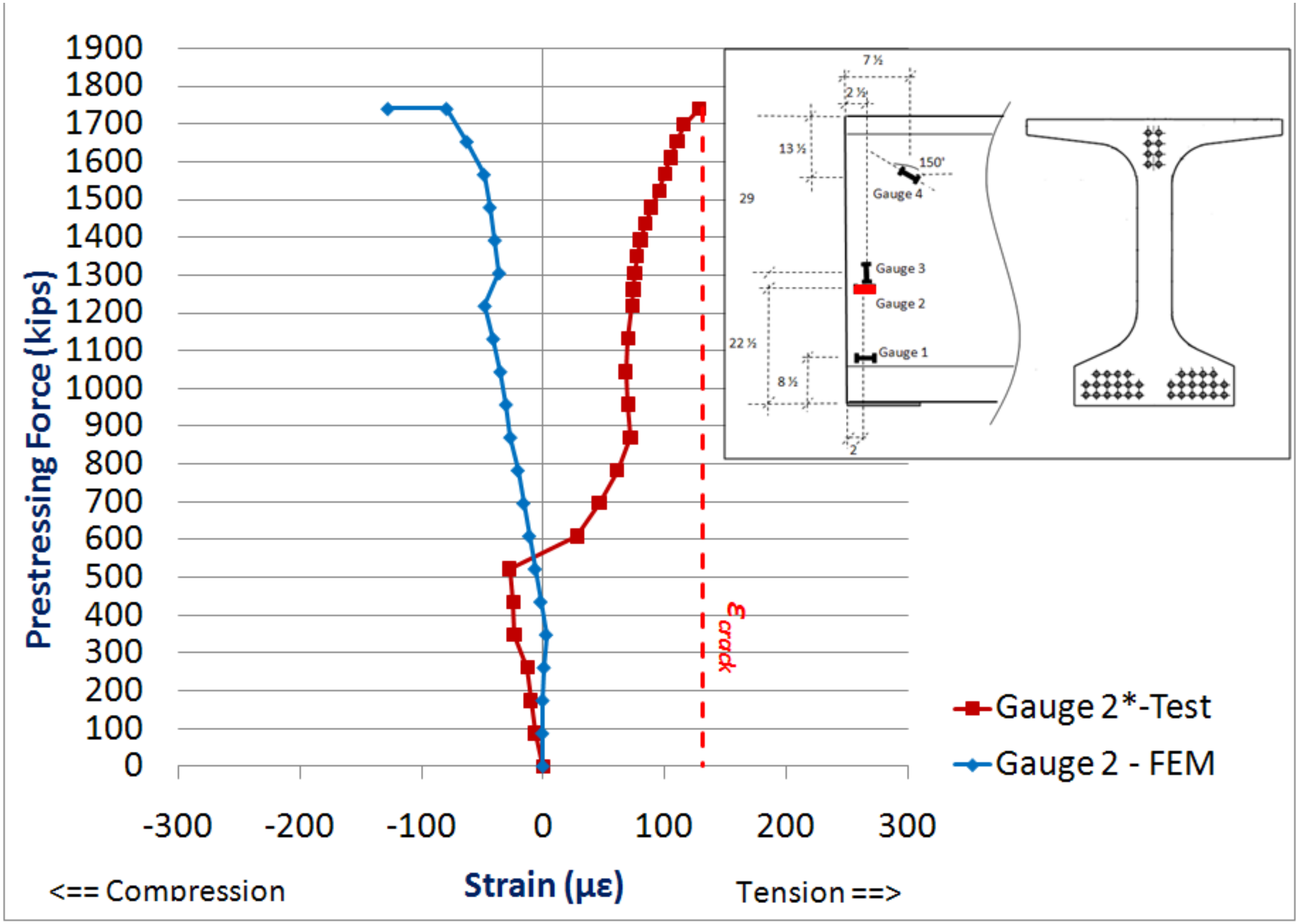
SPANCRETE W54 GIRDER - Strains



SPANCRETE W54 GIRDER – Test vs FEM



SPANCRETE W54 GIRDER – Test vs FEM



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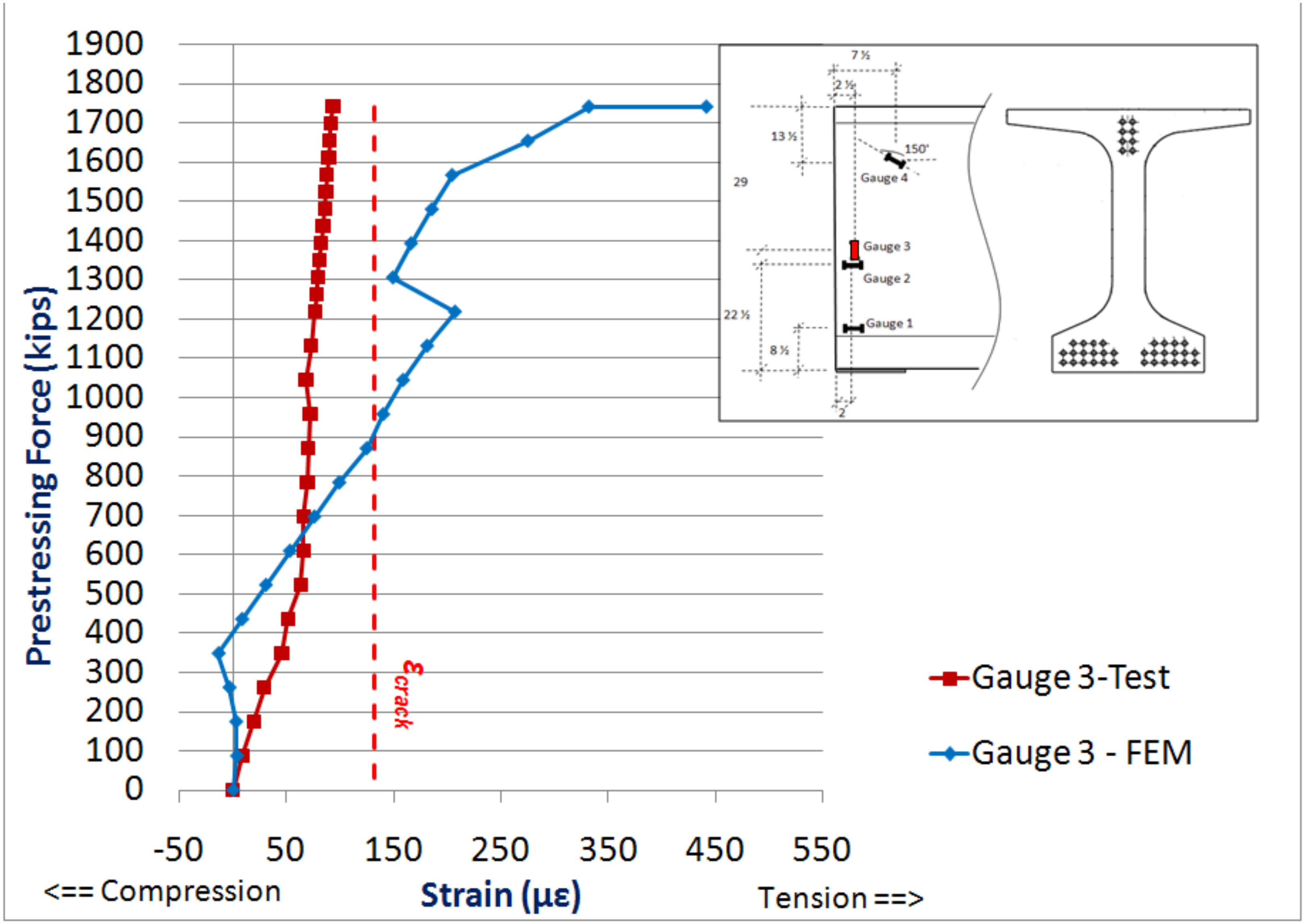
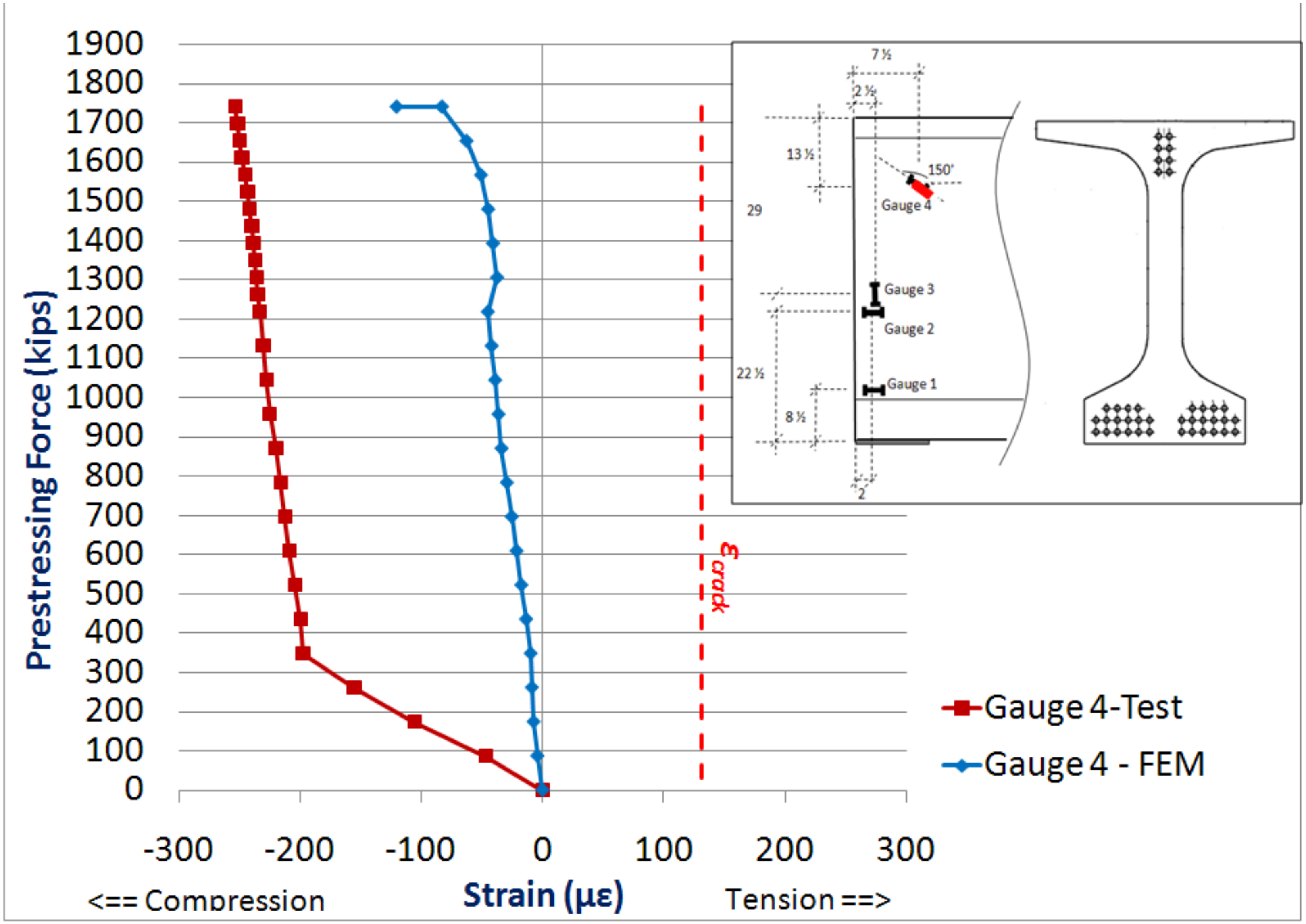
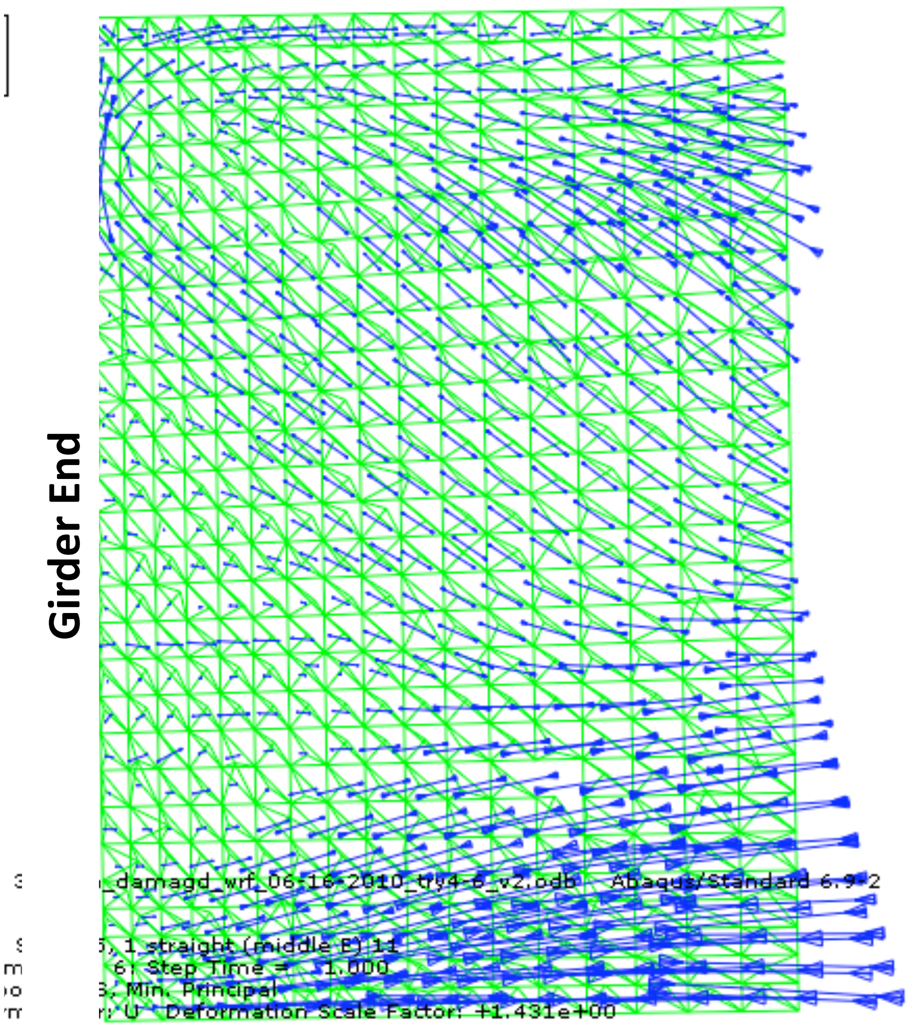


SPANCRETE W54 GIRDER – Test vs FEM

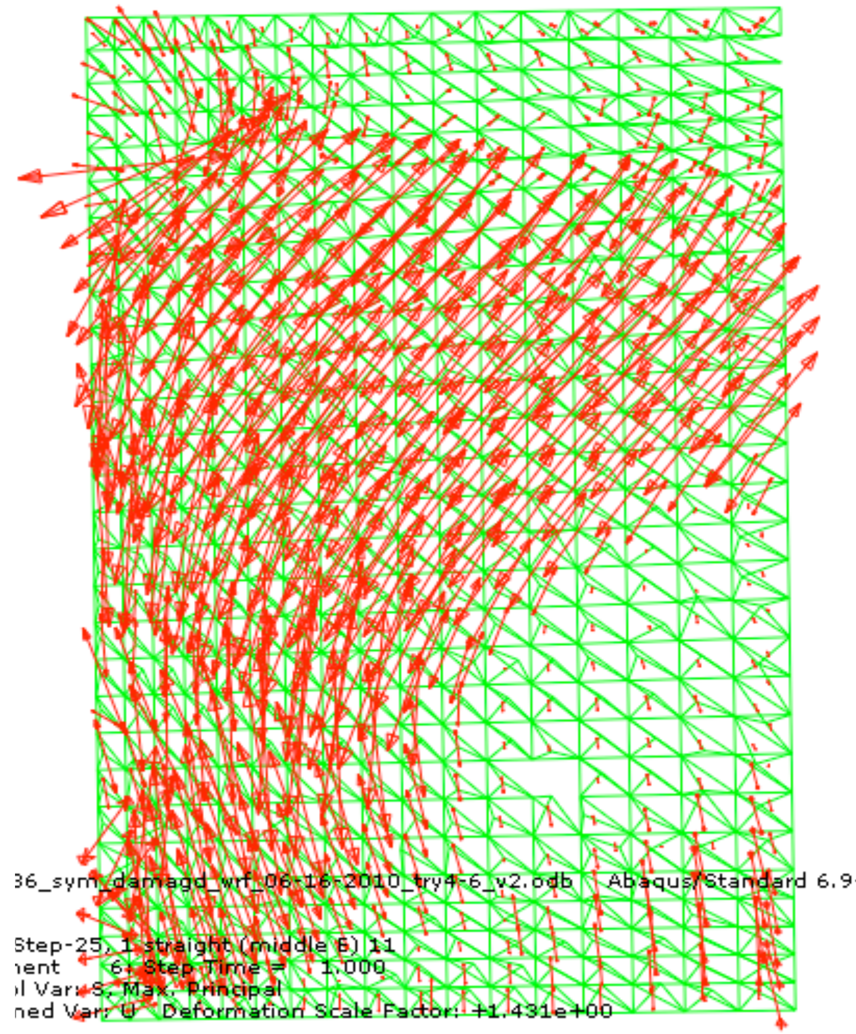


STRAIN FLOW at the ENDS

Girder End

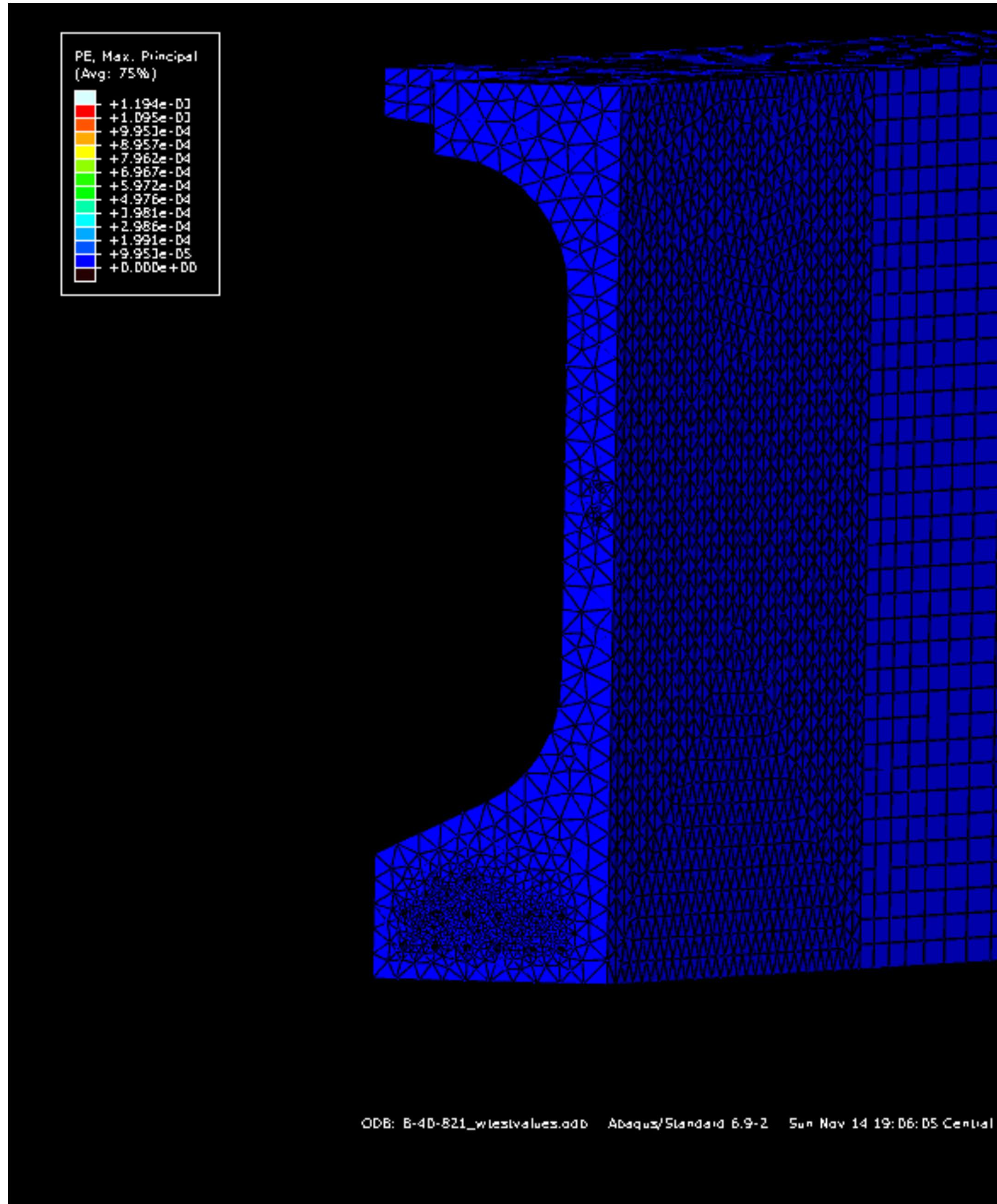


Principal Compression

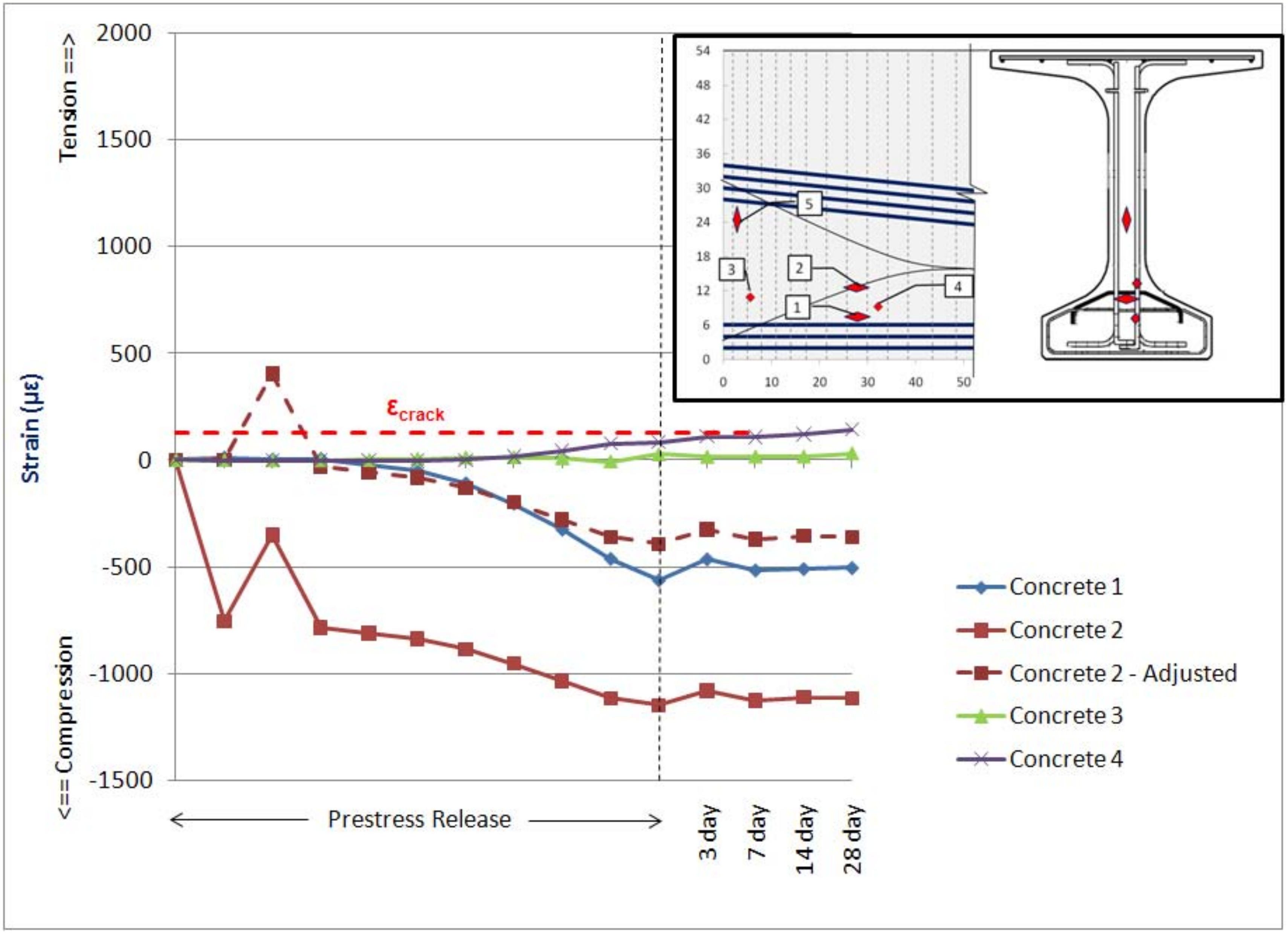


Principal Tension

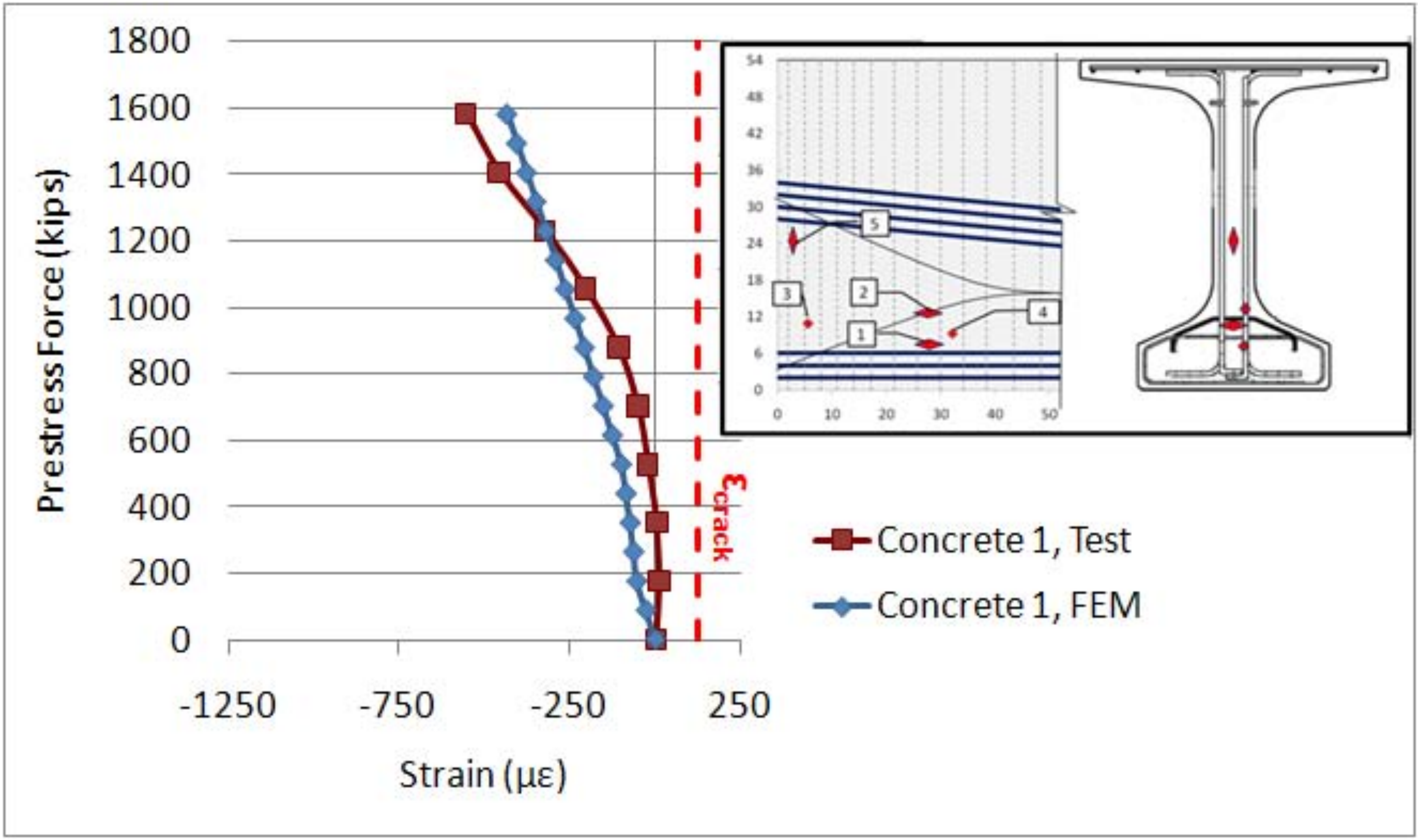
COUNTY W54 GIRDER - Cracks



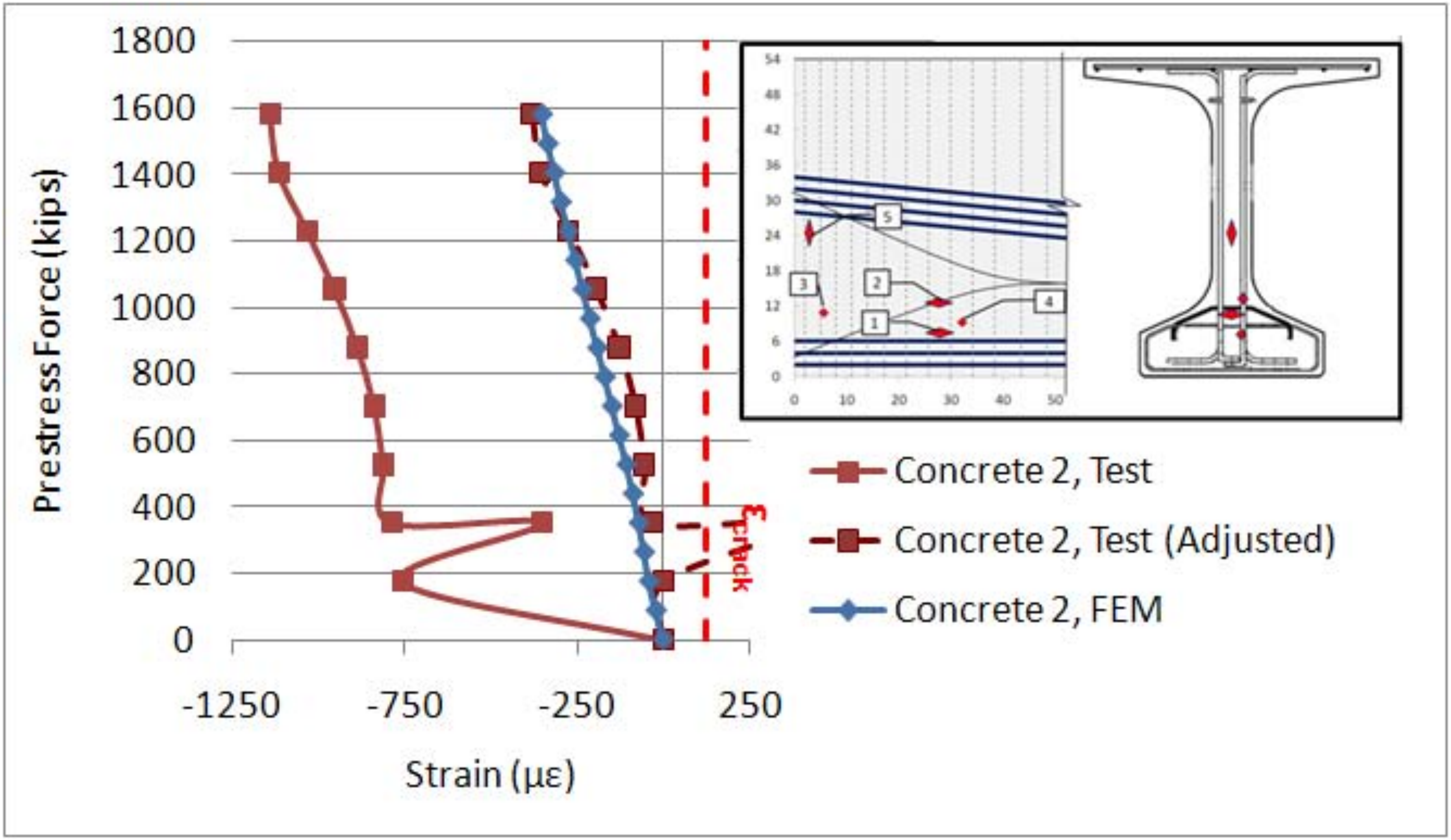
COUNTY W54 GIRDER - Strains



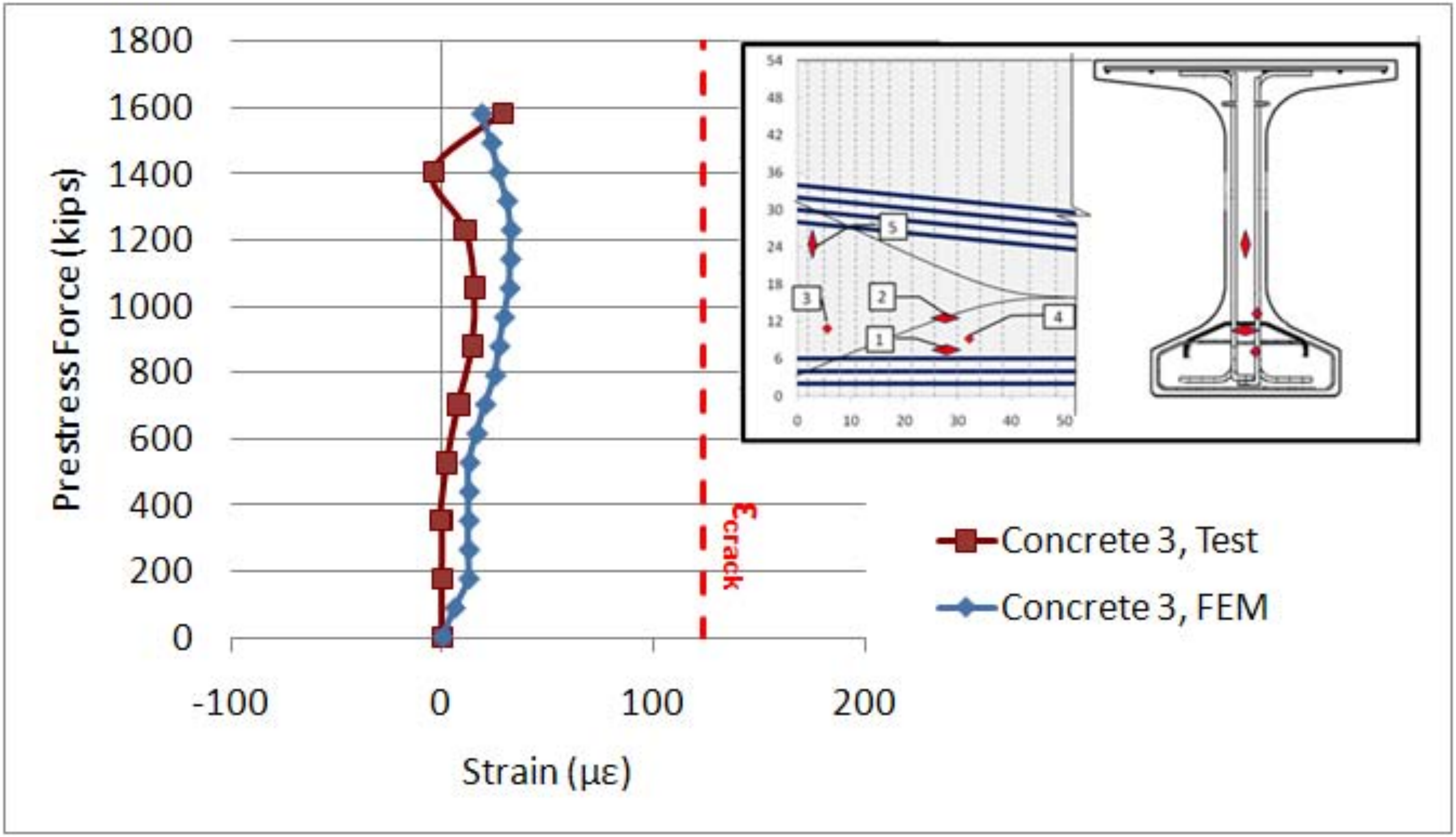
COUNTY W54 GIRDER – Test vs FEM



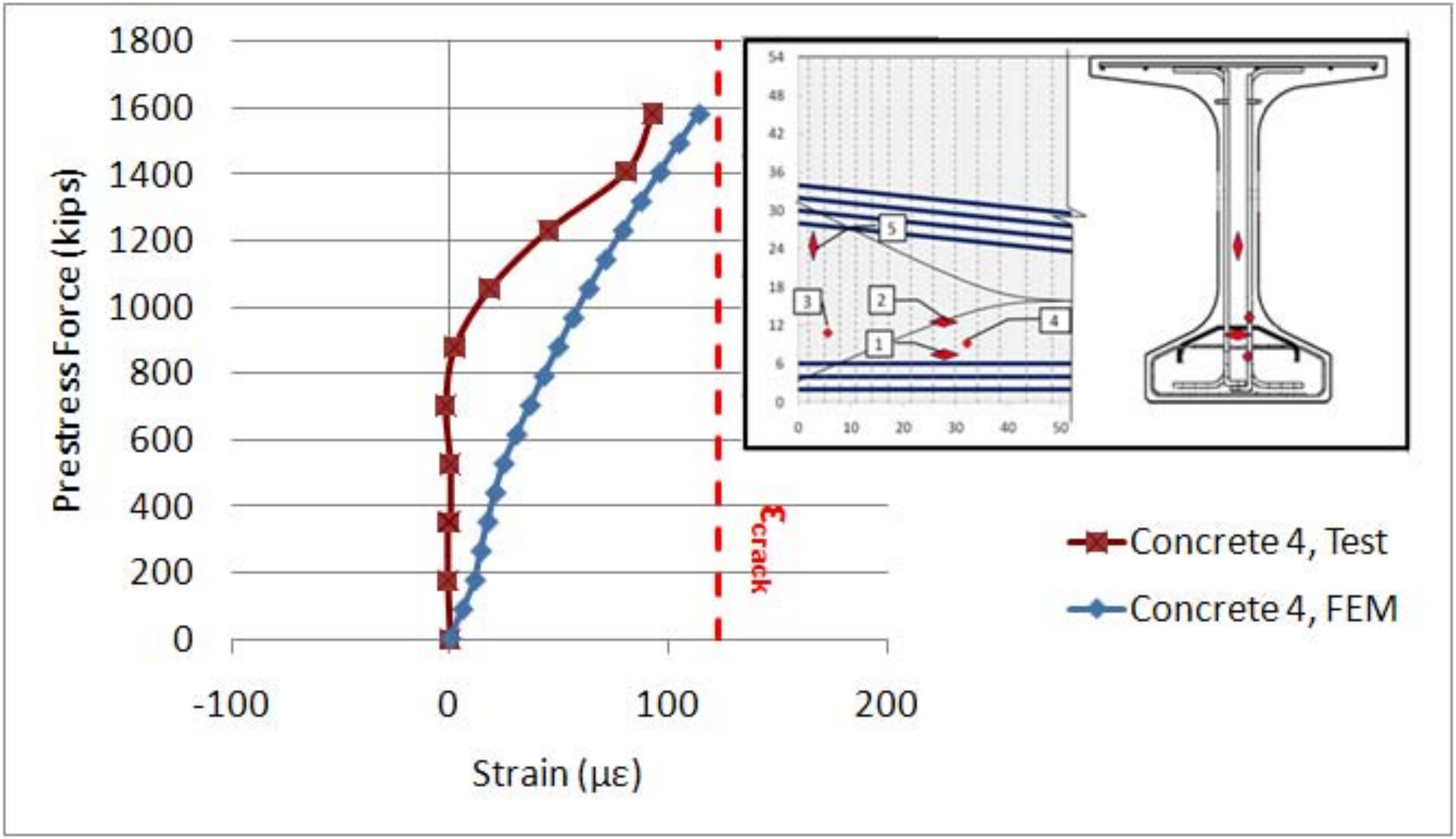
COUNTY W54 GIRDER – Test vs FEM



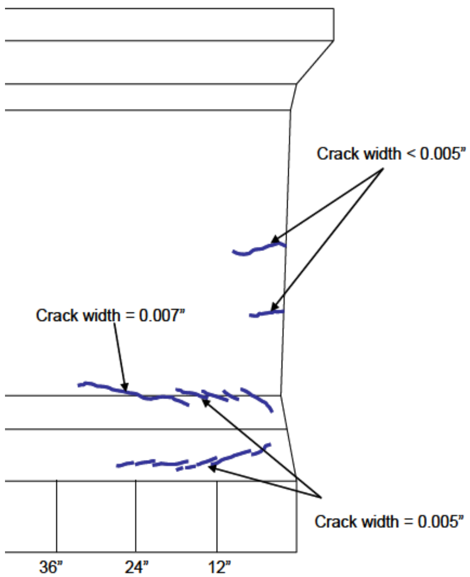
COUNTY W54 GIRDER – Test vs FEM

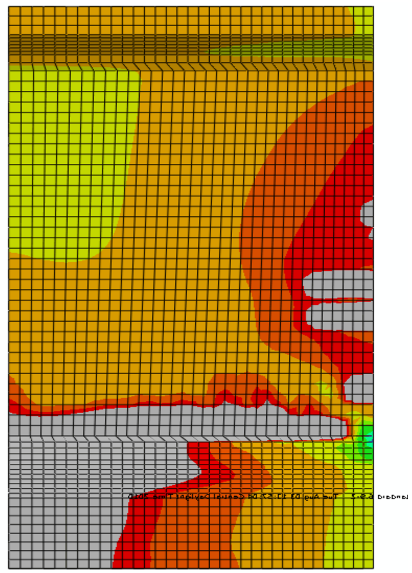


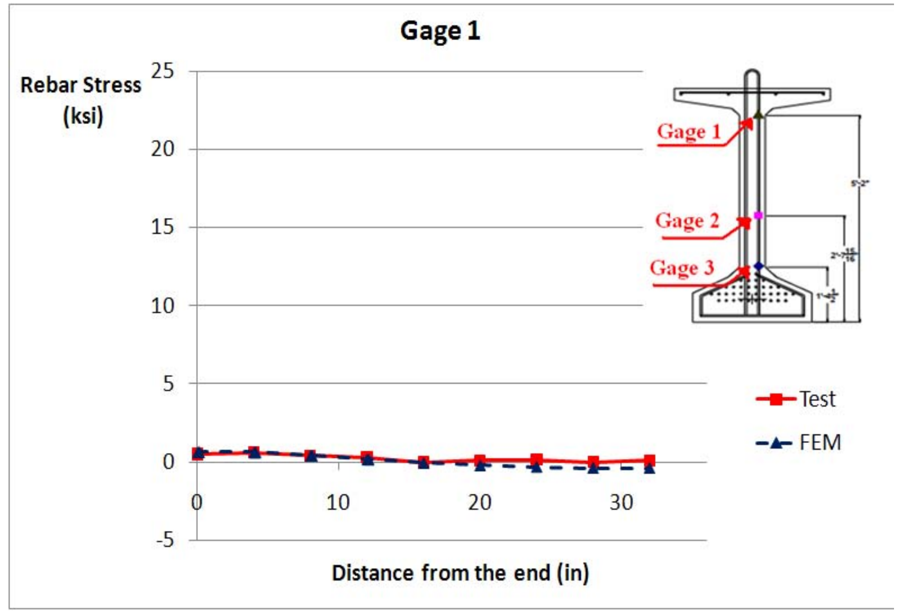
COUNTY W54 GIRDER – Test vs FEM

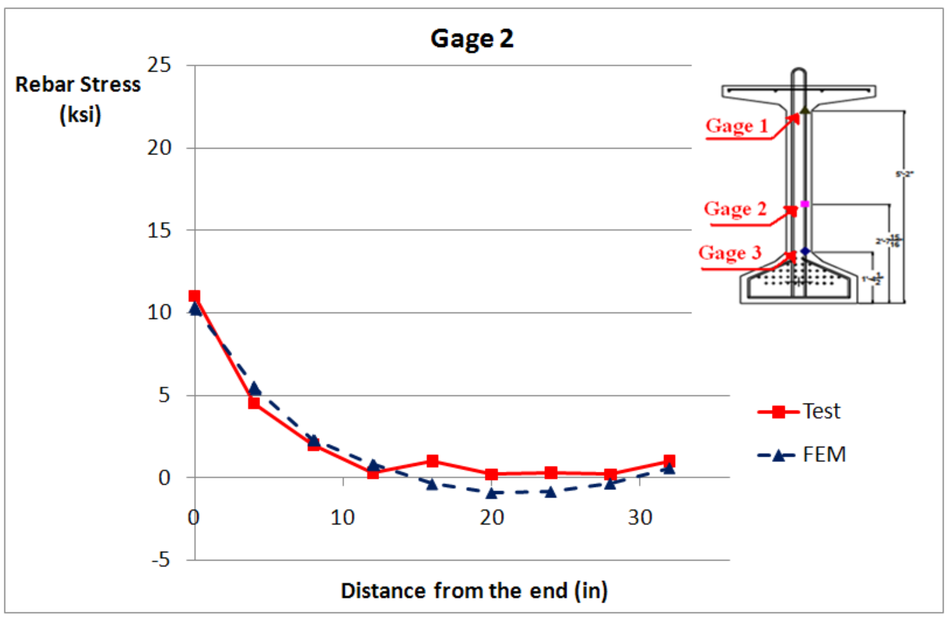


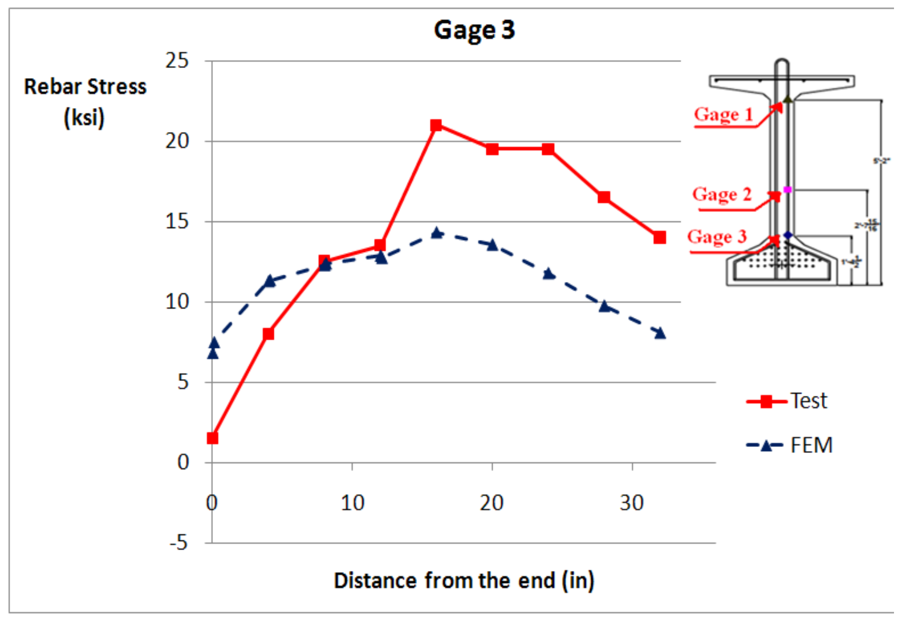
TEXAS Tx70 GIRDER – Test vs FEM











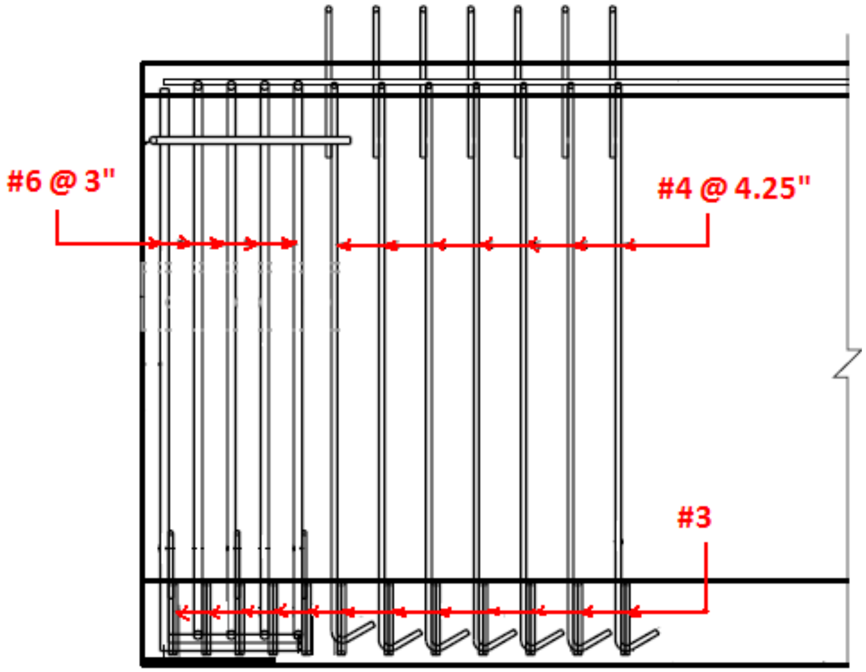
POTENTIAL SOLUTIONS

- Rebar Pattern
- Debonding Strands
- Combination of Debonding and Rebar Size
- Removing or Lowering draped strands
- Strand Cutting Order
- Coping Upper Flanges
- Limiting Number of Strands

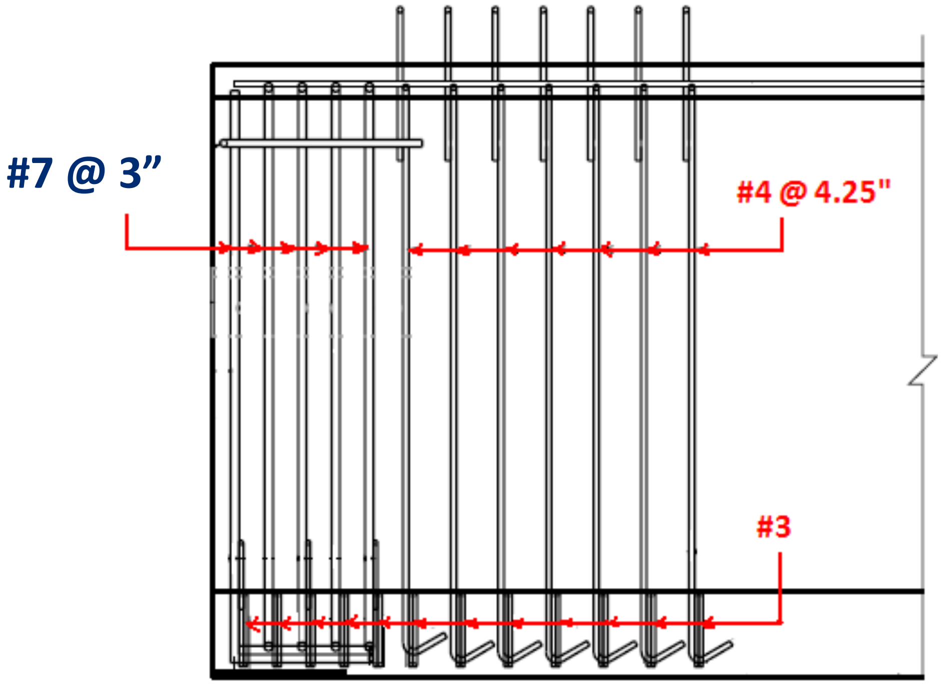
REBAR PATTERN – Web Cracks

Web cracks

REBAR CONFIGURATIONS

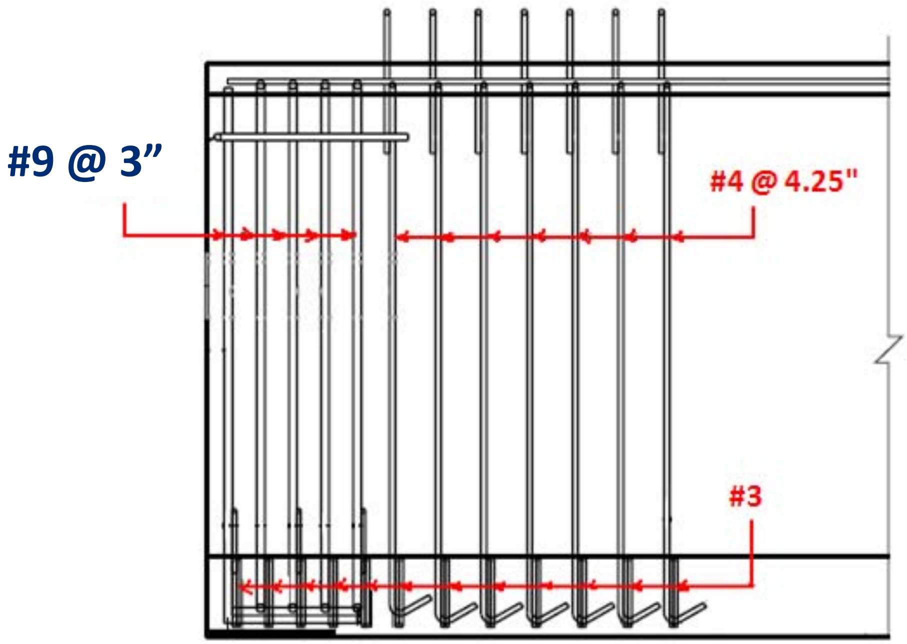


Standard RF

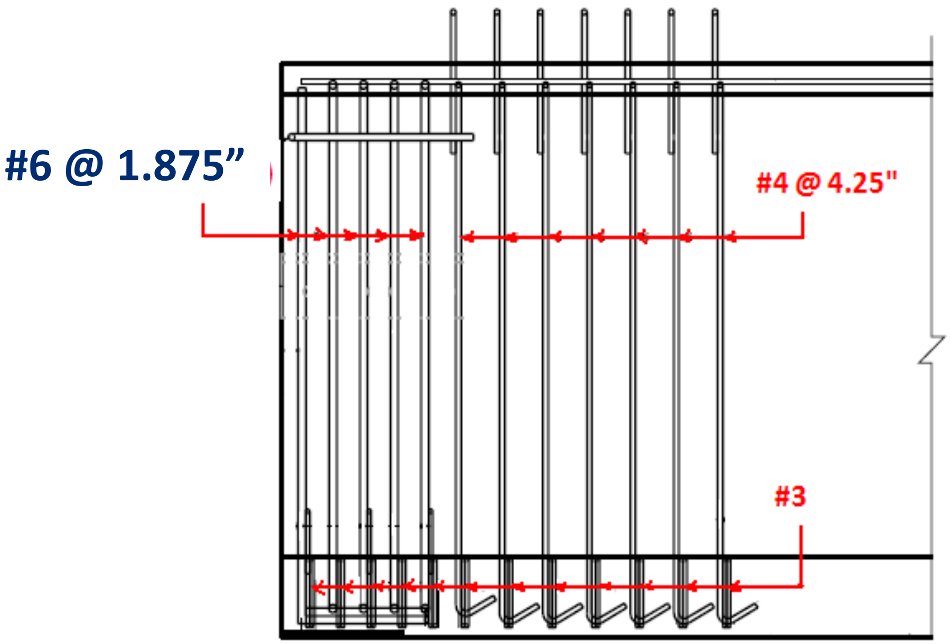


RF 1

REBAR CONFIGURATIONS

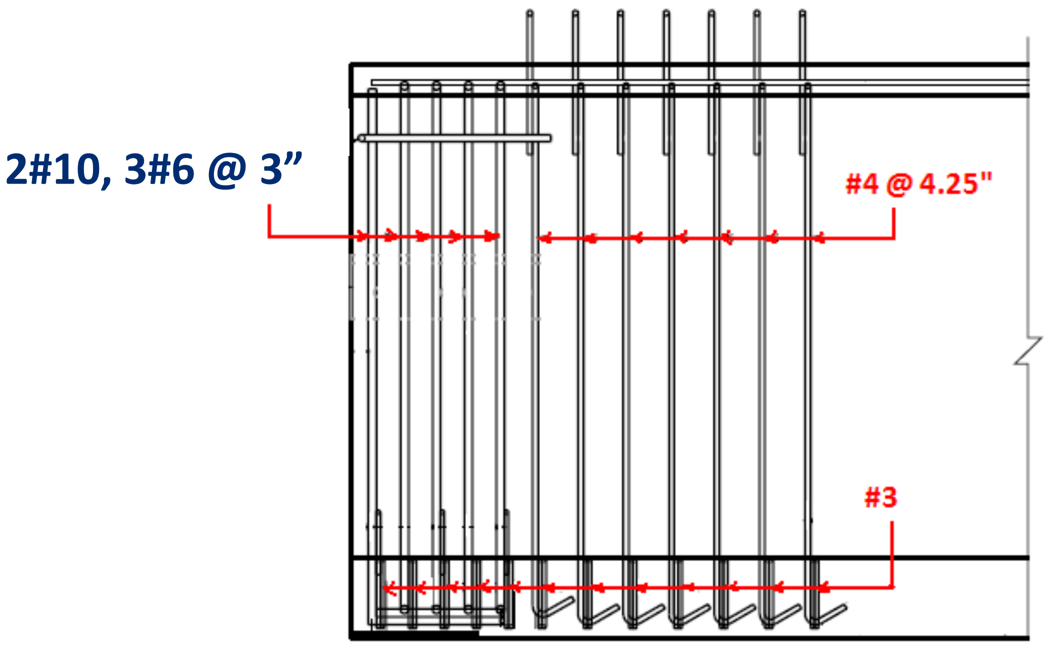


RF 5



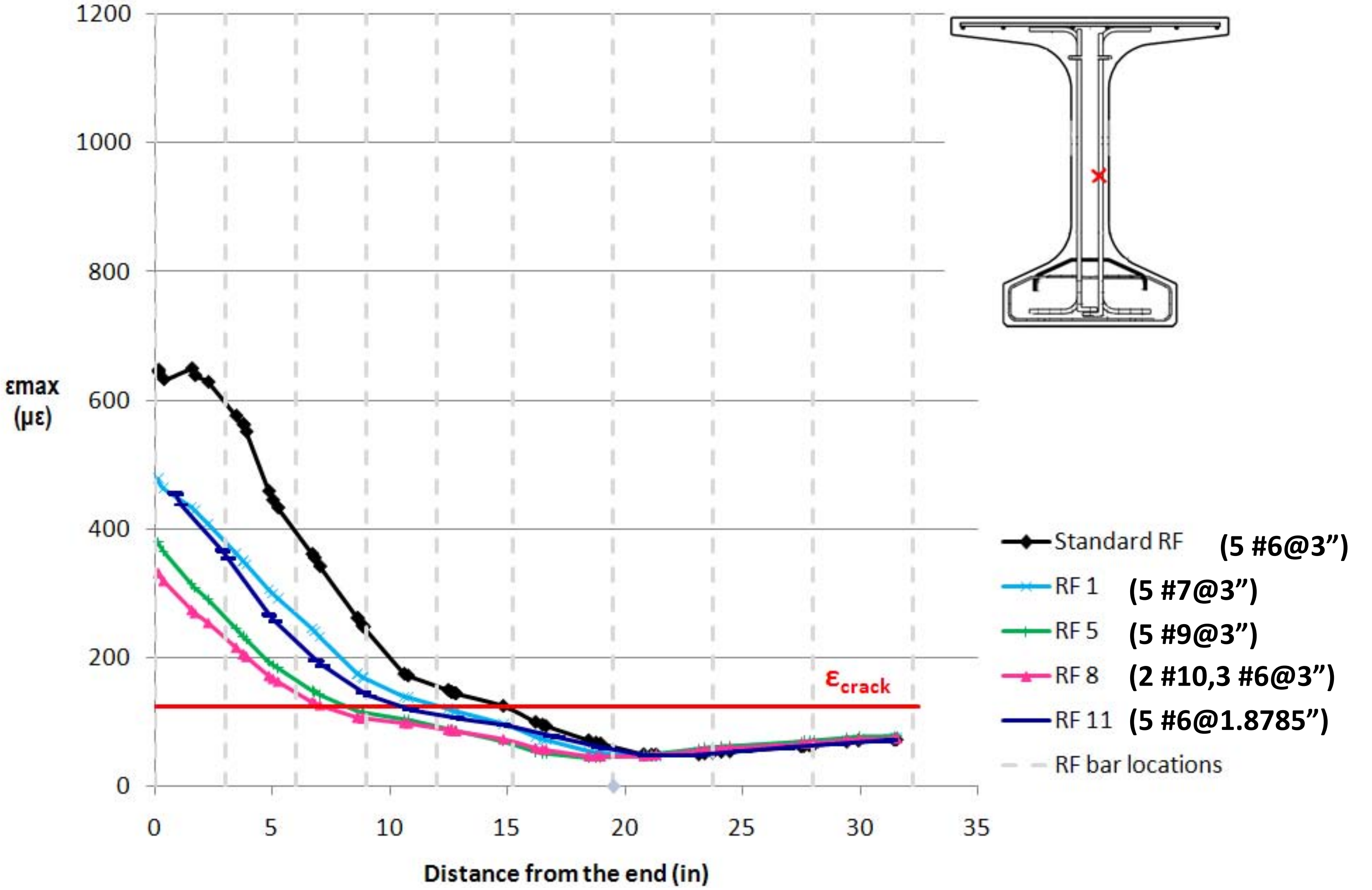
RF 11

REBAR CONFIGURATIONS



RF 8

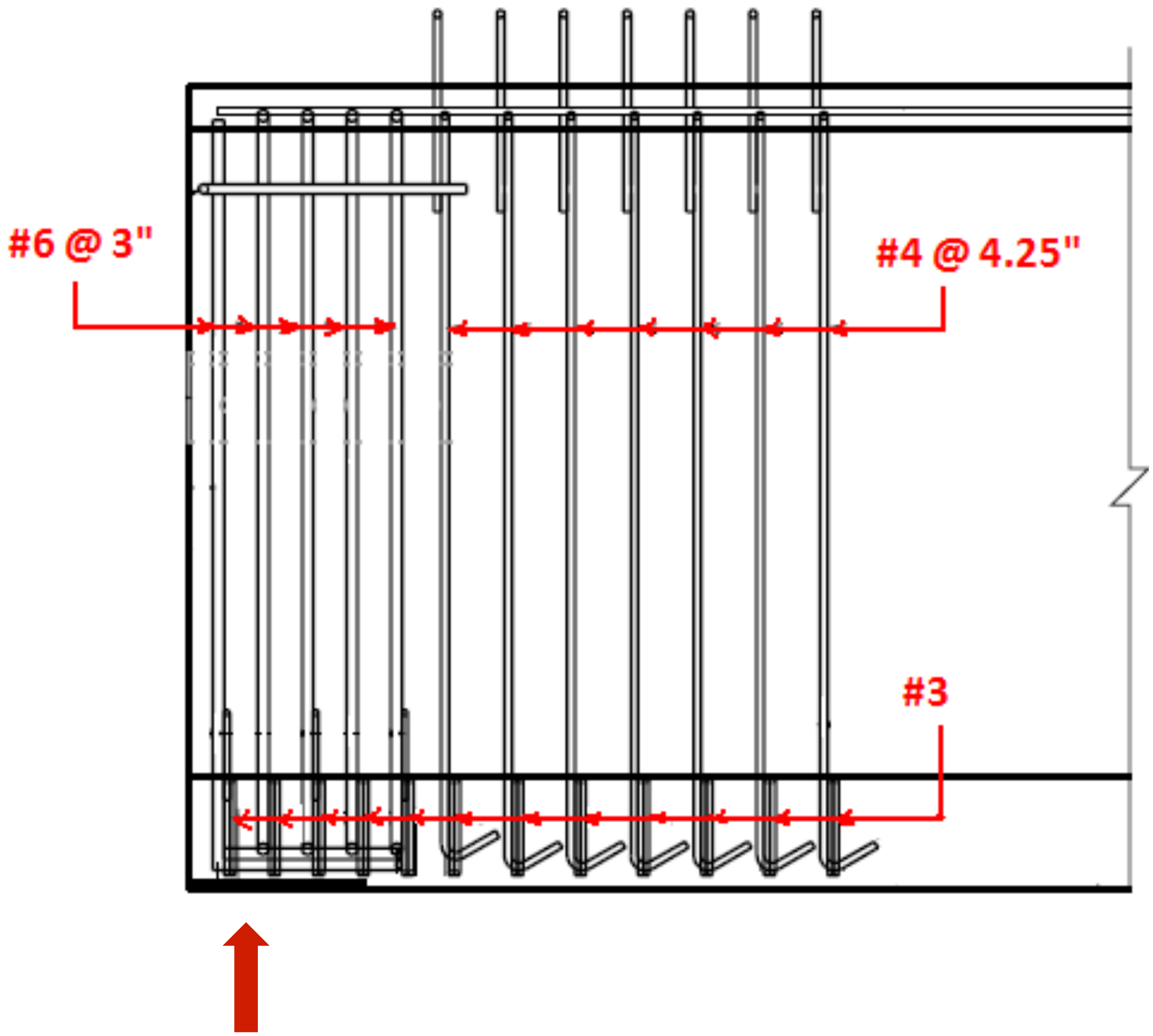
REBAR PATTERN - Strains



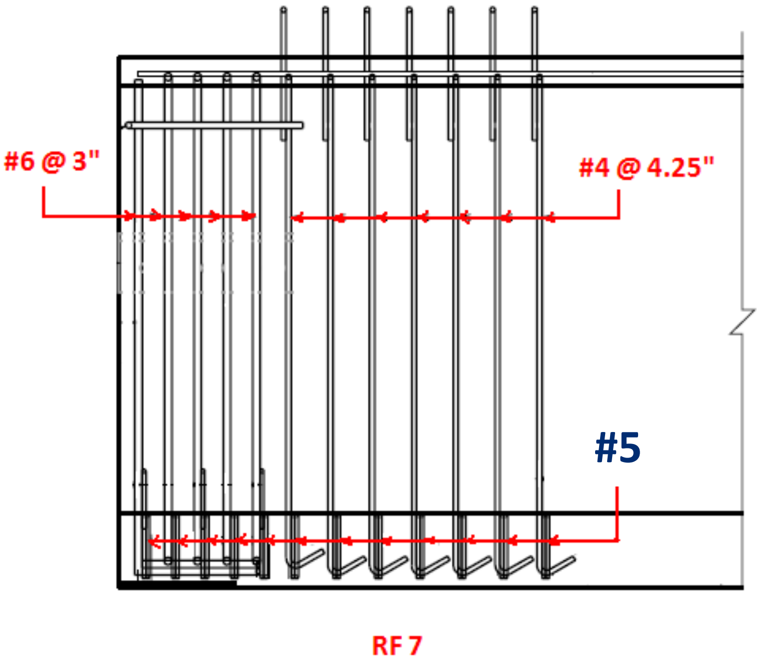
20% - 40% decrease in strains

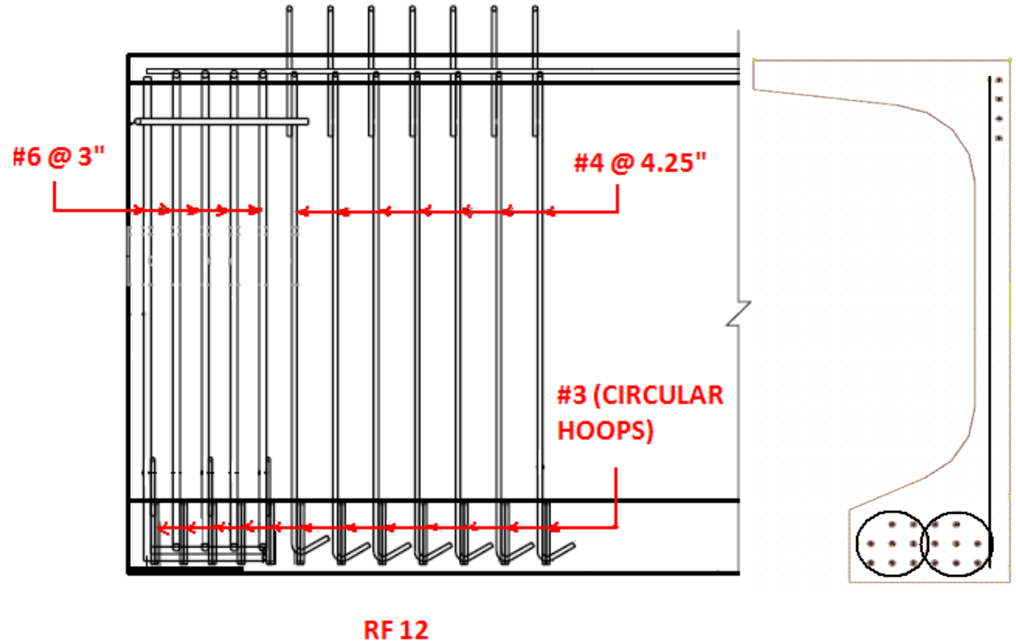
REBAR PATTERN

Which bars are the most effective?



BOTTOM FLANGE REINFORCEMENT

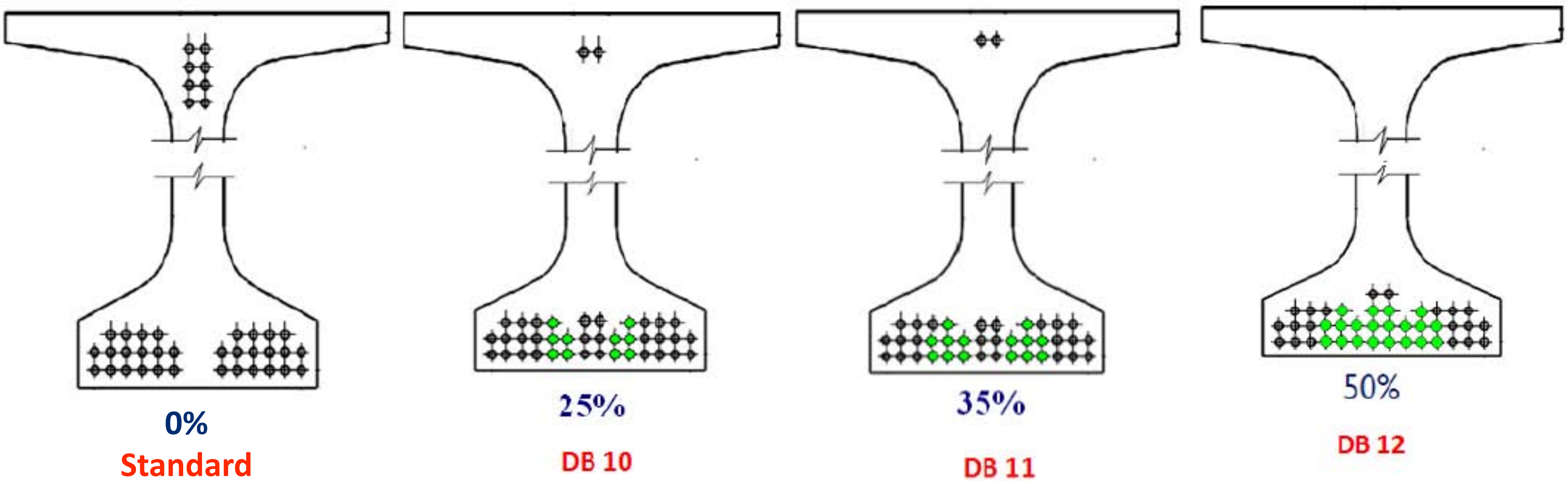




Negligible strain decrease at the ends

DEBONDING – Inclined & Y Cracks

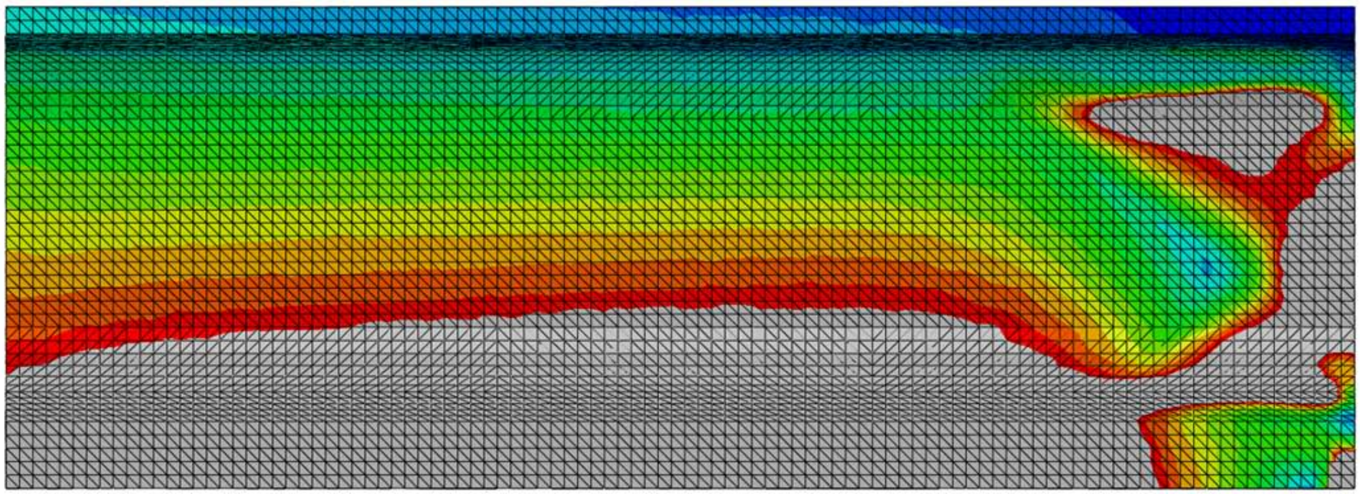
DEBONDING: 0%, 25%, 35%, 50%

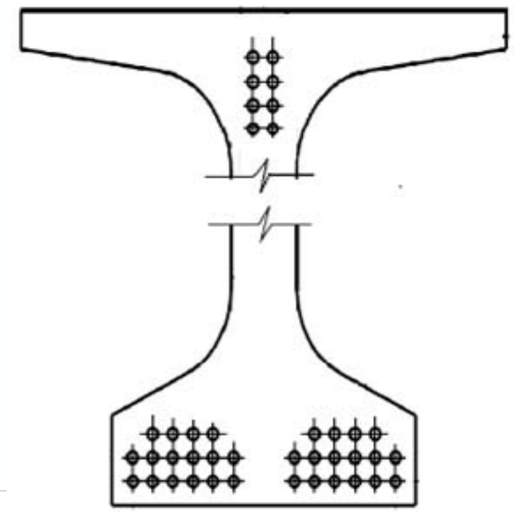


v

AASHTO Limit

NO DEBONDING – 0%



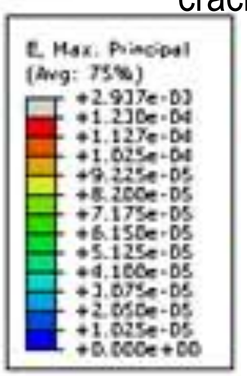


Standard

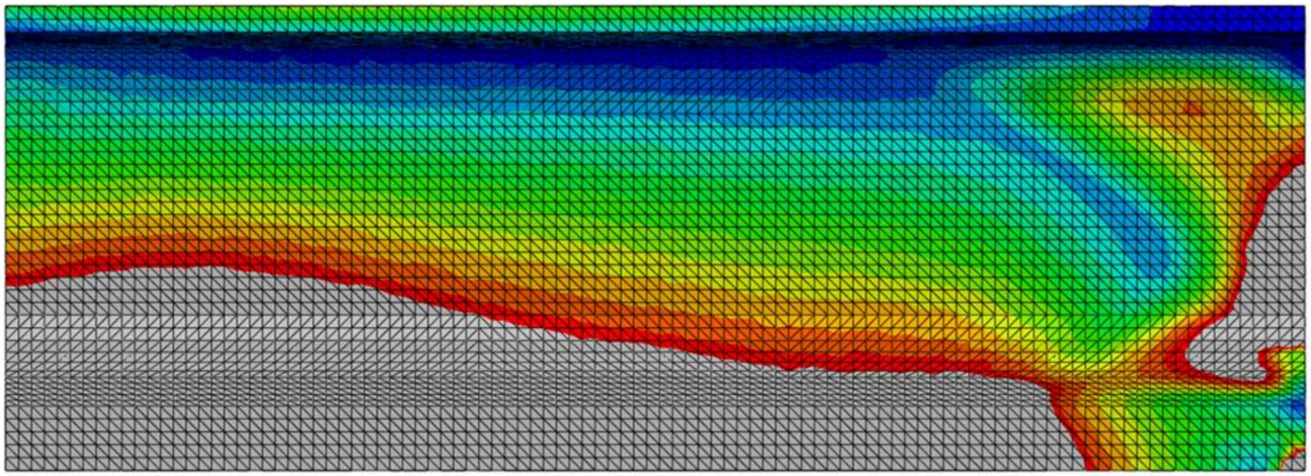
40 strands bonded

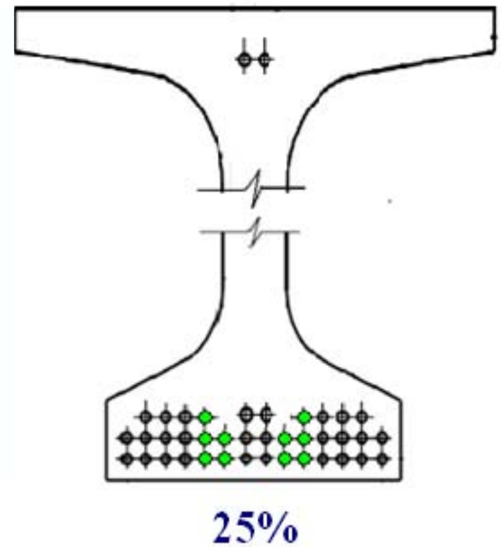
◄ 3 ft ►

ε > ε_{crack}



DEBONDING – 25%





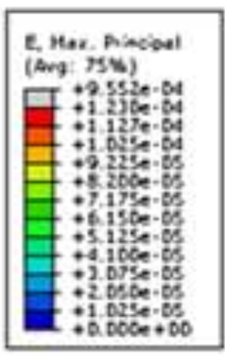
6 strands 3 ft

4 strands 3 ft

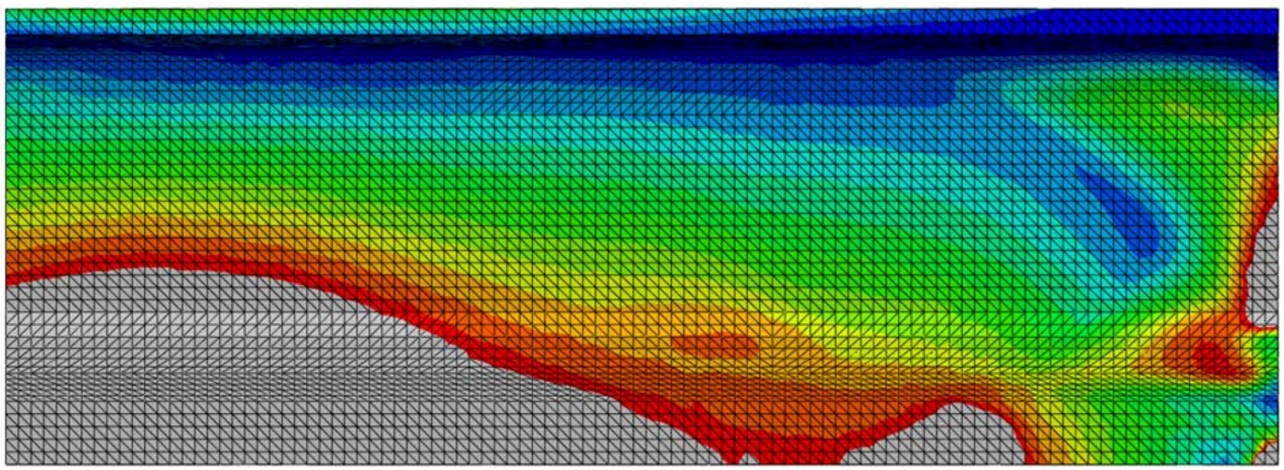
5 ft

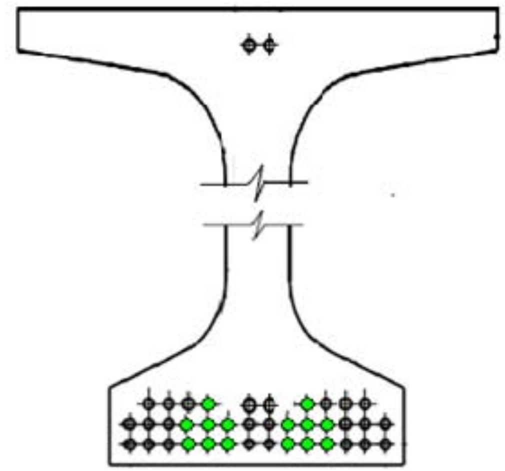
30 strands 3 ft

ε > ε_{crack}



DEBONDING – 35%





35%

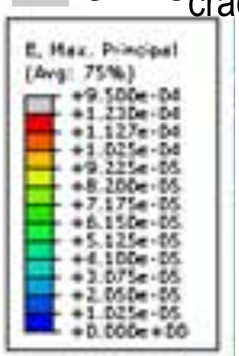
DB 11

26 strands

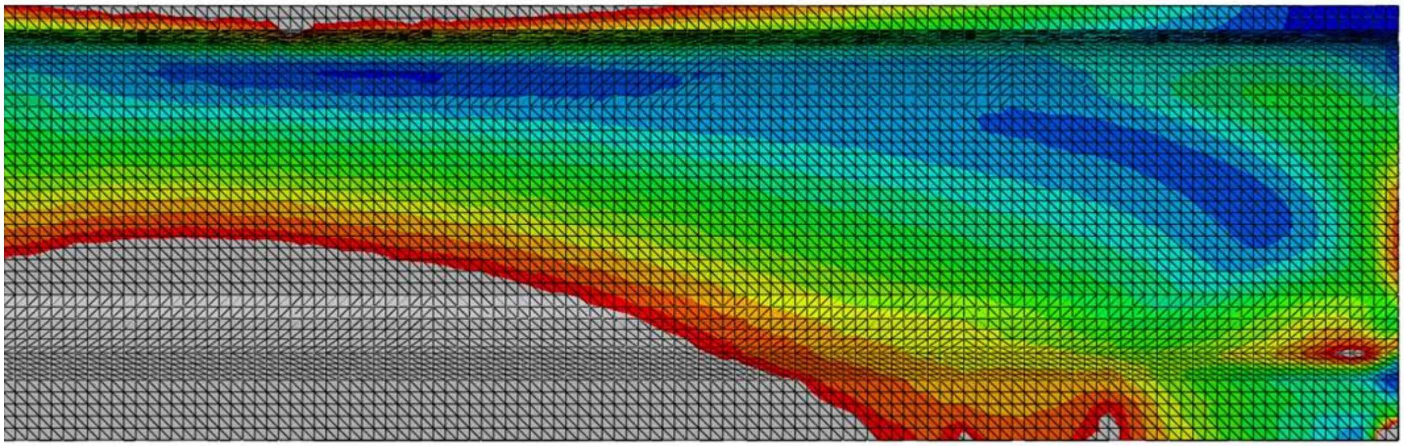
8 strands | 6 strands

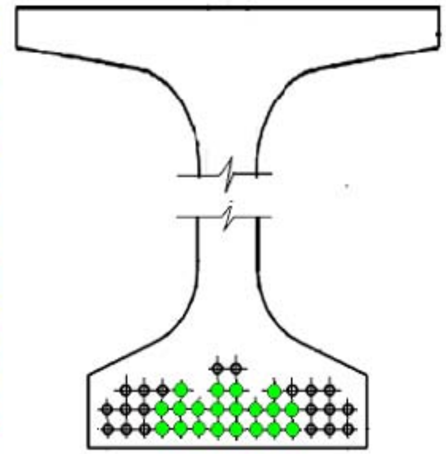
3 ft | 3 ft | 5 ft | 3 ft

$\varepsilon > \varepsilon_{crack}$



DEBONDING – 50%



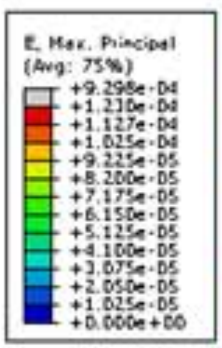


20 strands

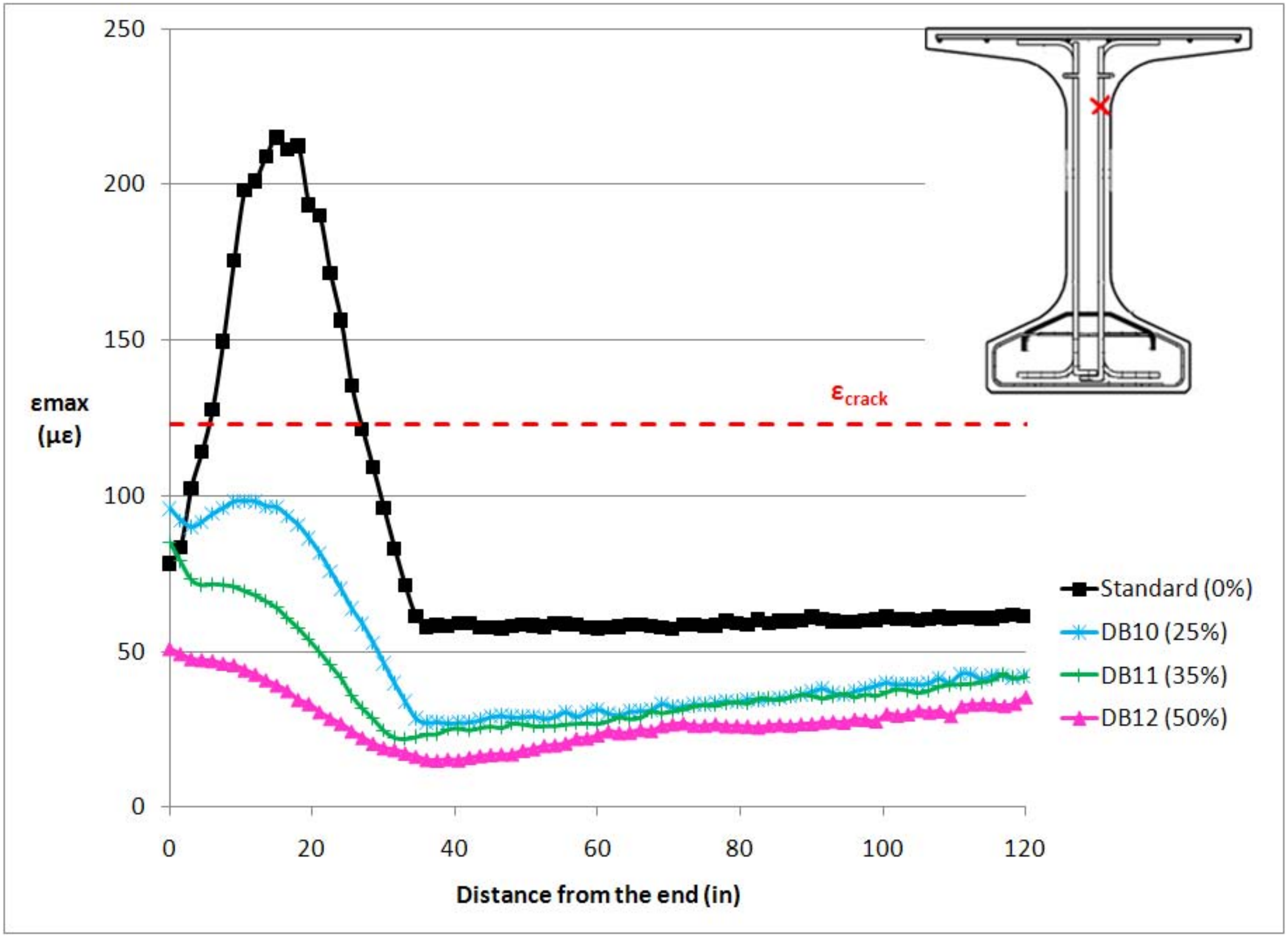
4 strands | 8 strands | 6 strands | 3 ft

3 ft | 3 ft | 3 ft | 4 ft

$\varepsilon > \varepsilon_{crack}$

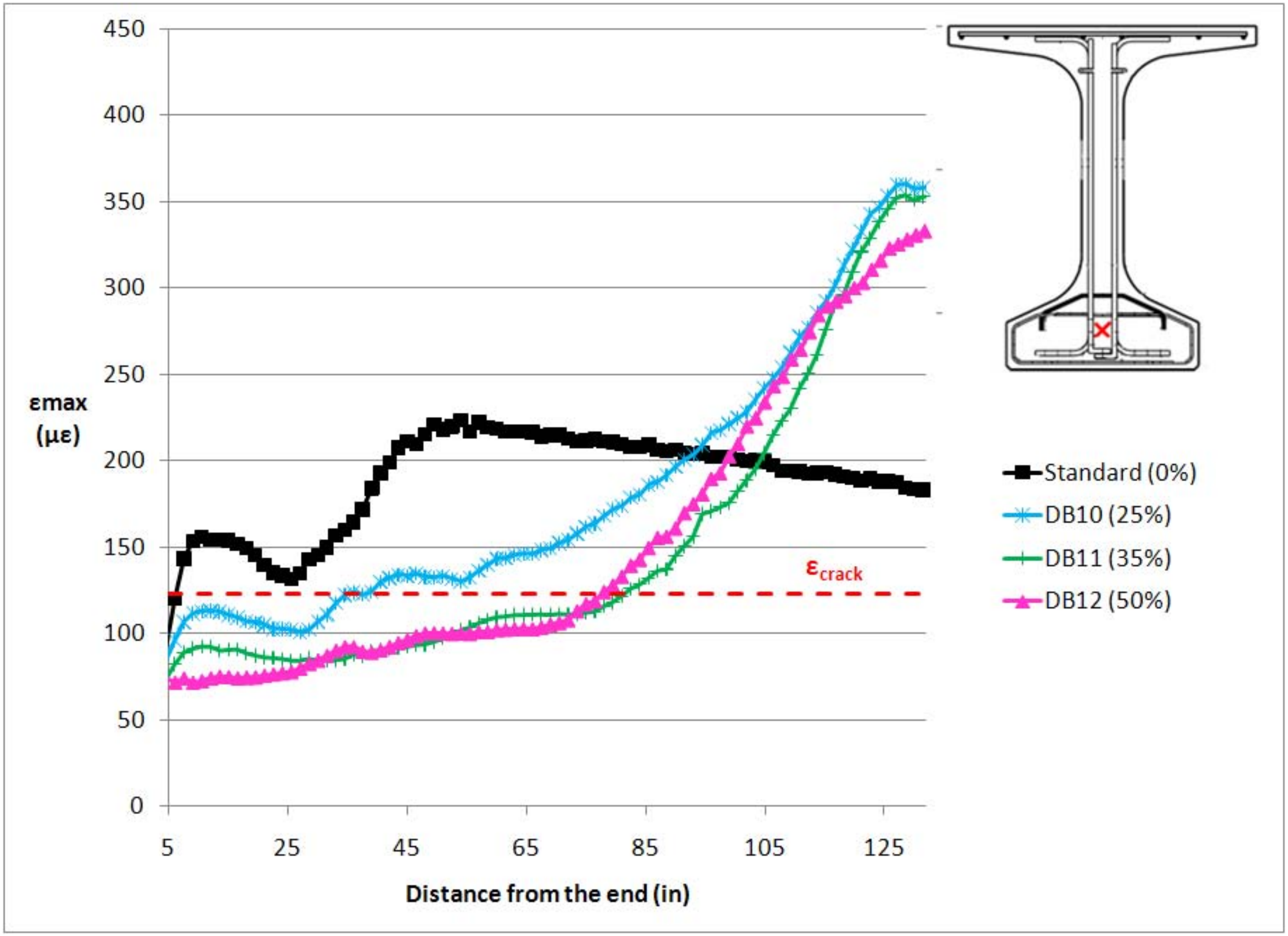


DEBONDING – Inclined Crack

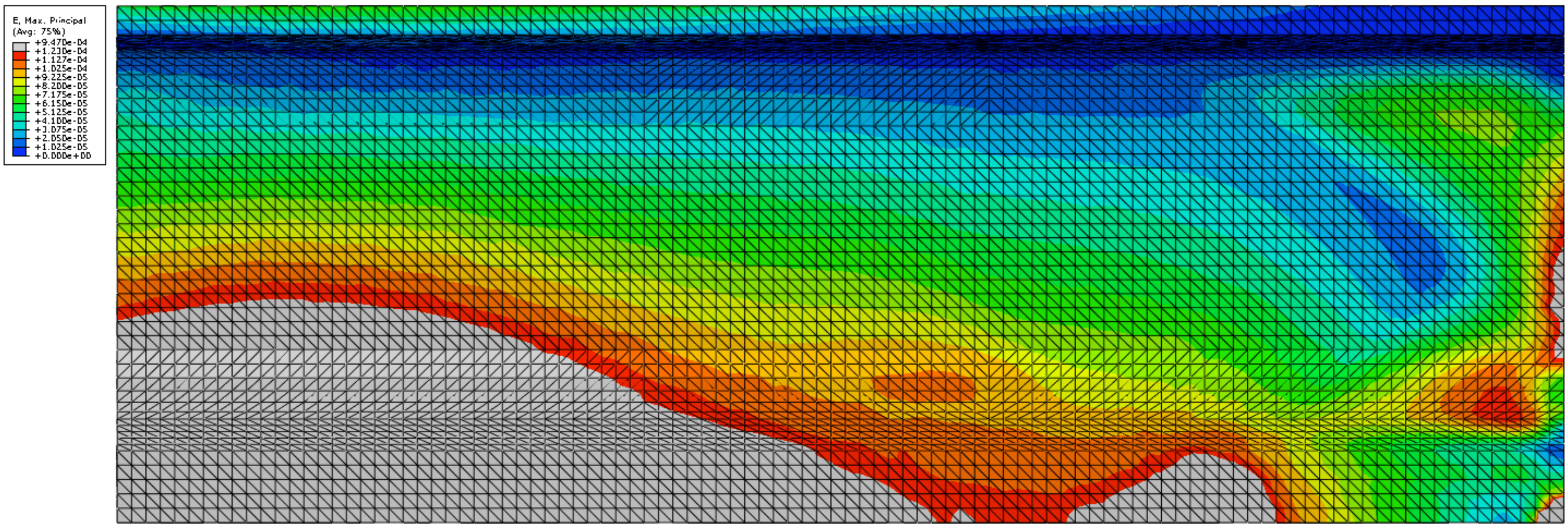


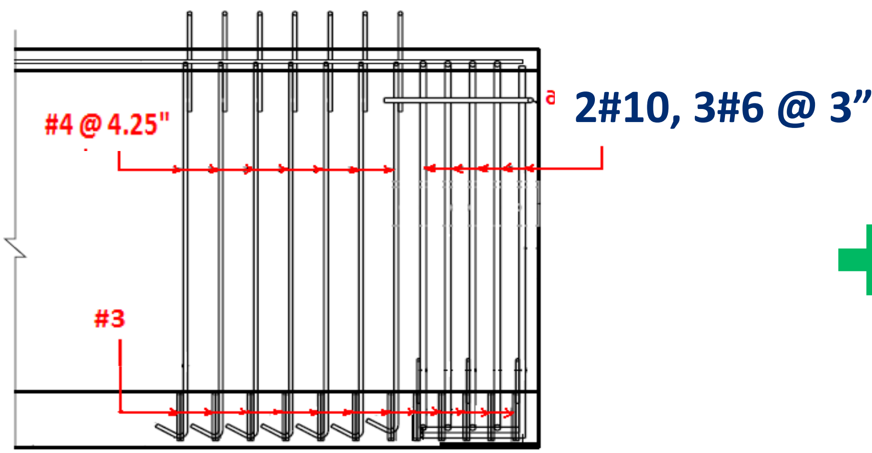
Debonding or **Removing the draped strands** **decrease strains 50-70%.**

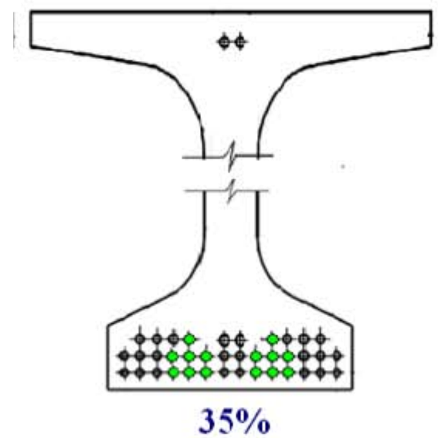
DEBONDING – Y Cracks



REBAR PATTERN & DEBONDING

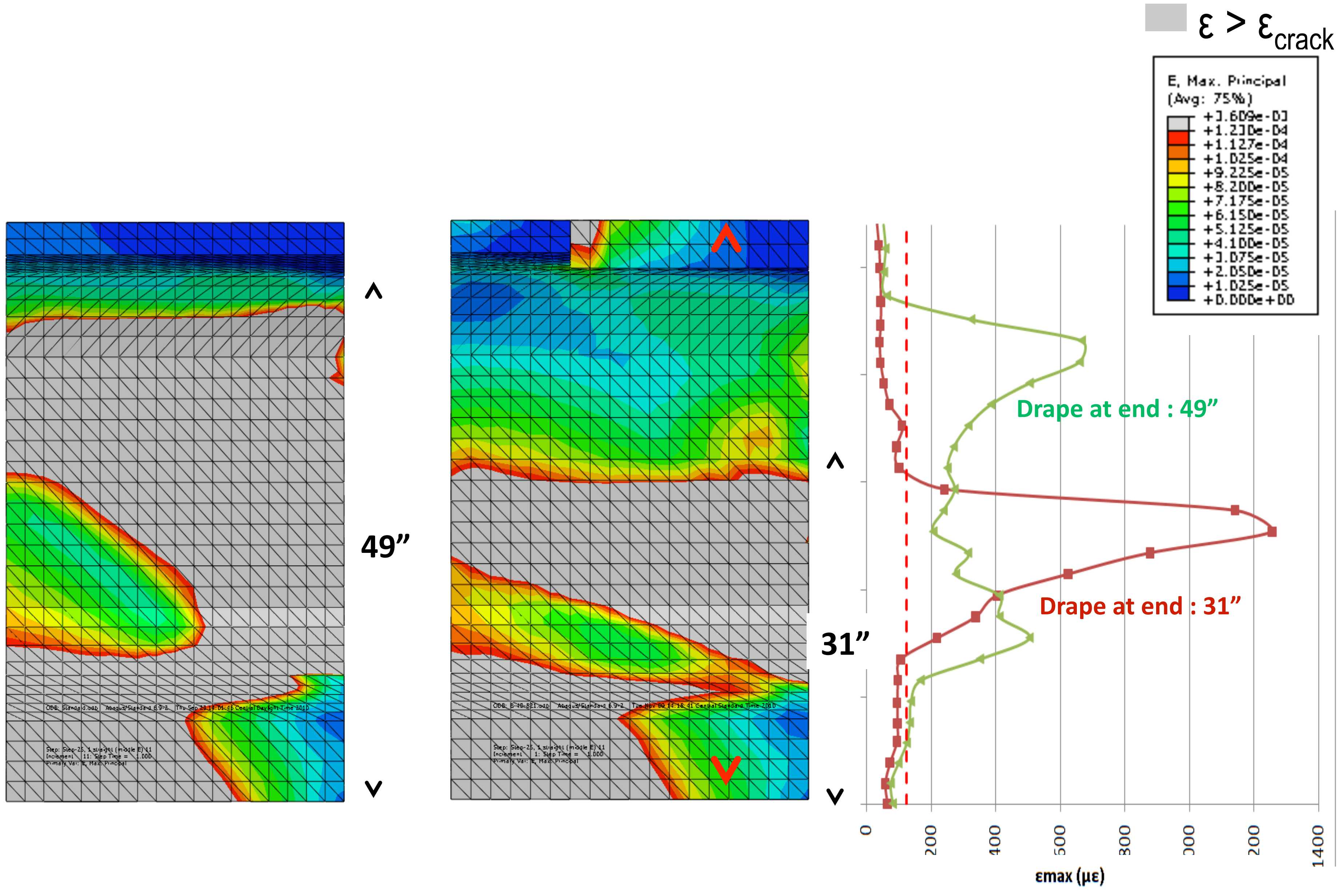




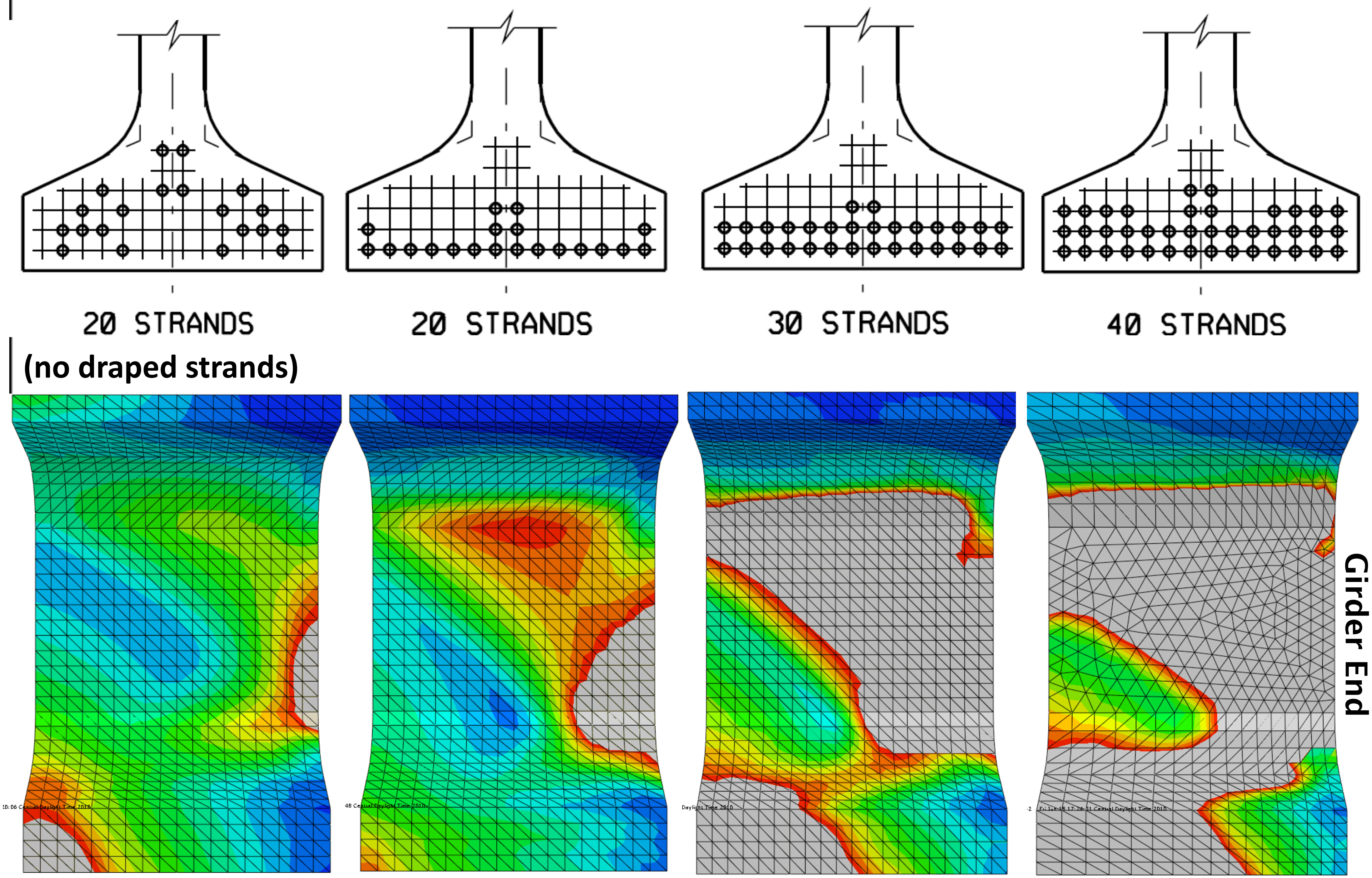


Debonding or Rebar Size can work together

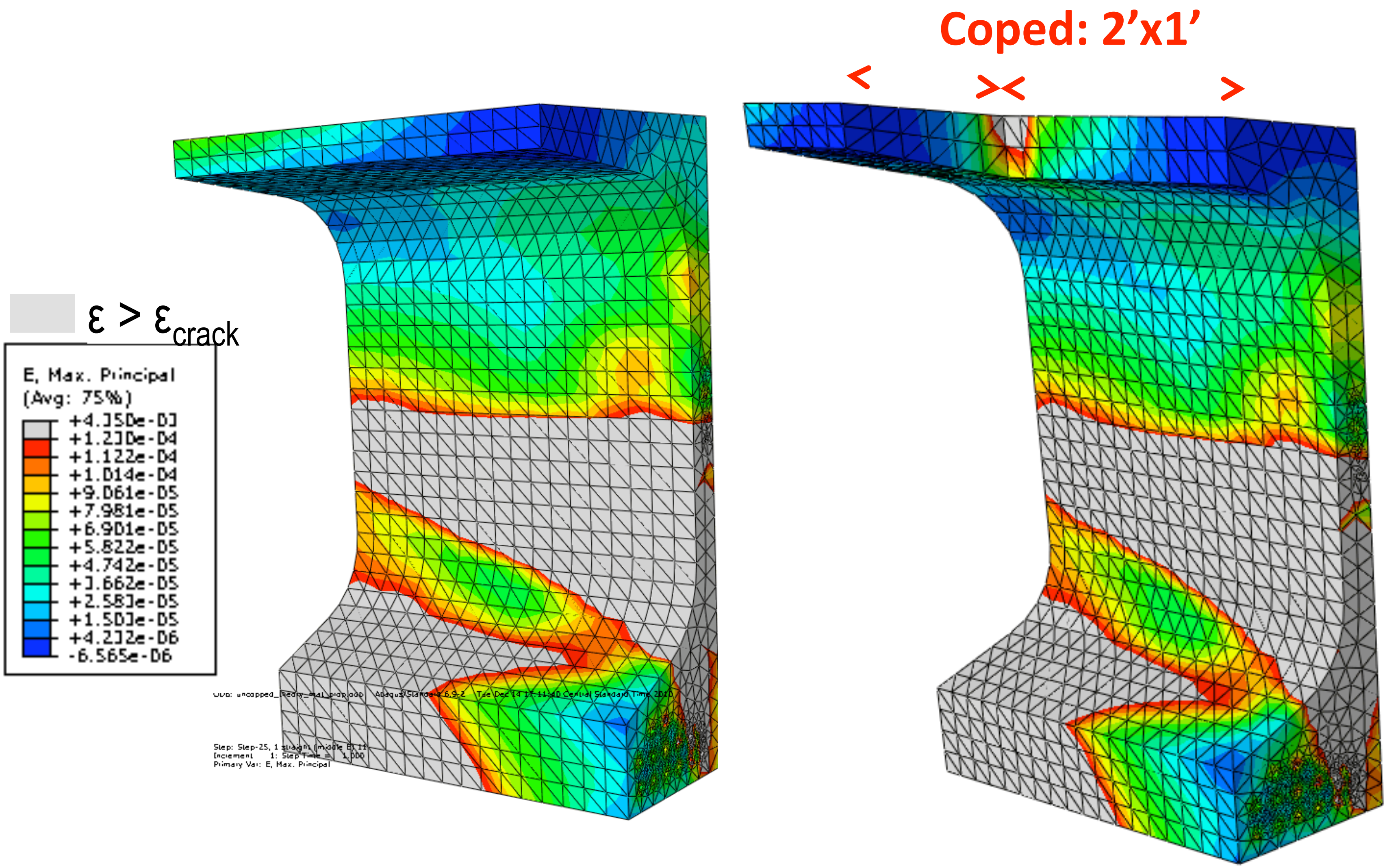
LOWERING the DRAPED STRANDS



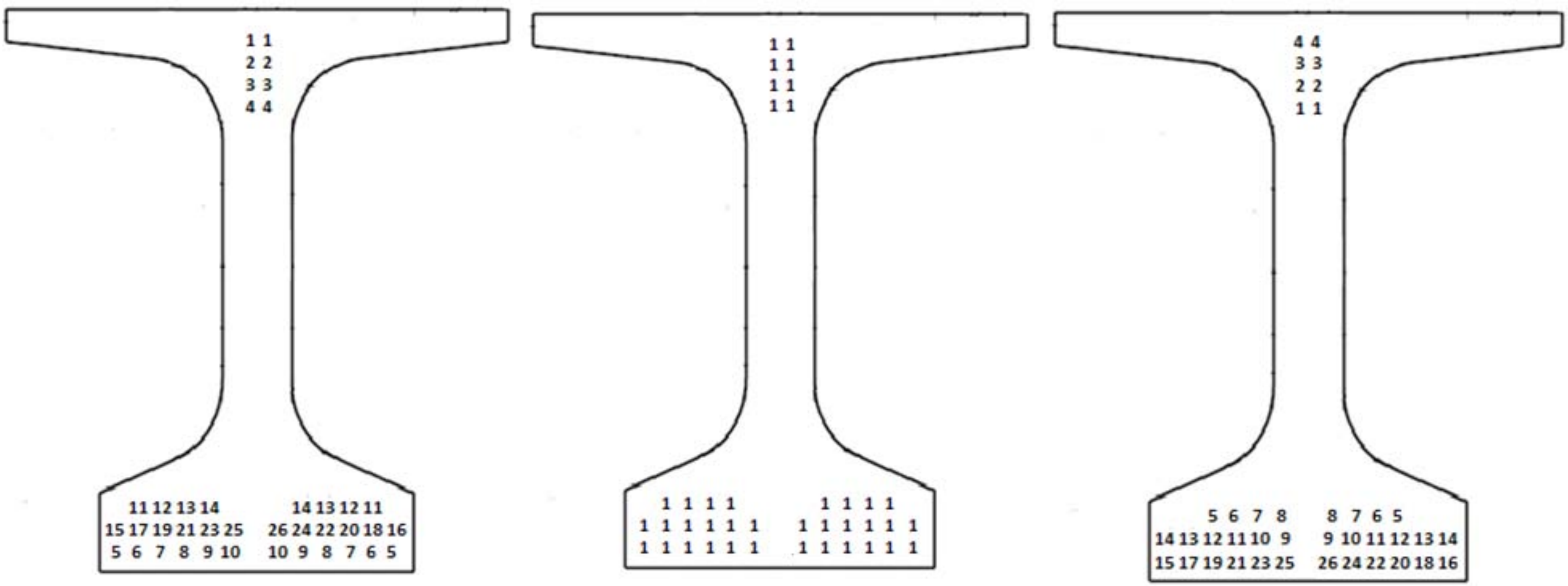
NUMBER of STRANDS



COPING the UPPER FLANGES



STRAND CUTTING ORDER



Almost identical results

CONCLUSIONS

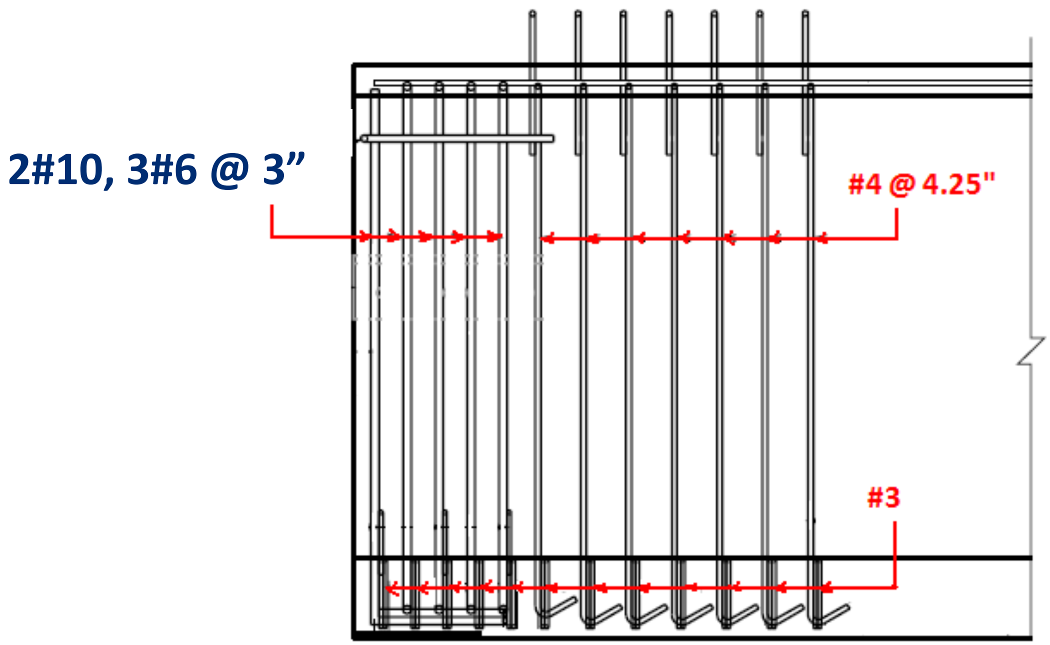
- ✓ The rebar size increase leads to 20%-40% strain decrease in the mid web at the girder ends

CONCLUSIONS

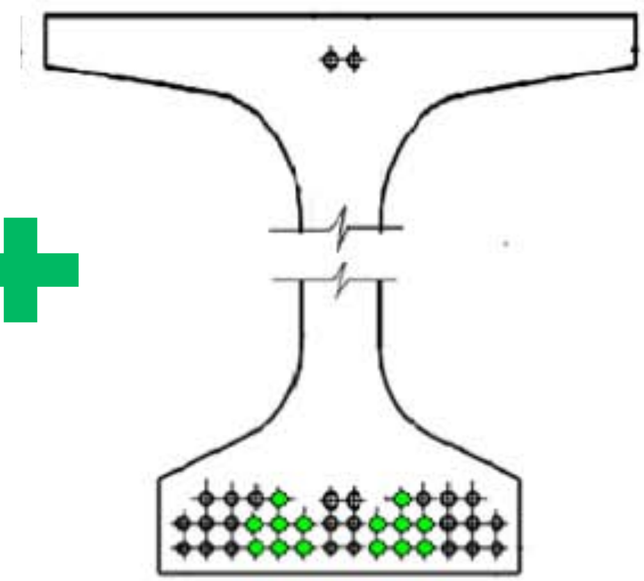
- ✓ Debonding leads to 50-70% strain decrease, and could be helpful especially for inclined and Y cracks at the girder ends
- ✓ Removal of the draped strands eliminates the inclined cracks

CONCLUSIONS

✓ A combination of mild debonding and rebar size increase is a viable option



RF 8



35%

DB 11

CONCLUSIONS

- ✓ Girder lifting causes the strains to jump and cracks to open

CONCLUSIONS

- ✓ Coping the upper flanges or changing the order of strand cutting does not affect the results
- ✓ Lowering the draped strands condenses the cracked area but does not decrease the strains at the ends

SUGGESTED FUTURE TASKS

- Build a girder with debonding, inspect cracks and test for shear
- Model girders with no draped strands
- Model the girder lift & crack opening
- Model the rebar slip for more realistic results
- Investigate bottom flange bursting strains further
- Create models to simulate the cracks explicitly

THANK YOU

QUESTIONS

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