CONFINED MASONRY: THEORETICAL FUNDAMENTALS, EXPERIMENTAL TEST, FINITE ELEMENT MODELS, AND FUTURE USES

By: LAN NGUYEN

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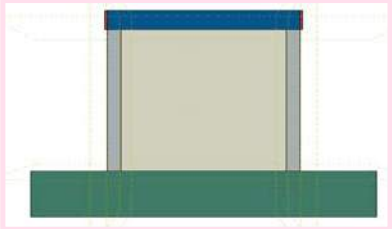
EXPERIMENTAL TESTING

NGUYEN'S WALLS

QUINUN'S WALLS

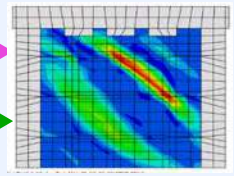
TOMAZEVIC'S WALLS

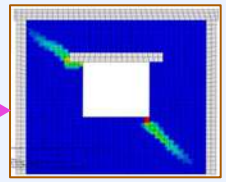


COMPONENTS TEST

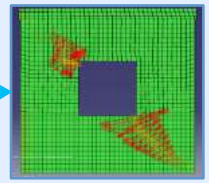
FINITE ELEMENT ANALYSIS

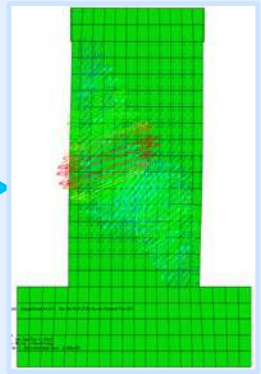
FINITE ELEMENT USER SUBROUTINE

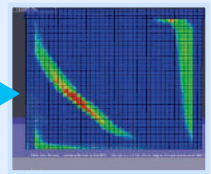




BUILT IN MODELS

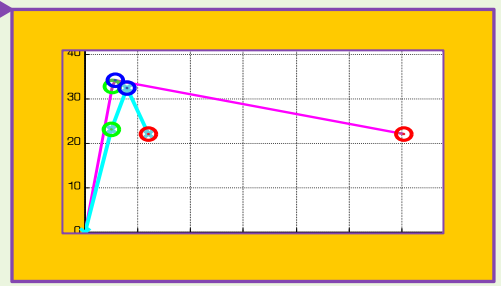




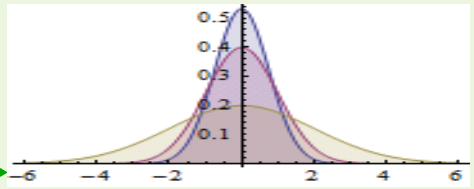


MACRO ANALYSIS

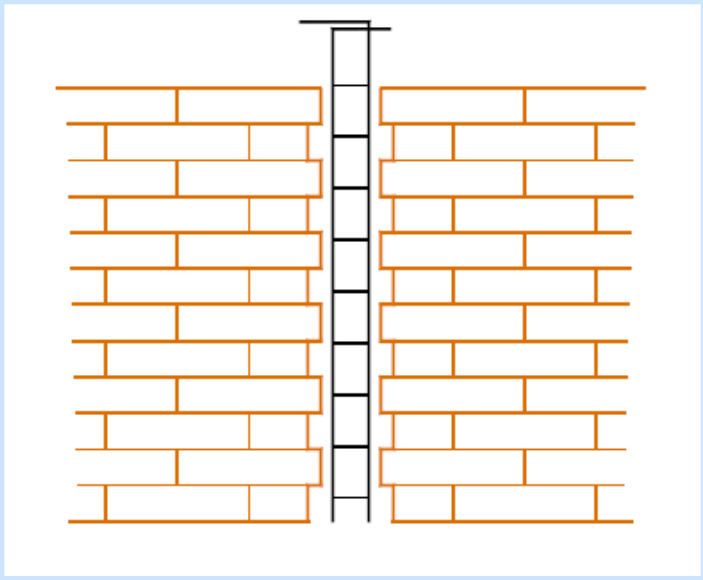
RESPONSE PREDICTION

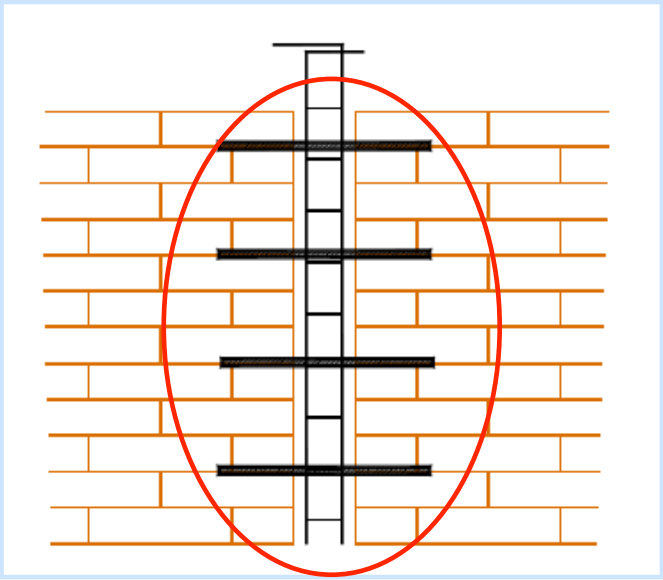


SAFETY DESIGN ASPECT



ADDRESS THE NEEDS IN CM BUILDING GUIDELINE





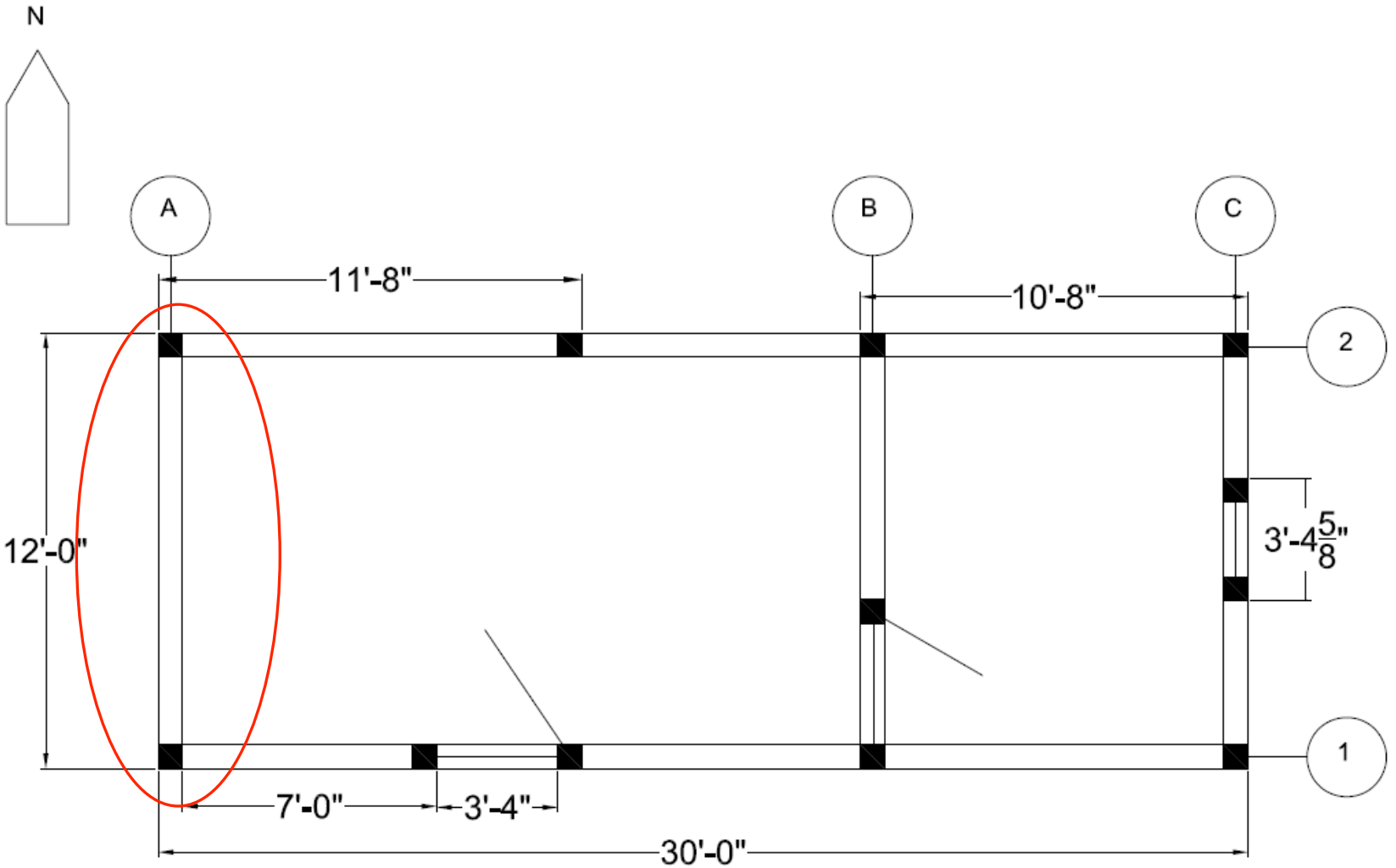
Smooth Wall Configuration → Potentially can be used for retrofitting purposes.

Photos: EERI, 2010

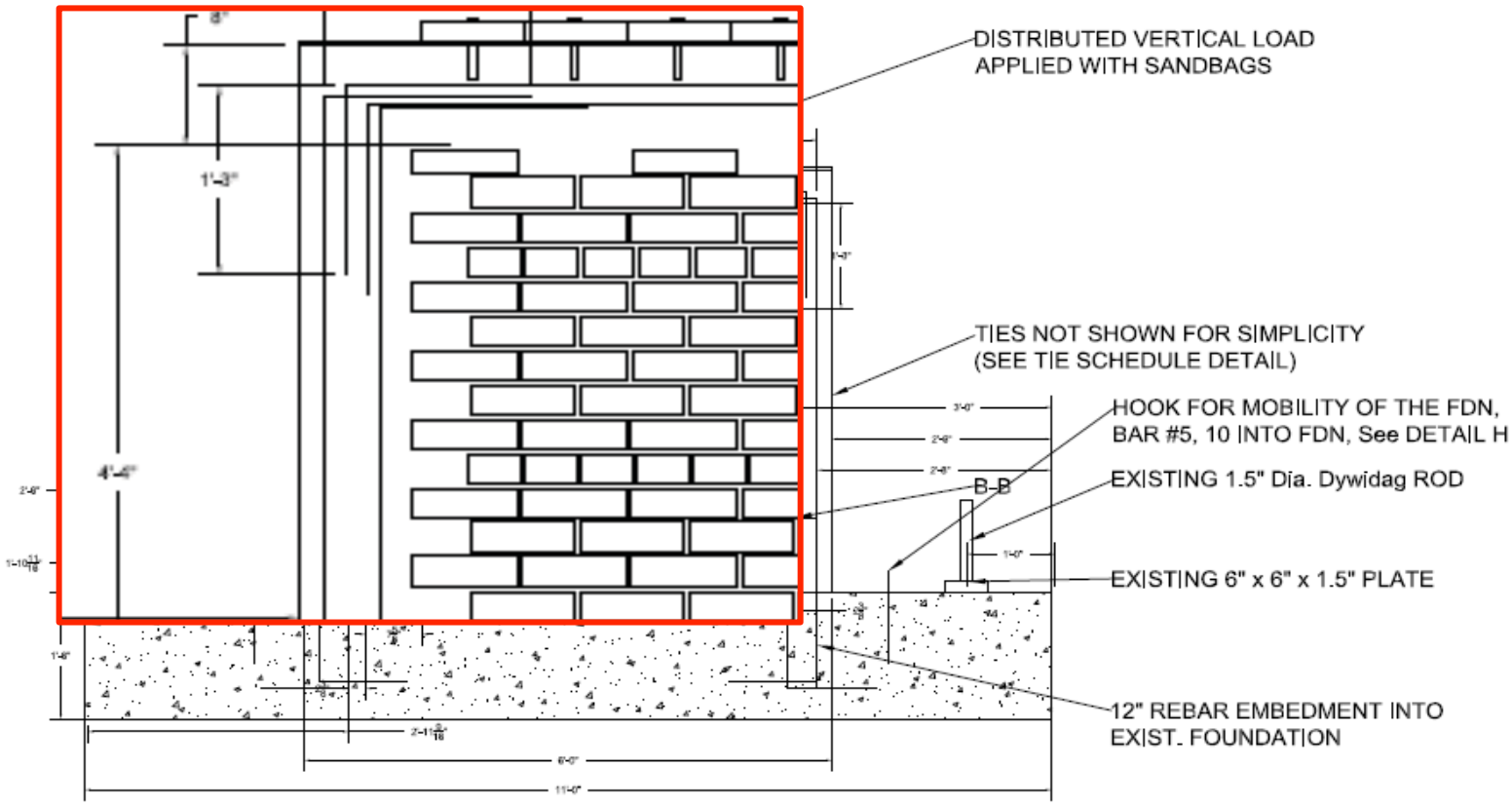
Some interesting CM experimental tests have been done, including tests done by: Tomazevic (1997), Bartolome & Quiun (2003), Quiun (2008-2013), Ashraf et al. (2011), Sarrafi & Eshghi (2011), Janaraj & DhanaseKar (2013), Singal &Rai (2013).

- **Capacities of toothed wall configuration and smooth wall configuration = an open question.**

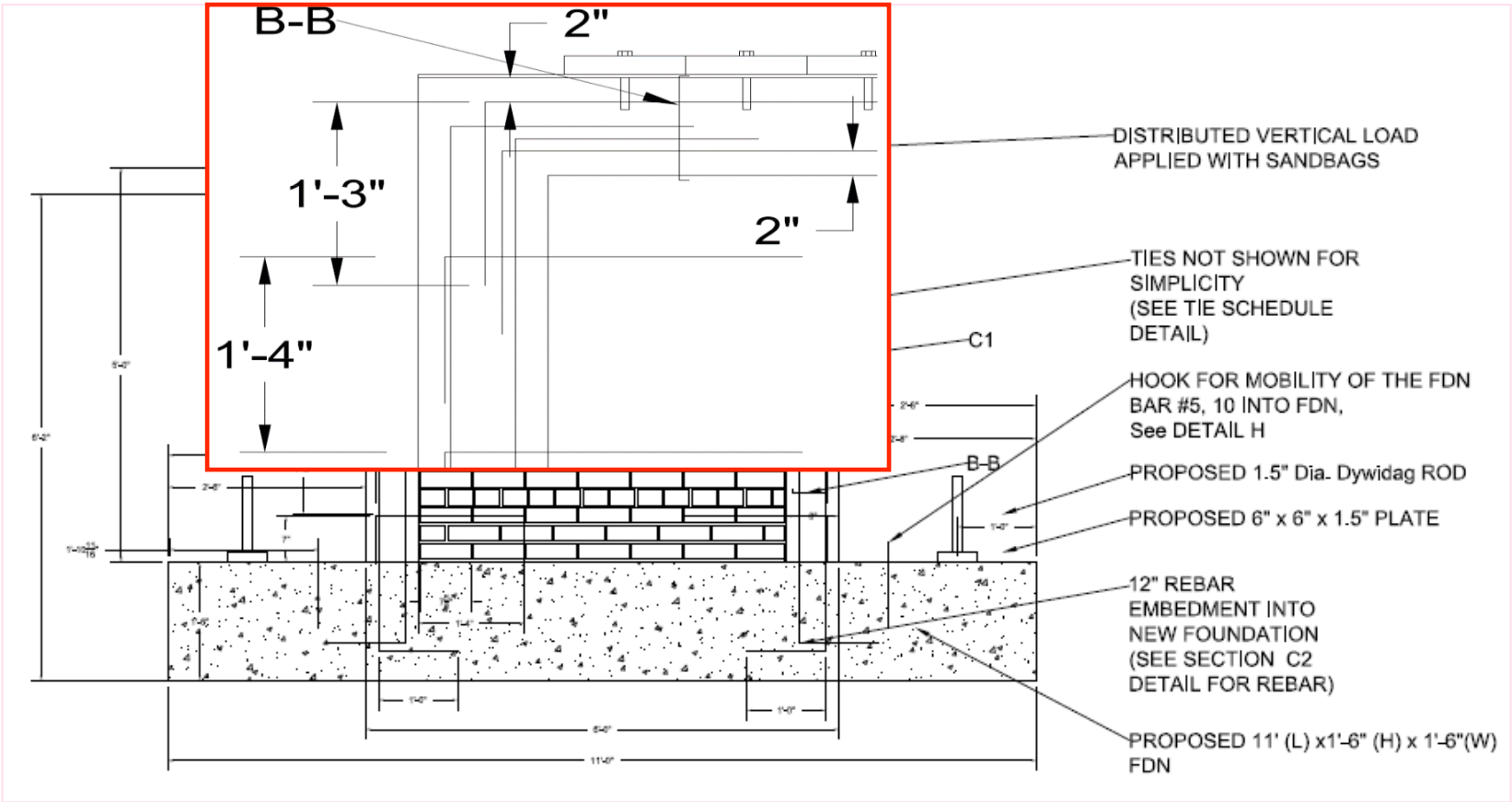
WALL TYPE OF INTEREST



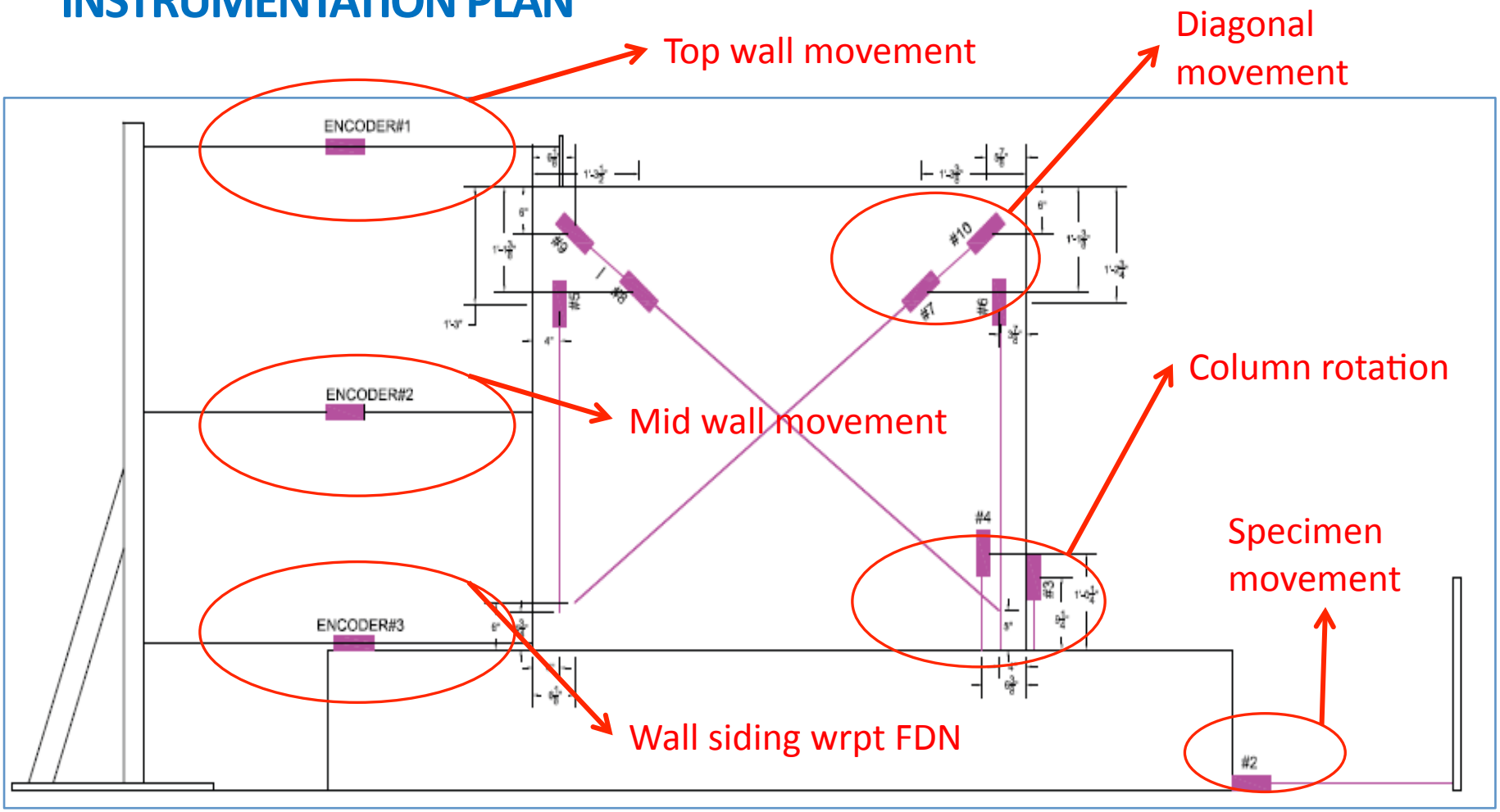
CM WALL 1


DISTRIBUTED VERTICAL LOAD
APPLIED WITH SANDBAGS
TIES NOT SHOWN FOR SIMPLICITY
(SEE TIE SCHEDULE DETAIL)
HOOK FOR MOBILITY OF THE FDN,
BAR #5, 10 INTO FDN, See DETAIL H
EXISTING 1.5" Dia. Dywidag ROD
B-B
EXISTING 6" x 6" x 1.5" PLATE
12" REBAR EMBEDMENT INTO
EXIST. FOUNDATION
1'-3"
4'-4"

CM WALL 2

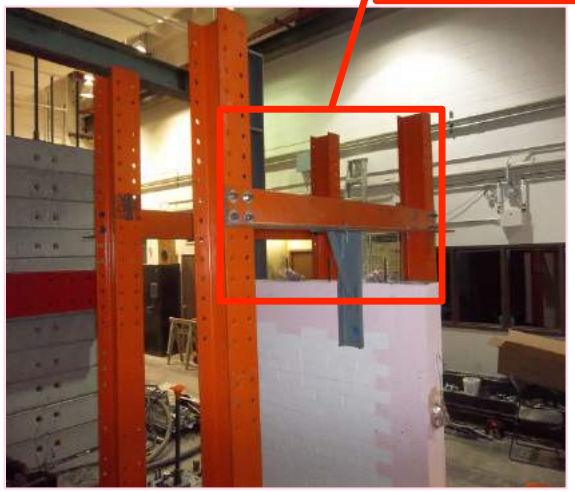

B-B
2"
1'-3"
2"
1'-4"
DISTRIBUTED VERTICAL LOAD
APPLIED WITH SANDBAGS
TIES NOT SHOWN FOR
SIMPLICITY
(SEE TIE SCHEDULE
DETAIL)
C1
HOOK FOR MOBILITY OF THE FDN
BAR #5, 10 INTO FDN,
See DETAIL H
B-B
PROPOSED 1.5" Dia. Dywidag ROD
PROPOSED 6" x 6" x 1.5" PLATE
12" REBAR
EMBEDMENT INTO
NEW FOUNDATION
(SEE SECTION C2
DETAIL FOR REBAR)
PROPOSED 11' (L) x1'-6" (H) x 1'-6"(W)
FDN

INSTRUMENTATION PLAN

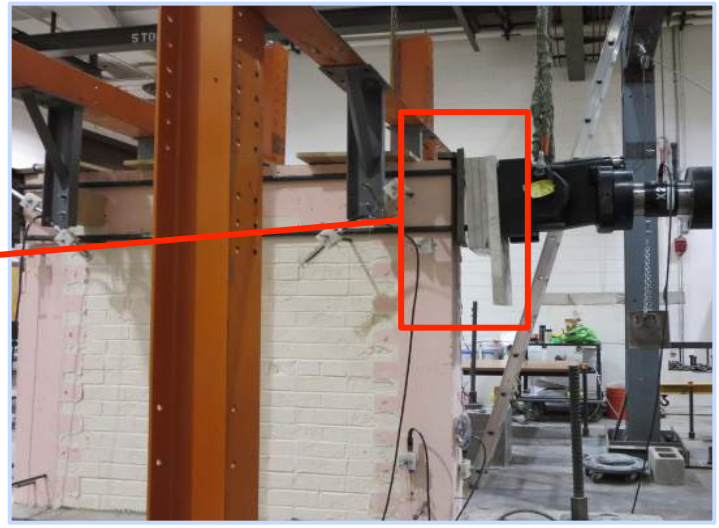


WALL TEST SET UP

Post-tension bolts



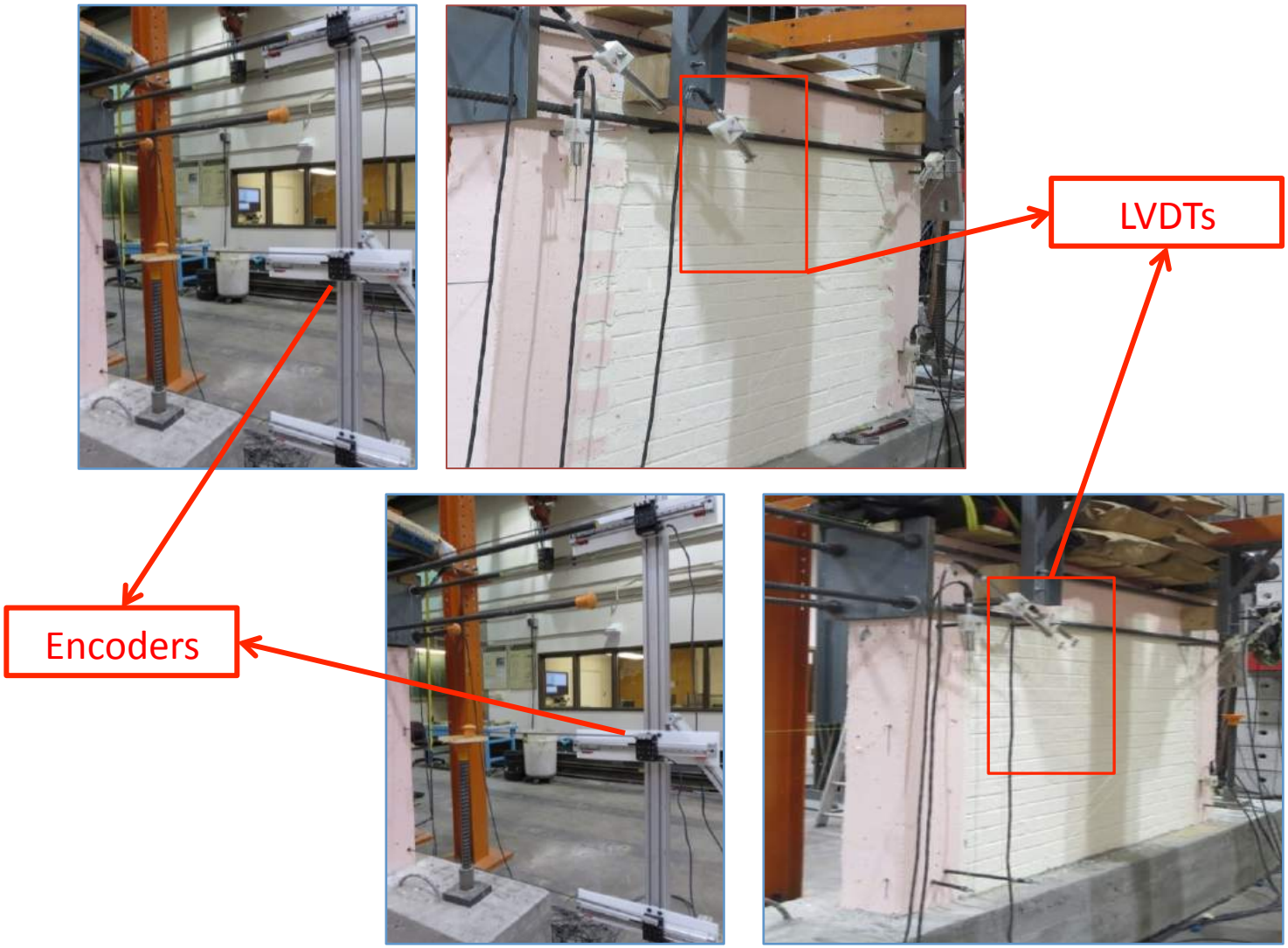
Out of plane brace



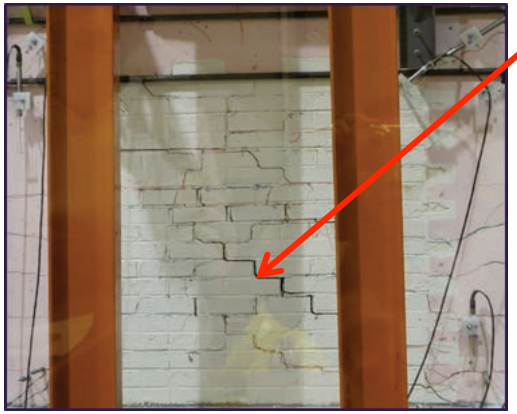
Loading point

Distributed load

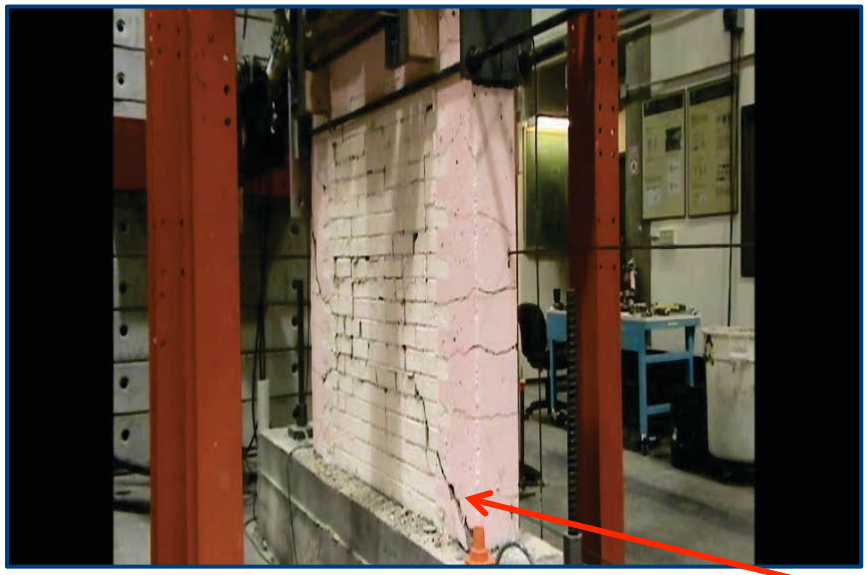
INSTRUMENTATION SETUP

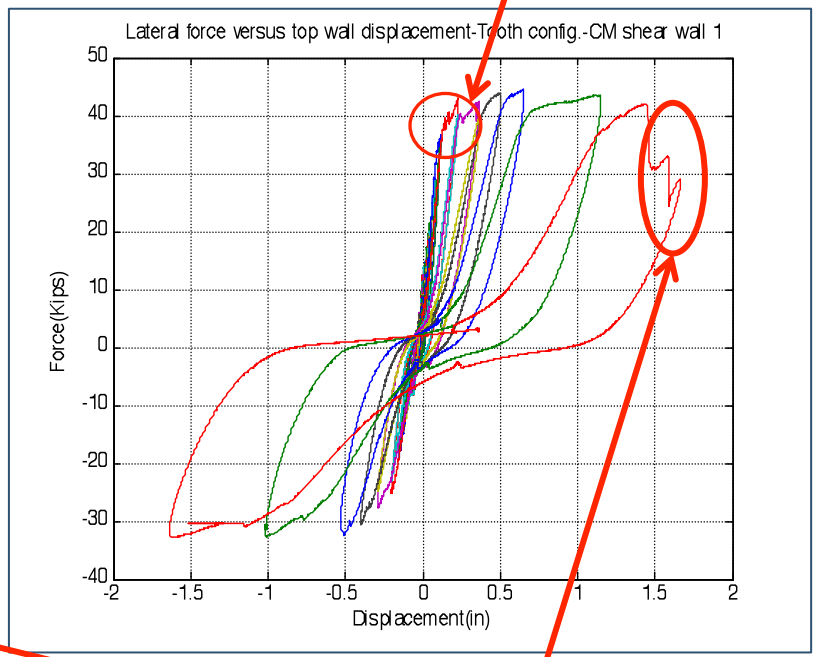


WALL TEST 1 RESULT



1st crack at 39.2 Kips



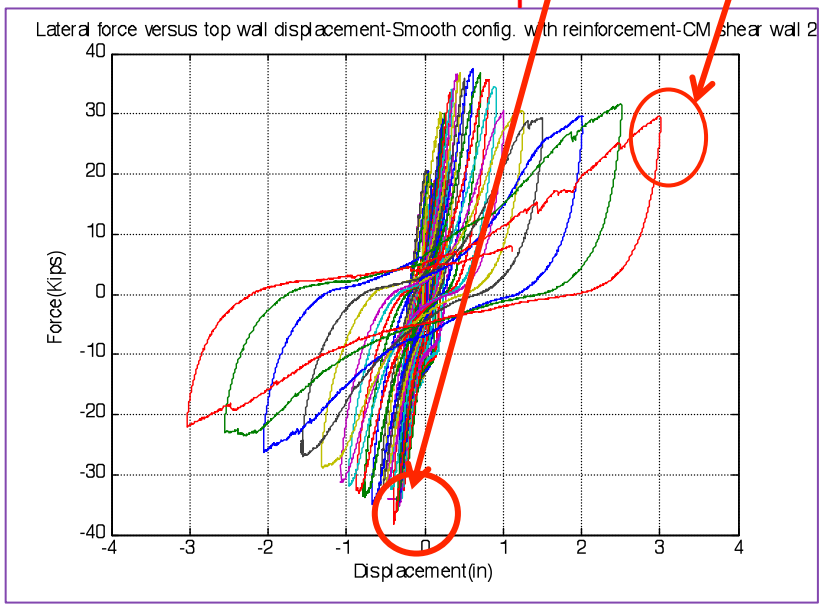


Shear occurs in column

WALL TEST 2 RESULT

1st crack at 31.7 Kips

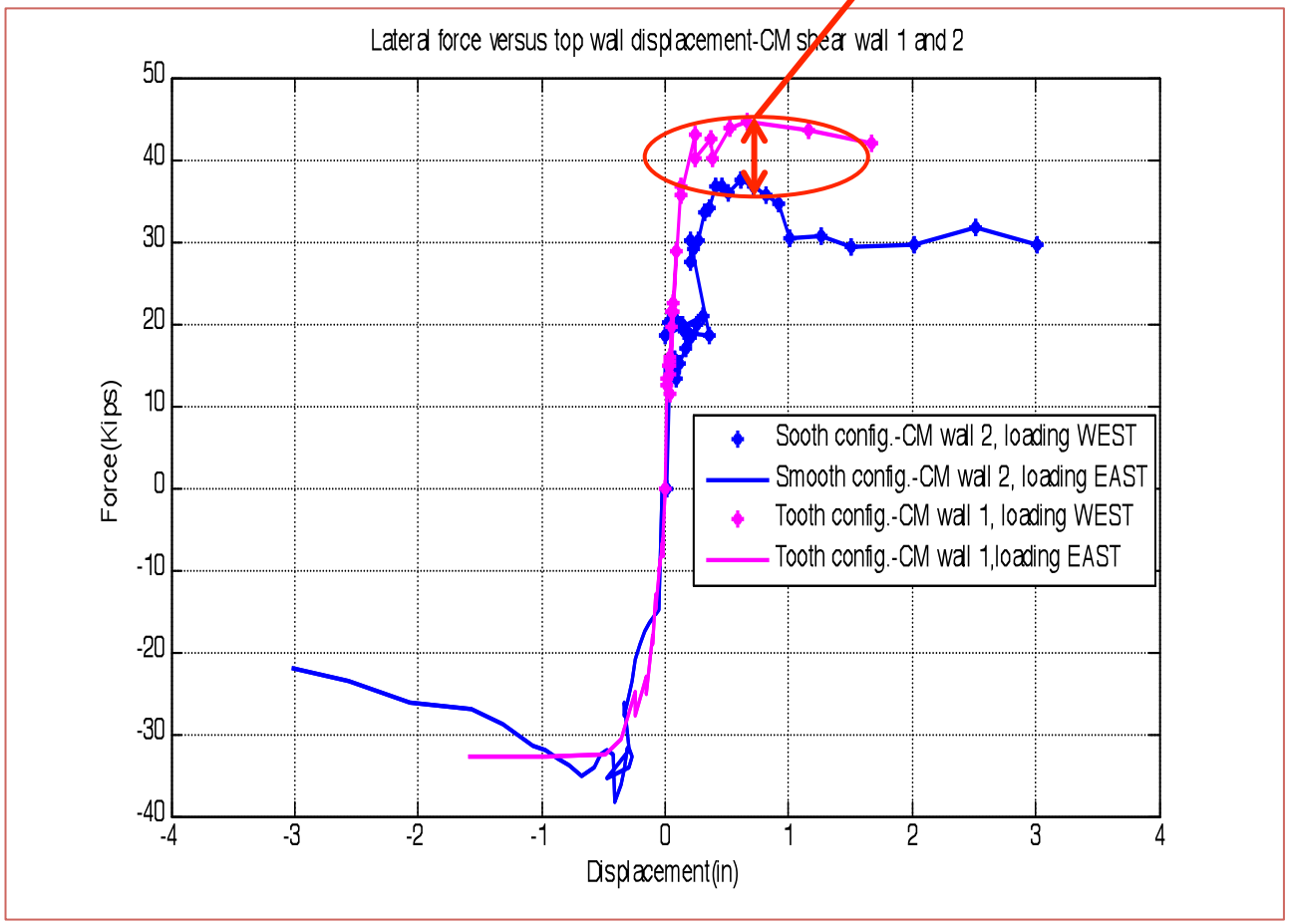
Shear in column at 36.6 Kips



FORCE COMPARISON

7.00 kips = shrinkage force from concrete frame

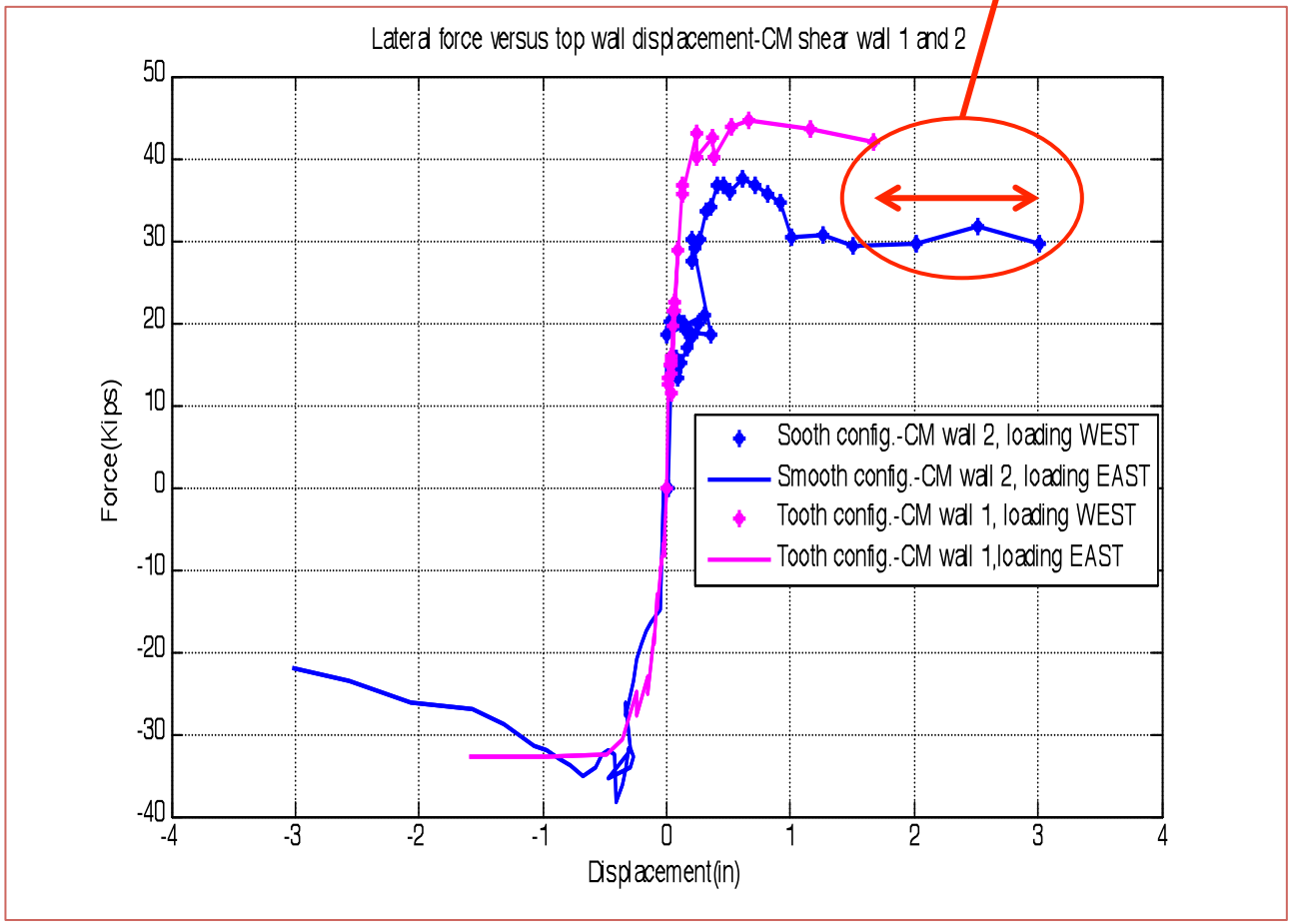
- Drift ratio in wall 1= 2.39%
- Drift ratio in wall 2= 4.79%



DUCTILITY COMPARISON

1.12”= ductility provides from rebar

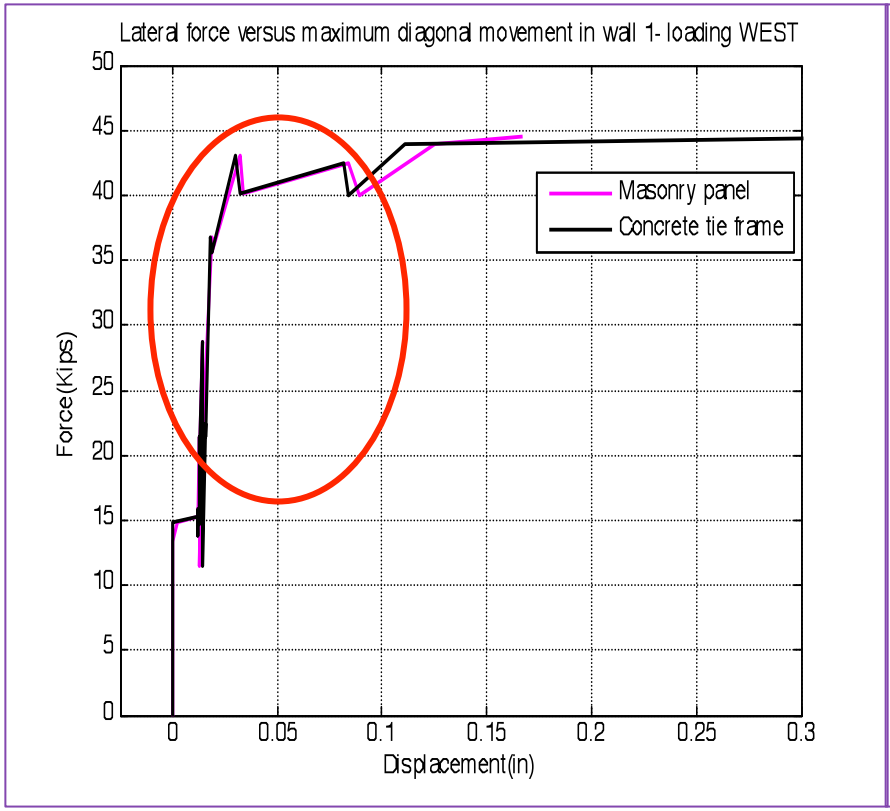
- Drift ratio in wall 1= 2.39%
- Drift ratio in wall 2= 4.79%



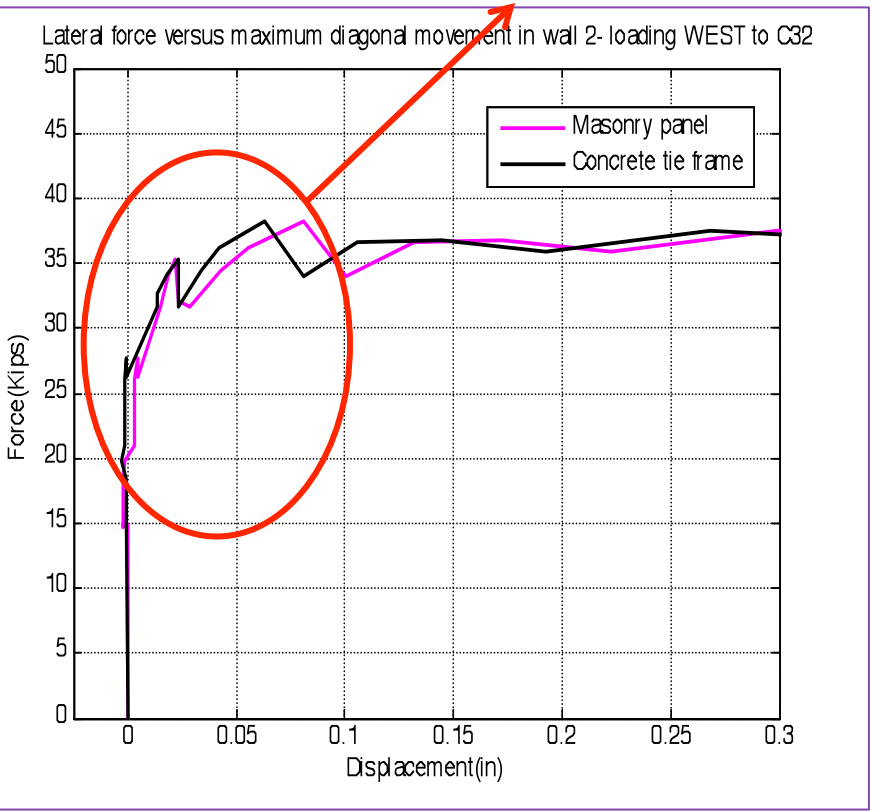
CONFINEMENT FROM TIE ELEMENTS

Separation in smooth wall occurs much sooner than CM1

Wall 1



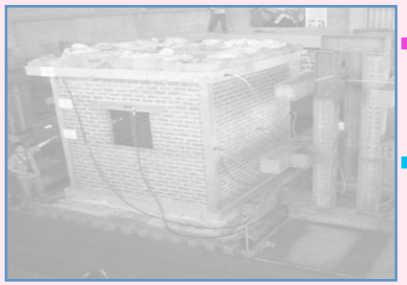
Wall 2



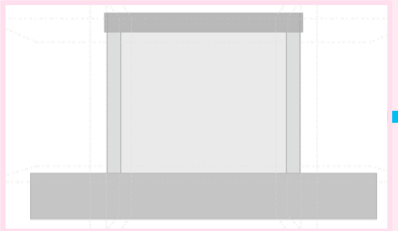
EXPERIMENTAL TESTING

NGUYEN'S WALLS

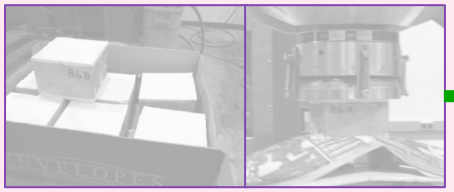
QUINN'S WALLS



TOMAZEVIC'S WALLS

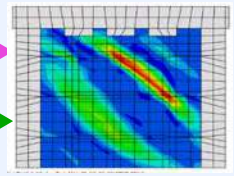


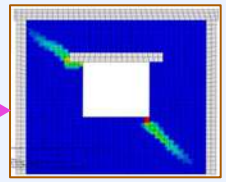
COMPONENTS TEST



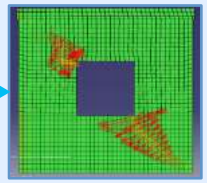
FINITE ELEMENT ANALYSIS

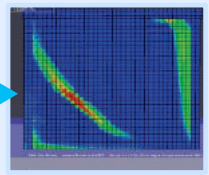
FINITE ELEMENT USER SUBROUTINE

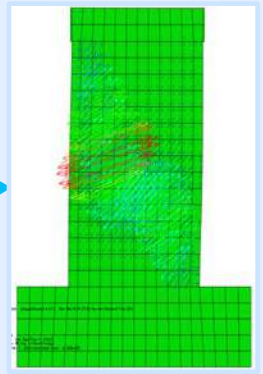




BUILT IN MODELS



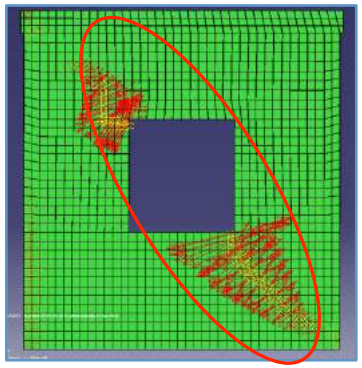




FE MODEL 2

- Model Features:

- Software: ABAQUS
- Damage plasticity model
- 1380 elements
- Small strain theory

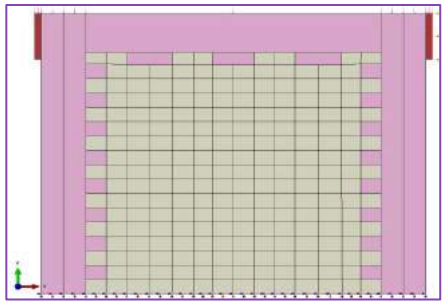


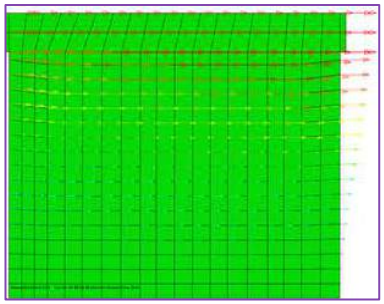
	Experimental	Numerical Result	Difference
Maximum Base Shear (kN)	151	136	11.0%

FEA OBSERVATION FOR MODEL 1 AND MODEL 2	
Model converged?	YES
Crack pattern defined?	YES
Damaged and undamaged elements defined?	NO
Damage appears to occur in more than 1 element?	YES

VALIDATION ON CM WALL 1

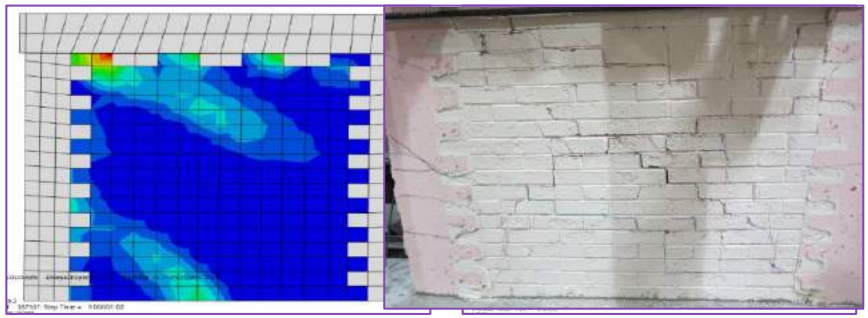
FE Model

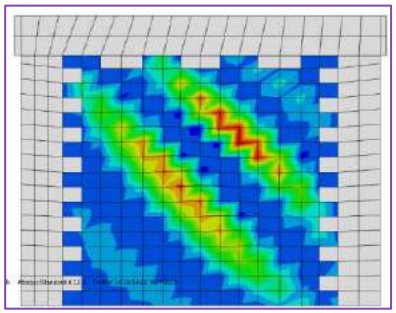


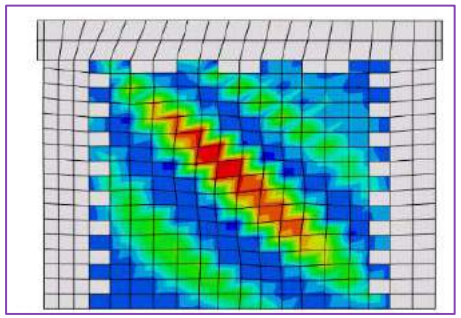


- Model Features:
  - Software: ABAQUS
  - Using my user subroutine
  - 384 4-node 2D plane stress elements
  - Mesh size of 3.4inx3.4in
  - Finite strain theory

Damage propagates

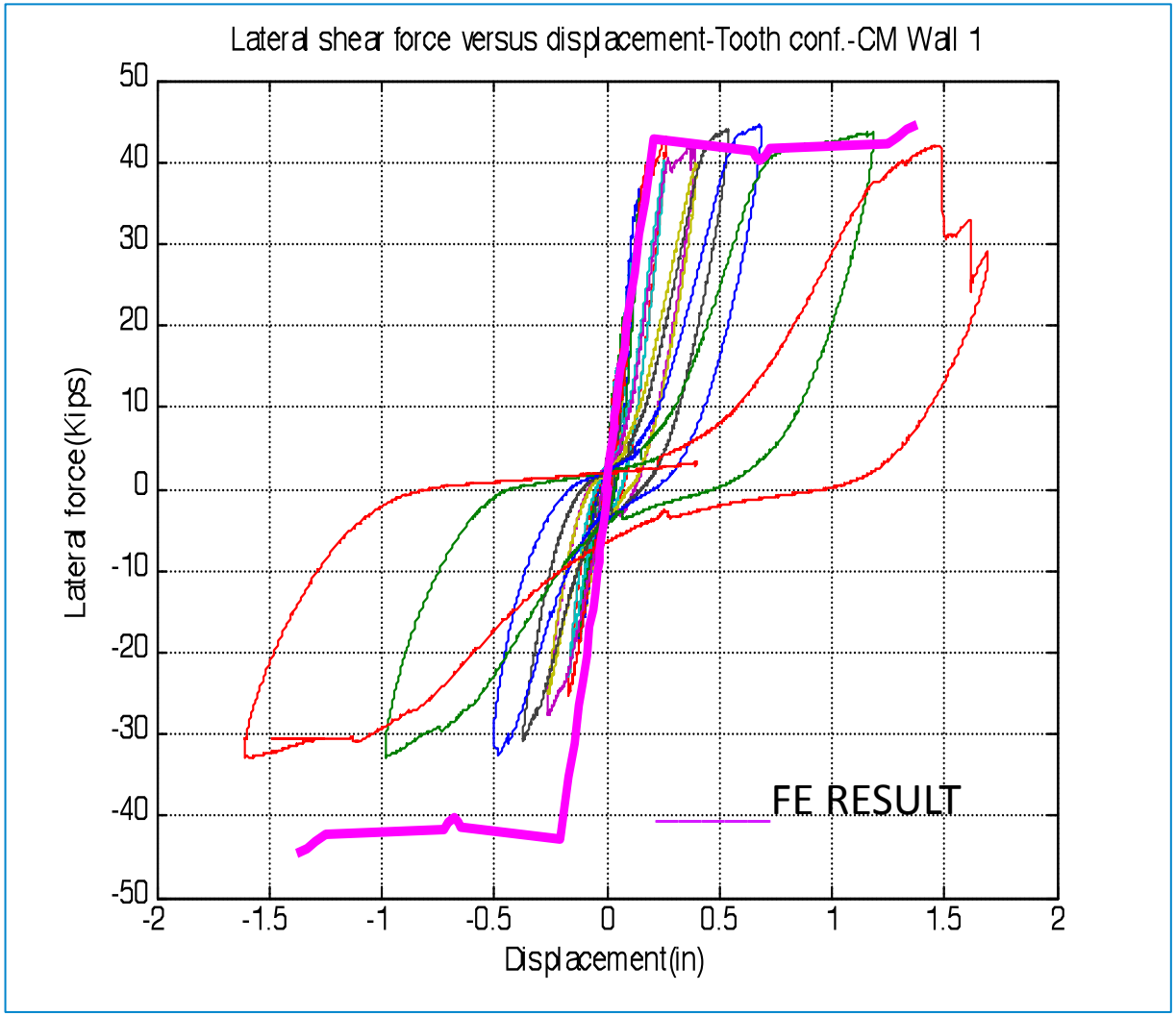






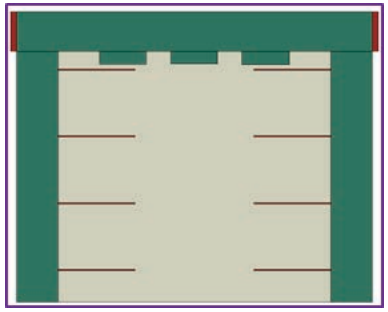
VALIDATION ON CM WALL 1

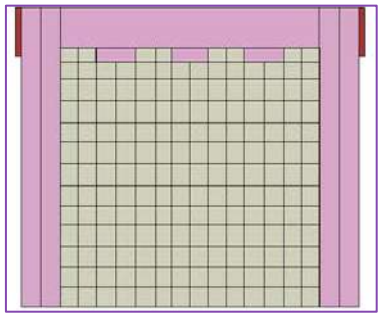
- 4.8Kips stiffer on the East loading direction
- 14.0 kips stiffer on the West loading direction.
- Time step of 0.001” in 100 increments



VALIDATION ON CM WALL 2

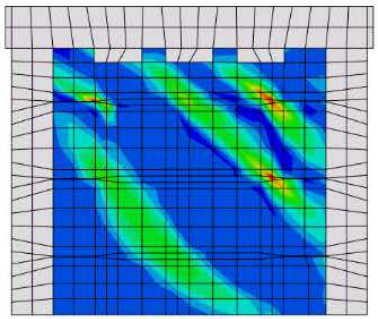
FE Model

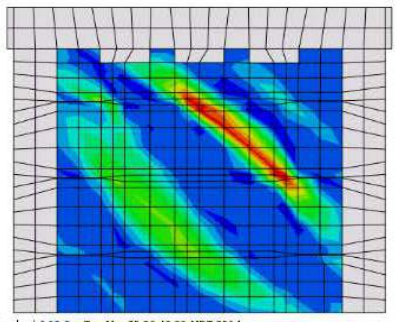


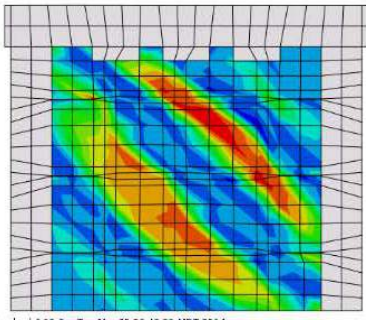


- Model Features:
- Software: ABAQUS
- Using user subroutine
- 402 4-node 2D plane stress elements
- Mesh size of 3.4inx3.4in
- Finite strain theory

Damage propagates



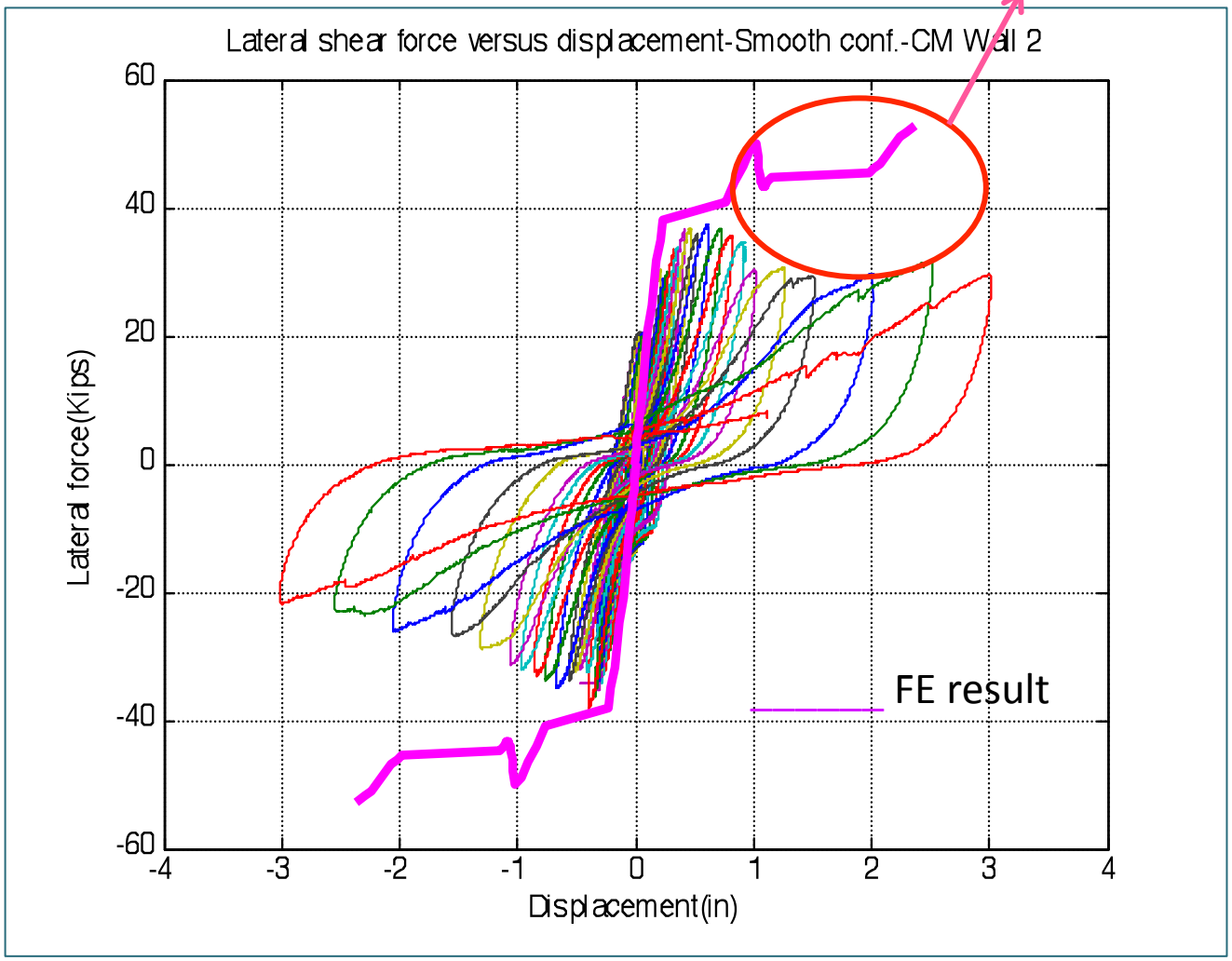




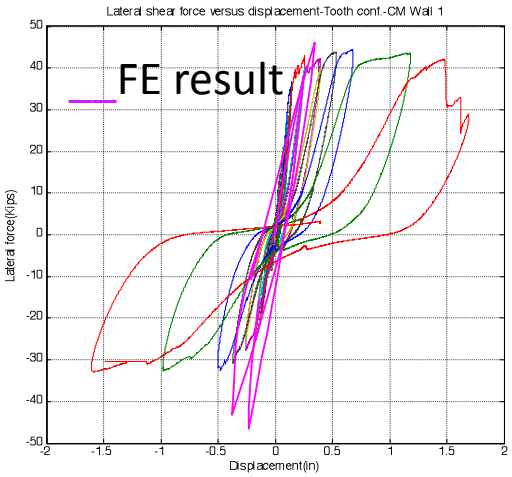
VALIDATION ON CM WALL 2

Sensitivity of FE result to perfect plasticity in steel

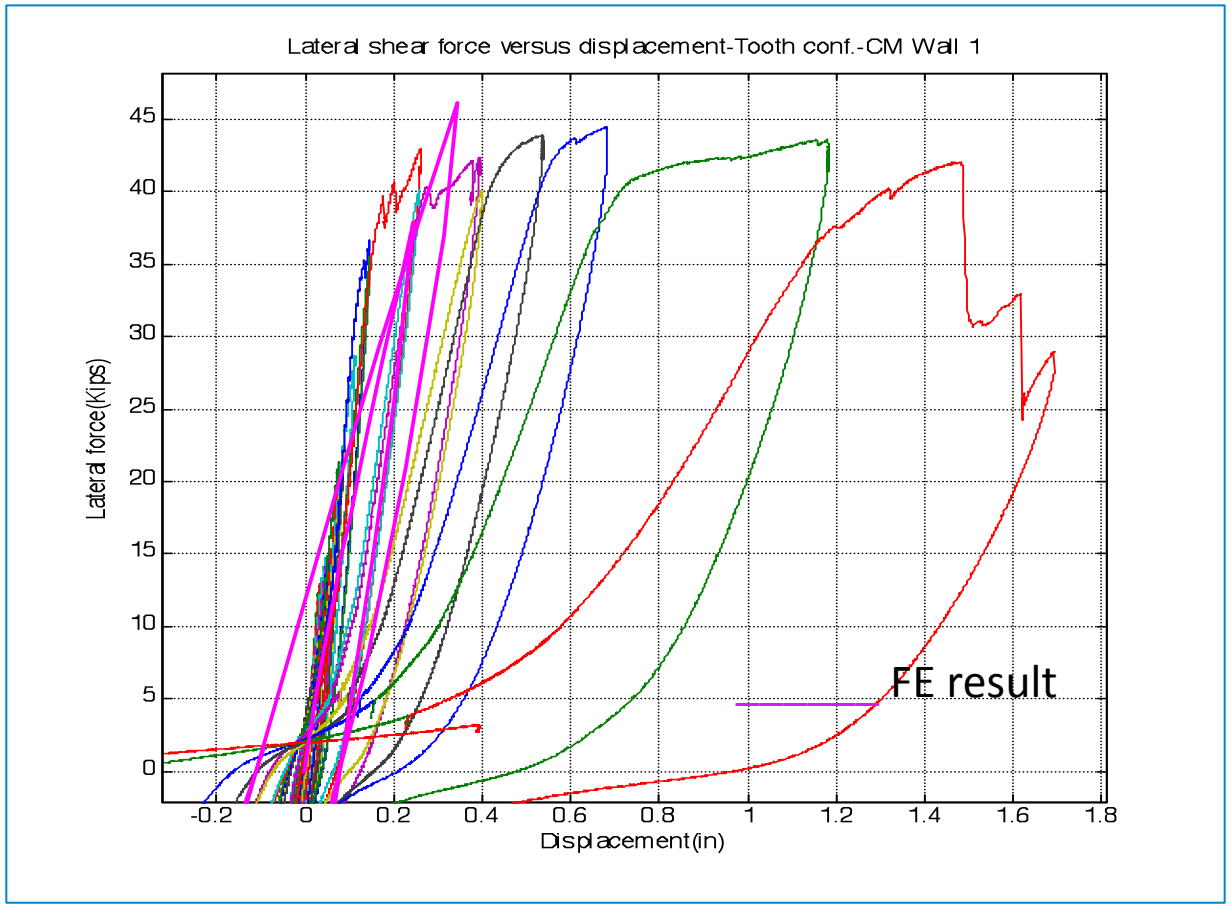
- 12 Kips stiffer on the East and West loading direction
- Time step of 0.001” in 1000 increments and 0.003” in 1000 increments



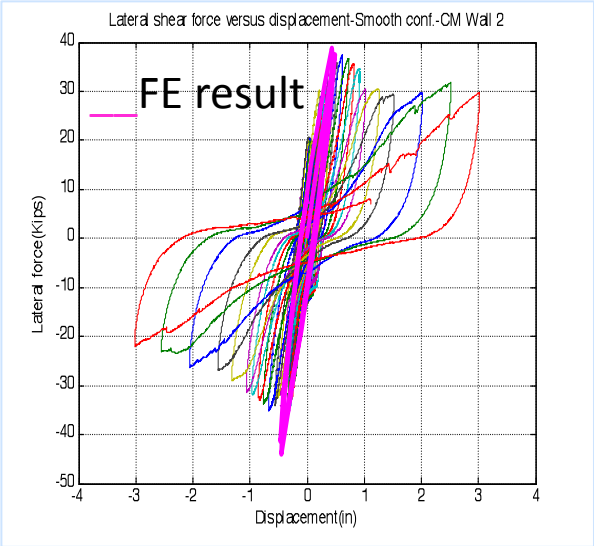
VALIDATION ON CYCLIC LOADING CM WALL 1



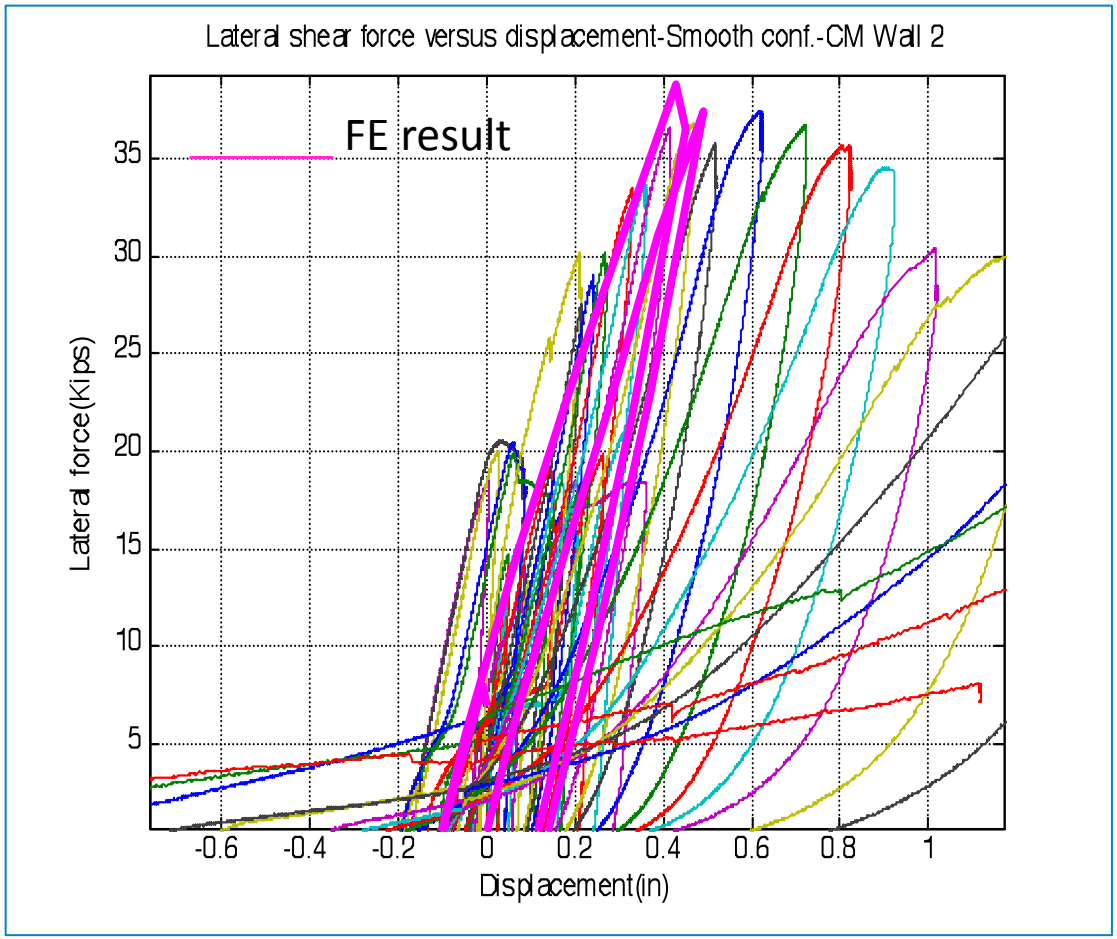
- Two cycles
- 0.001” and 0.00125” in 100 increments



VALIDATION ON CYCLIC LOADING CM WALL 2



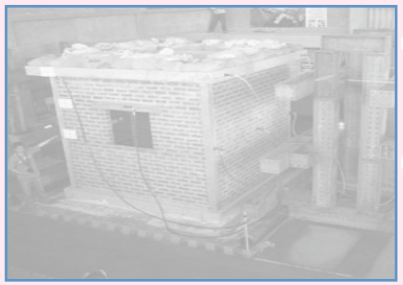
- Two cycles
- 0.001” and 0.003” in 100 increments



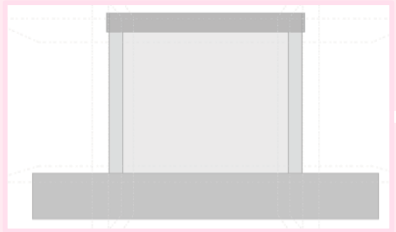
EXPERIMENTAL TESTING

NGUYEN'S WALLS

QUINUN'S WALLS



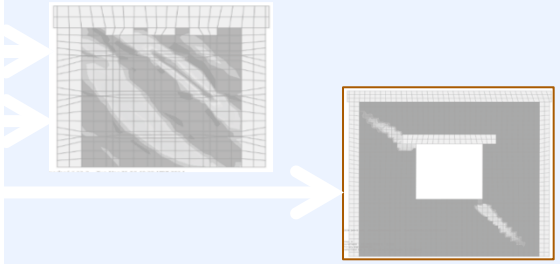
TOMAZEVIC'S WALLS



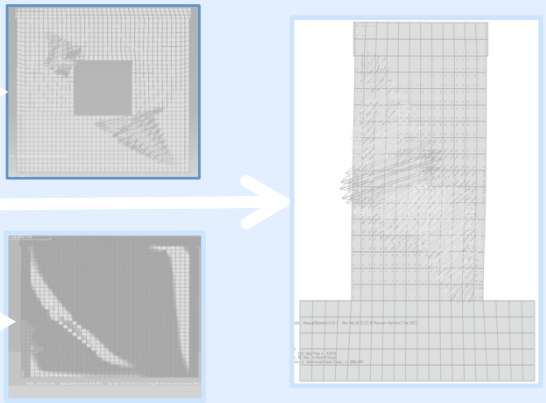
COMPONENTS TEST

FINITE ELEMENT ANALYSIS

FINITE ELEMENT USER SUBROUTINE

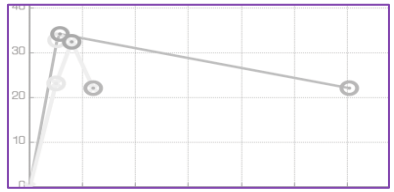


BUILT IN MODELS

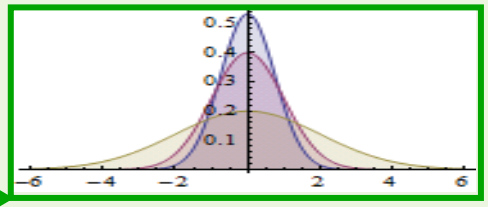


MACRO ANALYSIS

RESPONSE PREDICTION



SAFETY DESIGN ASPECT



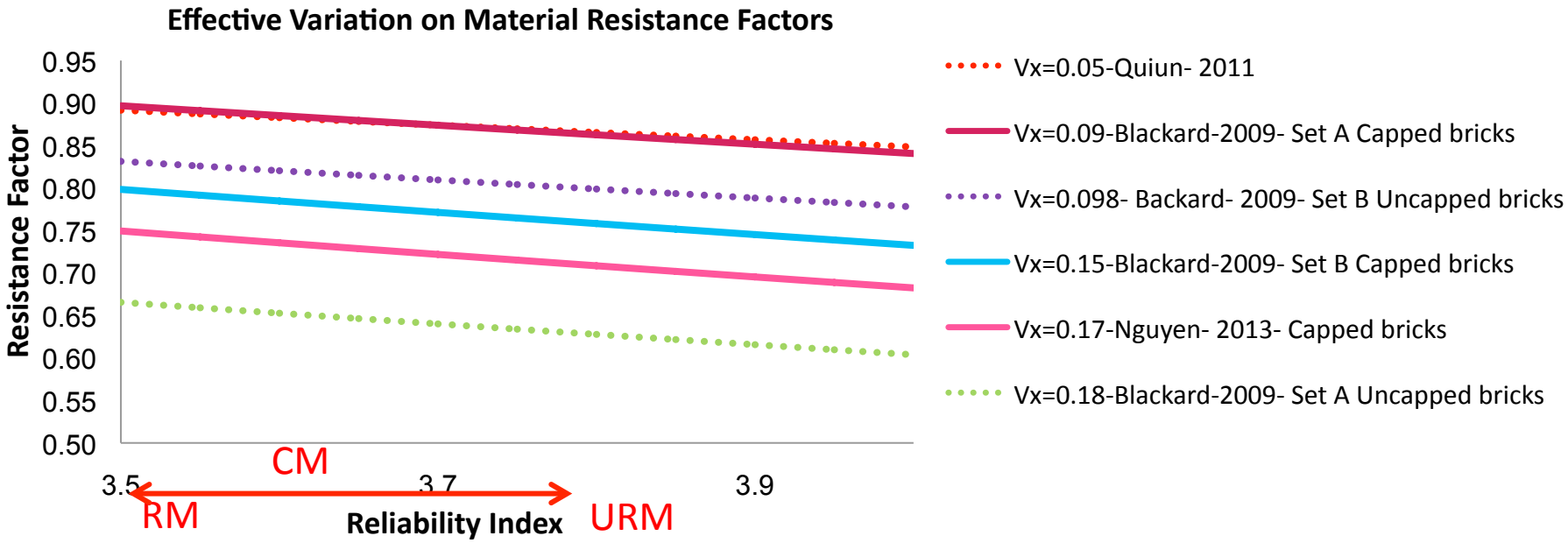
INVESTIGATE THE EFFECT OF MATERIAL PROPERTIES ON STRUCTURAL RELIABILITY OF CM

- Relationship between resistance factor $\emptyset$ and reliability index β:

  - Correction factor C
  - Average strength and nominal member strength ratio $\frac{R}{R_n}$
  - Coefficient of variation V_x.

$$\emptyset = C\frac{R}{R_n}e^{-0.75\beta V_x}$$

Adapted from Prof. Kazemi's study, 2011



STUDY CONTRIBUTIONS

- Introduced CM, and behavior of CM shear walls subjected to in plane loading.
- Provided the answer for the impact of different configurations and design aspects on the CM shear wall
- Constructed a finite element model to perform numerical analysis for CM shear walls.
- Investigated the effect of material properties on structural reliability of CM.

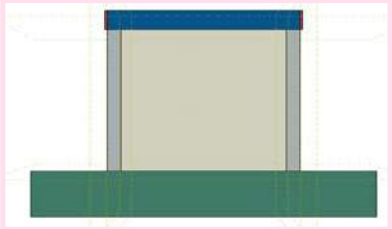
PROJECT RECAP

EXPERIMENTAL TESTING

NGUYEN'S WALLS

QUINUN'S WALLS

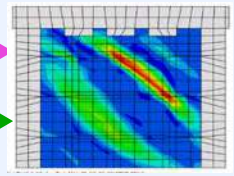
TOMAZEVIC'S WALLS

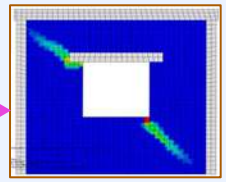


COMPONENTS TEST

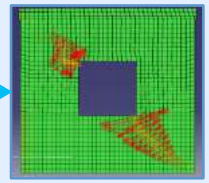
FINITE ELEMENT ANALYSIS

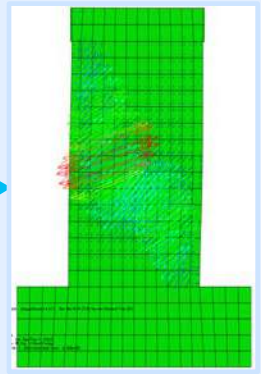
FINITE ELEMENT USER SUBROUTINE

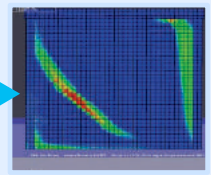




BUILT IN MODELS

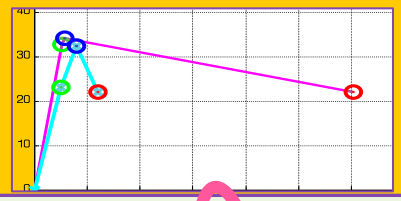






MACRO ANALYSIS

RESPONSE PREDICTION



SAFETY DESIGN ASPECT