

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? 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

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

moisture

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

stress

To be included

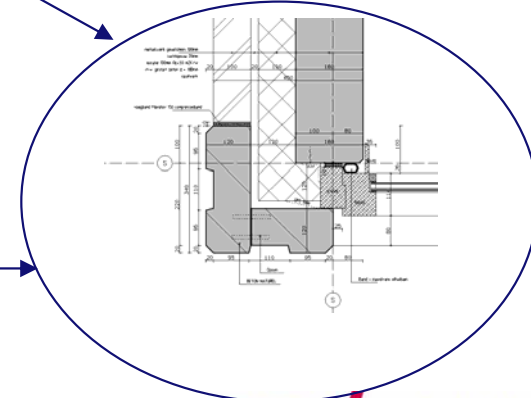
HOW? Modeling based on physics

Optimal Abstraction level

Multi
Buildings
(HAMBase)



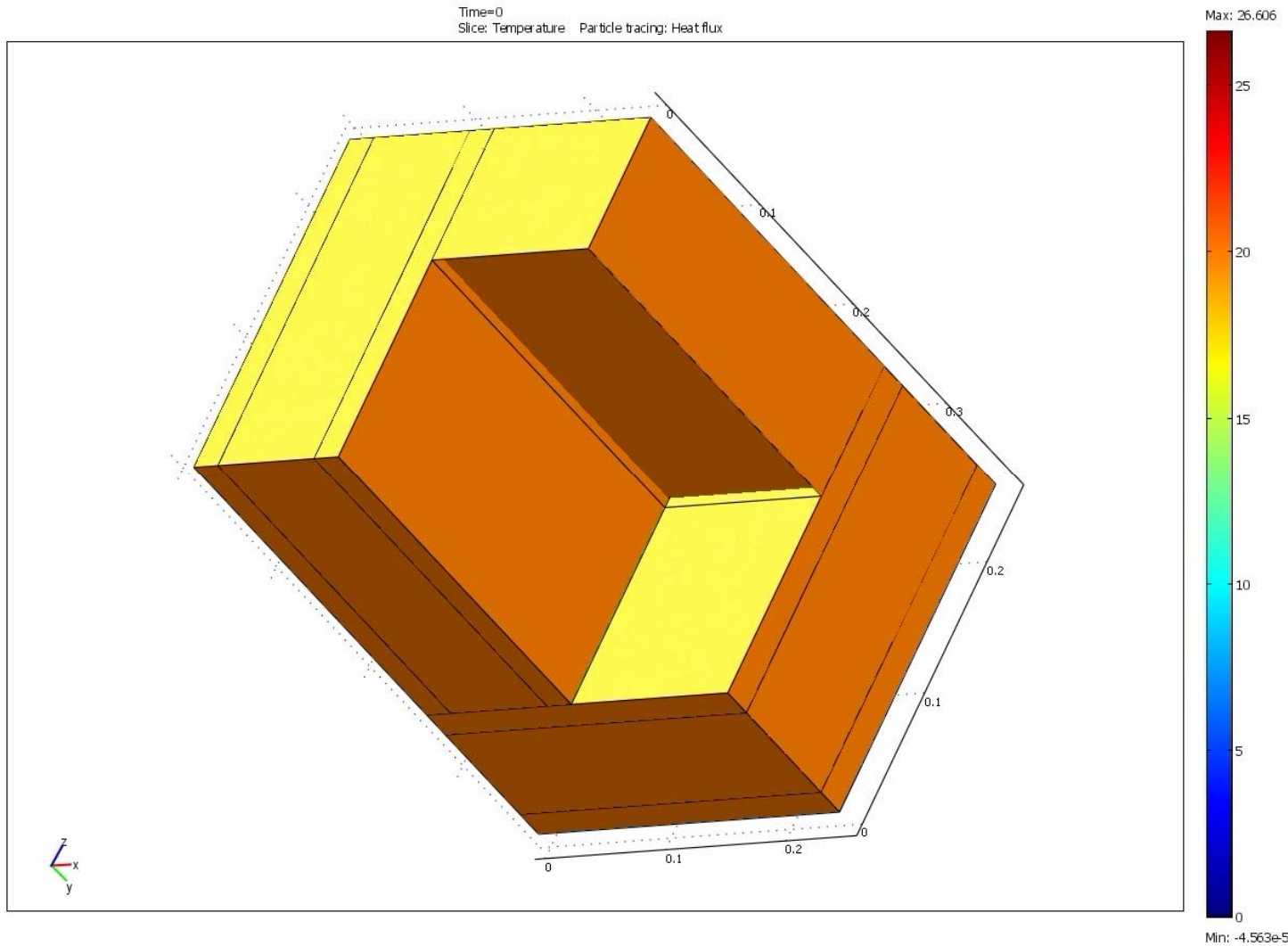
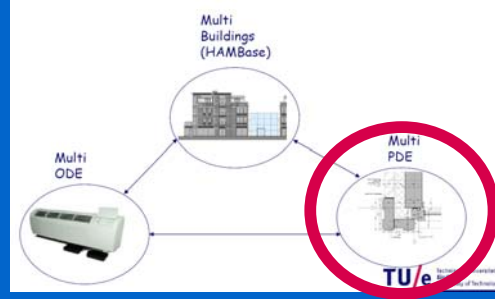
Multi
PDE



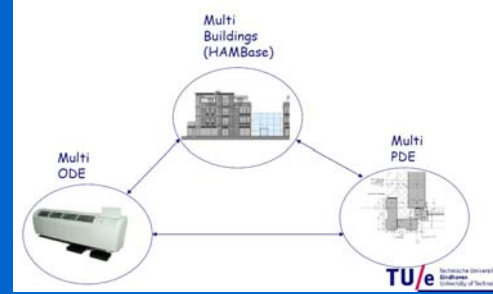
Multi
ODE



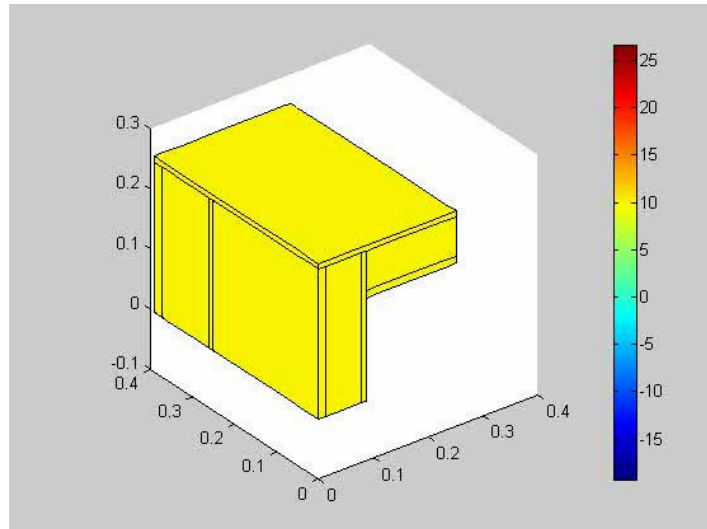
Multiphysics 3D Heat



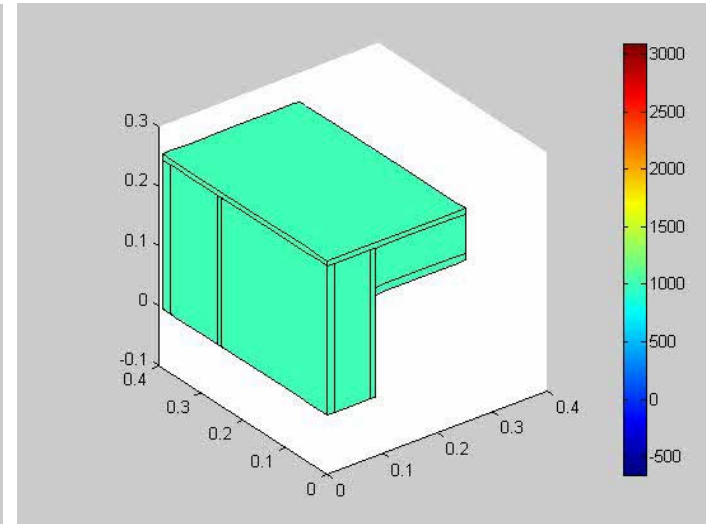
Multiphysics 3D Heat Moisture Air



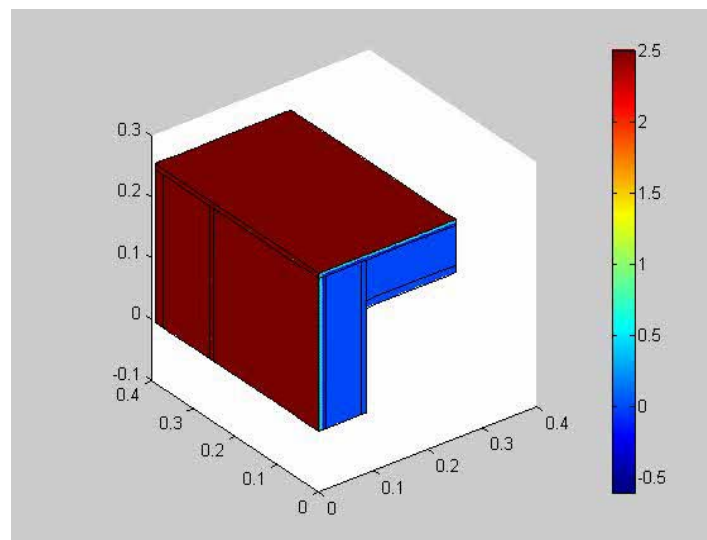
Heat



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.

y

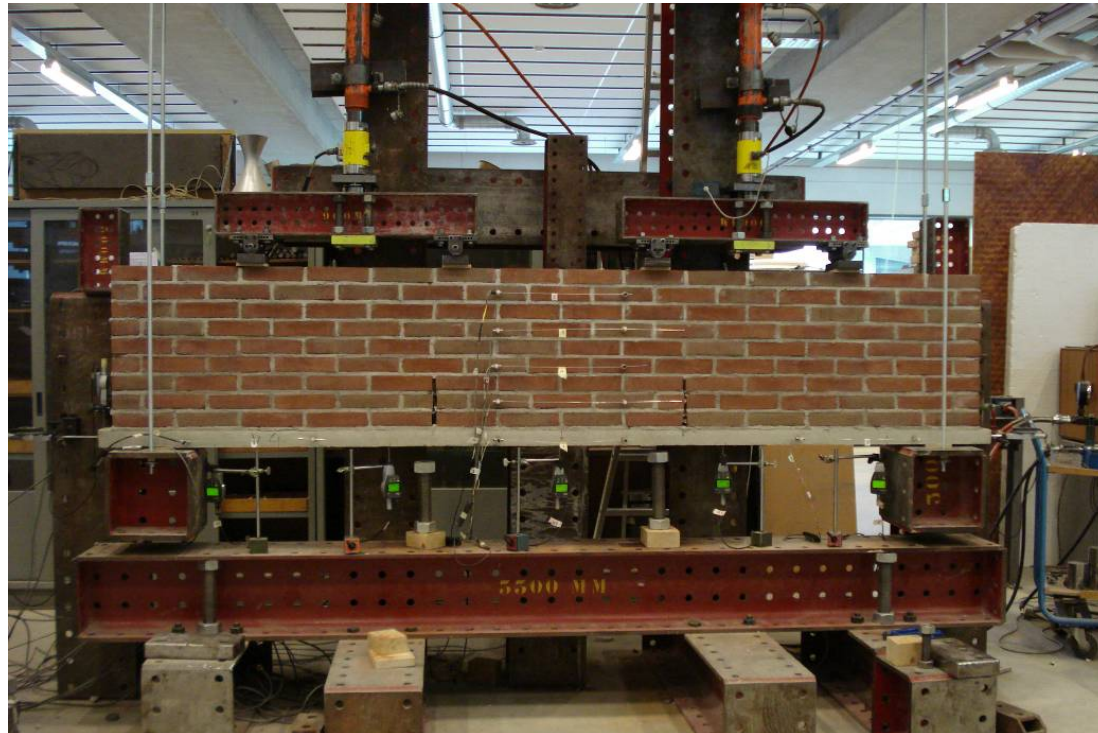
Solution

Multidisciplinary Teamwork!

- **Collogue dr. Ad Vermeltoort**
- **Start with a more elementary case**
- **Using existing measurements**
- **Modeling**
- **Evaluation**

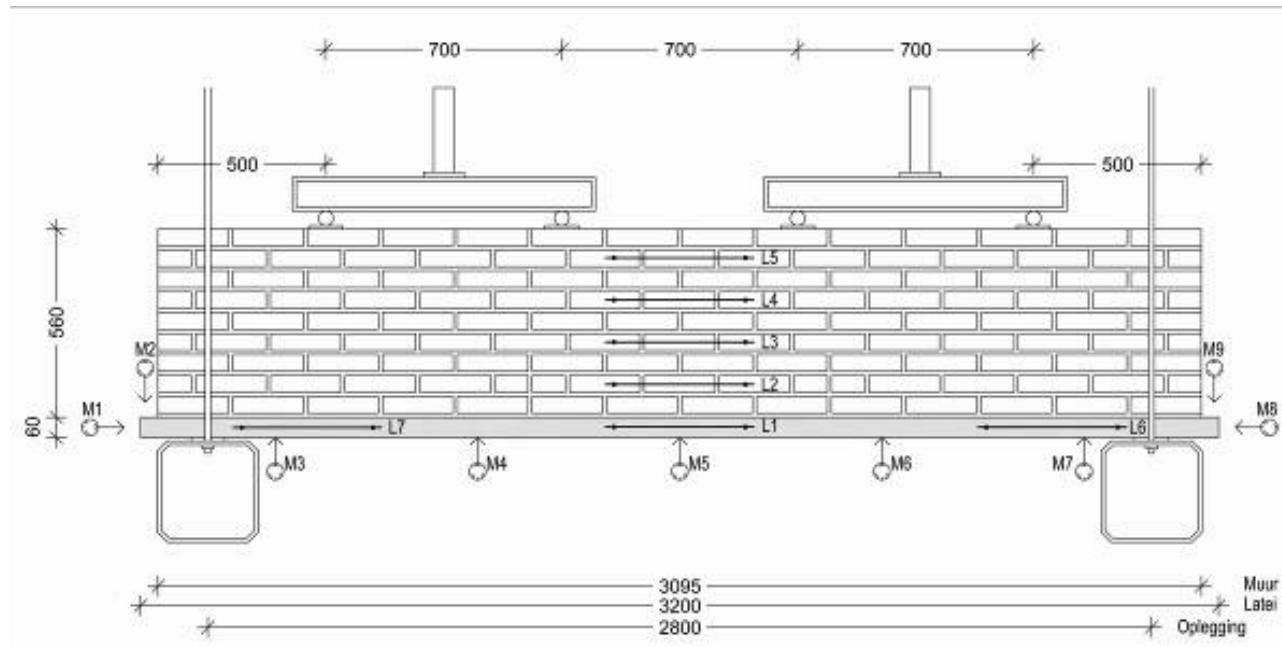
Lintel-Masonry Experiments

- Test set-up



Lintel-Masonry Experiments

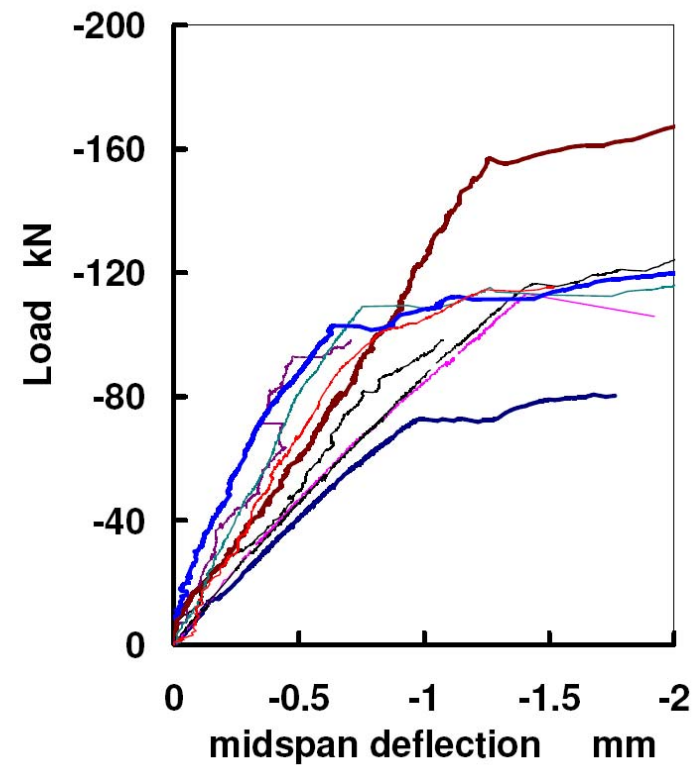
- Test set-up scheme



Lintel-Masonry Experiments

9 constructions

- Cracked walls & Load deflection graphs

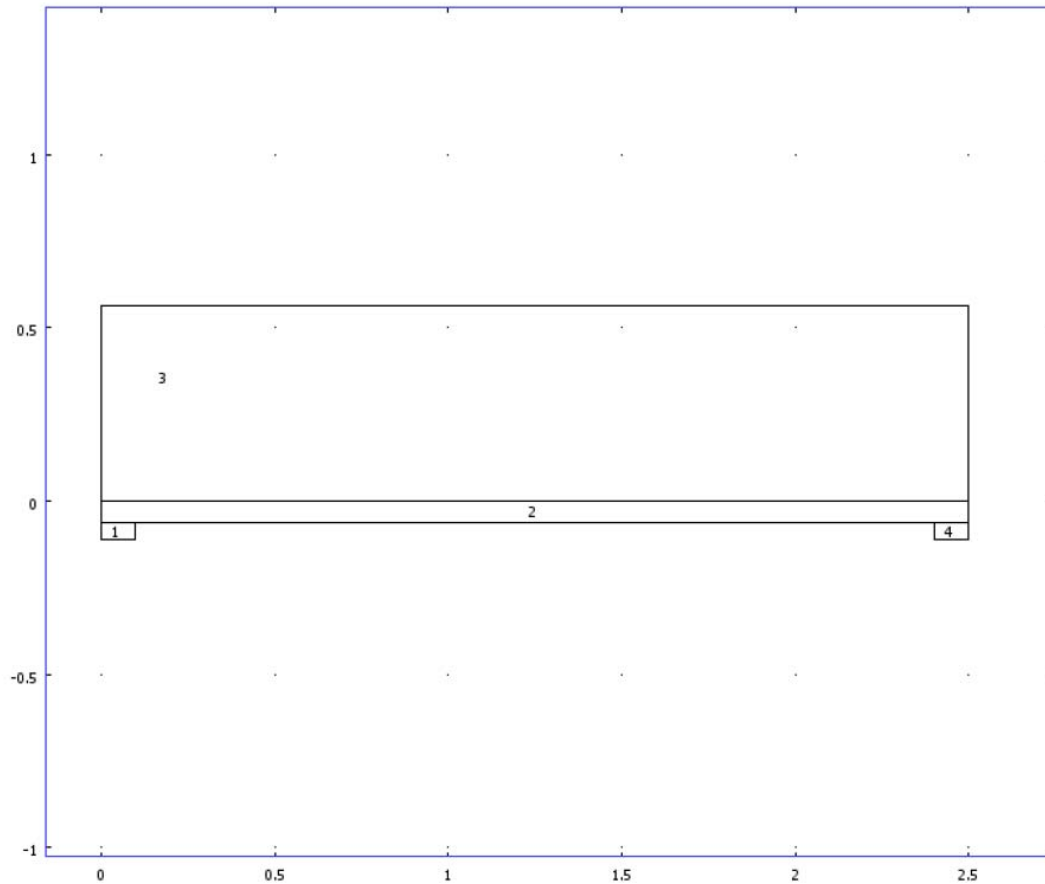


Cracking Load

- **Individual Loads [kN] after calibration**
- **55; 56; 52; 37; 58; 59; 41; 42; 80**

- **Mean 53**
- **St. dev. 13**

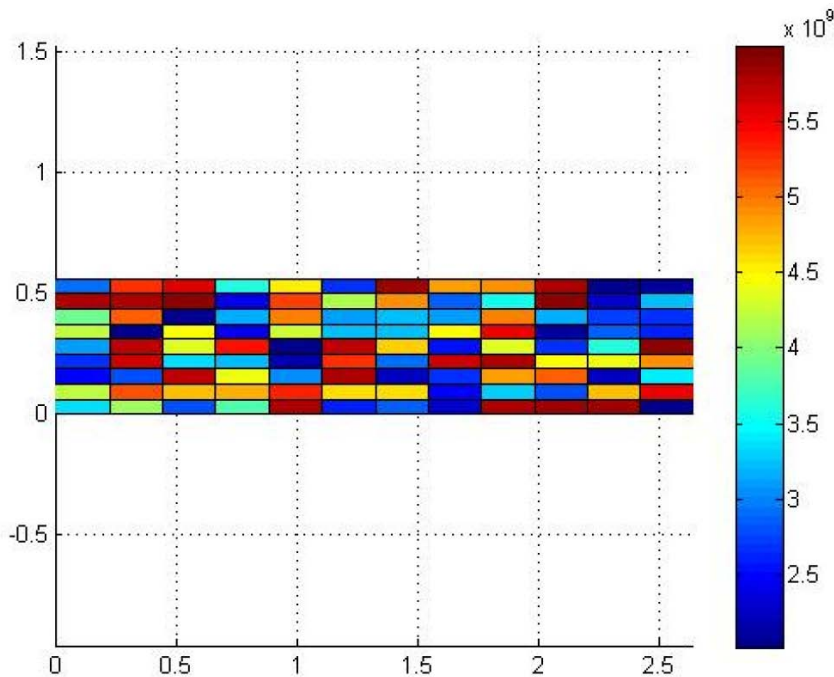
Modeling



Subdomain		1, 4	2	3
Young's modulus (E)	Pa	5e9	35e9	Efun(x,y)
Density (rho)	kg/m ³	2500	2500	2000
Poisson's ratio (nu)		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);
ny=length(y);

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

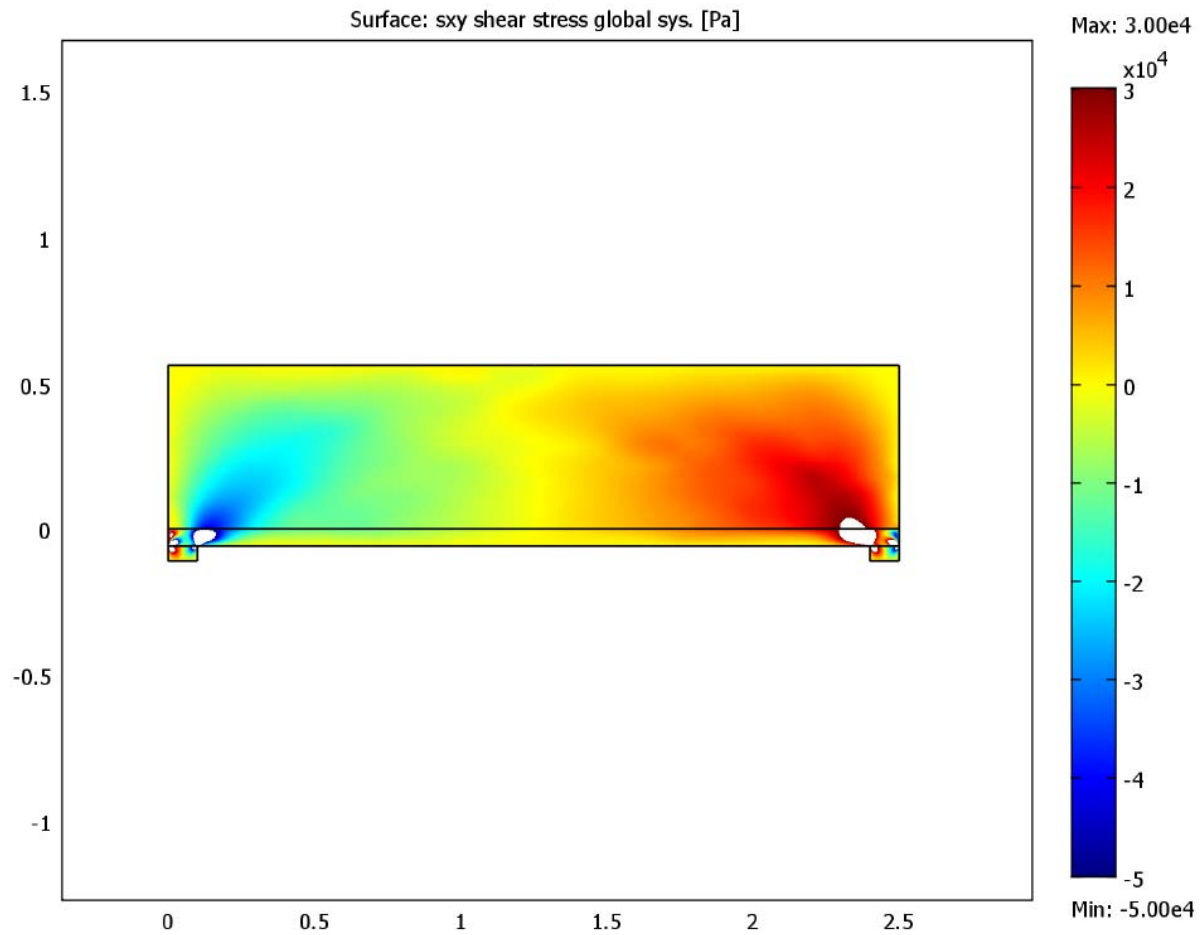
Fine grid
x2=0:0.02:12*0.22;
y2=0:(0.0625/4):9*0.0625;
[xi,yi] = meshgrid(x2,y2);

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');

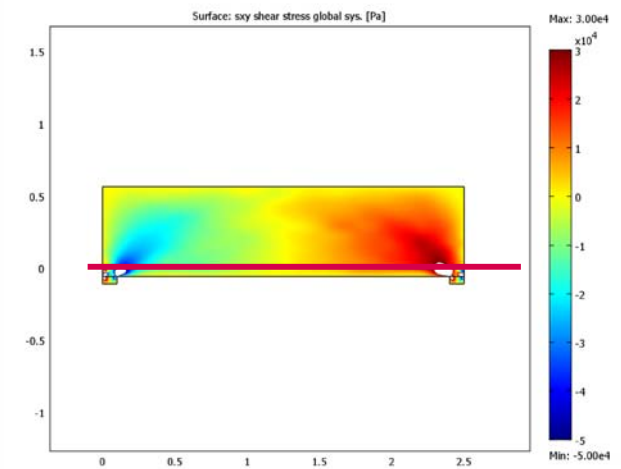
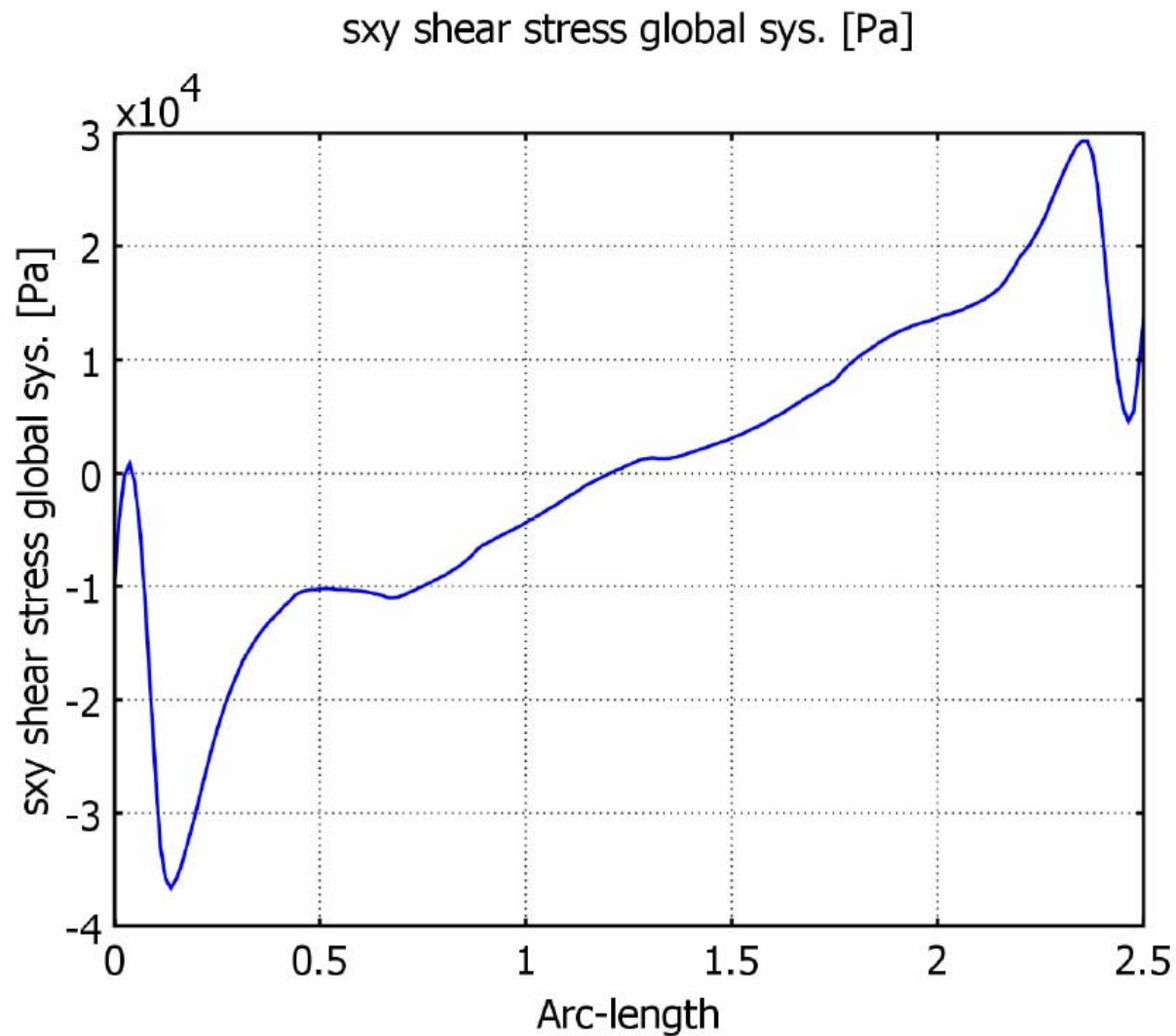
STEP 3: Create data structure for COMSOL
Efun.x=x2;
Efun.y=y2;
Efun.data=data;
```

Modeling Result

Sxy shear stress

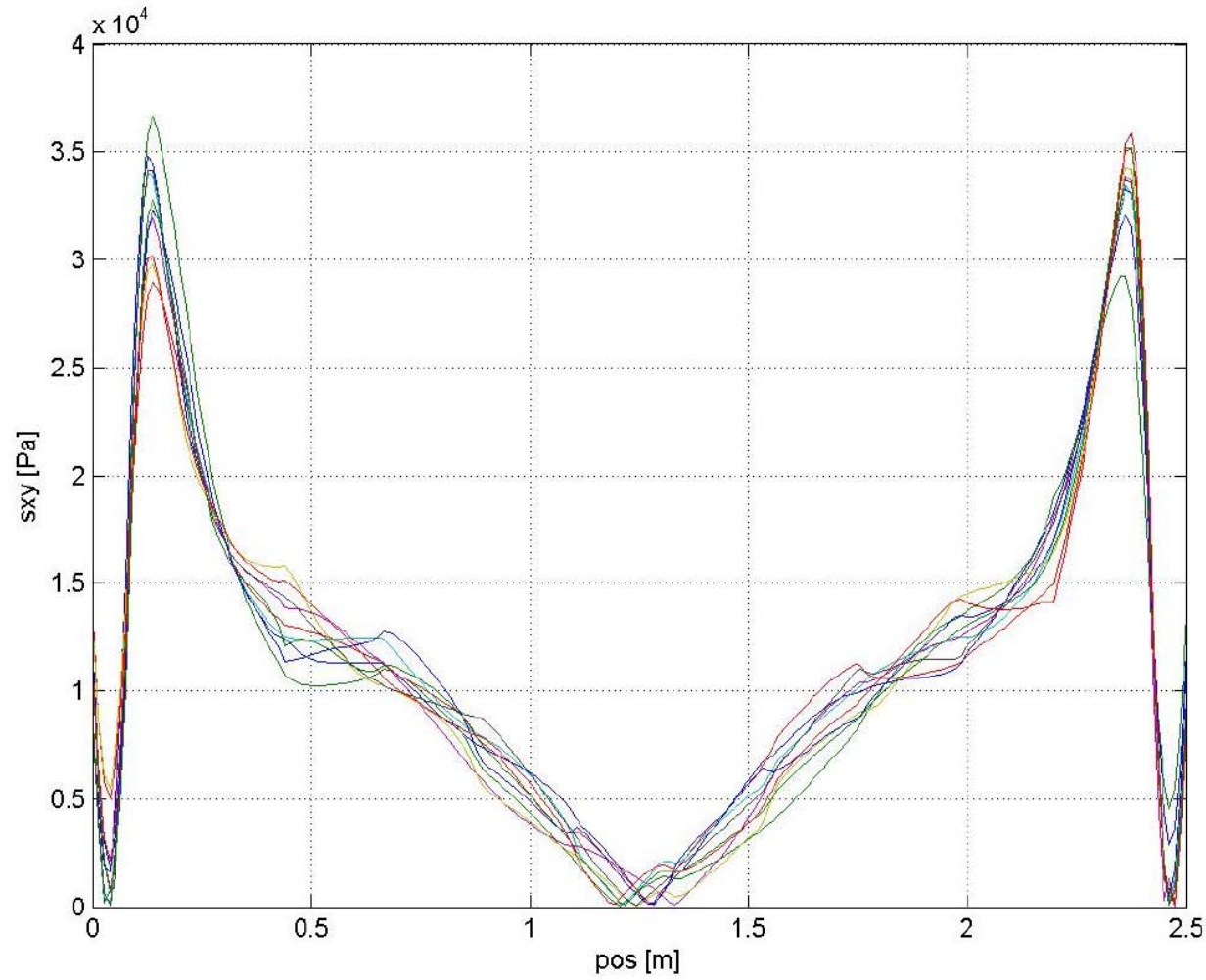


Modeling Result

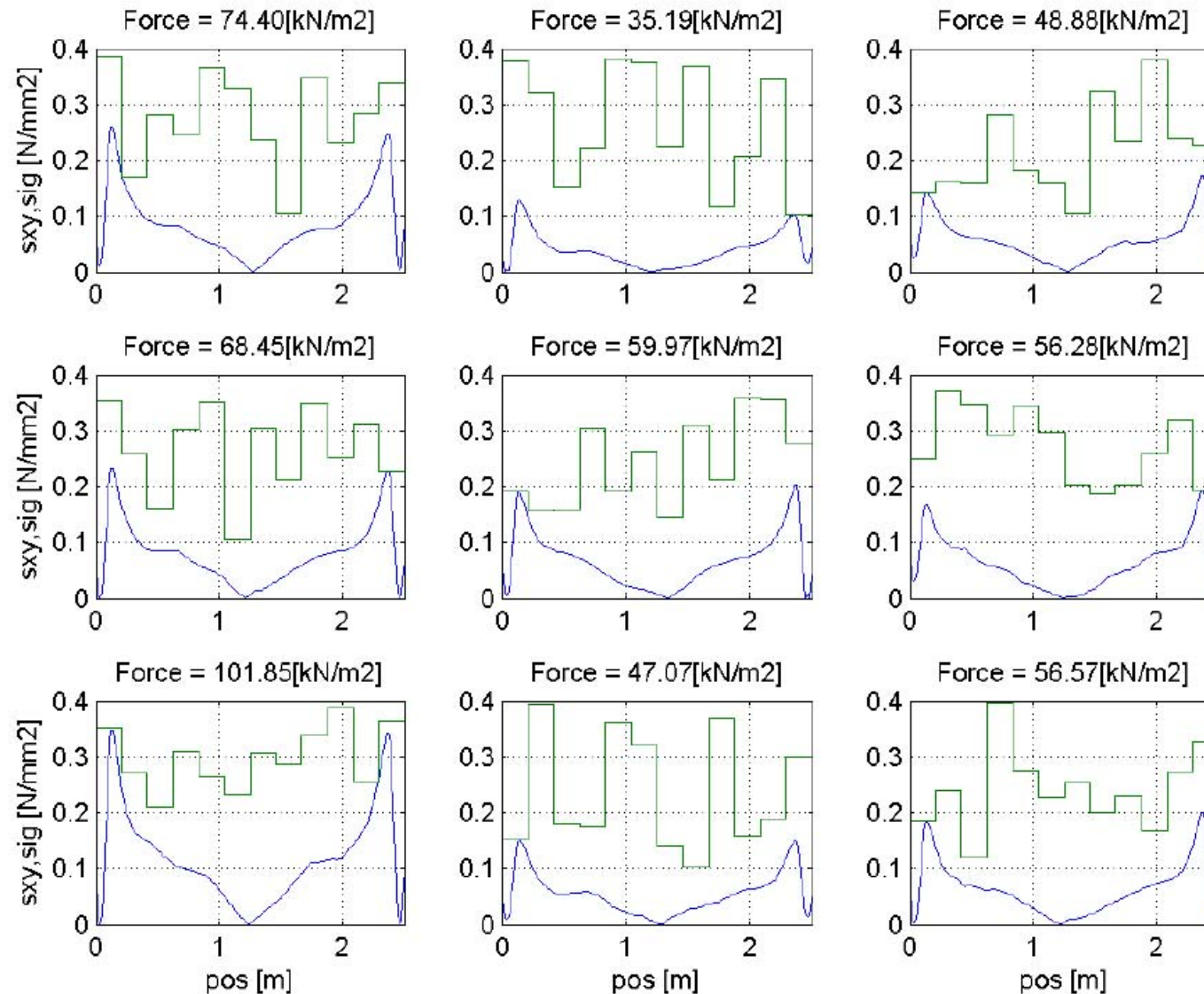


Modeling Result

9 numerical experiments



Modeling Result including simulated Strength 9 numerical experiments



Exp
Avg 53
Std 13

	Fmax kN
1	74.40
2	35.19
3	48.88
4	64.45
5	59.97
6	56.28
7	101.85
8	47.07
9	56.57
avg.	60.52
std.	19.07
CoV	32 %

Figure 18 Shear stress (-) and strength (-) for nine simulated runs

Conclusion

Modeling of Lintel-Masonry

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 ?**

