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Investigation of Steel-Plate Composite (SC) Wall-to-Concrete Basemat Anchorage Connections

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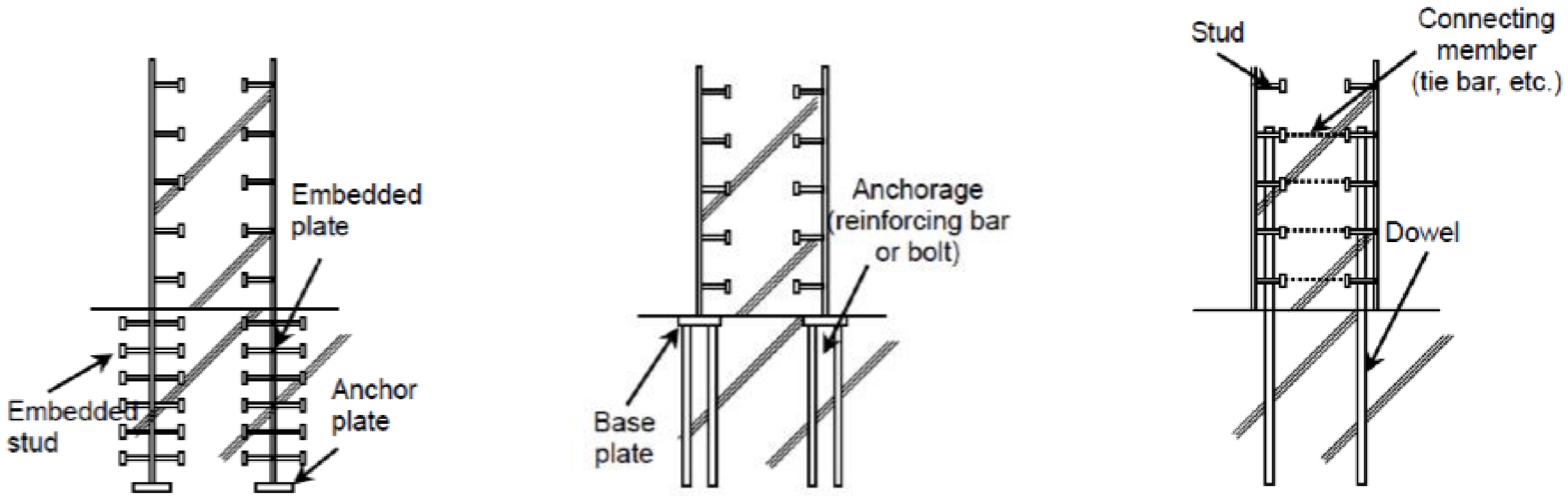
Structural Mechanics in Reactor Technology

Possible Anchorage Methods of SC Wall to Basemat



a) Embedding the plates b) Using anchors c) Using dowel bars

Connection Design Philosophy

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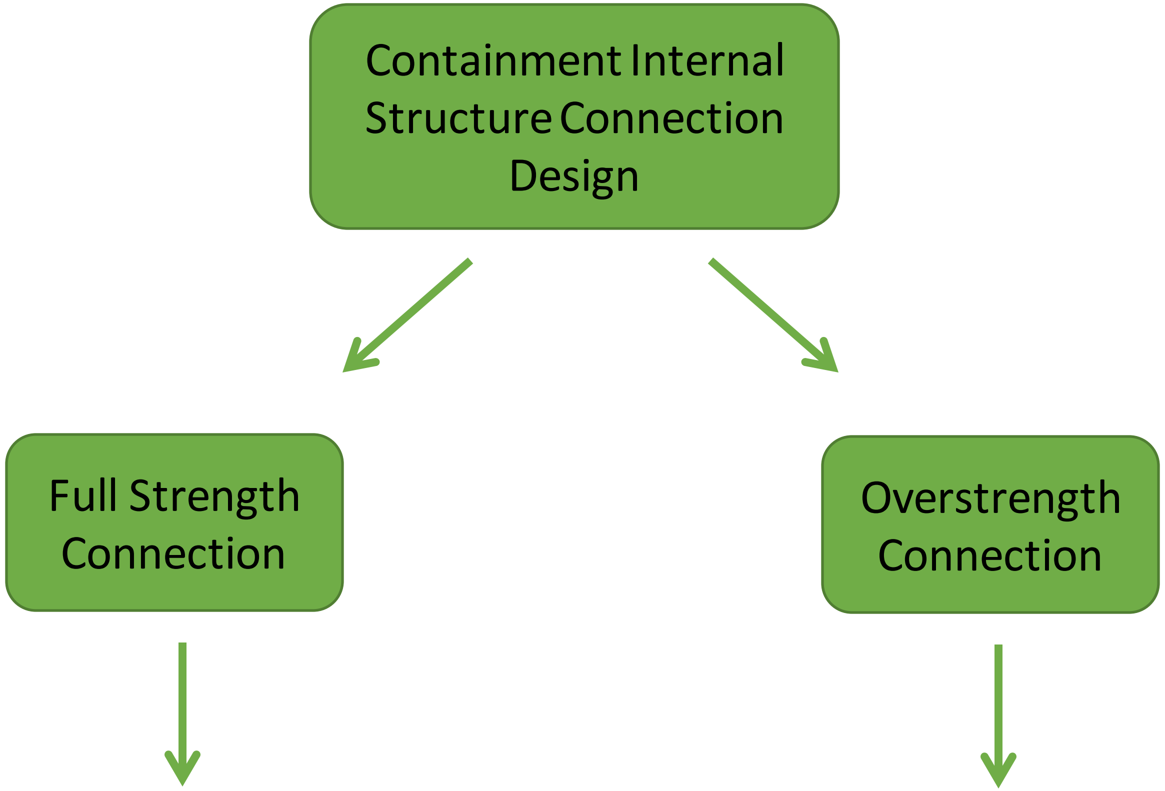

Transfers the individual expected strengths of the *weaker of the two* connected parts

Developing *significant overstrength* with respect to the design forces (200% of the seismic loads, 100% of the non-seismic loads, etc.)

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Tests on SC Walls (Full-Strength)

In-plane tests

Parameters:

- Aspect ratio (Height/Length)
- Shear stud or tie bar spacing
- Wall thickness
- Steel and concrete material properties

Tests on SC Walls (Full-Strength)

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Full strength connection

• The specimens developed the expected lateral load capacities (Both Out-of-plane and In-plane)

• The anchors remained in the elastic range up to the peak load

• Walls exhibited significant inelastic deformations

pictures close to the bottom of the specimens where inelastic deformations are concentrated

Out-of plane specimen ~peak load

In-plane specimen ~peak load

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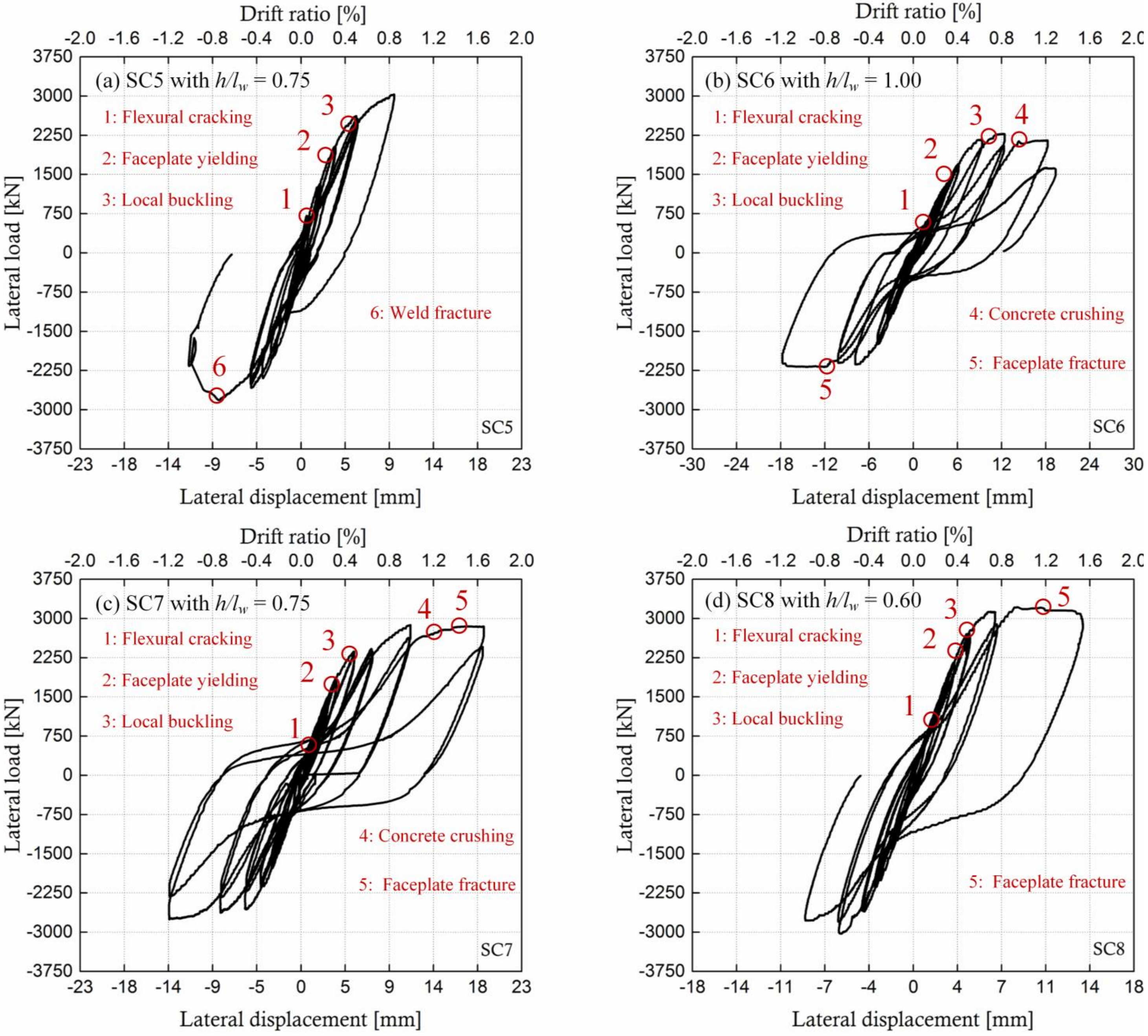
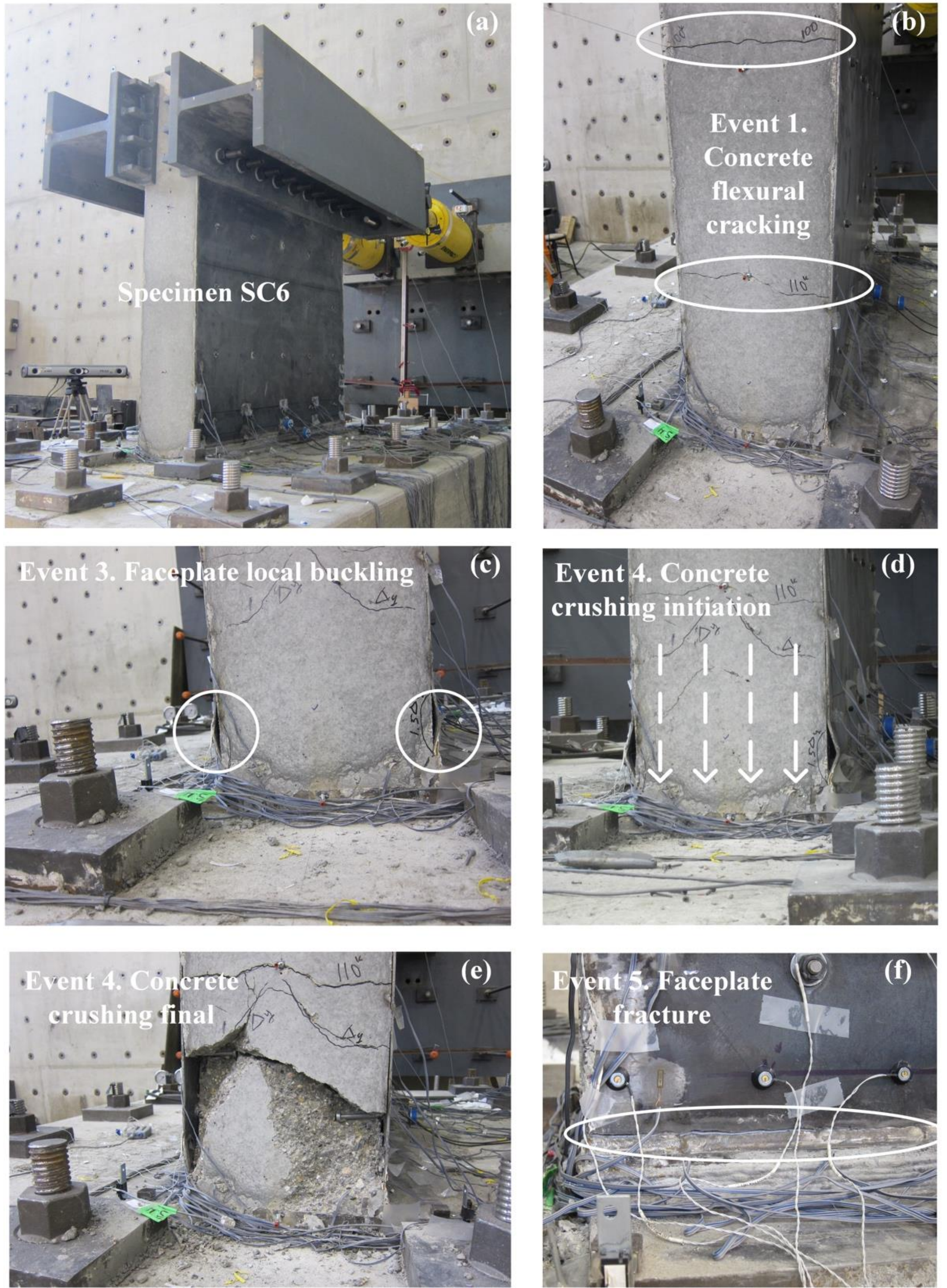


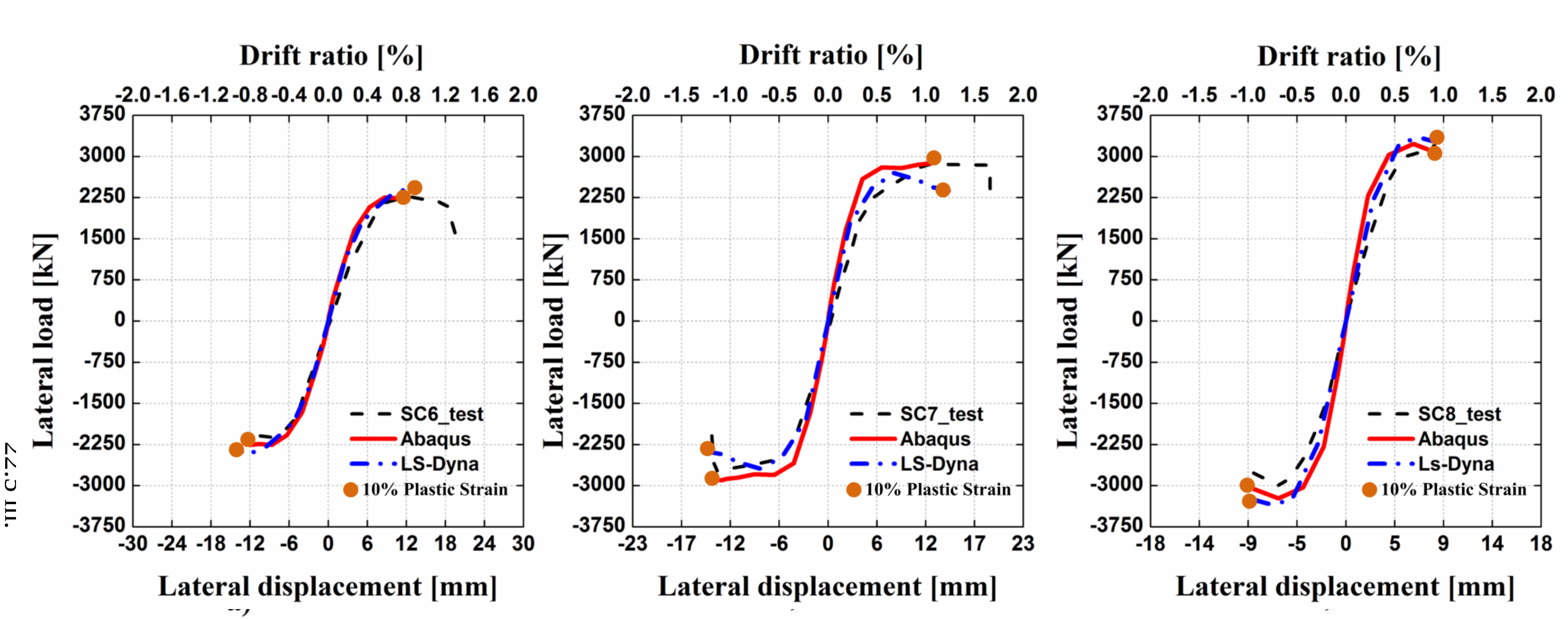
Drift ratio [%]
(a) SC5 with h/l_w = 0.75
1: Flexural cracking
2: Faceplate yielding
3: Local buckling
6: Weld fracture
SC5
(b) SC6 with h/l_w = 1.00
1: Flexural cracking
2: Faceplate yielding
3: Local buckling
4: Concrete crushing
5: Faceplate fracture
SC6
(c) SC7 with h/l_w = 0.75
1: Flexural cracking
2: Faceplate yielding
3: Local buckling
4: Concrete crushing
5: Faceplate fracture
SC7
(d) SC8 with h/l_w = 0.60
1: Flexural cracking
2: Faceplate yielding
3: Local buckling
5: Faceplate fracture
SC8
Lateral load [kN]
Lateral displacement [mm]



(a)
Specimen SC6
(b)
Event 1. Concrete flexural cracking
(c)
Event 3. Faceplate local buckling
(d)
Event 4. Concrete crushing initiation
(e)
Event 4. Concrete crushing final
(f)
Event 5. Faceplate fracture

Tests on SC Walls (Full-Strength)

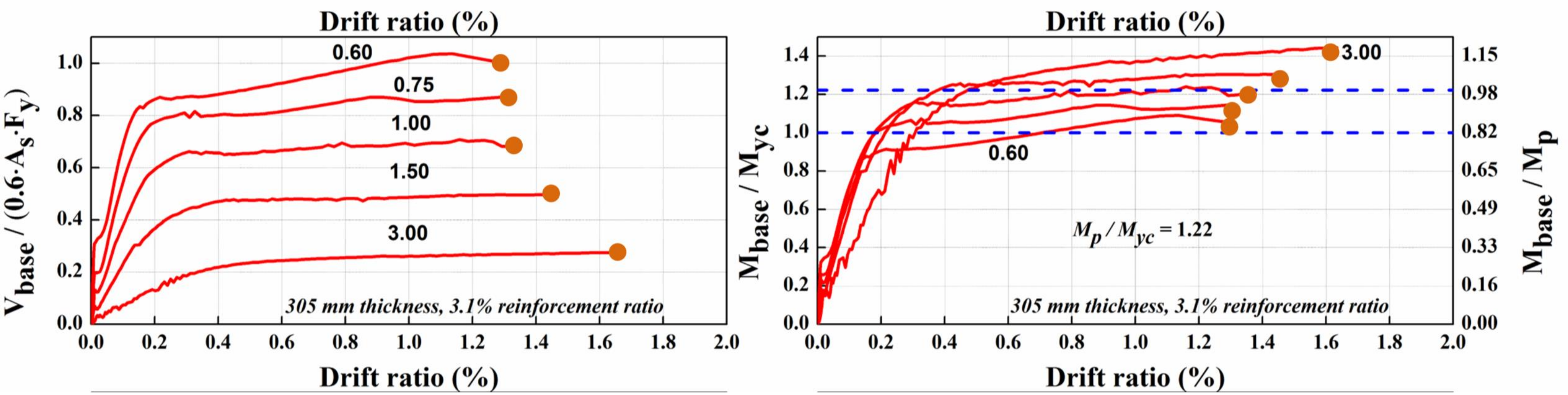
- *Benchmarking of FEMs (Ls-Dyna & Abaqus)*



Tests on SC Walls (Full-Strength)

Calculating the inplane capacity (analyses)

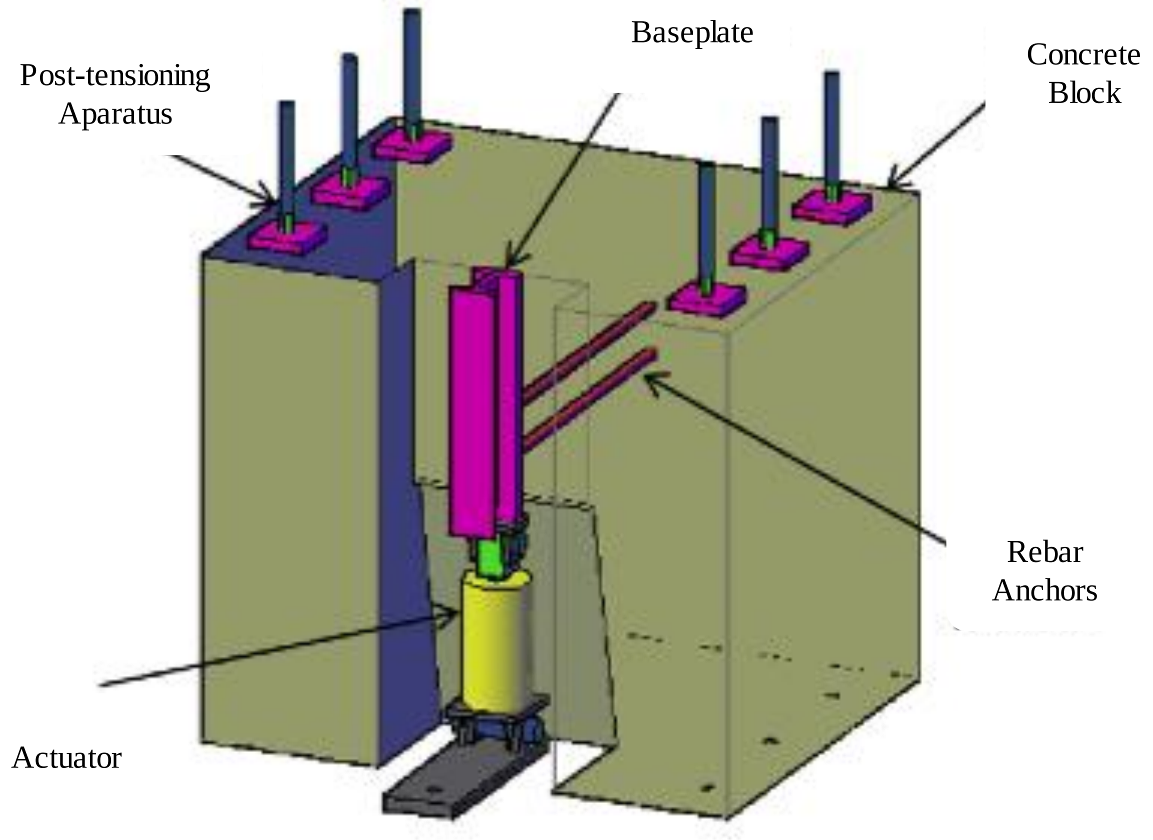
- *Parametric studies for different aspect and wall thicknesses*



Direct Shear Tests

Direct shear tests of basemat anchorage rebar-coupler system

- *Parametric studies for different aspect and wall thicknesses*



Direct shear tests of

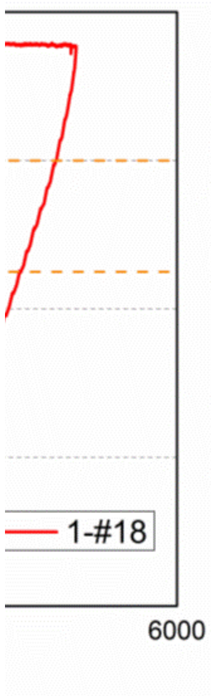
i) Two #11 rebars

ii) One #18 rebar

Direct Shear Tests

(b) Fractured Couplers and #11 Anchor Rebars in Specimen Block

(c) Fractured Couplers Welded at Basemat



Tests on SC Walls (Overstrength Connection)

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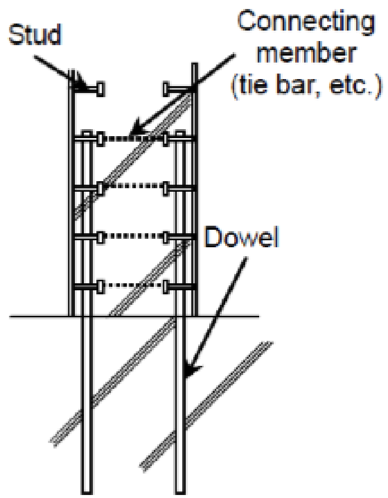

Dowel Bar Connection

Flexural Failure

- SC behavior
- Reinforced concrete behavior
- In-between behavior
- Controlling the failure location

Shear Failure

- Friction based capacity
- $F_{fric} = \mu \times A_{reb} \times f_{yreb}$
- Higher strength compared to RC/SC behavior

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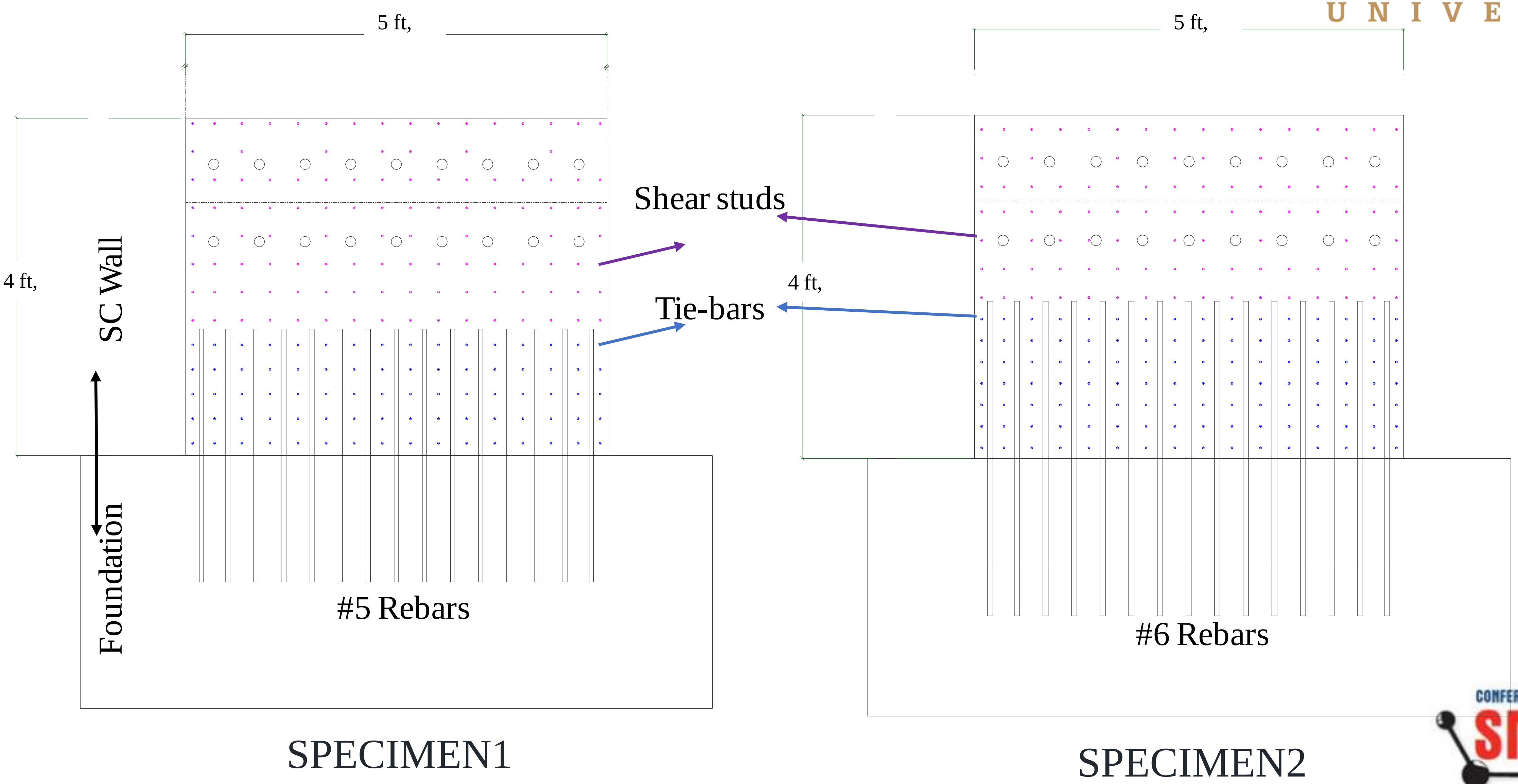
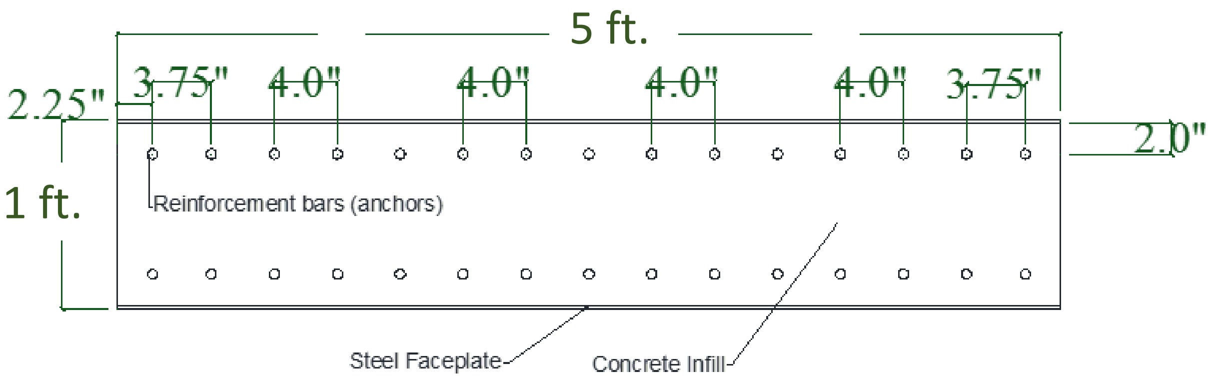
Tests on SC Walls (Overstrength Connection)

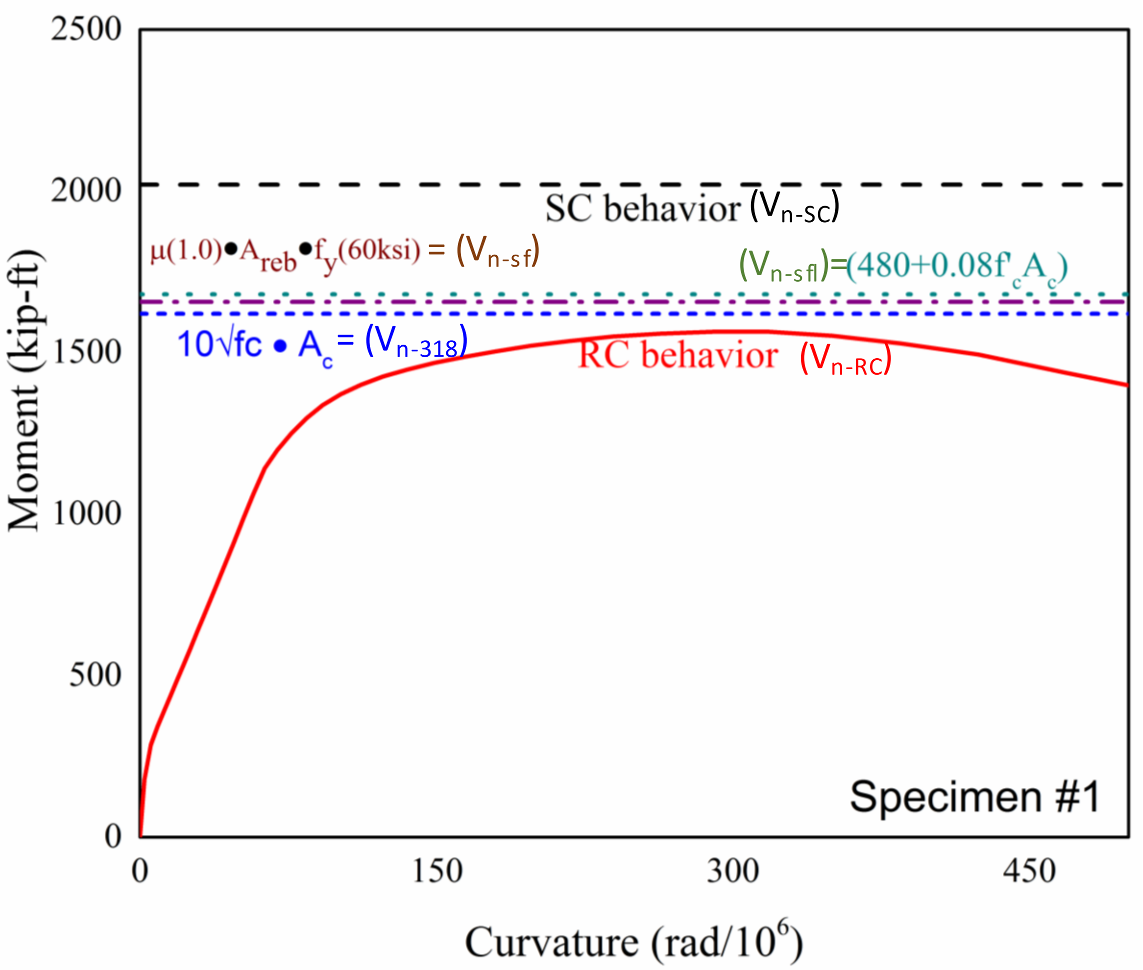


Tests on SC Walls (Overstrength Connection)



Reinforcement bar (anchors) layout

Tests on SC Walls (Overstrength Connection)



Comparison of lateral load capacities for Specimen#1

Limit state	Lateral load capacity	Force (kips)
Yielding of the rebars	$V_{n\text{-}RC}$	521
Yielding of the faceplates	$V_{n\text{-}SC}$	673
Sliding failure	$V_{n\text{-}318}$	540
Shear friction	$V_{n\text{-}sf}$	552
Shear friction upper limit	$V_{n\text{-}sfl}$	560

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Tests on SC Walls (Overstrength Connection)

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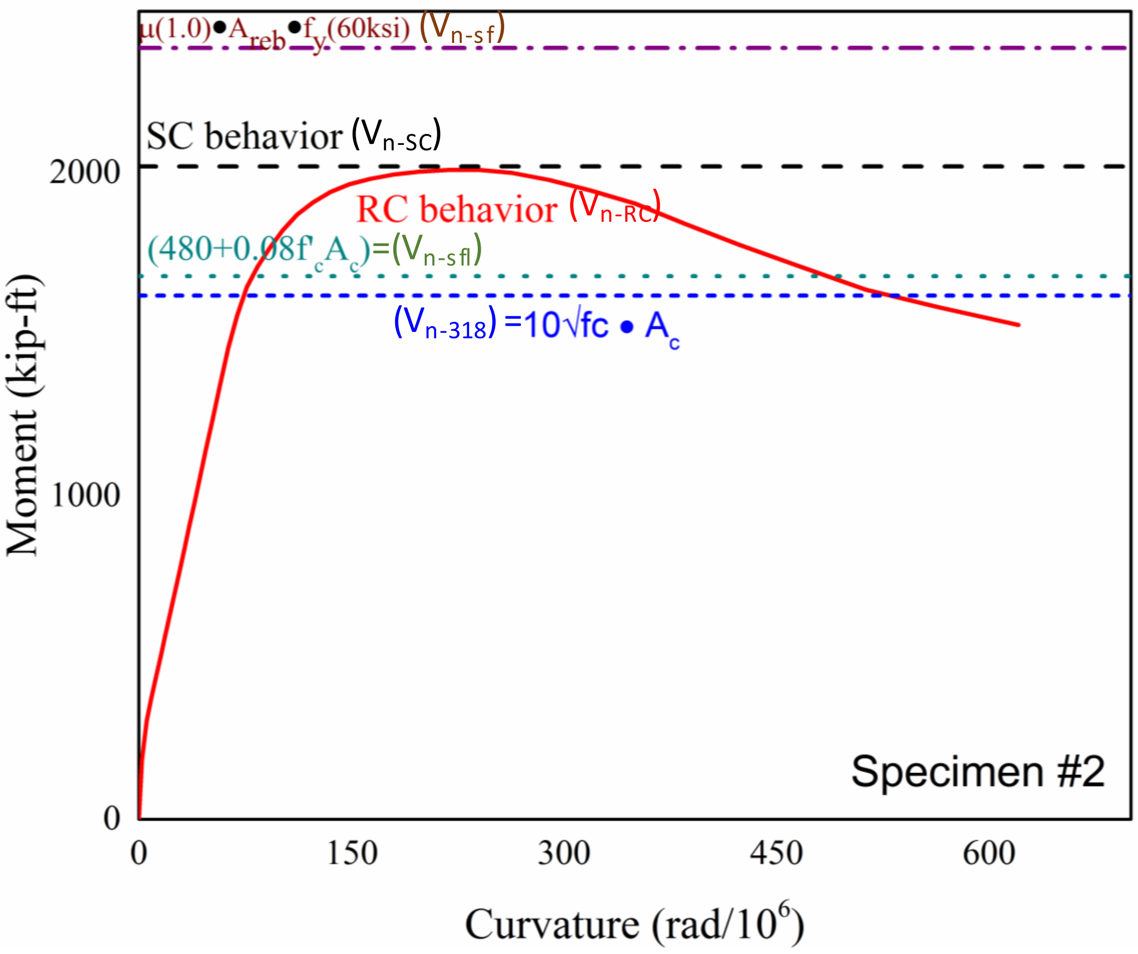

Comparison of lateral load capacities for Specimen#2

Limit state	Lateral load capacity	Force (kips)
Yielding of the rebars	$V_{n\text{-}RC}$	669
Yielding of the faceplates	$V_{n\text{-}SC}$	673
Sliding failure	$V_{n\text{-}318}$	540
Shear friction	$V_{n\text{-}sf}$	795
Shear friction upper limit	$V_{n\text{-}sfl}$	560

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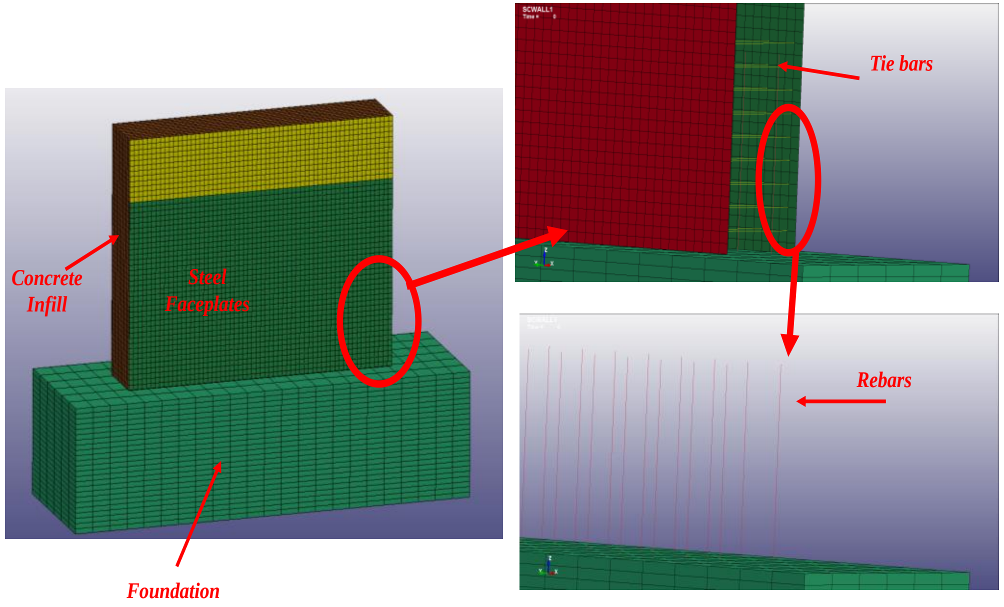
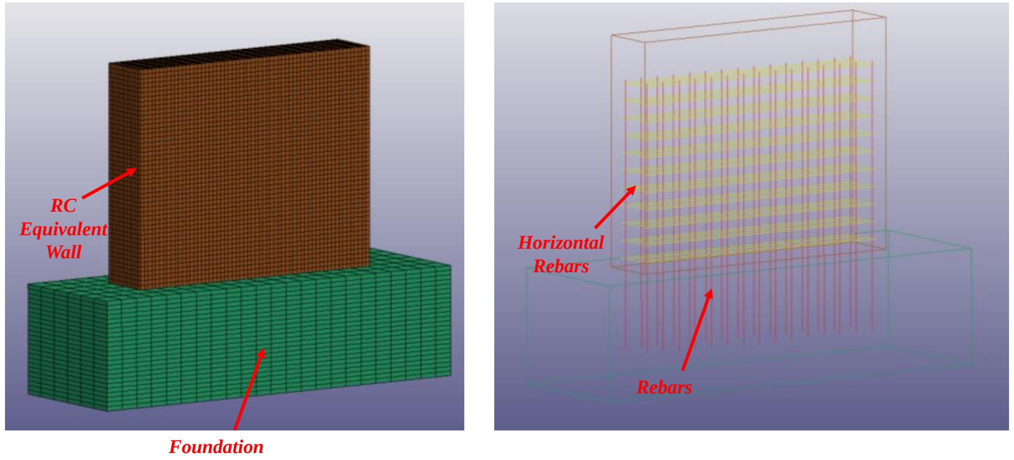
FEMs (Overstrength Connection)



SC Wall Pier with rebar anchors and foundation



Equivalent RC Wall Pier

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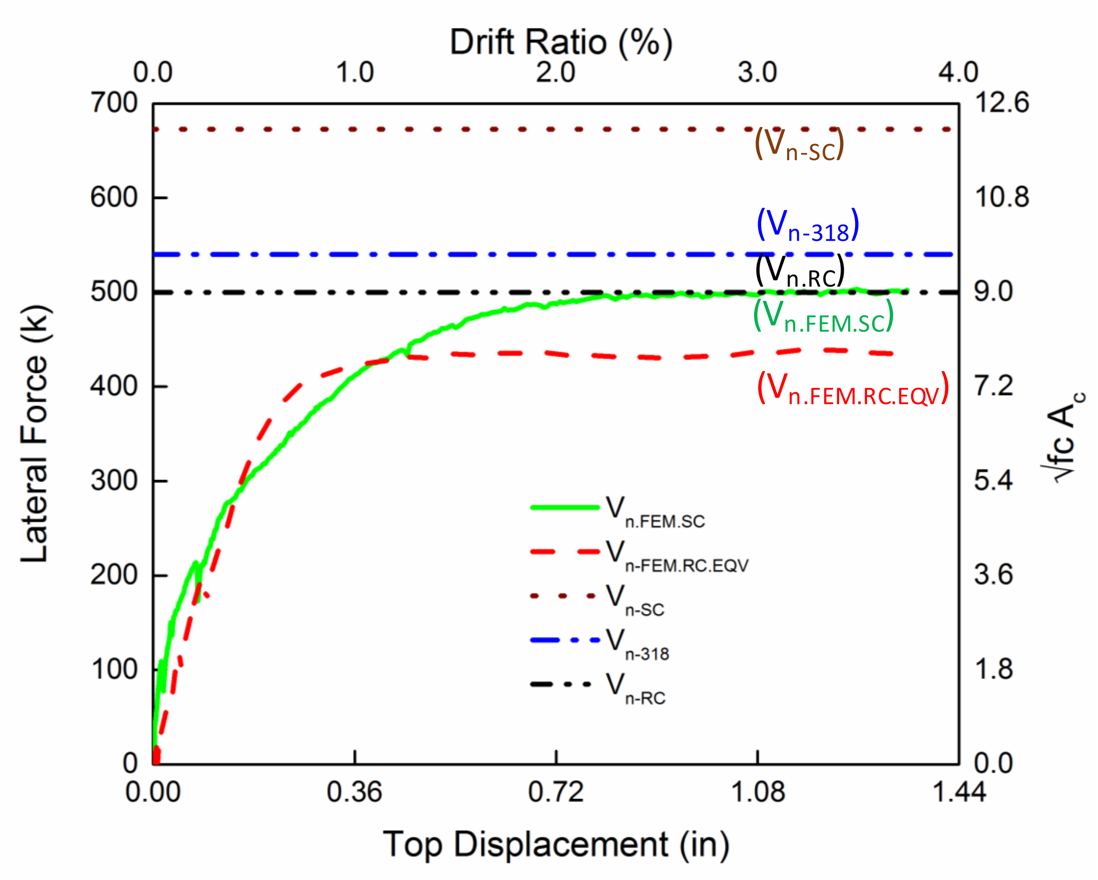
FEMs (Overstrength Connection)

Specimen#1



$V_{n\text{-}SC}$: SC wall capacity (full-strength)

$V_{n\text{-}318}$: ACI-318 limitation for RC wall piers

$V_{n\text{-}RC}$: Moment-Curvature analysis (RC)

FEMs (Overstrength Connection)

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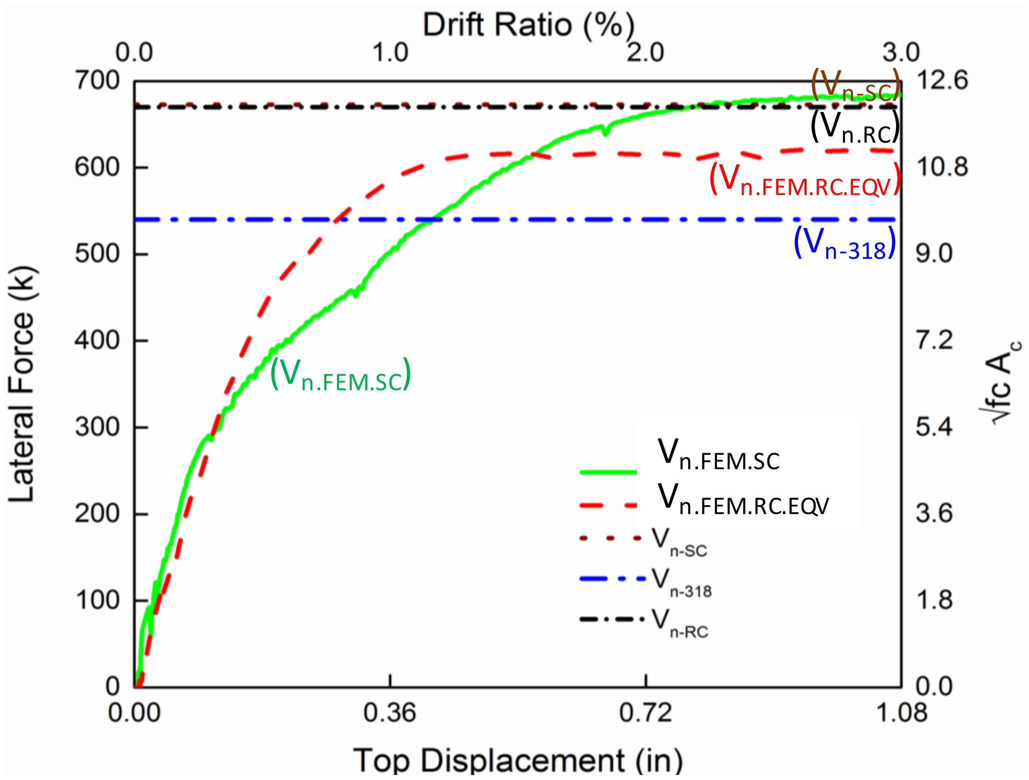
Specimen#2



$V_{n\text{-}SC}$: SC wall capacity (full-strength)

$V_{n\text{-}318}$: ACI-318 limitation for RC wall piers

$V_{n\text{-}RC}$: Moment-Curvature analysis (RC)

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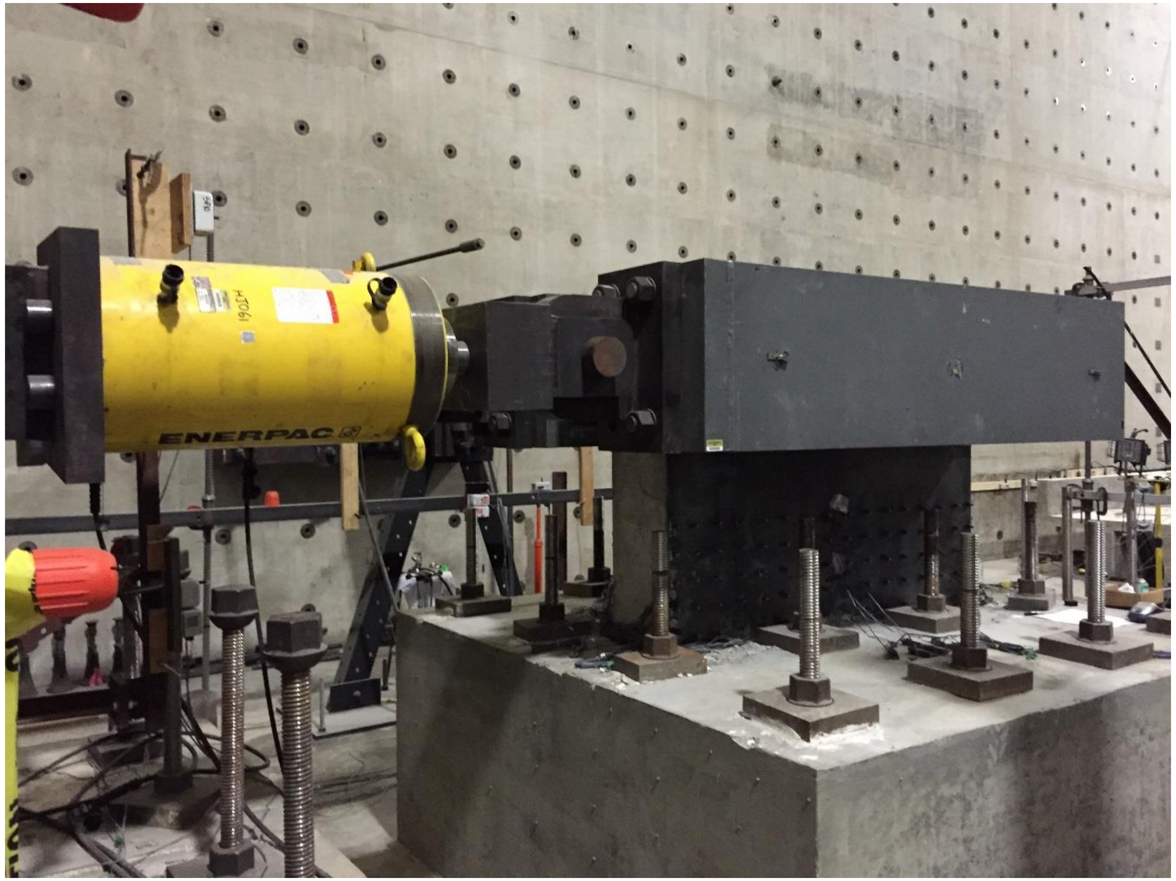
Test Specimen (Overstrength Connection)



Test Specimen (Overstrength Connection)

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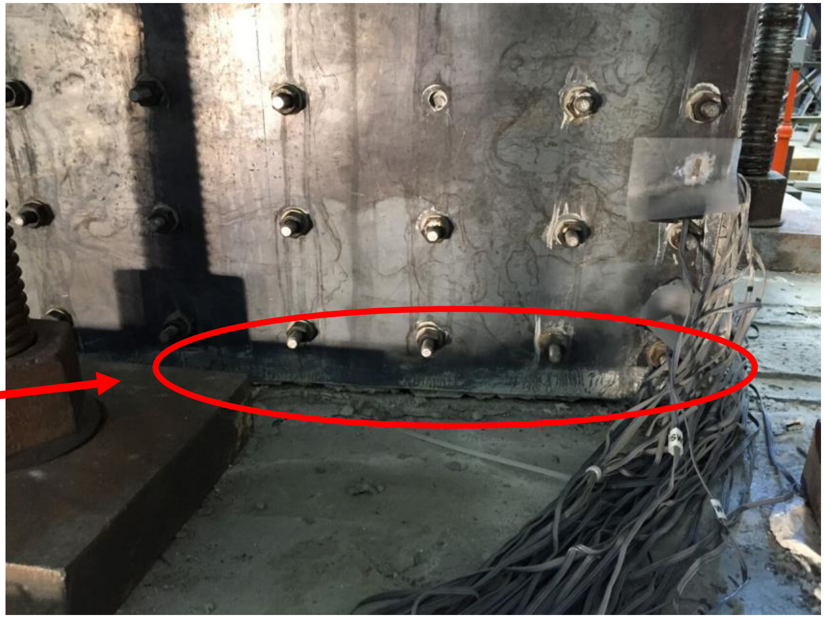

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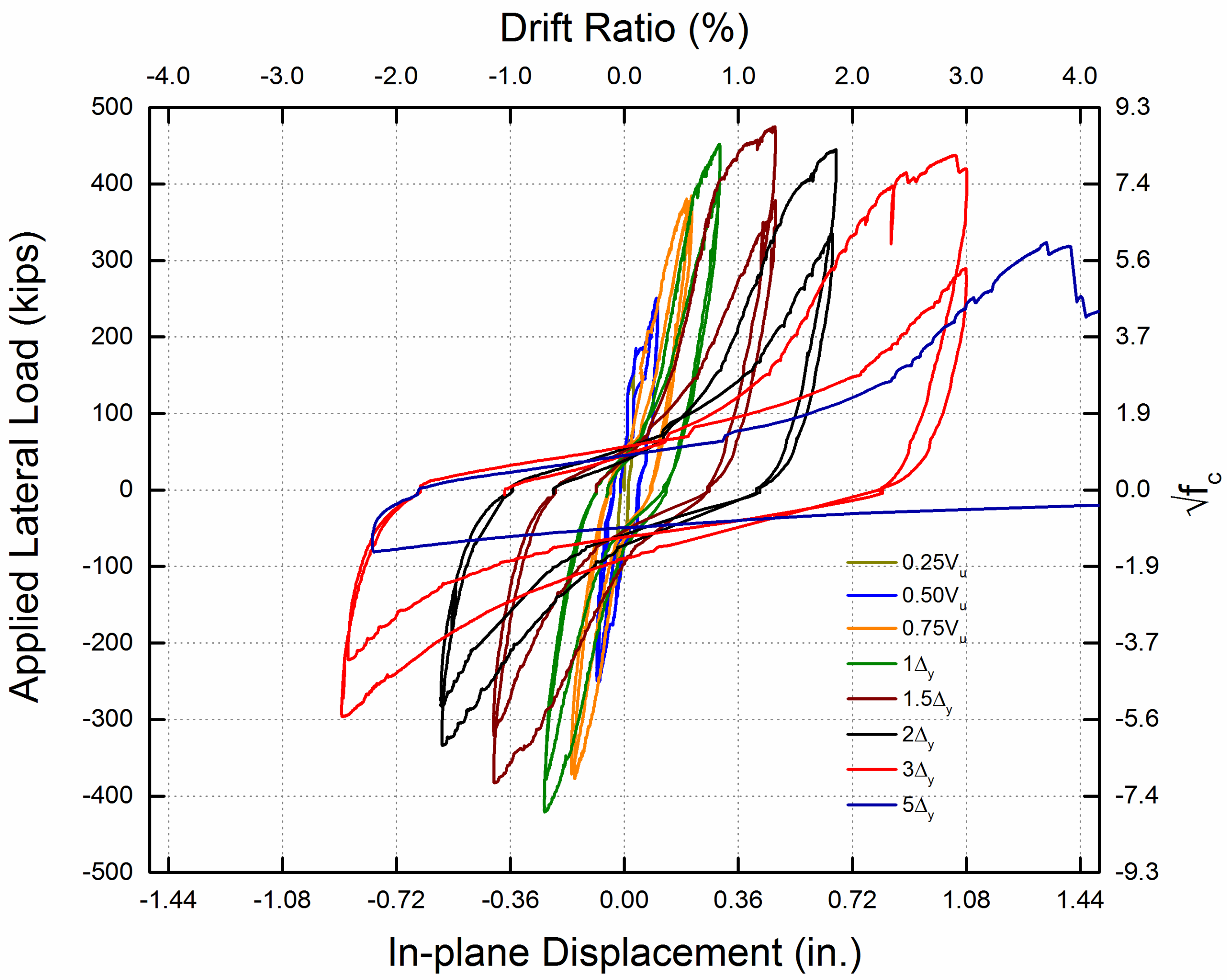
Test Specimen (Overstrength Connection)



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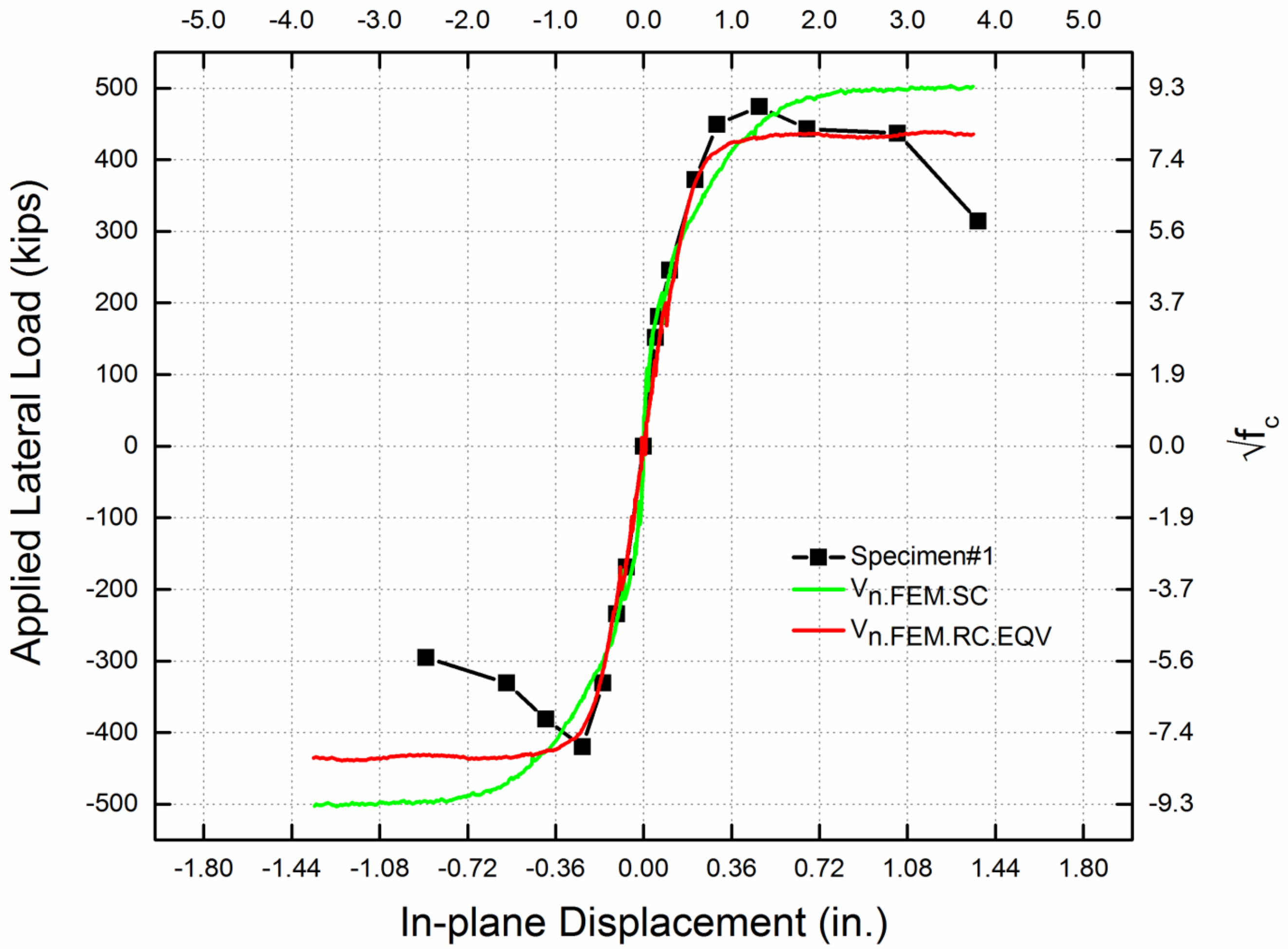
Test Specimen (Overstrength Connection)



Conclusions

1. SC wall piers with aspect ratios of 0.60, 0.75, and 1.0 reach their lateral load capacities at story drift ratios of 0.9%, 1.0%, and 1.3%, respectively. The lateral load capacities of the SC wall piers increased with decreasing aspect ratio (h/l_w) and increasing wall thickness (T).

2. SC wall piers with aspect ratios greater than or equal to 0.60 failed due to in-plane bending or flexure. Their behavior and failure was governed by cyclic yielding and local buckling of the steel faceplates, compression crushing of the concrete infill, and eventually fracture of the steel faceplates.

Conclusions

3. Direct shear tests of rebar-coupler specimens showed that the capacity of the connection was more than 200% of $0.6nA_{se}f_{uta}$. The specimens failed due to the fracture of the couplers rather than the fracture of the reinforcement bars.
4. Overstrength connection specimens were designed, built and ready for testing. The connection consist of reinforcement bars as anchors.
5. One of the overstrength connection specimens is designed to fail by the flexural capacity of the RC section of the wall (capacity calculated by moment curvature). The second specimen is designed to have failure mechanism as sliding shear failure. The tests will be conducted in near future and the results of the tests will be published.

Selected Publications

- Kurt, E.G., Varma, A.H., Booth, P.N., and Whittaker, A., (2015). "In-plane Behavior and Design of Rectangular SC Wall Piers Without Boundary Elements." ASCE *Journal of Structural Engineering*, Revision Submitted September 2015
- Kurt, E., Varma, A., Epackachi, S., and Whittaker, A. (2015) "Rectangular SC Wall Piers: Summary of Seismic Behavior and Design." Proceedings of Structures Congress 2015: pp. 1042-1051. http://dx.doi.org/10.1061/9780784479117.089
- Kurt, E.G., and Varma, A.H. (2015). "Preliminary Investigation of Steel-Plate Composite (SC) Wall-to-Concrete Basemat Anchorage Connections." Transactions of SMiRT 23 in Manchester, UK, Paper ID 718, IASMIRT, North Carolina State University, Raleigh, NC, pp. 1-10, http://smirt23.uk/attachments/SMiRT-23_Paper_718.pdf
- Epackachi, S., Nguyen, N., Kurt, E., Whittaker, A. and Varma, A.H. (2014). “In-Plane Behavior of Rectangular Steel-Plate Composite Shear Walls.” Journal of Structural Engineering, ASCE, http://dx.doi.org/10.1061/(ASCE)ST.1943-541X.0001148
- Epackachi, S., Whittaker, A., Varma, A.H., and Kurt, E. (2015). “Finite Element Modeling of Steel-Plate Concrete Composite Wall Piers.” Engineering Structures, Elsevier Science, Vol. 100, pp. 369-384, http://dx.doi.org/10.1016/j.engstruct.2015.06.023
- Kurt, E., Varma, A.H., Booth, P.N., and Whittaker, A. (2013). “SC Wall Piers and Basemat Connections: Numerical Investigation of Behavior and Design.” Transactions of SMiRT 22, IASMIRT, NCSU, Raleigh, NC, pp. 1-10. http://www.iasmirt.org/transactions/22/Pap_872_ver_3.pdf