Modeling of Lintel-Masonry Interaction Using COMSOL

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Contents

• Introduction (my research)
• Lintel-wall test set-up
• Lintel-wall modeling
• Conclusions
WHAT? Multiscale coupling
time, geometry

Whole Building (scale 10 m)
Coupled
Systems & Control
Local

Detail (scale 0.01 m)
Construction
Local

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**WHAT?** Multiphysics coupling
heat, air, moisture, stress, ..

heat
\[
\rho C_p \frac{\partial T}{\partial t} + \nabla \cdot (-\lambda \nabla T) + \rho C_p \mathbf{u} \cdot \nabla T = 0
\]

air
\[
\rho \left( \frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} \right) = -\nabla p + \nabla \cdot \mathbf{T} + \mathbf{f},
\]

moisture
\[
\frac{\partial p_v}{\partial t} + \nabla \cdot (-D \nabla p_v) + \mathbf{u} \cdot \nabla p_v = 0
\]

stress

To be included
HOW? Modeling based on physics
Optimal Abstraction level

Multi Buildings (HAMBase)

Multi PDE

Multi ODE
Multiphysics
3D Heat
Multiphysics
3D Heat Moisture Air

Heat

Moisture

Air

Solution 48 hours period
Problem
Implementing stress into our models

Example

The wooden organ pipes had cracks at the tuning caps due to warping and shrinking of the wooden edges.
Solution
Multidisciplinary Teamwork!

- Collogue dr. Ad Vermeltfoort
- Start with a more elementary case
- Using existing measurements
- Modeling
- Evaluation
Lintel-Masonry Experiments

- Test set-up
Lintel-Masonry Experiments

- Test set-up scheme
Lintel-Masonry Experiments
9 constructions

- Cracked walls & Load deflection graphs
Cracking Load

- Individual Loads [kN] after calibration
  - 55; 56; 52; 37; 58; 59; 41; 42; 80
- Mean 53
- St. dev. 13
Subdomain | 1, 4 | 2 | 3
---|---|---|---
Young’s modulus (E) | Pa | 5e9 | 35e9 | Efun(x,y)
Density (rho) | kg/m³ | 2500 | 2500 | 2000
Poisson’s ratio (nu) | 1 | 0.3 | 0.3 | 0.2

Subdomain 1 and 4 represent the support blocks, subdomain 2 is the concrete lintel and subdomain 3 represents masonry.
Modeling individual stones

Position of the bricks
x = [0:0.22:12*0.22];
y = [0:0.0625:9*0.0625];

Number of bricks
nx = length(x);
yy = length(y);

mesh
[xx, yy] = meshgrid(x, y);

Fine grid
x2 = 0:0.02:12*0.22;
y2 = 0:(0.0625/4):9*0.0625;
[xi, yi] = meshgrid(x2, y2);

STEP 1: Uniform between 2e9 and 4e9
Exy = 2e9 + 4e9 * rand(ny, nx);

%STEP 2: interpolate on fine grid
data = interp2(xx, yy, Exy, xi, yi, 'nearest');

STEP 3: Create data structure for COMSOL
Efun.x = x2;
Efun.y = y2;
Efun.data = data;
Modeling Result
Sxy shear stress
Modeling Result

sxy shear stress global sys. [Pa]

Arc-length

sxy shear stress global sys. [Pa]

x10^4

0

0.5

1

1.5

2

2.5

0

1

2

3

-3

-2

-1

0

1

2

3

4

-4
Modeling Result
9 numerical experiments
Modeling Result including simulated Strength
9 numerical experiments

Figure 18 Shear stress (●) and strength (●) for nine simulated runs
6. Conclusion and subsequent research

It is concluded that the presented method is promising for simulation of the stochastic behaviour of the experiments. More research is needed to validate the presented methodology.

Further research is required into the effect of stresses perpendicular to the shear direction on the shear strength. The application of a Mohr-Coulomb criterion in the model may be considered.

The shear stress variation is hardly affected by the random variation of the Young’s modulus; however, the principal stresses may locally be (much) higher than expected on a uniform value for the Young’s modulus.

A randomly assigned shear strength affects the failure load considerably as shown by Figure 18. Failure may not only be induced by exceeding shear strength. Exceeding the maximum principle tensile stress somewhere in the wall is probably a better criterion. Compressive strength is hardly ever a criterion in masonry.

More detailed subsequent work can concentrate on: the explanation of differences between experimental and simulation results, effects of energy release when cracking starts and on the behaviour of the lintel-wall assembly after the first crack occurs.
Conclusion
Multi(building)physics & COMSOL

- COMSOL is a state-of-art Multiphysics modeling tool for doing research in the area of building physics
- High performance on
  - 1, 2 & 3D capabilities
  - Grid & solvers techniques
  - Visualisation
  - Flexibility due to PDE abstraction level
- Also a excellent tool for education
- Our models are available at http://sts.bwk.tue.nl/hamlab/
• Thank you

• Questions ?