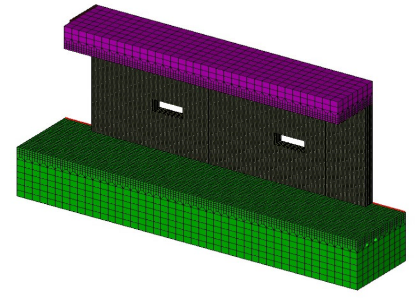
SAND2018-11663 C

Using FEA to Predict Failure Mechanisms in RC Shear Walls



PRESENTED BY

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Overall Project Contributors

Sandia National Laboratories

- Joshua Hogancamp
- Scott Sanborn

University of Notre Dame

- Robert Devine
- Steve Barbachyn
- Ashley Thrall
- Yahya Kurama

AECOM

- Matthew Van Liew

Introduction

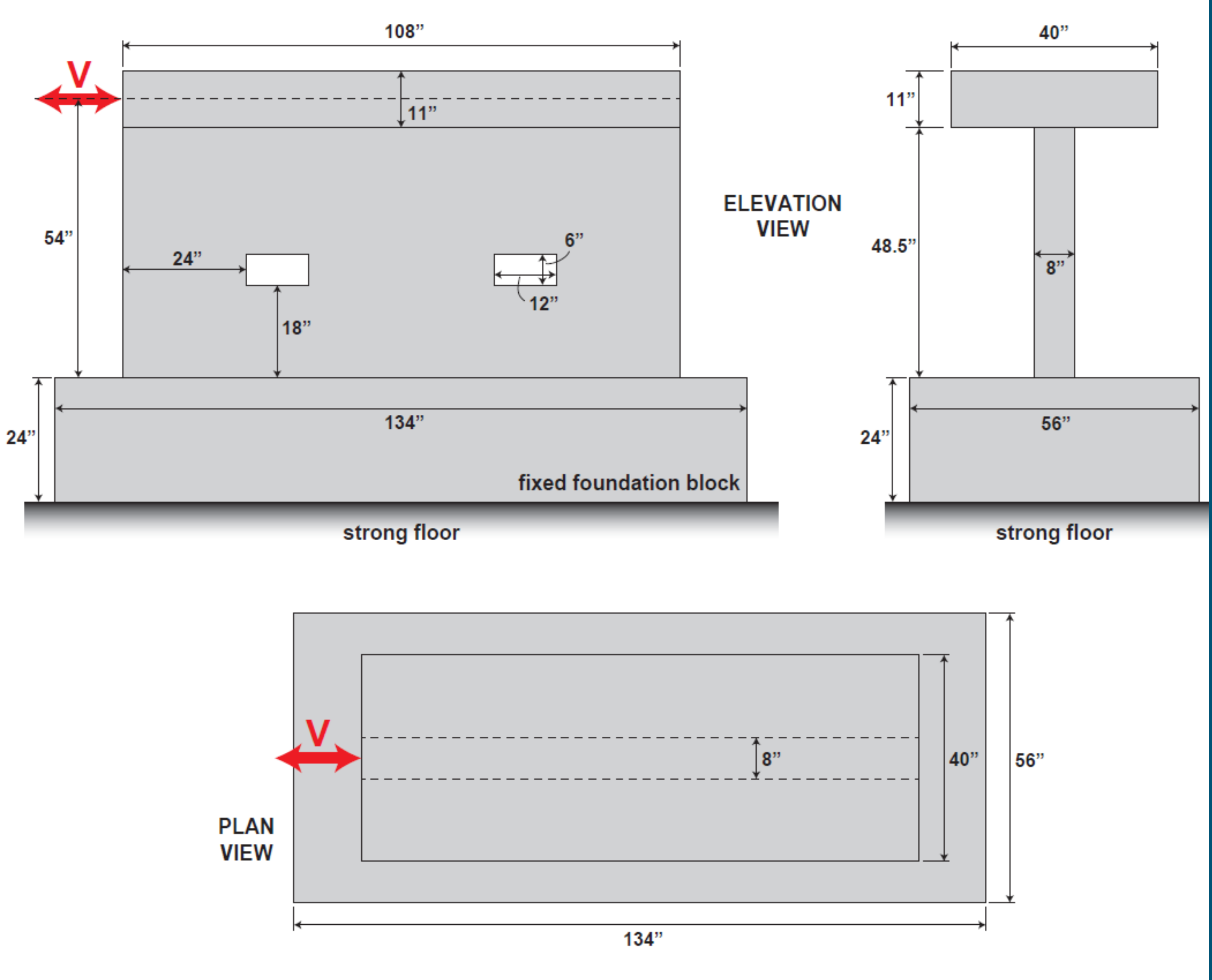
Project goal: to reduce the field construction times and fabrication costs of RC nuclear structures

- High-strength steel rebar
- Prefabricated rebar assemblies with headed anchorages
- High-strength concrete

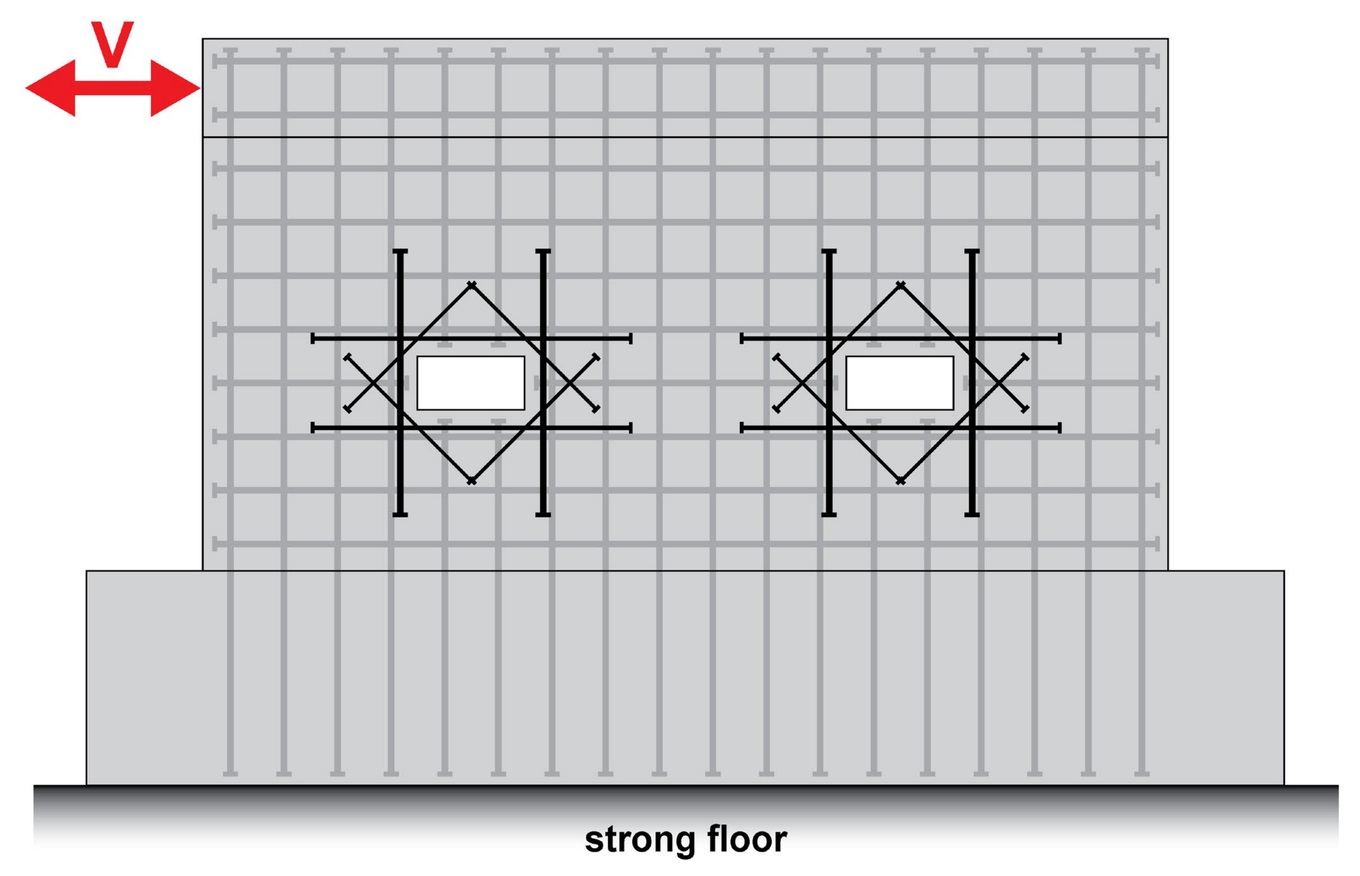
FEA goal: to create a validated numerical model that can extrapolate experimental results to geometries not tested in the lab

- Predict total strength
- Predict lateral displacement capacity
- Predict initial lateral stiffness
- Predict crack patterns and damage propagation
- Determine ultimate failure mechanism

Wall Geometry

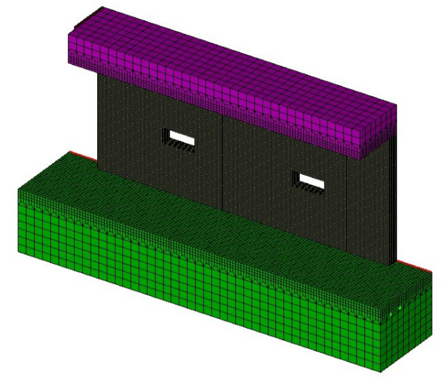


Rebar Layout



Single layer of overlapping bars on each face at 6” o.c.
No. 6 bars for normal-strength steel, No. 4 bars for high-strength steel.
Additional trim reinforcement around penetrations.

FEA Geometry and Mesh

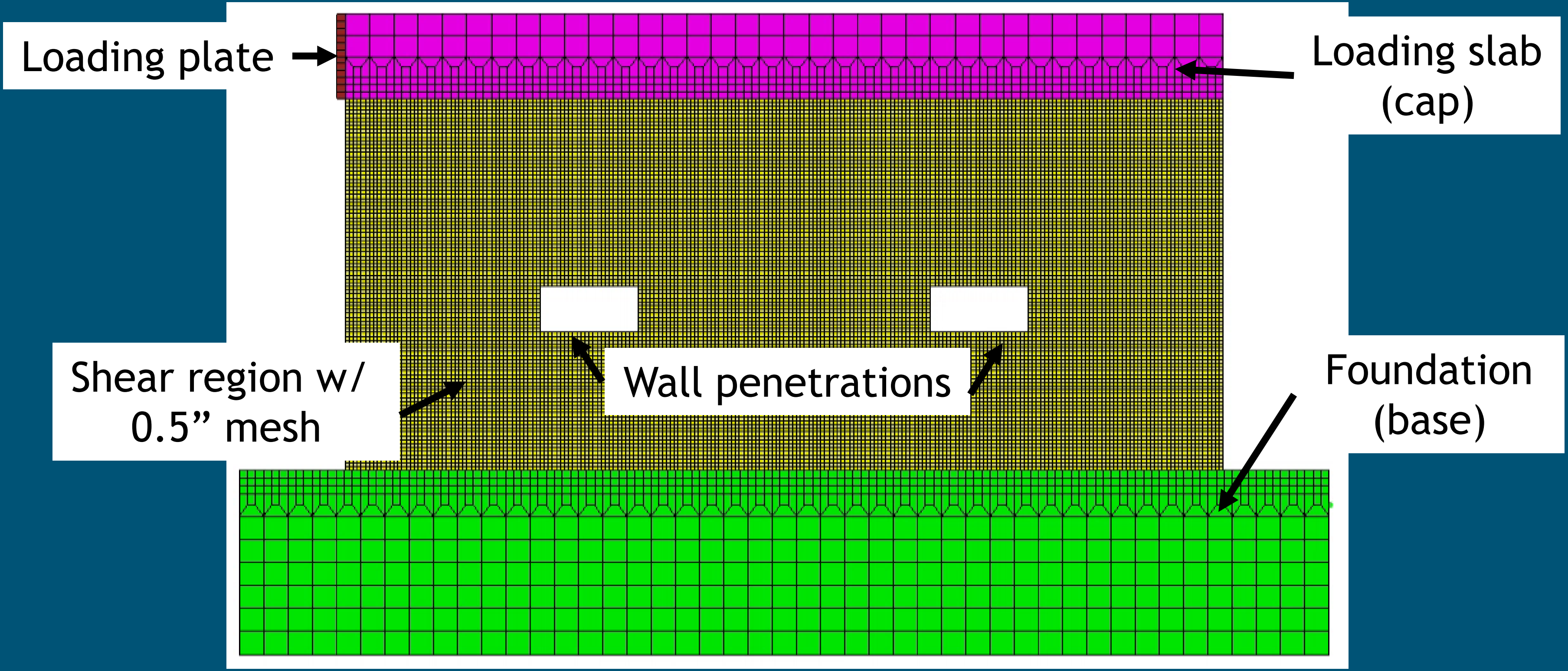


Half-symmetry simulation

0.5” mesh element size on the shear wall

Wall cap and base were modeled as elastic while the shear wall could accrue damage

Concrete was modeled with a total of 192,222 8 -noded hexahedral elements



Loading plate

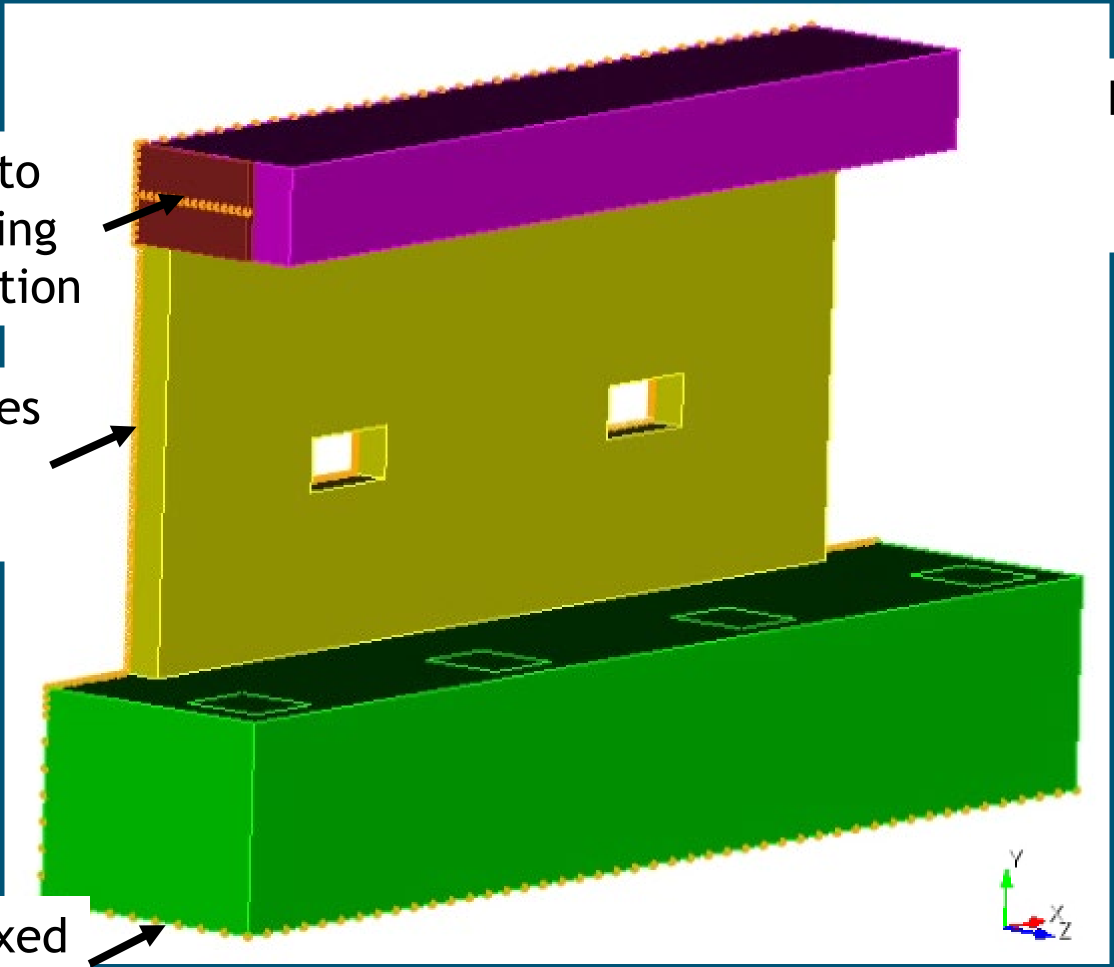
Loading slab (cap)

Shear region w/ 0.5” mesh

Wall penetrations

Foundation (base)

Boundary Conditions and Load Application



Load applied to center of loading Plate in X-direction

Loading plate fixed to concrete but free to rotate

Symmetry nodes fixed in Z-direction

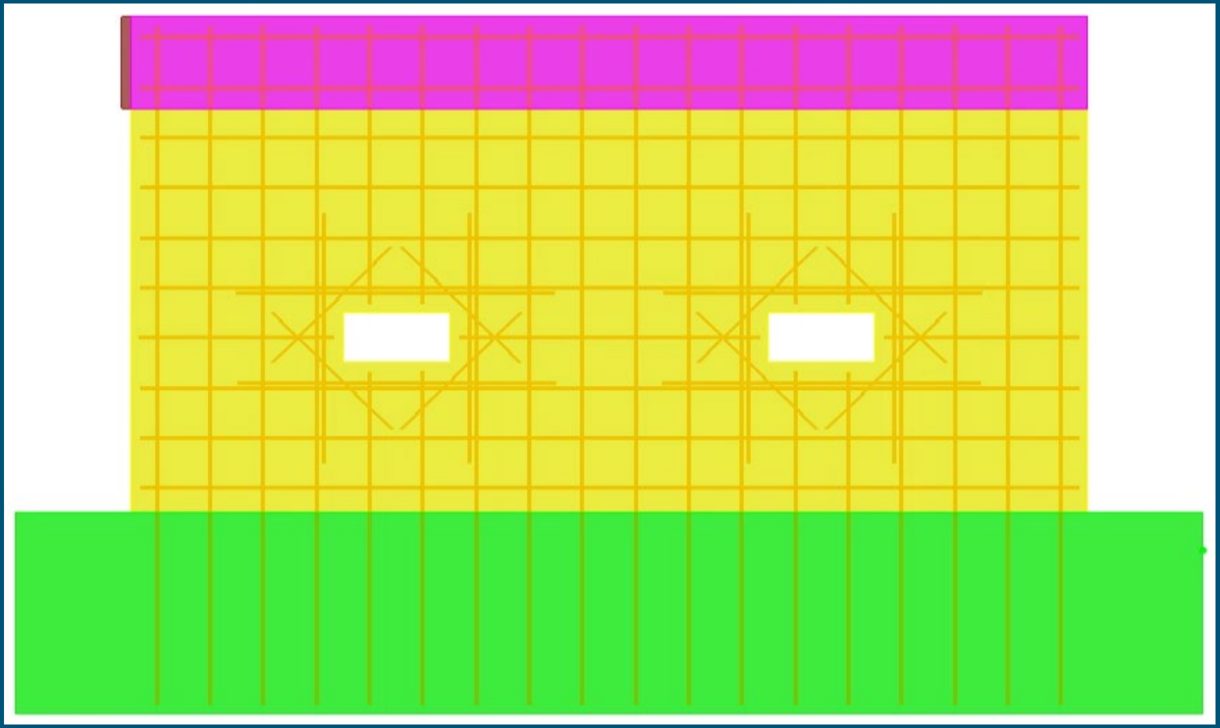
Base nodes fixed in all DOF

FEA Rebar Geometry

0.5” mesh elements on all rebar

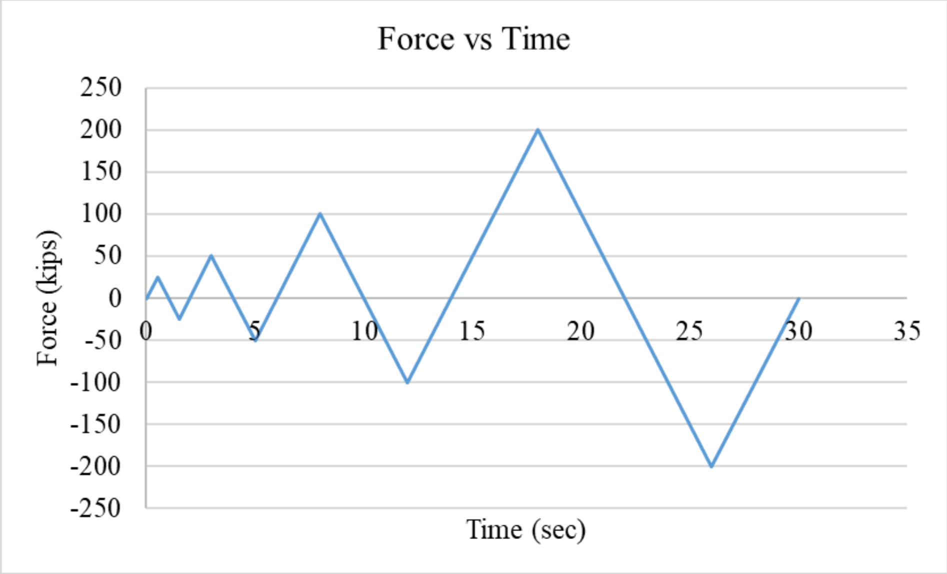
Rebar was modeled with a total of 5,774 2-noded beam elements

Beam elements were fully embedded in the concrete with no slip and extruded to the proper diameter (No. 6, No. 4, etc.)

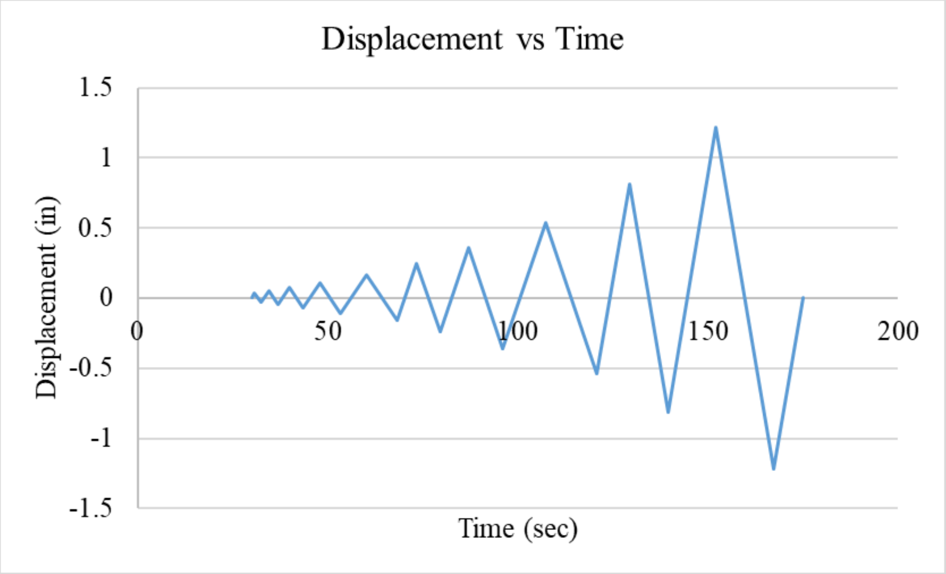


Loading Protocol

Elastic regime

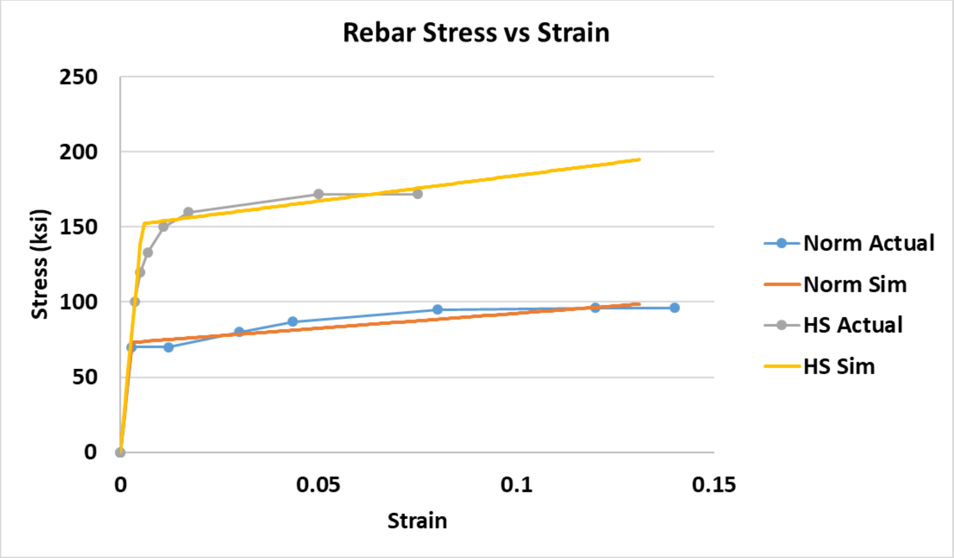


Damaging regime



Material Model Assumptions

Rebar: modeled as bi-linear elastic plastic

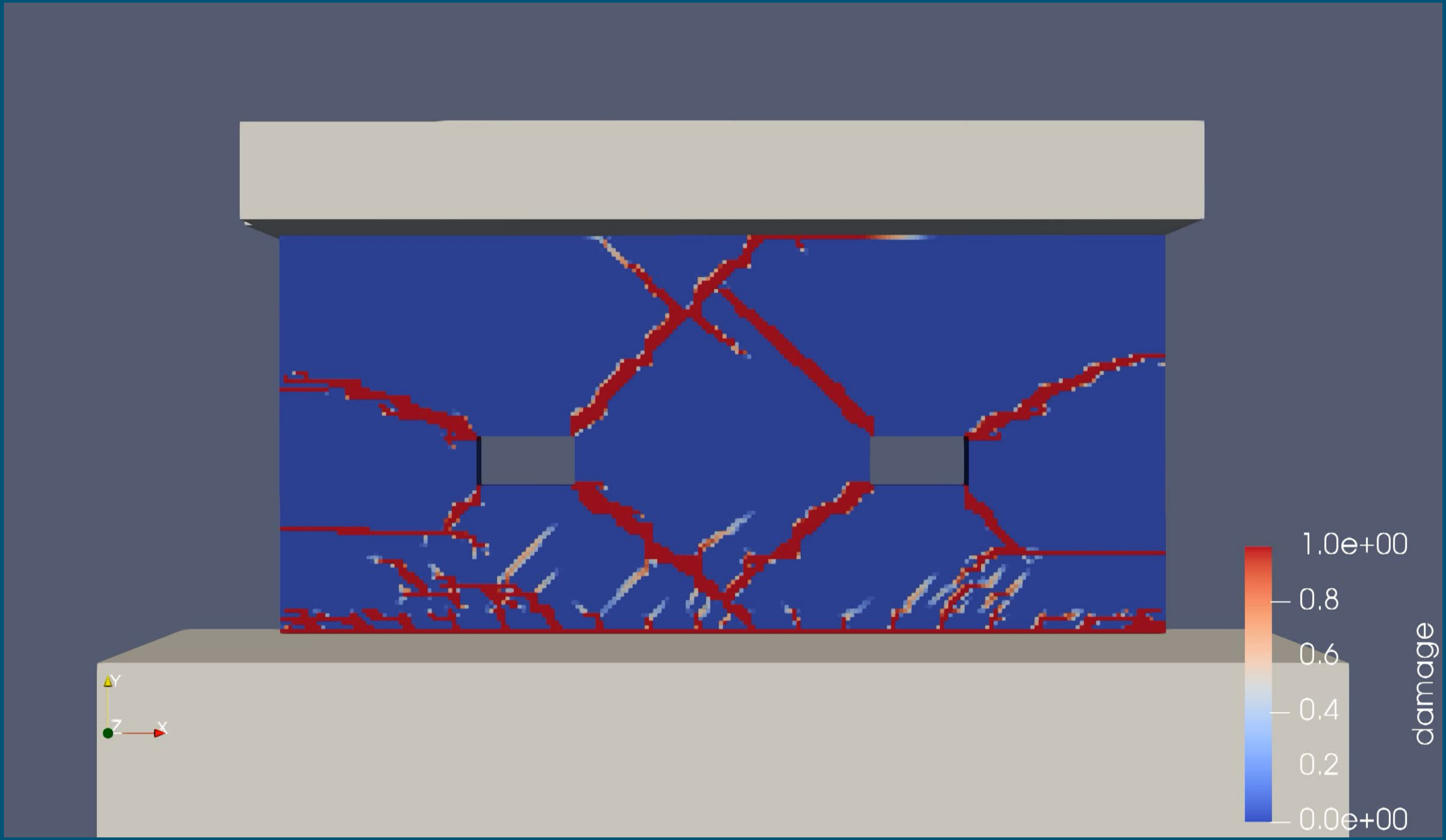


Concrete: modeled as either pure elastic or Holmquist Johnson Cook concrete

- Normal strength f'c = 7 ksi, high strength = 15 ksi
- Shear wall base and cap (foundation and loading block) were modeled as pure elastic
- Shear wall center portion modeled with Holmquist Johnson Cook concrete model
  - Accrues damage and is designed to remain stable in all FEA simulations
  - Strength can increase with confining pressures
  - All variables in the model are based on experiment as dictated in the original paper

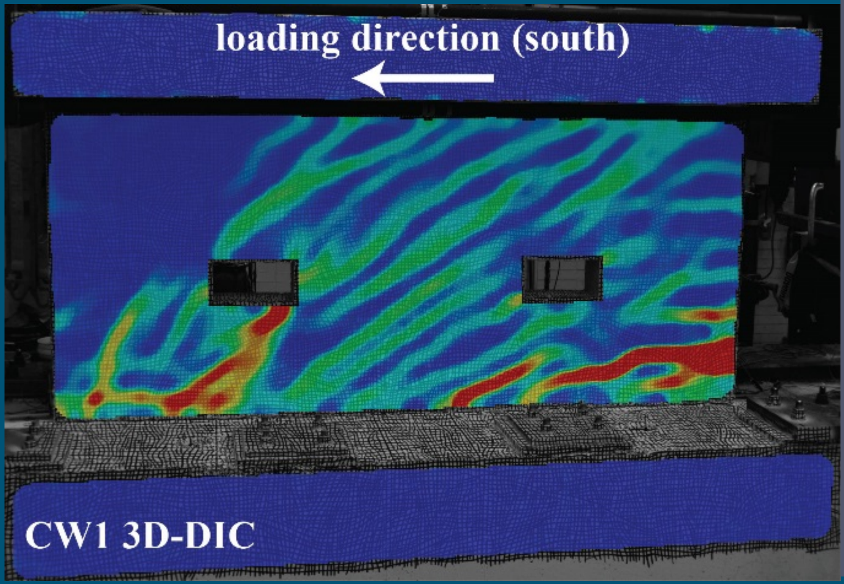
Results

Normal-Strength Concrete and Rebar

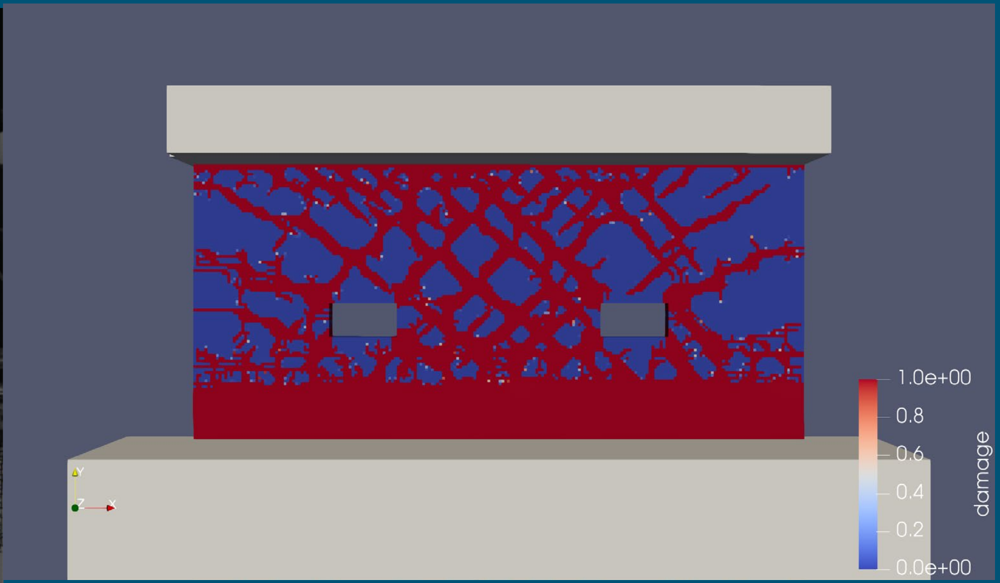


Normal-Strength Wall Cracking and DIC Comparison

3D DIC

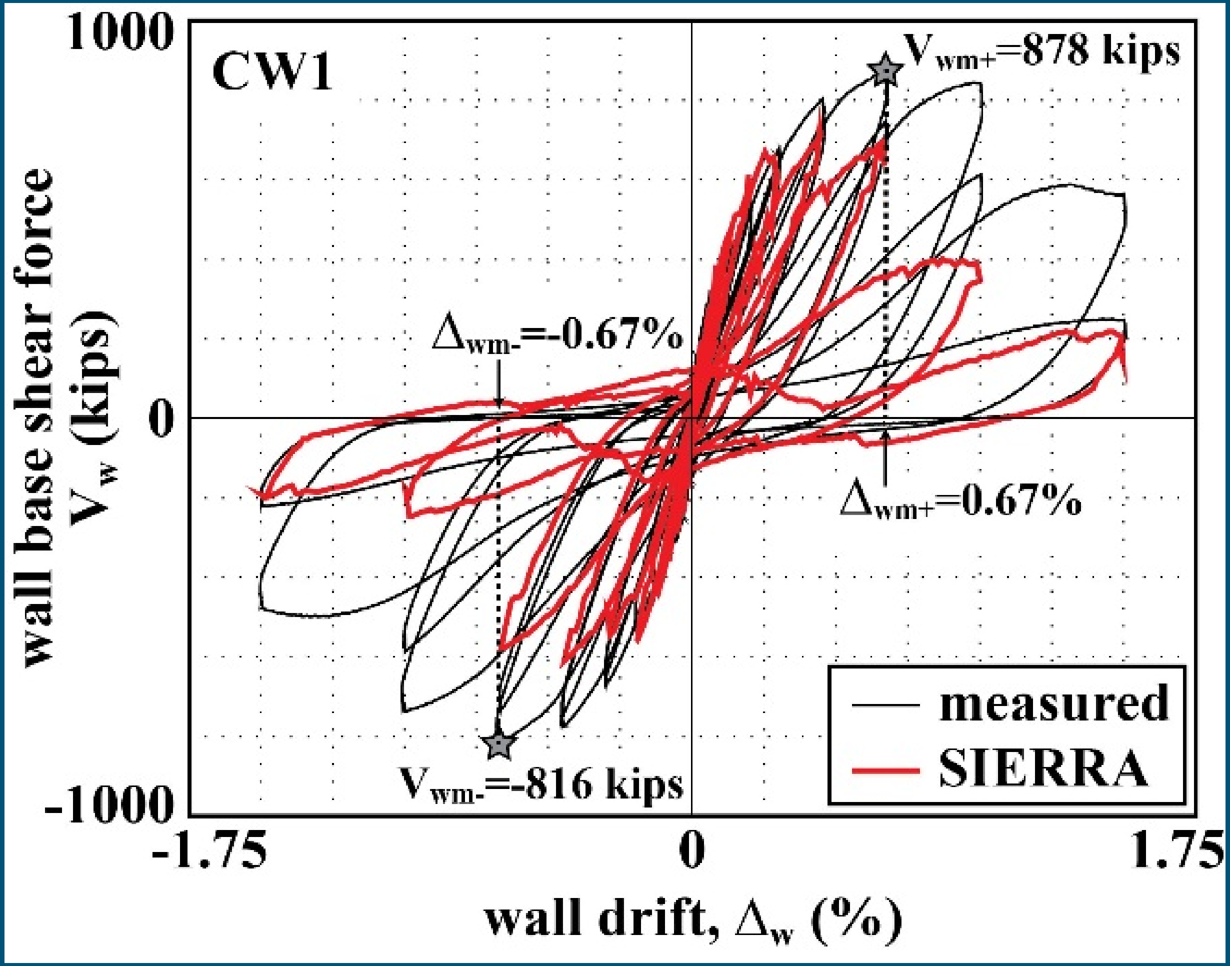


FEA Damage

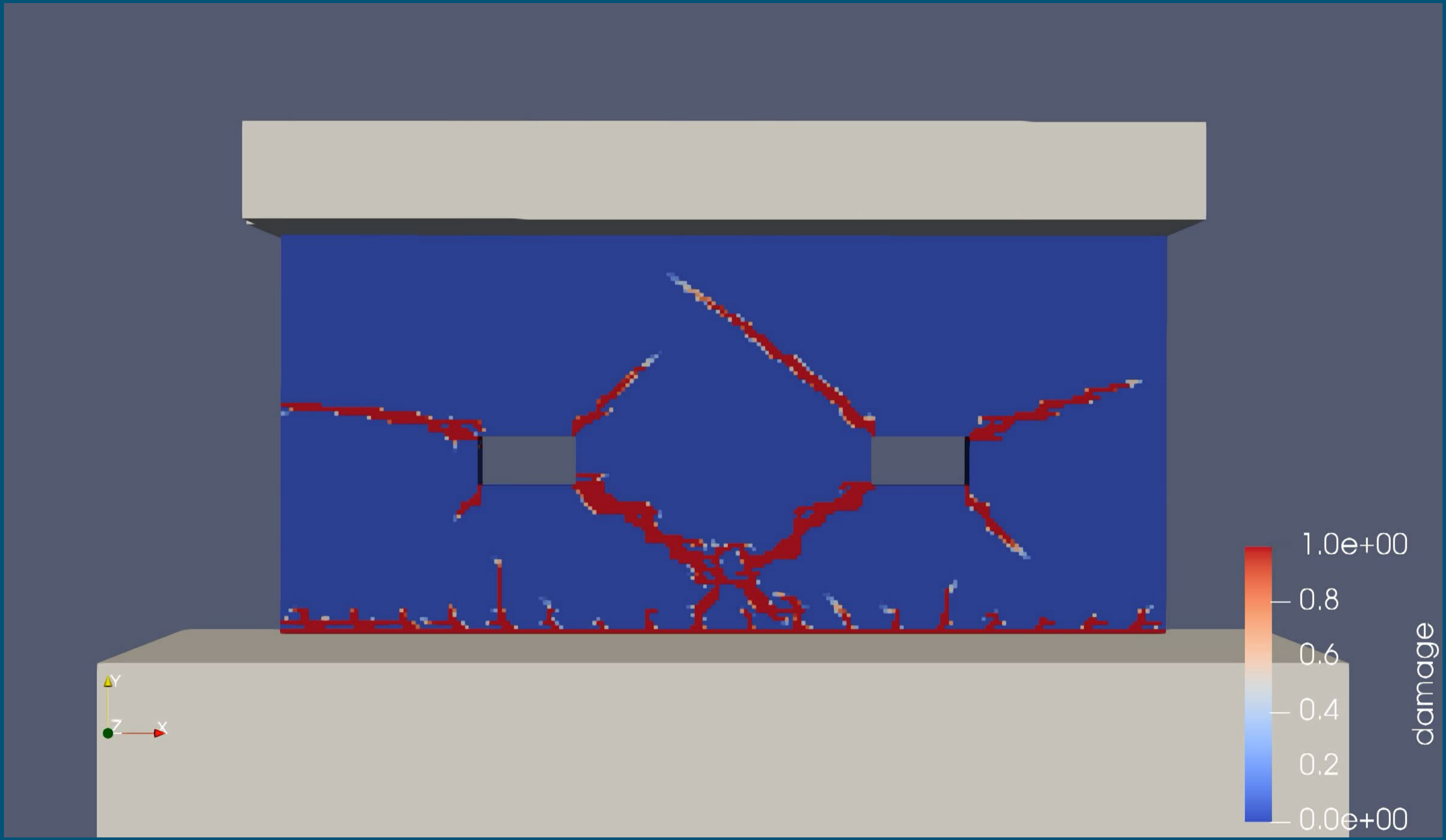


3D DIC is a non-contact near-full-field optical measurement technique that calculates surface deformations within a specified field-of-view on the test specimen .

Normal-Strength Concrete and Rebar Force Results

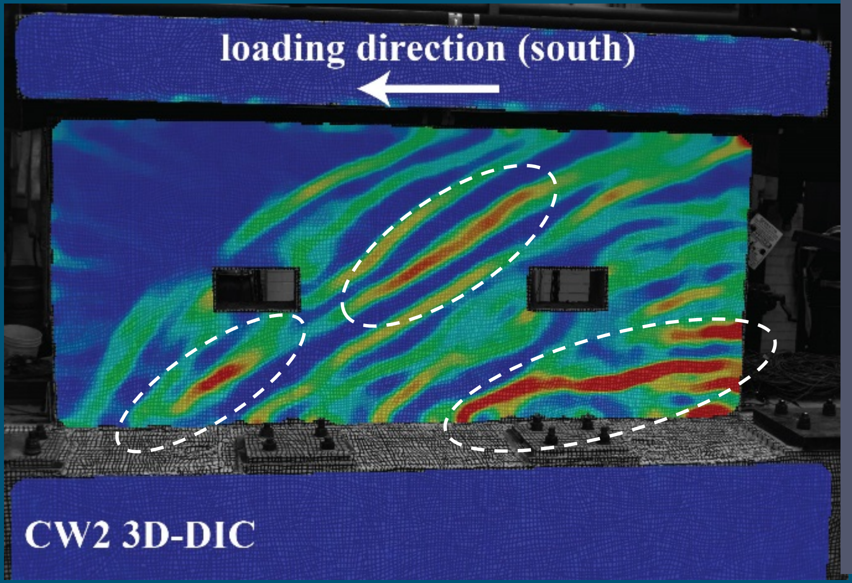


High-Strength Concrete and Rebar

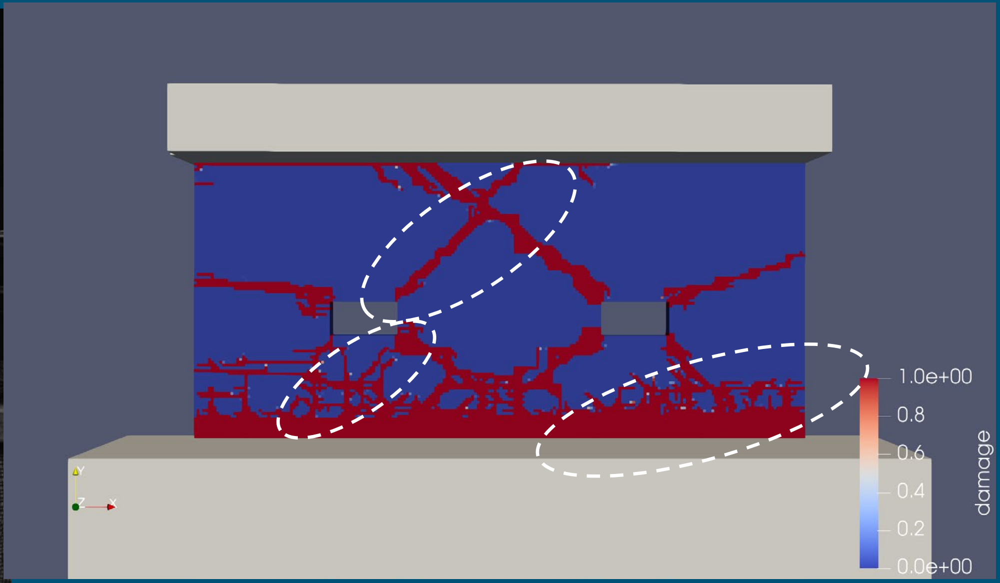


High-Strength Wall Cracking and DIC Comparison

3D DIC



FEA Damage



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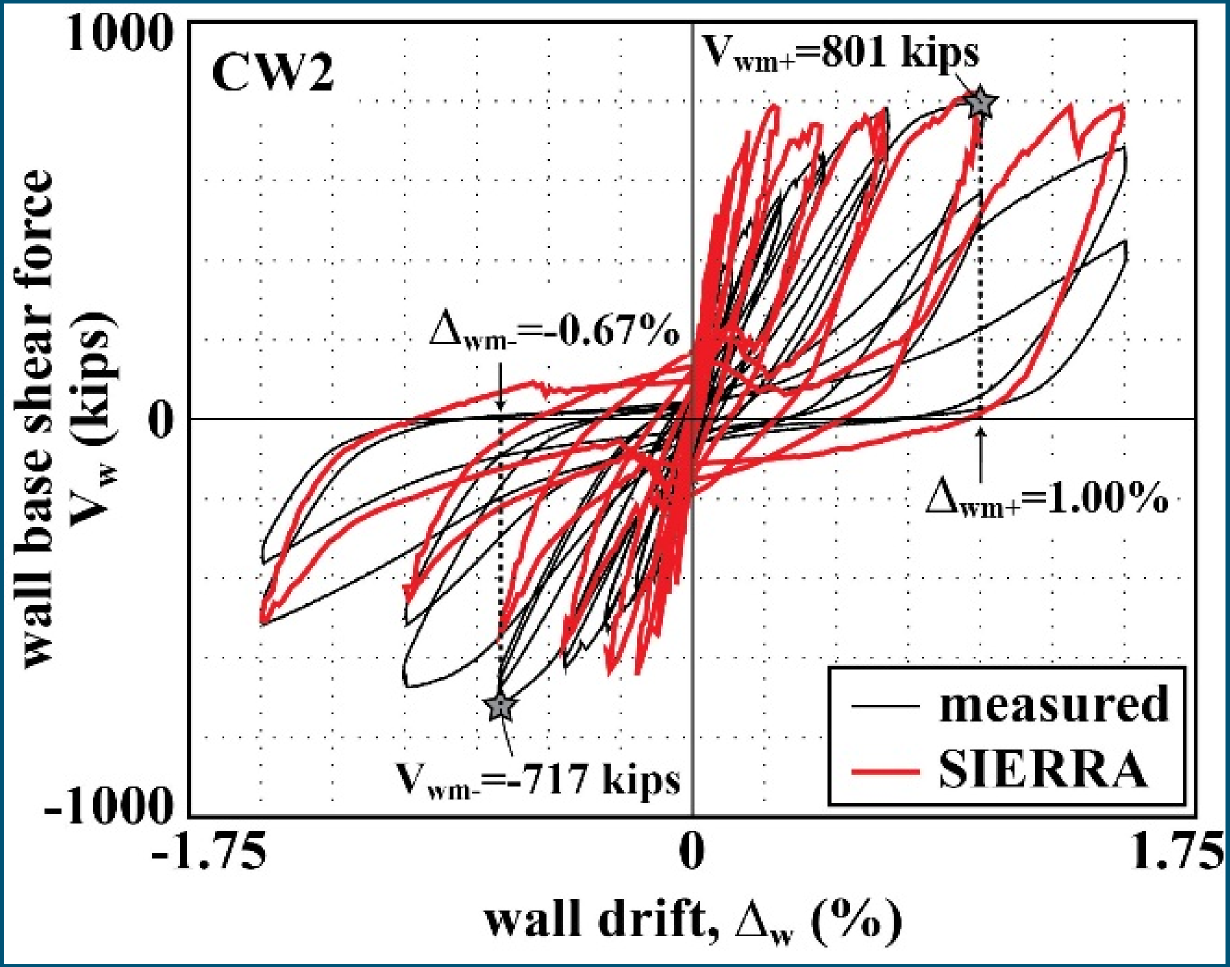
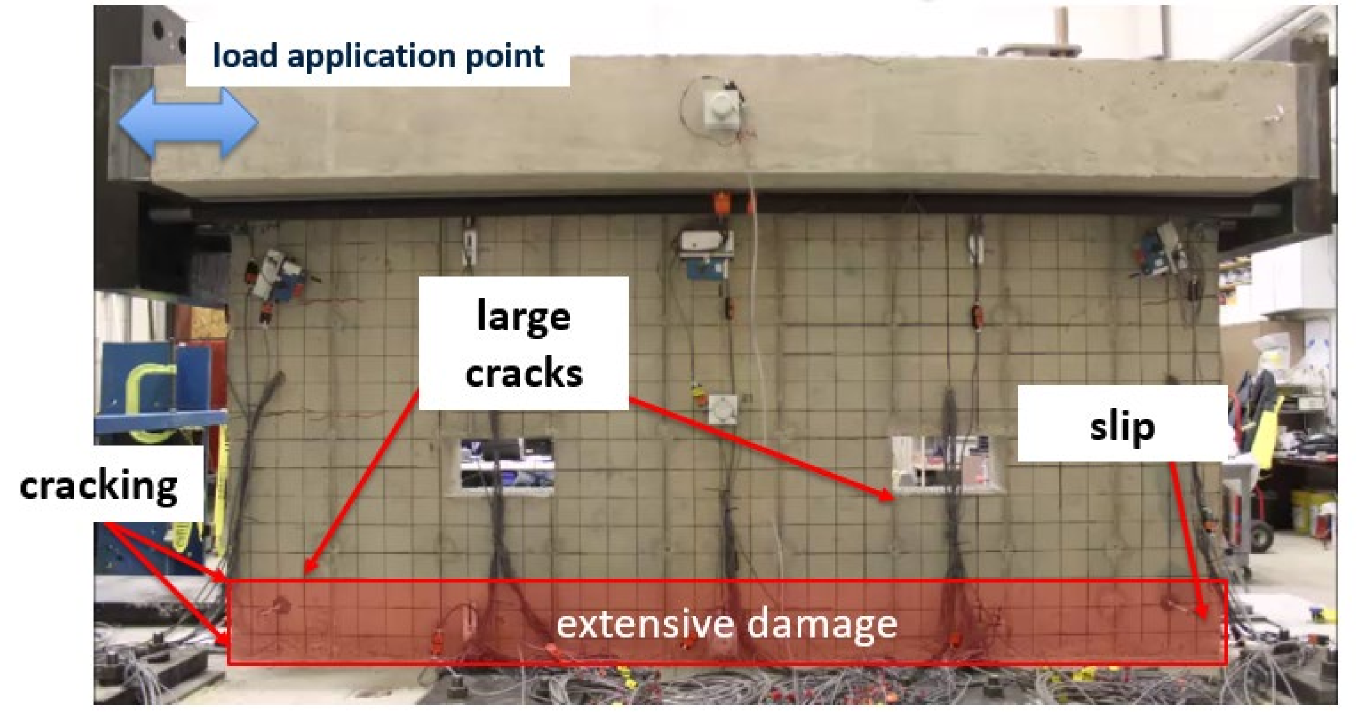
High-Strength Concrete and Rebar Force Results



Final Failure Mechanism (both walls)



Wall final failure mechanism was shear slipping along the base along with extensive concrete cracking and spalling.

Conclusions

The FEA simulation was able to capture the behavior of the shear wall including damage propagation and final failure mechanism.

Both FEA simulations (NS and HS) show wall cracking patterns similar to observed in experiment.

Normal-strength material wall conclusions:

- Accurately predicted lateral stiffness
- Predicted a lower peak strength than was seen in experiment

High-strength material wall conclusions:

- Accurately predicted peak strength
- Accurately predicted initial undamaged lateral stiffness
- Predicted a higher lateral stiffness between undamaged and fully damaged than was seen in experiment

References

Holmquist, T.J.; Johnson, G. R.; and Cook, W.H., "A Computational Constitutive Model for Concrete Subjected to Large Strains, High Strain Rates, and High Pressures," *International Symposium on Ballistics*, 1993, pp. 591-600.

Barbachyn, S. M.; Devine, R. D.; Thrall, A. P.; Kurama, Y. C., "Effect of High Strength Materials on Lateral Strength of Shear-Critical RC Walls," *ACI Struct. J.*, 114(4), 2017, 923-936

Devine, R.; Barbachyn, S.; Thrall, A.; Kurama, Y.; Sanborn, S.; Van Liew, M.; Hogancamp, J. "An Experimental Evaluation of the Combined and Isolated Effects of High-Strength Concrete and Steel in Shear Critical RC Structures." ACI 2018 Spring Convention, ACI 349 Committee Meeting, Salt Lake City, UT.