Shear Strength of Masonry Walls

Micro Modeling of Masonry-Mortar Interfaces

Leonie Mester, Dr. Carlos Cruz Noguez, Clayton Petit
Department of Civil and Environmental Engineering, 9211-116 Street NW, Edmonton, AB, T6G 1H9

Introduction

Masonry as a construction material does not only have structural advantages, such as solidity, durability and low maintenance. But also offers advantages in terms of building physics, such as sound absorption and fire protection.

Nevertheless, in the past century the masonry use has declined significantly mostly due to economical reasons. Furthermore the underdeveloped masonry code and lack of insight into the behaviour have led to dropping behind other construction materials.

Shear failure is the most common failure mode of masonry structures subjected to lateral loading, such as wind and earthquakes.

To rationalize and validate current engineering design of structural masonry as well as to asses existing masonry structures numerical models are fundamental.

Approach

Experimental:
Generally masonry is subjected to a combination of shear and compression, due to the self-weight and floor loads. Therefore, the prism will be exposed to load normal, as well as parallel to the mortar joints.

The test set-up shown in Figure 2 is recommended by EN 1052-4 as it combines both load cases. The work of [Calderón, 2017] is used to validate the model.

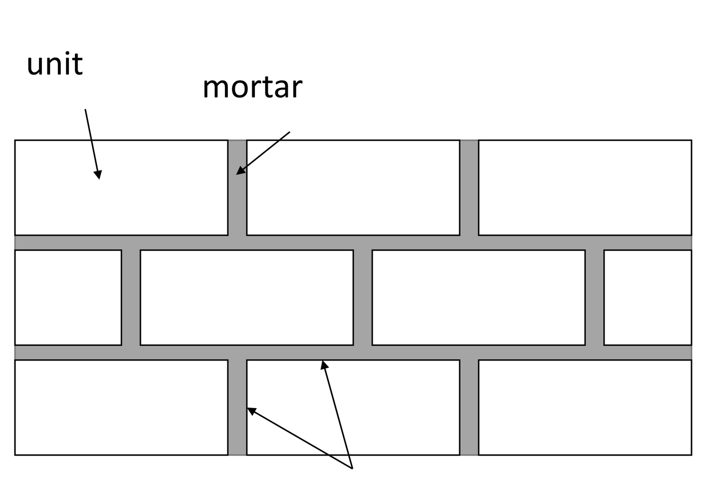

Figure 1: considered components of a masonry composite

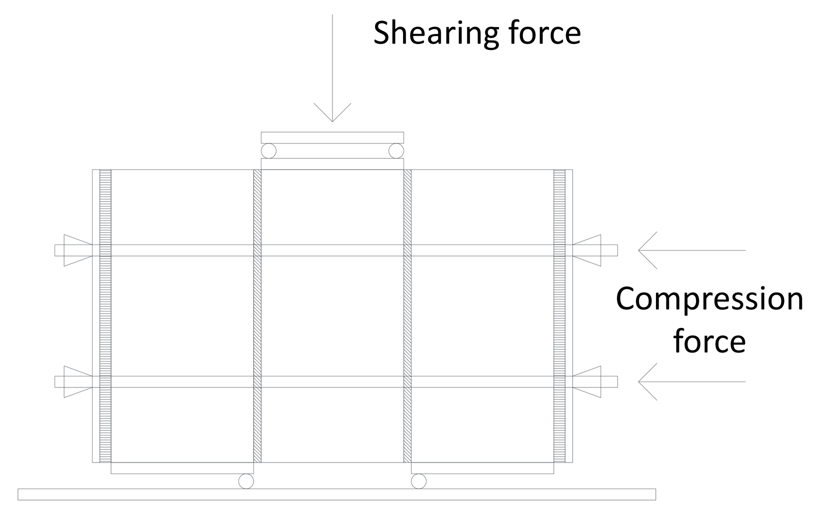

Figure 2: Shear test set-up proposed by EN 1052-4

Numerical:
A detailed micro-model of a three block prism is to be developed. This approach is the most accurate, but most demanding due to minimizing structural idealization.
The software Abaqus® is used for analyses.

Detailed micro-model

In the present study a 2D plane stress detailed micro-model was implemented and analysed in Abaqus®. A similar approach was used by [Calderón, 2017], to be able to validate the model with the results obtained by his work the input parameters were adopted. It should be noted that all parameters are typical for Chile, where the work was published, and do therefore not apply to Canadian Standards.

Bricks and Mortar: are represented by 8-noded plane stress continuum elements (namely CPS4 in Abaqus). Continuum elements are the standard volume elements and can be used for linear and nonlinear analysis including contact and plasticity.

Table 1: Material properties for brick and mortar

Material	Property	Value	
Brick	Size	290x140x110	mm3
	Young's Modulus	6787.6	MPa
	Poisson's ratio	0.15	[-]
	Compressive strength	15.28	MPa
	Tensile strength	1.04	MPa
Mortar	Young's Modulus	8925.25	MPa
	Poisson's ratio	0.15	[-]
	Compressive strength	6.83	MPa
	Tensile strength	1.64	MPa

The constitutive behaviour of brick and mortar is assumed to be nonlinear until failure occurs for the compressive strength and a strain ε=0.002. After crushing the strength decreases linear.

Interfaces: are modelled using 4-noded continuum cohesive elements. Cohesive elements are used for modeling adhesives, bonded interfaces and rock fracture. The cohesive elements are connected to adjacent elements by sharing nodes.

Table 2: Material properties of the interfaces

Material	Property	Value
Interfaces	Cohesion	0.96
	Internal friction angle	0.54
	Tensile strength	0.06

[Lourenço, 1996] proposed two different failure modes for interfaces:

- Tension (mode 1)
- Shear (mode 2)

Implementing the Mohr-Coulomb friction model for the interfaces accounts for both possible failure modes.
The shear force resistance is defined by:

$$\tau = c + \sigma \cdot tan\phi$$

Where σ is positive in compression.

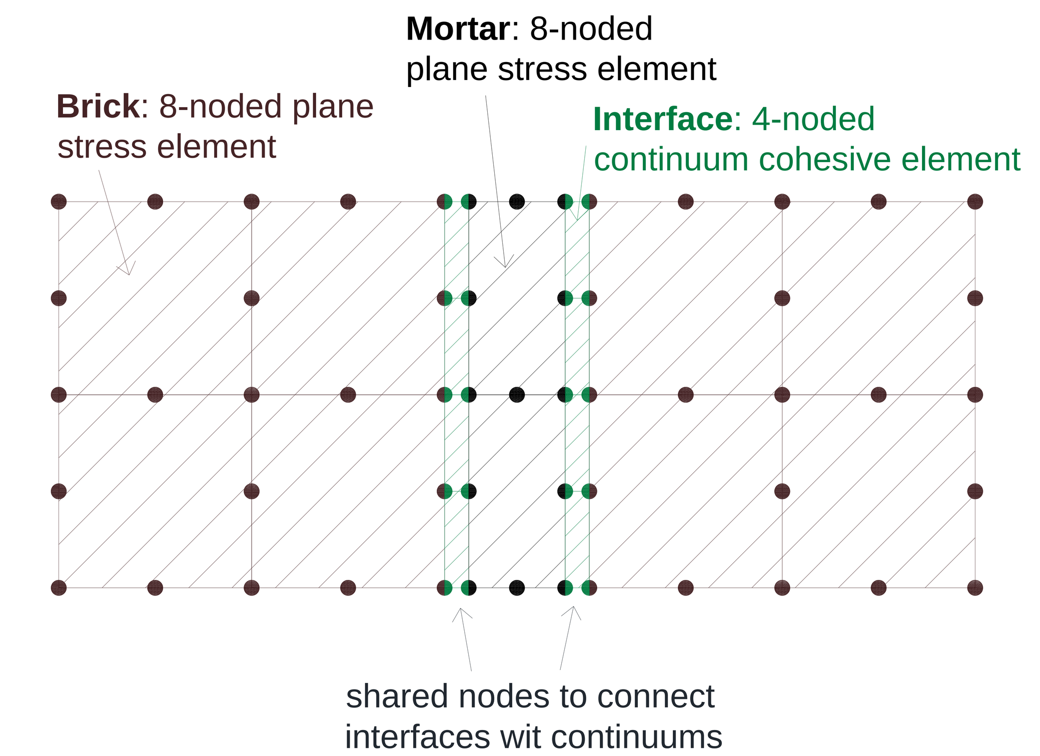

Figure 3: schematic set-up of model

Results

Investigating the van Mises stress, the highest stresses occur in the areas, where failure appeared first during the experimental tests. Overall the model behaves as expected. However, to be able to fully validate the model the input parameters have to be adjusted and the stress development has to be investigated in more detail.

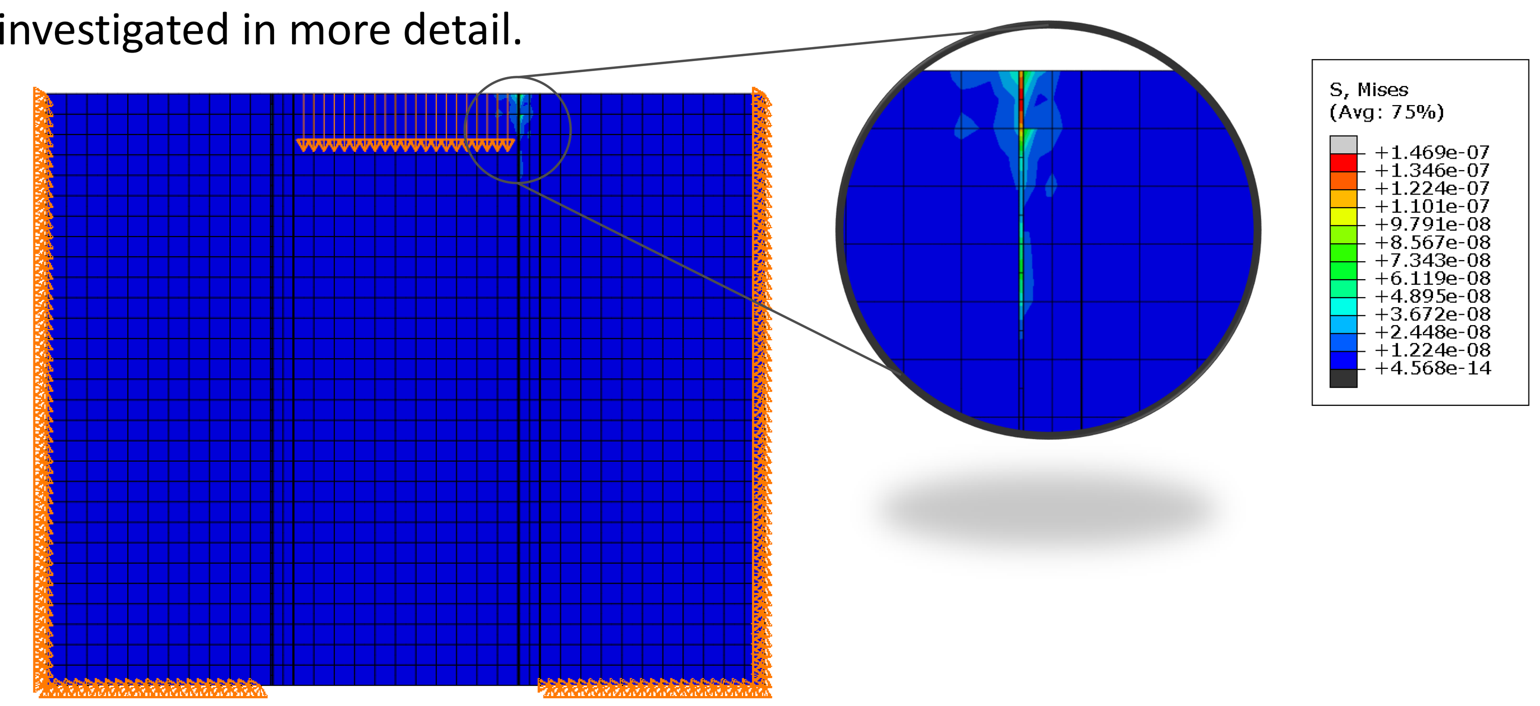

Figure 4: van Mises stress under a shear force of 0.01 N/mm²

Once the validation of the model is finalized the model parameters can be adjusted to represent Canadian material properties. More experimental testing can be conducted at the University of Alberta to further develop the model in order to be able to correctly predict the interaction of unit and mortar.

References

[Calderón, 2017] Calderón, S., Sandoval, C. & Arnau, O., 2017. Shear response of partially-grouted reinforced masonry walls with a central opening: Testing and detailed micro-modelling. Materials & Design, Volume 118, pp. 122-137.

[Lourenço, 1996] Lourenço, P. B., 1996. Computational strategies for masonry structures, Delft: Delft University of Technology.