Numerical modelling of URM buildings with timber diaphragms

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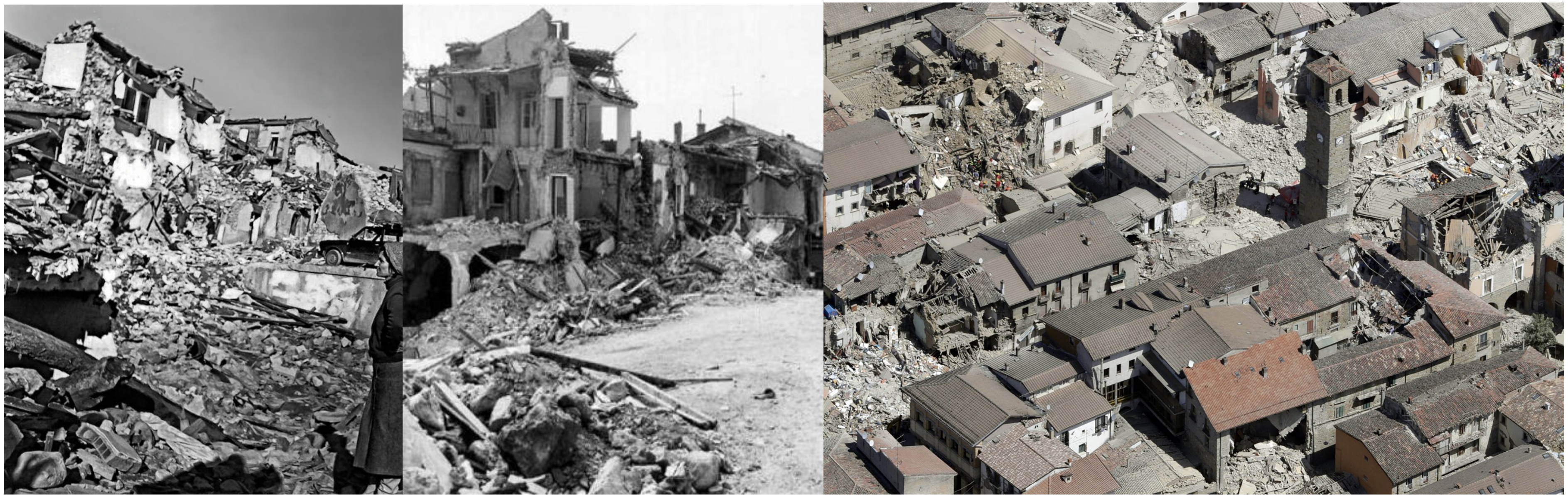
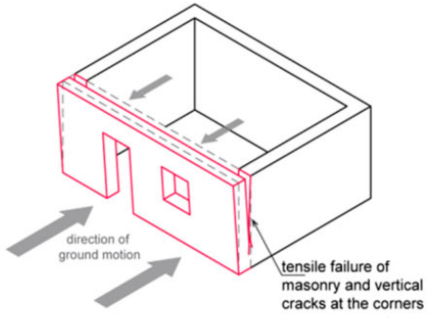


Introduction & Background

Seismic behaviour of URM buildings

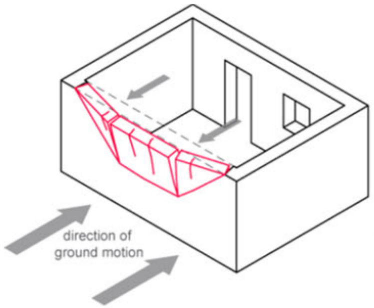
Local out-of-plane mechanisms

- ❑ Overturning
- ❑ Flexural failure



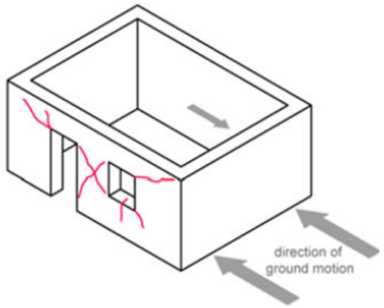
Global mechanism

- ❑ Interaction between out-of-plane and in-plane walls



Vulnerabilities

- ❑ Low material properties
- ❑ Unfavourable geometrical layout
- ❑ High mass
- ❑ <u>Inappropriate diaphragm stiffness</u>
- ❑ <u>Poor connections</u>



Ortega et al. (2018)

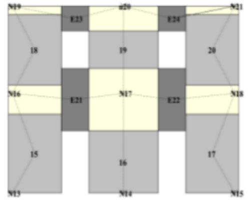
Modelling & Analysis

Macro-element models

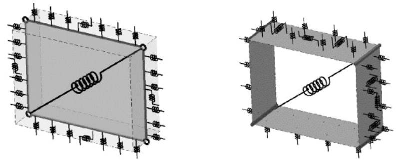
Refined FE models

Assumptions

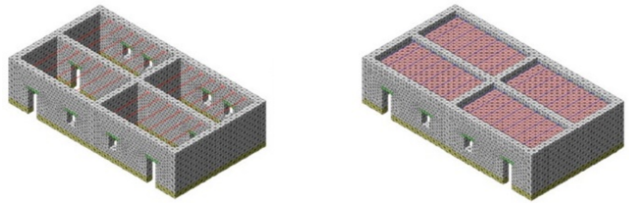
- ❑ Diaphragms:
  Linear elastic behaviour
- ❑ WTD connections:
  Hinged or fixed



Cattari et al. (2015)



Pantò et al. (2016)



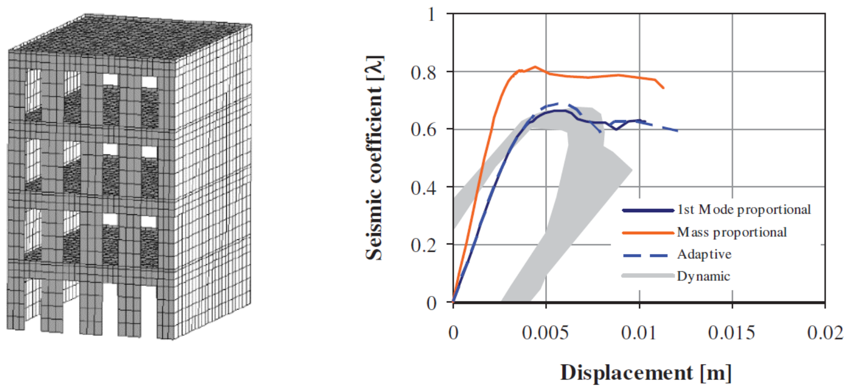
Ortega et al. (2018)

Time-history analysis

Pushover analysis

Assumptions

- ❑ Seismic input
- ❑ Control node



Mendes and Lourenço (2010)

Experimental tests

Overall structural behaviour

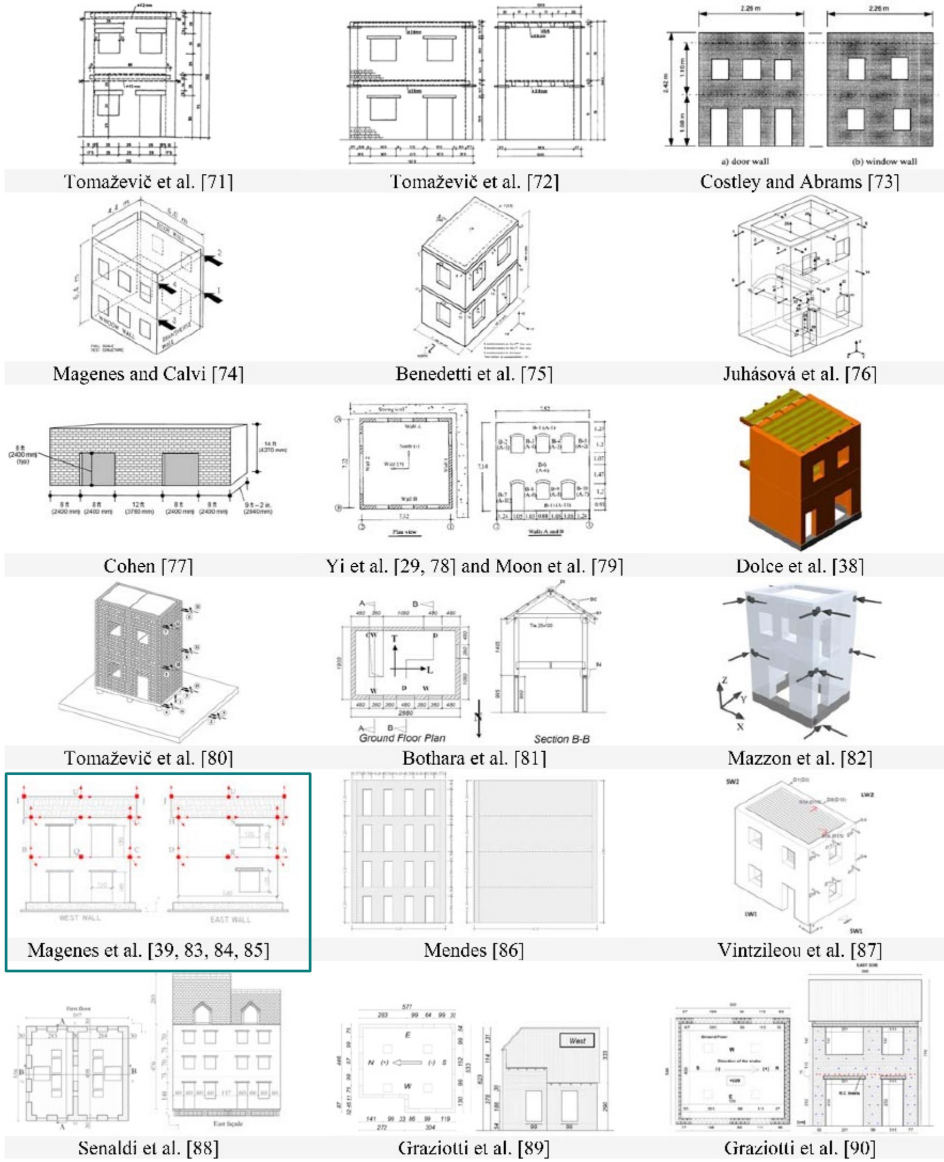
Strengthening techniques

Stiffer diaphragms

- ❑ Torsional effects
- ❑ Other failure mechanisms

Limitations

- ❑ Large variety
- ❑ Limited number of specimens
- ❑ Focused on masonry



Tomaževič et al. [71] | Tomaževič et al. [72] | Costley and Abrams [73]
Magenes and Calvi [74] | Benedetti et al. [75] | Juhásová et al. [76]
Cohen [77] | Yi et al. [29, 78] and Moon et al. [79] | Dolce et al. [38]
Tomaževič et al. [80] | Bothara et al. [81] | Mazzon et al. [82]
Magenes et al. [39, 83, 84, 85] | Mendes [86] | Vintzileou et al. [87]
Senaldi et al. [88] | Graziotti et al. [89] | Graziotti et al. [90]

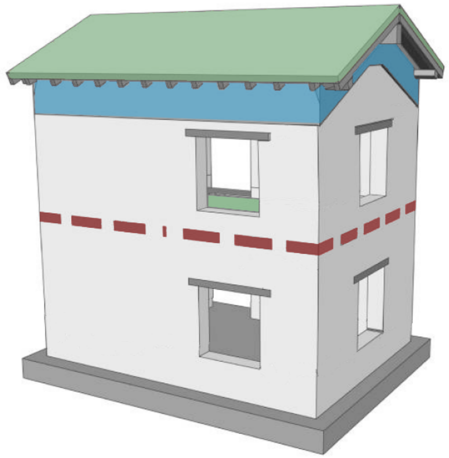
EUCENTRE experimental campaign

Full-scale prototype buildings (EUCENTRE)

Building 1

Unstrengthened configuration

Building 2



Double layer of planks
Steel ring beam
Masonry ring beam

Building 3

Double layer of planks
Steel ring beam
R.C ring beam
R.C. slab

Full-scale prototype buildings (EUCENTRE)

Building 1

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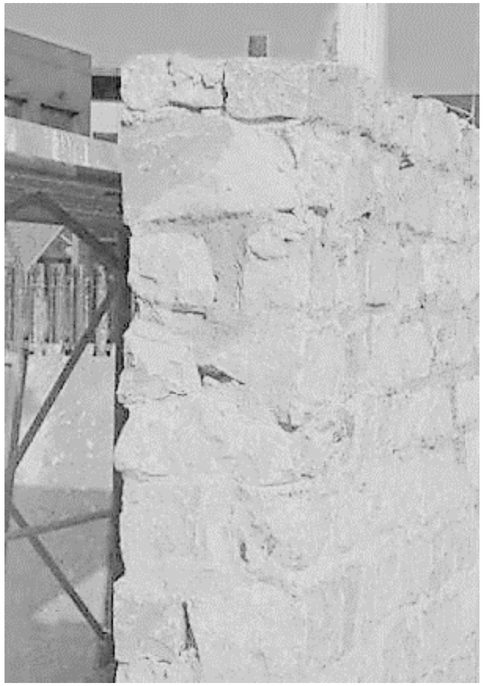
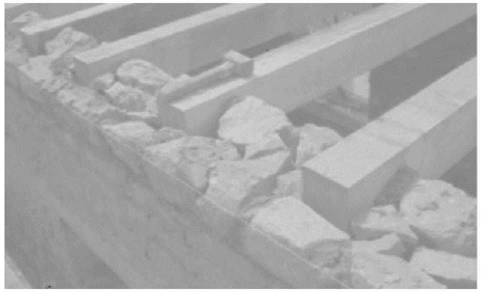
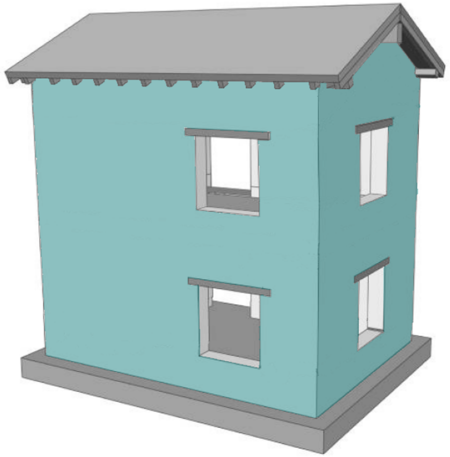




Senaldi (2014)

Full-scale prototype buildings (EUCENTRE)

Building 1



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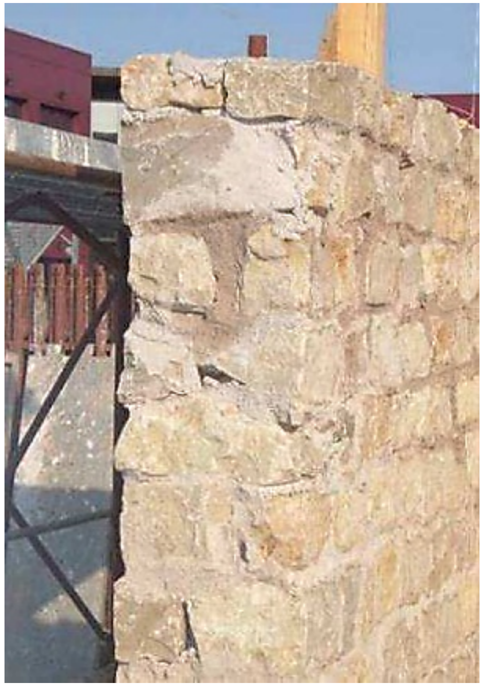

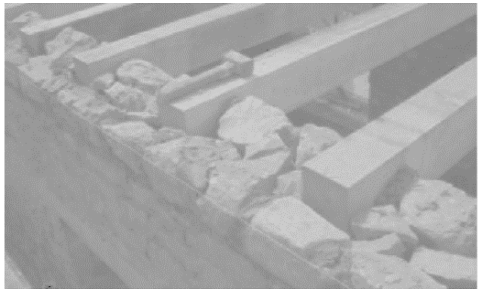

Senaldi (2014)

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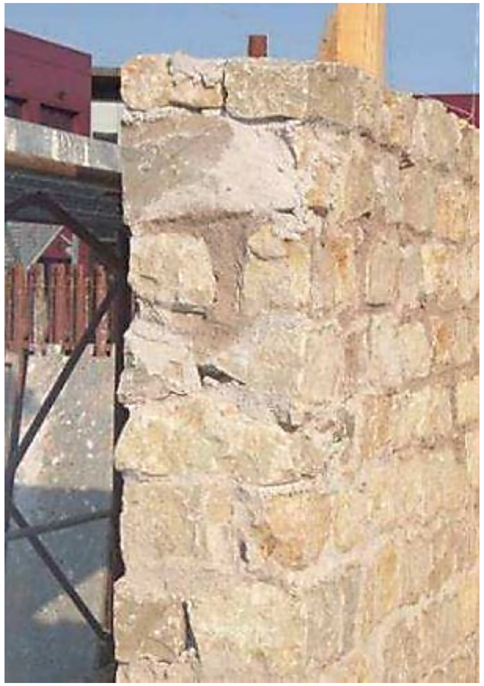

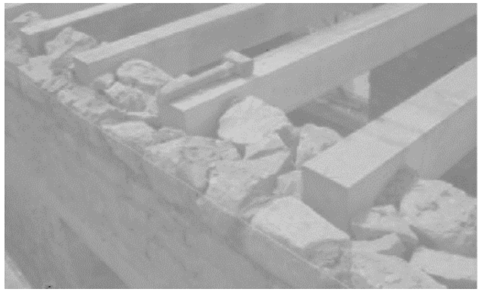

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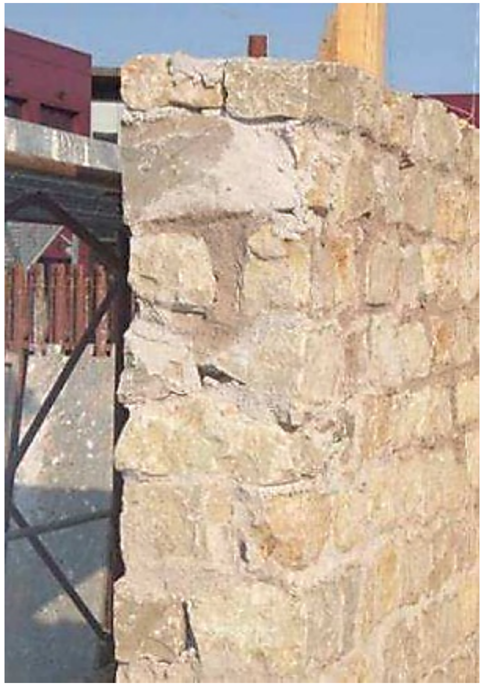
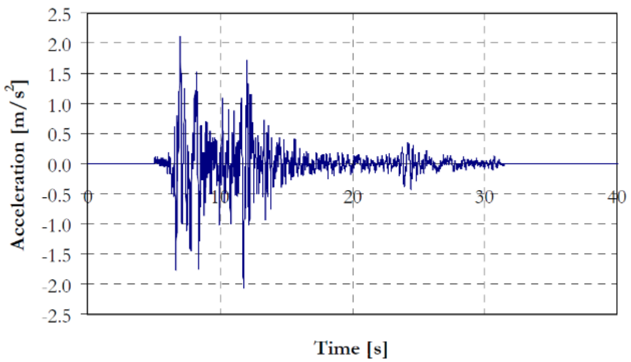


Senaldi (2014)

Incremental dynamic testing

Magenes et al. (2010)
https://www.youtube.com/watch?v=SspfD-nHCso

1979 Montenegro earthquake



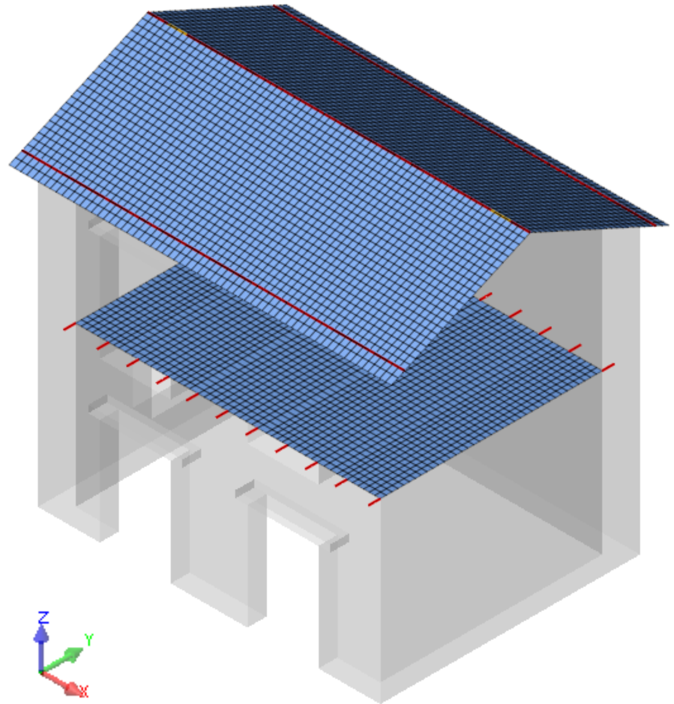
Test	Nominal PGA (g)	Actual PGA (g)
1	0.05	0.07
2	0.10	0.14
3	0.20	0.31
4	0.30	0.50
5	0.40	0.63

Numerical modelling

Numerical model

Timber diaphragms

- Shell elements
- Beam elements



Numerical model

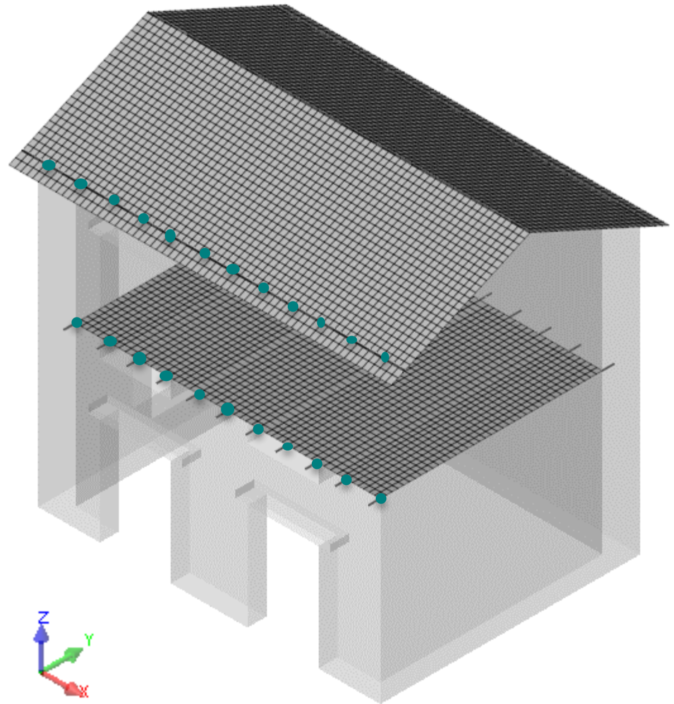
Timber diaphragms

- ❑ Shell elements
- ❑ Beam elements

Isotropic homogeneous and linear elastic behaviour

Beam elements (EN 338 2016)	
Modulus of elasticity (MPa)	10000
Poisson ratio v (-)	0.30
Equivalent specific weight (KN/m^3)	41.00
	266.00
	448.00

Shell elements (NZSEE 2017)	
Equivalent shear modulus (MPa)	8.83
Specific weight (KN/m^3)	~ 0.00



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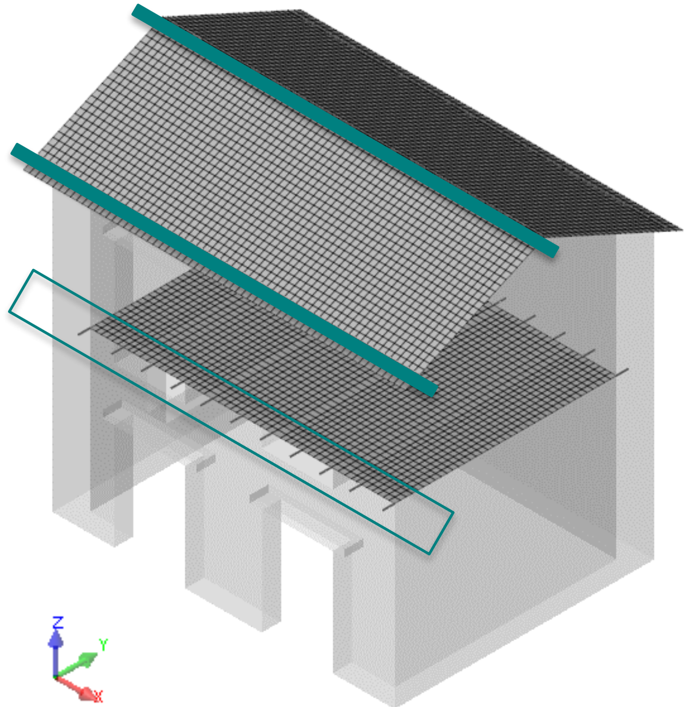

Numerical model

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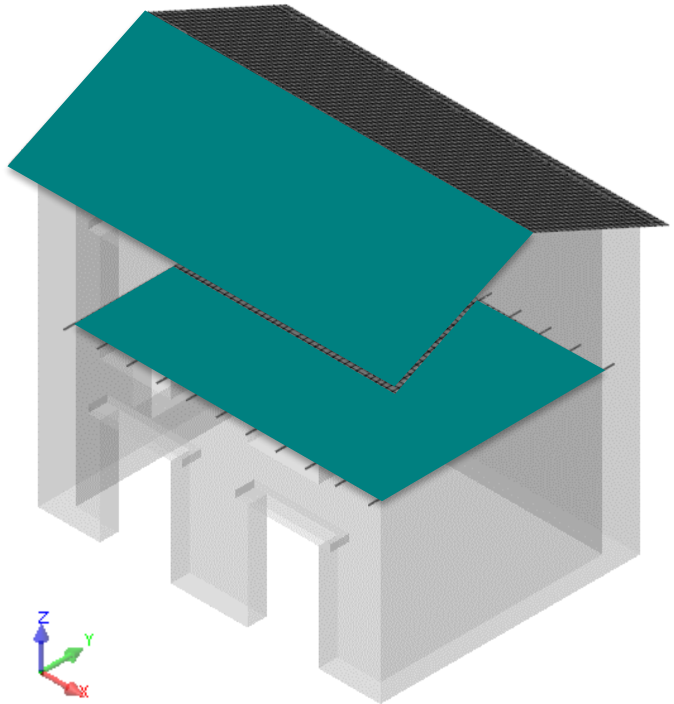

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Numerical model

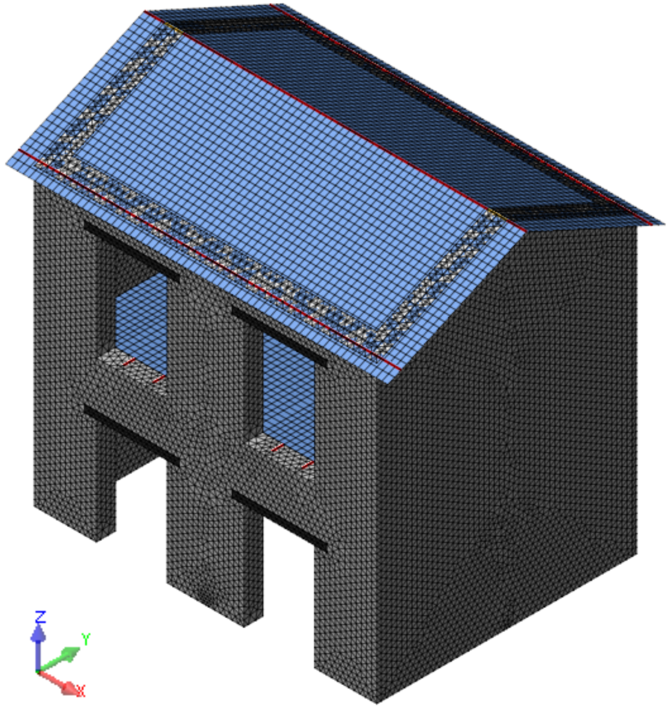
Masonry walls

- ❑ Solid elements

Nonlinear behaviour

- ❑ Total Strain Rotating Crack Model

Solid elements	
Modulus of elasticity (MPa)	2550
Poisson ratio v (-)	0.20
Compressive strength (MPa)	3.28
Tensile strength (MPa)	0.14
Fracture energy in compression (N/mm)	12.90
Fracture energy in tension (N/mm)	0.01
Specific weight (KN/m^3)	23.00



Numerical model

Masonry walls

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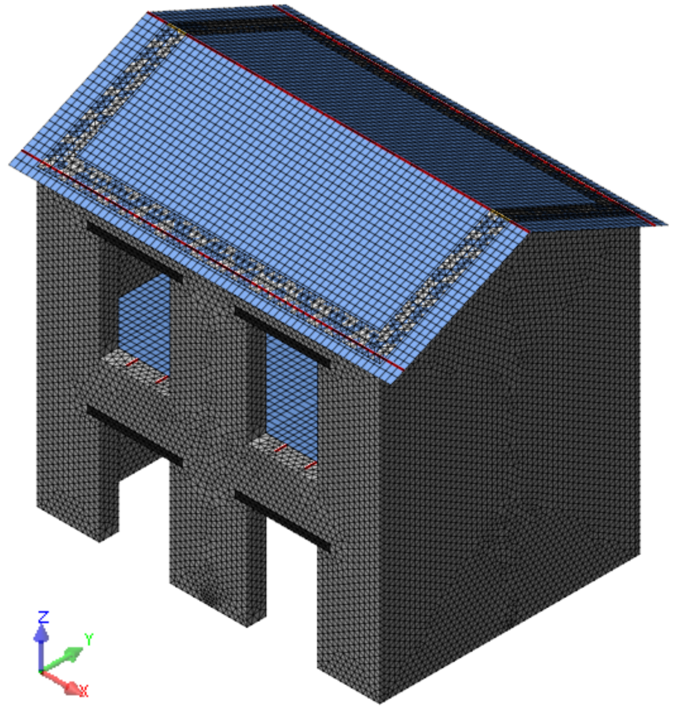

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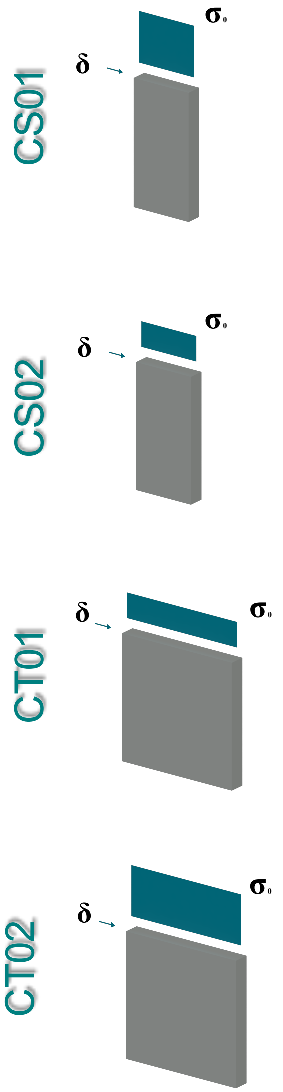
In-plane cyclic shear test simulation



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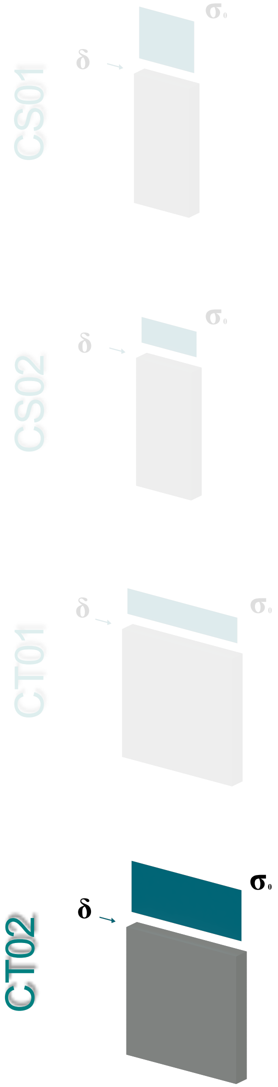


Geometry

- ❑ H = 2500 mm
- ❑ B = 2500 mm
- ❑ t = 320 mm

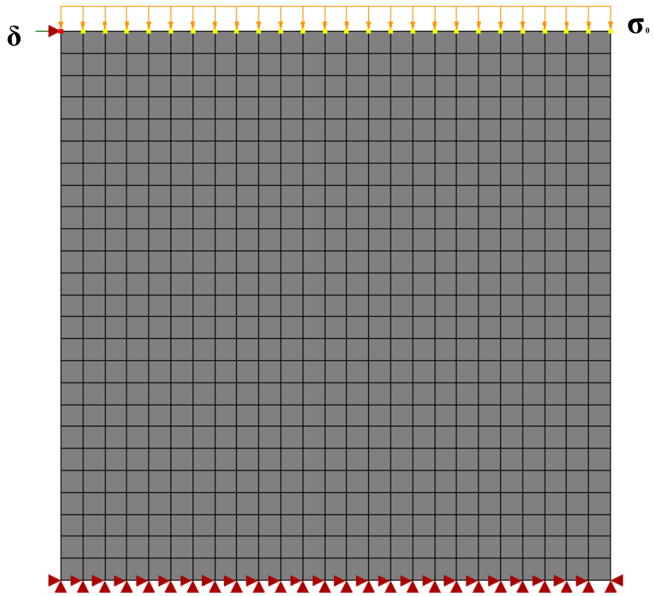
Axial load level (0.20 MPa)

Double bending condition

Magenes et al. (2010)

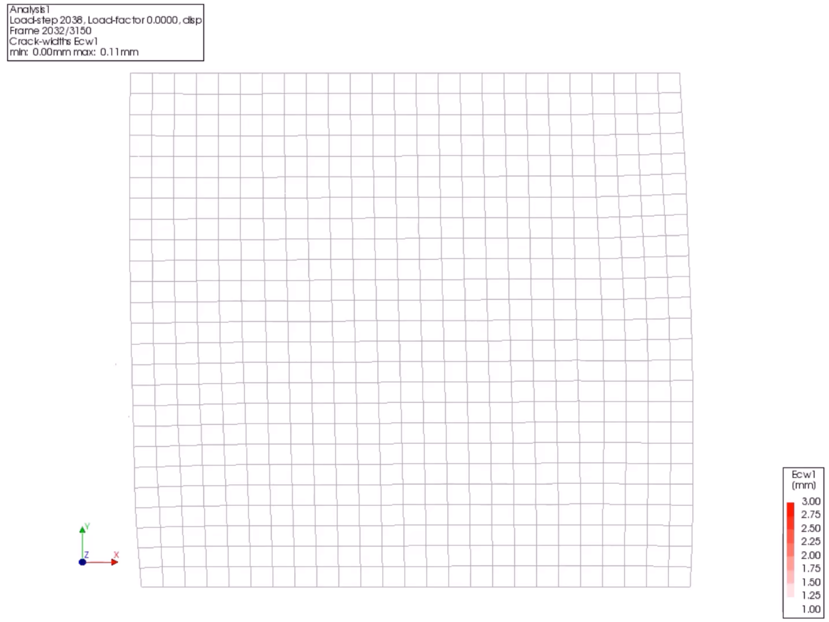
In-plane cyclic shear test simulation

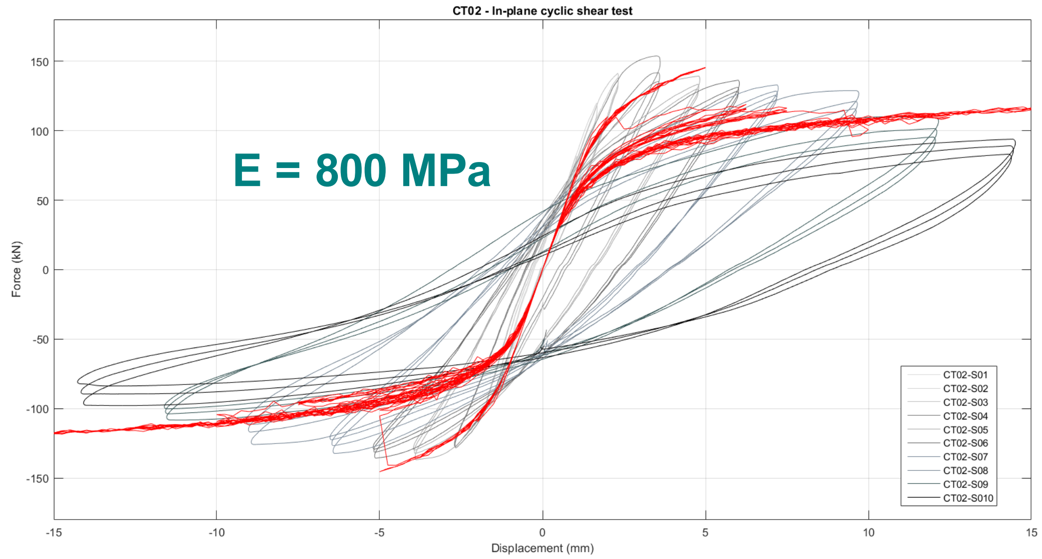
Plane stress model



In-plane cyclic shear test simulation

Plane stress model



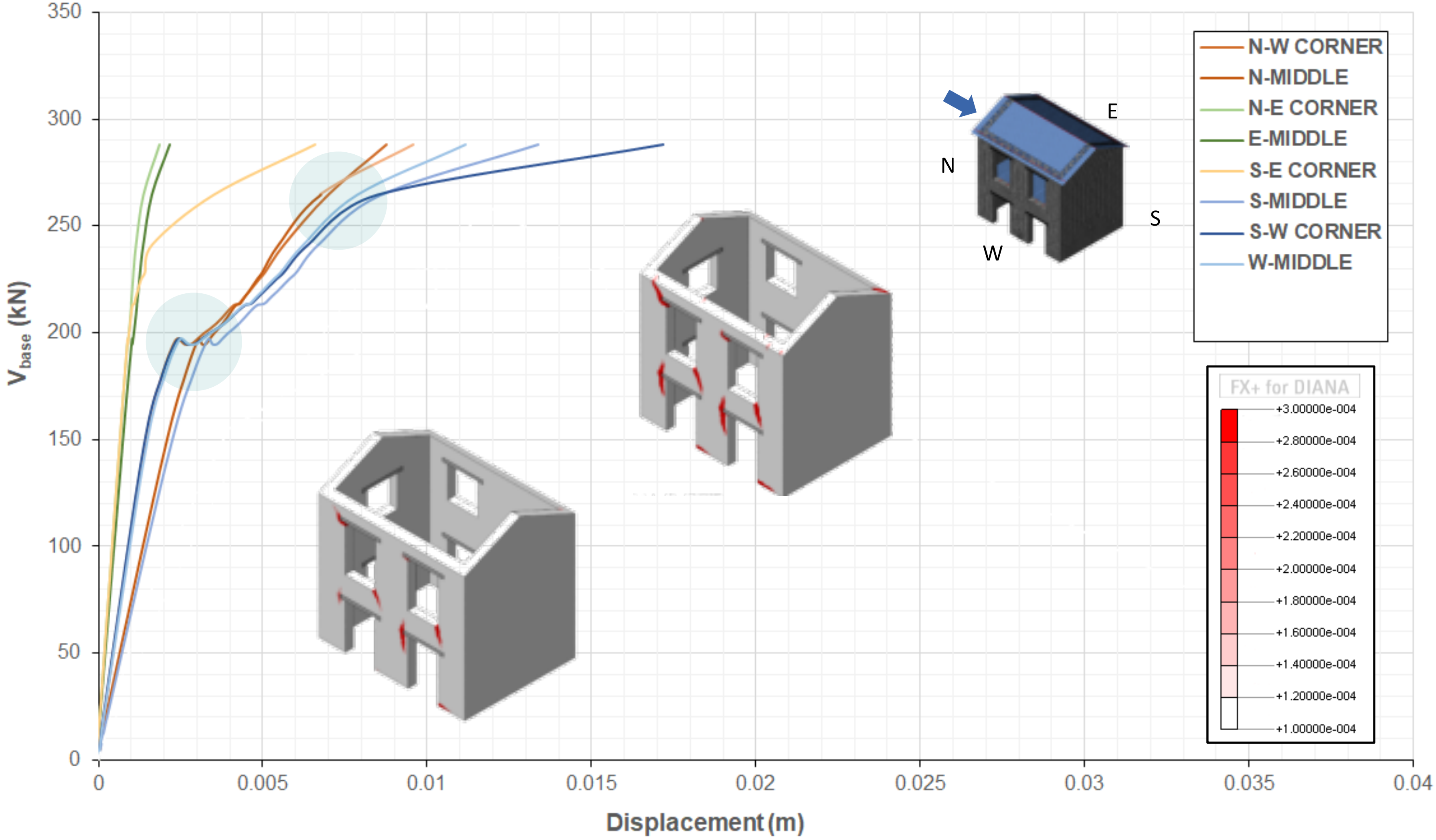


$$K = \frac{F}{\Delta} = \left[\frac{H^3}{12EI} + \frac{H}{A_v G}\right]^{-1} \qquad E = K\frac{H}{Bt}\left(\frac{H^2}{B^2} + 3\right)$$

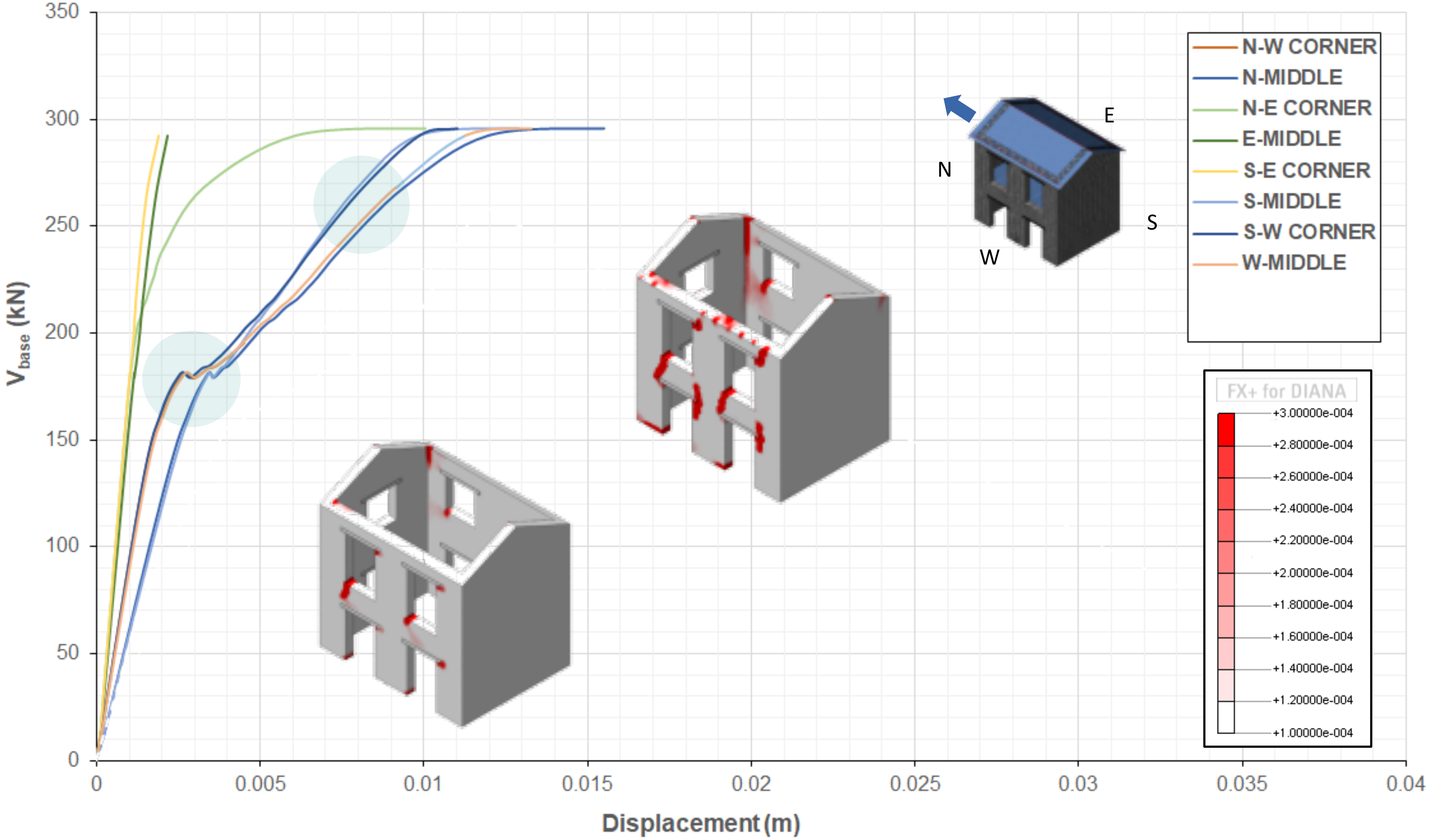
$$\mathbf{K = 73\frac{kN}{mm},} \qquad \mathbf{E = 900\ MPa}$$

Pushover analysis

Pushover analysis (N-S direction)

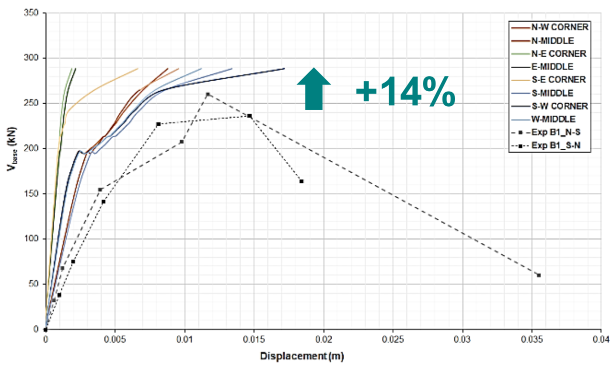


Pushover analysis (S-N direction)



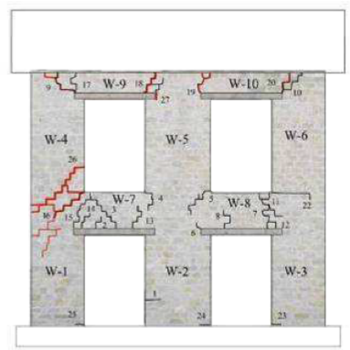
Comparison

Pushover N-S



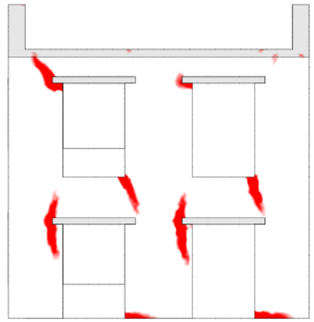
+14%

Experimental

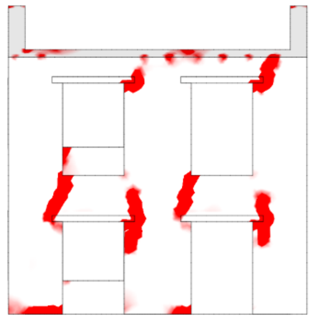


Senaldi (2014)

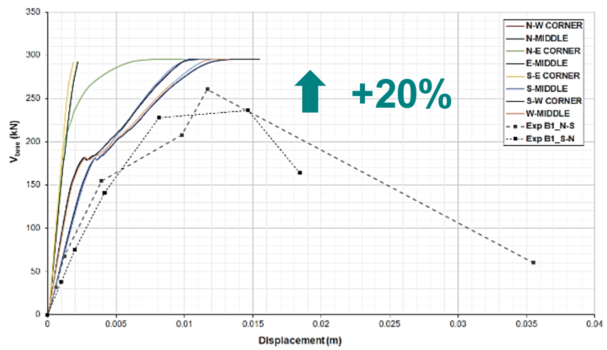
Pushover N-S



Pushover S-N

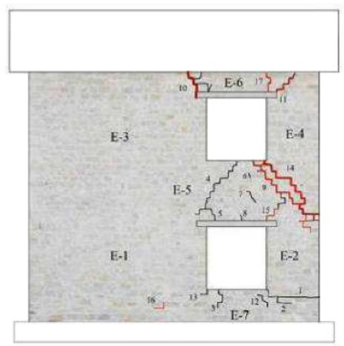


Pushover S-N



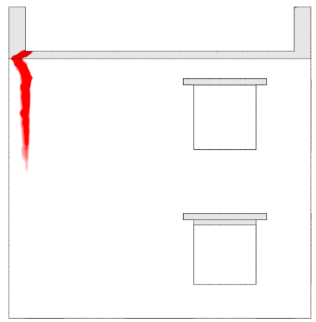
+20%

Experimental

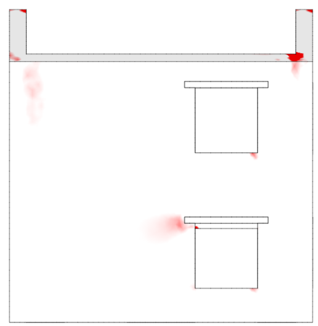


Senaldi (2014)

Pushover N-S



Pushover S-N



Conclusions & Future Work

Conclusions & Future Work

❑ Slight overestimation of lateral stiffness and capacity

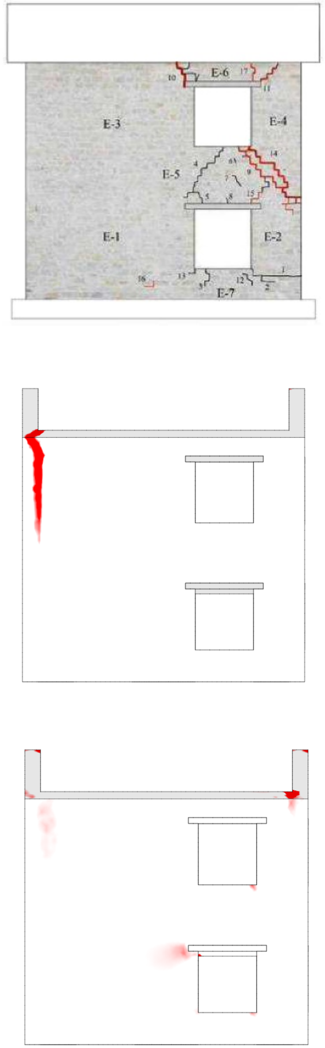
❑ Good damage correlation for the West wall

❑ Equivalent shear modulus of diaphragms

❑ Shear behaviour of masonry walls

❑ Wall intersection

❑ Implement nonlinear behaviour of WTD connections



East wall

Thank you

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