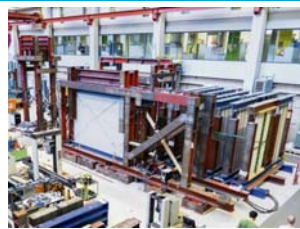


Cyclisch testen van wanden en samengestelde constructies voor het beoordelen van de capaciteitscurves onder seismische belasting in Groningen

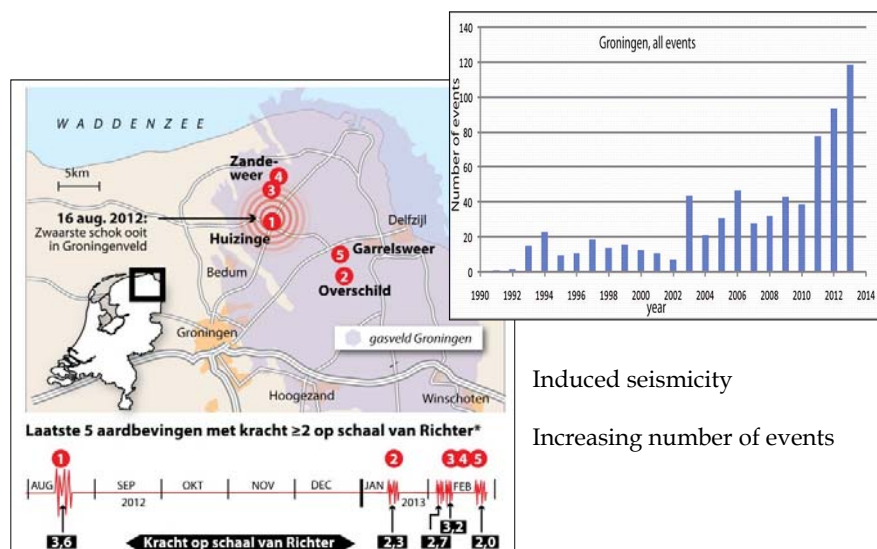
Cyclic testing of walls and assembled structures to evaluate the capacity curves under seismic loading in Groningen

Dr. Ir. Geert Ravenshorst
Delft University of Technology



Bouwen met Staal Techniekdag TU Delft 18 mei 2016

Seismic events due to gas extraction



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Impact on structures



Majority of structures = Unreinforced Masonry (URM)



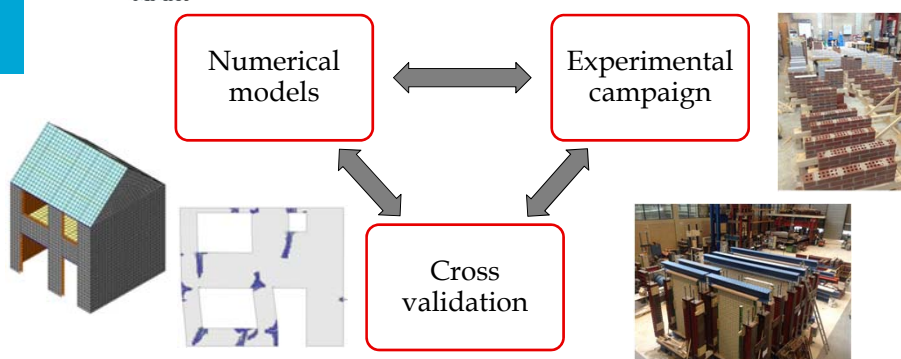
TU Delft

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Current research project

Assessment structural safety
Integrated approach



TU Delft
Delft University of Technology

EUCENTRE
European Centre for Training and Research in Earthquake Engineering

ARUP

TU Delft

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Experimental campaign at TU Delft in 2015



Material tests



Component tests



Full scale structure



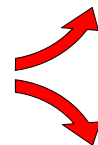
Bouwen met Staal Techniekdag TU Delft 18 mei 2016

Experimental campaign at TU Delft

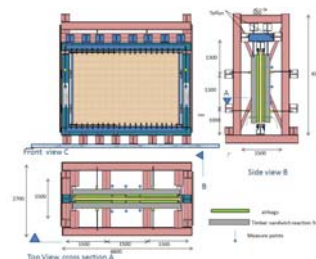
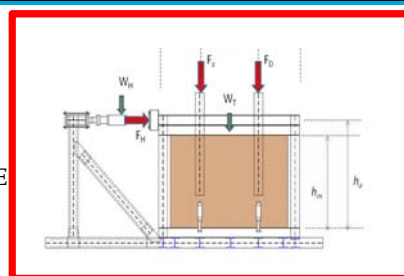


Component tests

IN-PLANE
TESTS



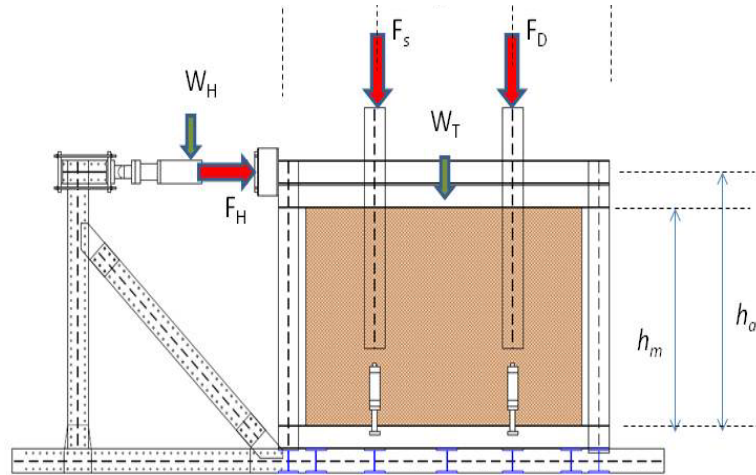
OUT-OF-PLANE
TESTS



Bouwen met Staal Techniekdag TU Delft 18 mei 2016

Experimental campaign at TU Delft

IN-PLANE TESTS

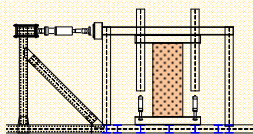


Bouwen met Staal Techniekdag TU Delft 18 mei 2016

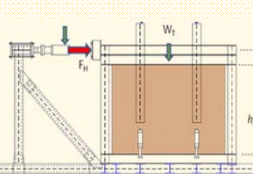
In-plane tests (CS bricks thickness 102 mm)

• 2 GEOMETRIES:

- SHORT WALLS
1,1m x 2,76m

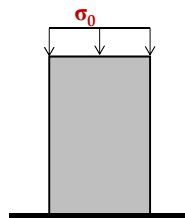


- LONG WALLS
4m x 2,76m



• 3 LEVELS of VERTICAL PRESSURE (σ_0):

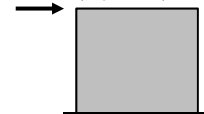
- 0,3 MPa*
- 0,5 MPa
- 0,7 MPa



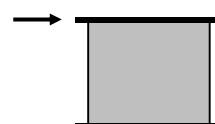
* For one specimen a pressure of 0,4 MPa in place of 0,3 MPa

• 2 BOUNDARY CONDITIONS:

- Cantilever
($H_0/H=1$)



- Double clamped
($H_0/H=0,5$)



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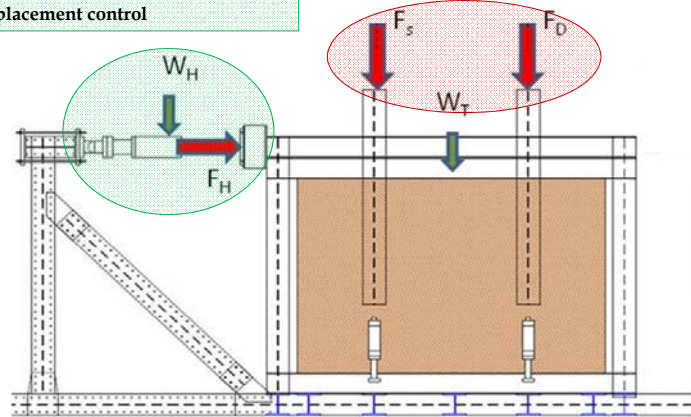
In-plane tests

Application of the load

Horizontal load applied by one horizontal actuator:
- Displacement control

Vertical load applied by two couples of actuators:

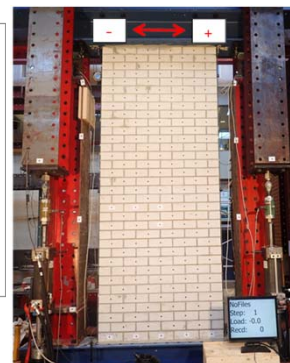
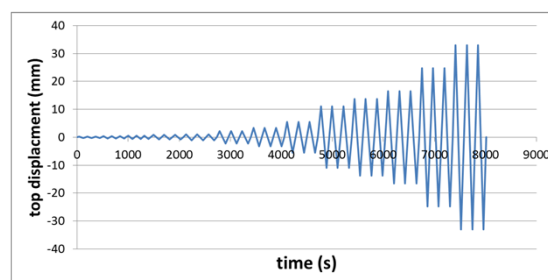
- Sum of forces (W_T) constant
- $F_S = F_D$ for cantilevers
- $F_S \neq F_D$ for double clamped walls (equal vertical displacements)



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In-plane tests

Loading scheme

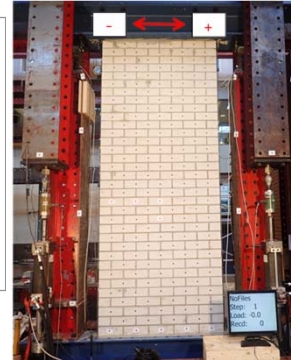
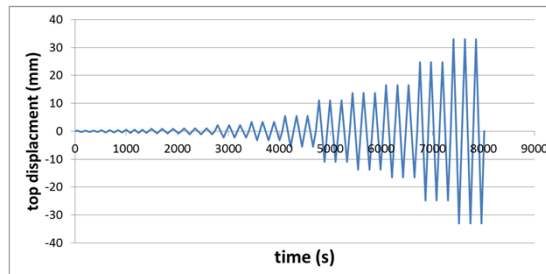


TUD-COMP-3



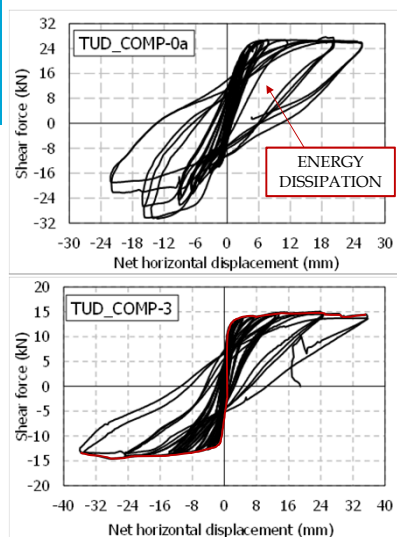
Bouwen met Staal Techniekdag TU Delft 18 mei 2016

Loading scheme

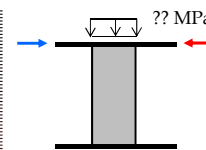
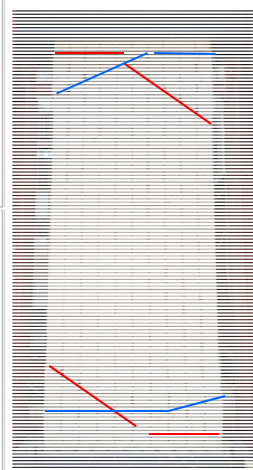


TUD-COMP-3

In-plane tests - SHORT WALLS



TUD_COMP-0a - TUD_COMP-3



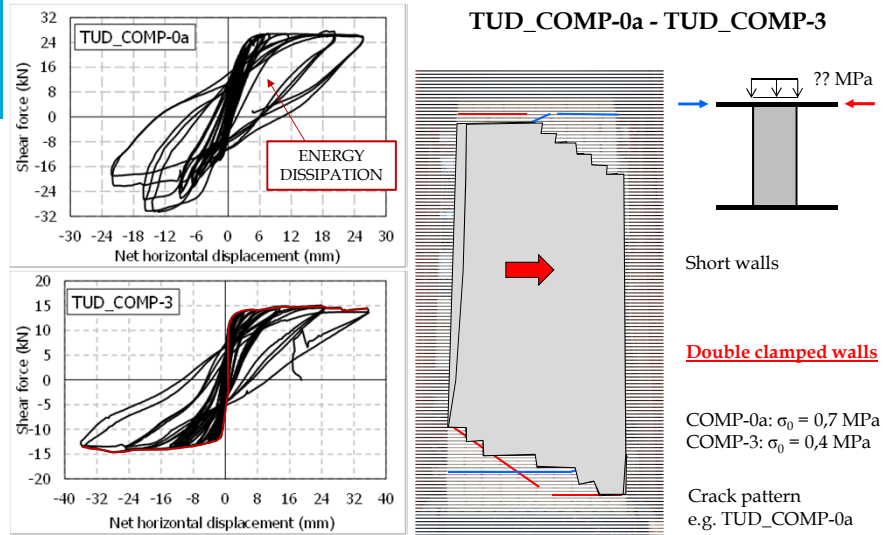
Short walls

Double clamped walls

COMP-0a: $\sigma_0 = 0,7 \text{ MPa}$
 COMP-3: $\sigma_0 = 0,4 \text{ MPa}$

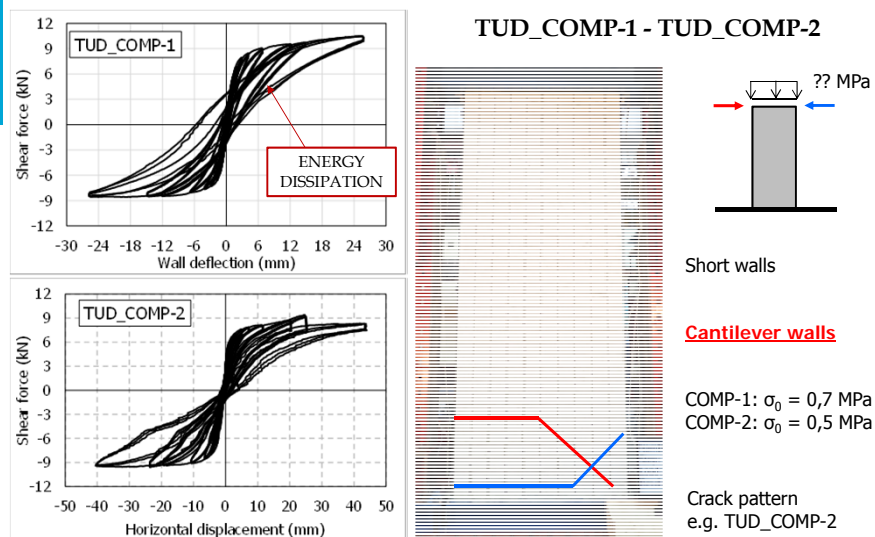
Crack pattern
 e.g. TUD_COMP-0a

In-plane tests - SHORT WALLS



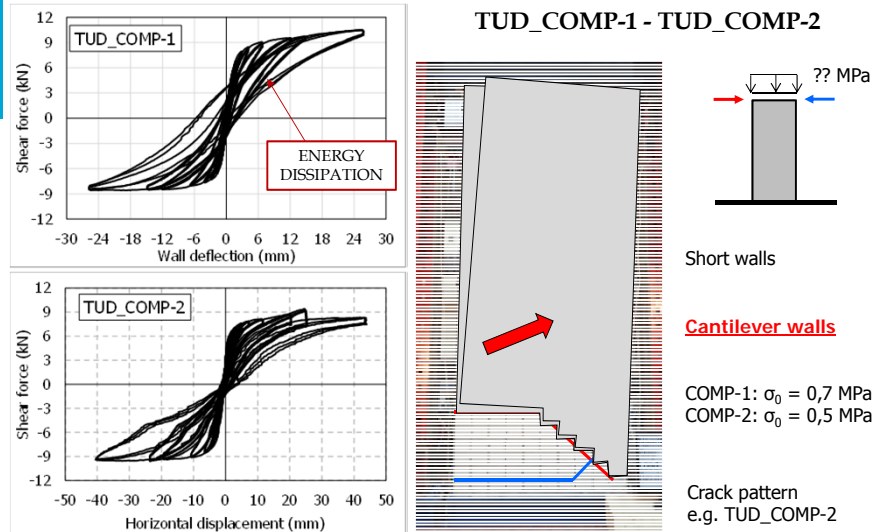
Bouwen met Staal Techniekdag TU Delft 18 mei 2016

In-plane tests - SHORT WALLS



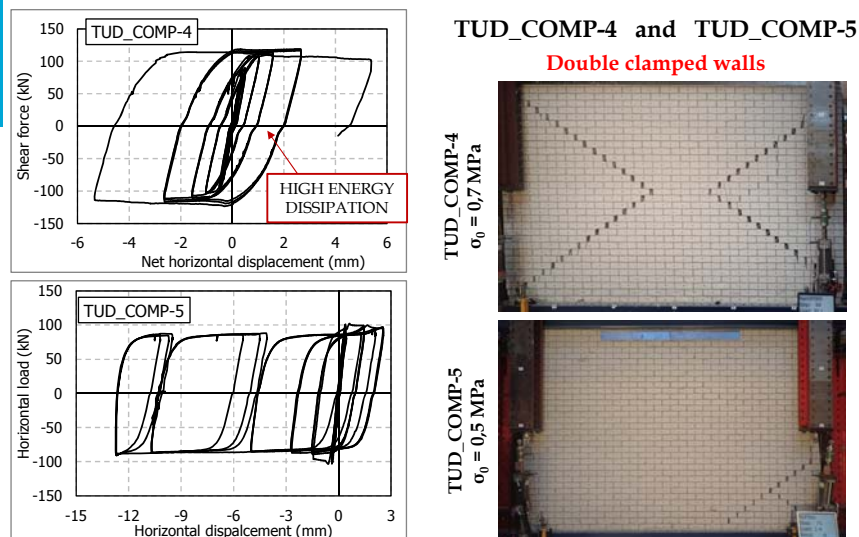
Bouwen met Staal Techniekdag TU Delft 18 mei 2016

In-plane tests - SHORT WALLS



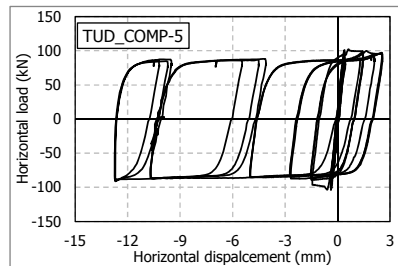
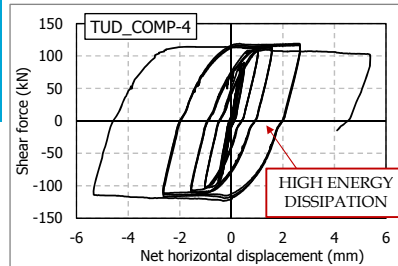
Bouwen met Staal Techniekdag TU Delft 18 mei 2016

In-plane tests - LONG WALLS



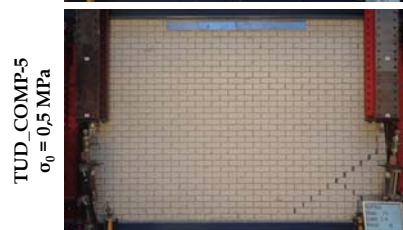
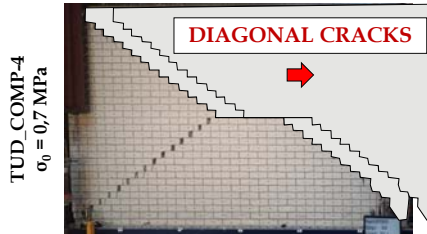
Bouwen met Staal Techniekdag TU Delft 18 mei 2016

In-plane tests - LONG WALLS



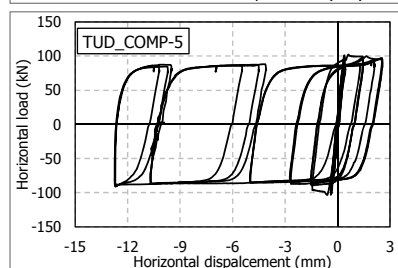
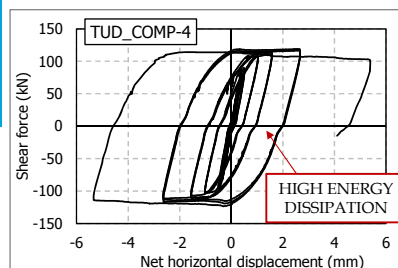
TUD_COMP-4 and TUD_COMP-5

Double clamped walls



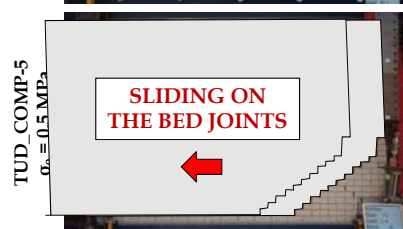
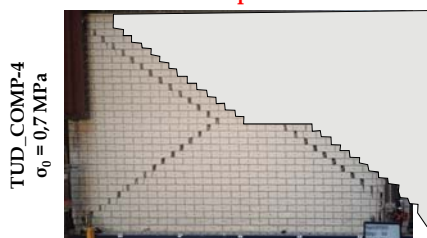
Bouwen met Staal Techniekdag TU Delft 18 mei 2016

In-plane tests - LONG WALLS



TUD_COMP-4 and TUD_COMP-5

Double clamped walls



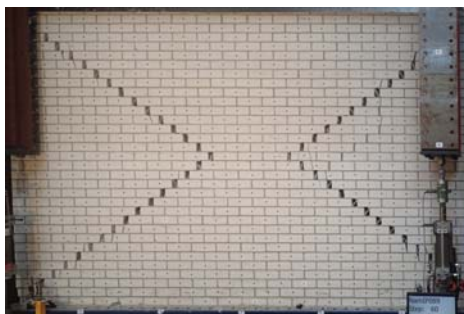
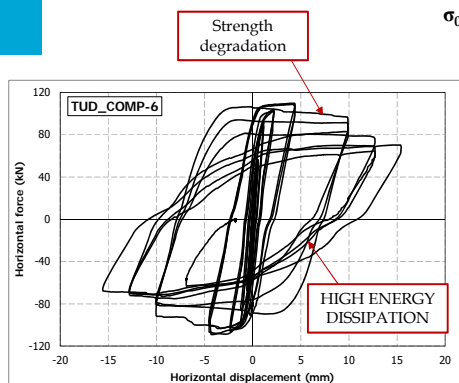
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In-plane tests - LONG WALLS

TUD_COMP-6

Cantilever wall

$\sigma_0 = 0.5 \text{ MPa}$



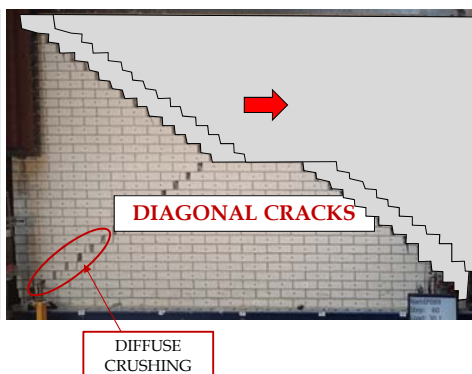
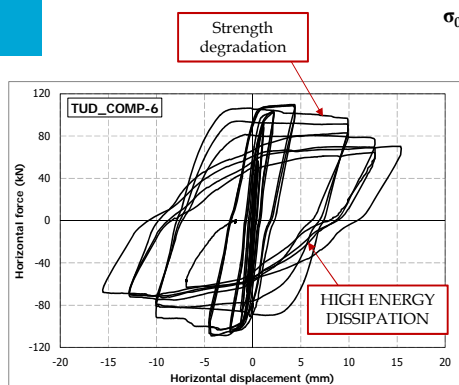
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In-plane tests - LONG WALLS

TUD_COMP-6

Cantilever wall

$\sigma_0 = 0.5 \text{ MPa}$



Bouwen met Staal Techniekdag TU Delft 18 mei 2016

In-plane tests – Some remarks

Peak strength and failure mechanism depend on (in order of influence):

1. **Geometry**
2. **Boundary conditions**
3. **Overburden**

Resistance and failure mechanisms in line with analytical and numerical provisions

Short walls: rocking/flexure

Long walls: shear failure

BOTH MAIN FAILURE MODES EVALUATED

Dissipated energy larger than that predicted thanks to influence of shear

Numerical models have to be adjusted (are in the process of being adjusted) to describe the observed hysteretic behaviour.

Subjects for investigation in 2016: (strengthened) timber floors and roofs and connections with masonry walls, steensmuren, spouwmuren.