The hygro-thermal improvement of a mounting anchoring system to fasten roof workmen to flat roofs

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Content

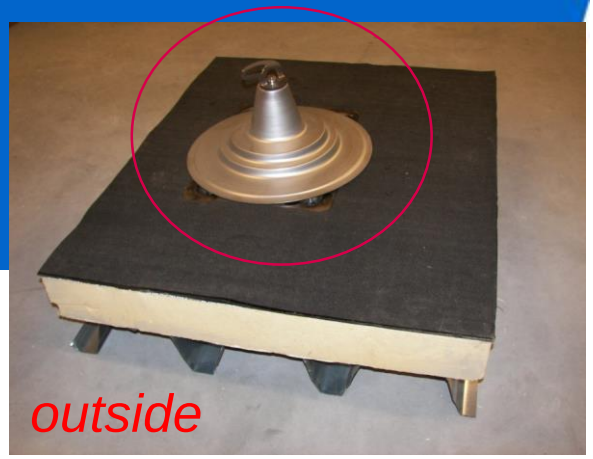
Introduction

- Protect workmen
- The anchoring system
- Steel rods
  – thermal bridges
- TU/e investigated:
  - Effect - COMSOL
  - Improvements
- Validation – measurements

The anchoring system

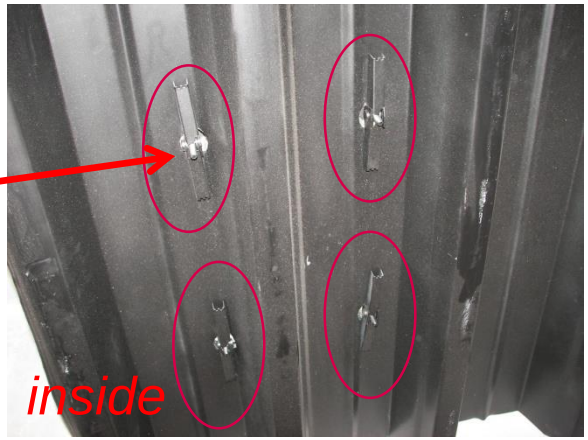
The anchoring system

- Upper side – base plate
- Drilled holes
- Threaded rods
- Expandable anchors
- Nuts – wire ends
- Anchoring system –
  Applied – sealed



base plate

expandable anchor



Theory

- **Heat transfer**

$$q_x = -\lambda \frac{\partial T}{\partial x}, \quad q_y = -\lambda \frac{\partial T}{\partial y}, \quad q_z = -\lambda \frac{\partial T}{\partial z}$$

- **Heat balance**
  - **unsteady state**

$$\rho c \frac{\partial T}{\partial t} = \text{div} \ \lambda \ \text{grad} \ T$$

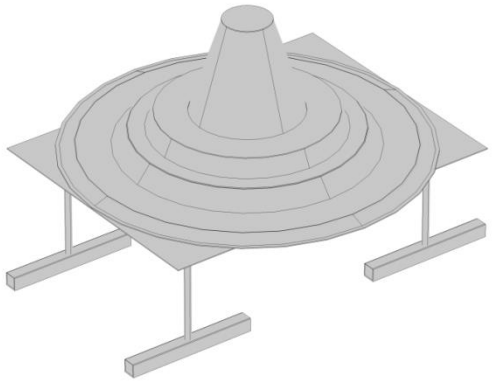
- **Heat balance**
  - **steady state**
  - **constant surface coefficients**

$$-\lambda \left(\frac{\partial T}{\partial z} \right)_s = (h_{cv} + h_r)(T_{rcv} - T_s)$$

- **Anchors → complex heat–conductive structure solvable: three-dimensional modeling**

Finite element method

- → Comsol
- Anchoring system – Model Builder



- Material properties

Table 1.

Thermal conductivity [W/mK]	
Steel	44.5
Stainless steel	20
Aluminum	200
Insulation	0.04
Nylon	0.26

- Boundary conditions

Table 2.

	Air temperature [°C]	Heat transfer coefficient [W/m²K]
Indoor	20	7.7
Outdoor	-10	25

Study of variants

Variants:

1) **Existing anchoring system, mounted on a steel roof**
2) **Afterwards insulated holes**
3) **Isolation of the nuts in relation to the base plate**
4) **Afterwards insulated nuts by filling the holes**
5) **Thermal insulation of the folding steel anchors**

Results:

1) **Additional heat loss**
2) **Temperature ratio**

   dimensionless lowest indoor temperature

$$f = \frac{\theta_{si,\min} - \theta_e}{\theta_i - \theta_e}$$

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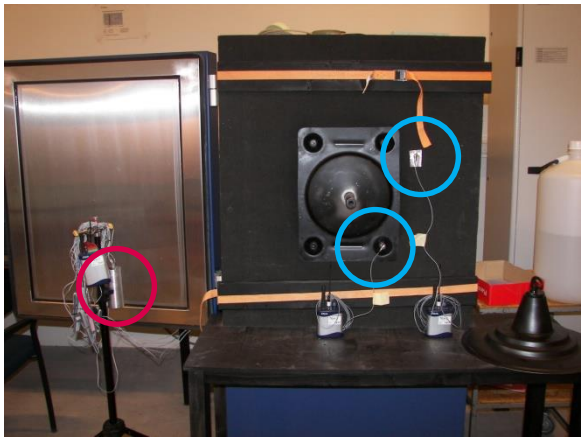
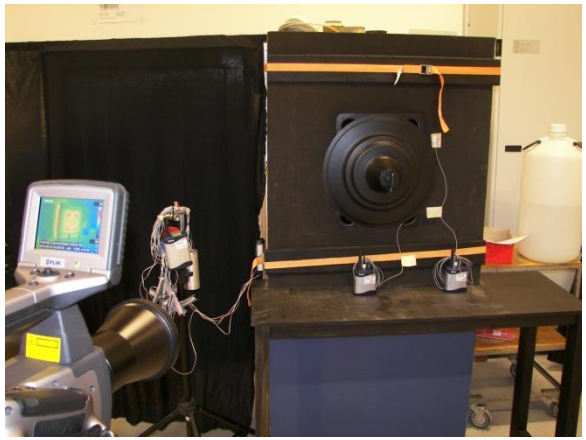
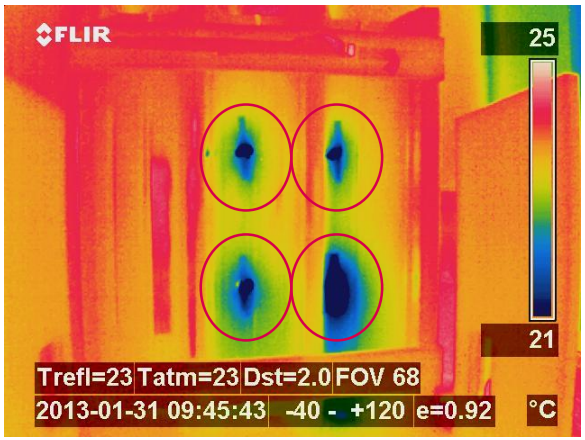
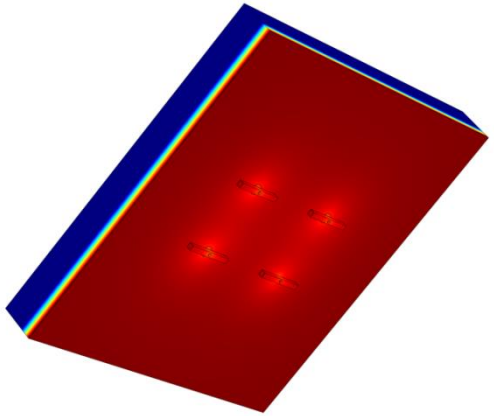
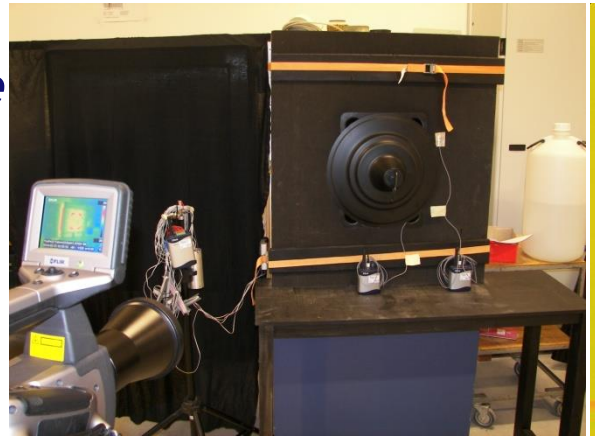
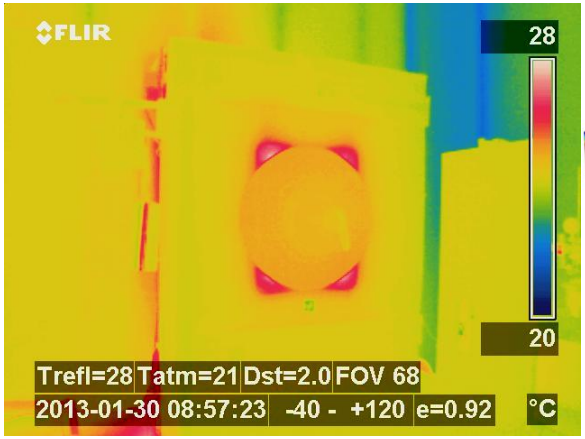
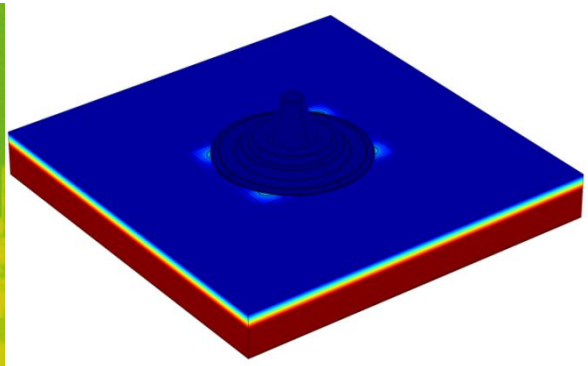
Measurements

- Test set-up anchoring system
- Temperature sensors:
  - Inside/outside air
  - Surface slightest/largest thermal bridge
- Infrared thermal camera





Results

	Test set-up	Measurement	Simulation
inside			
outside			

Conclusions

Comparison Comsol with mock-up results:

1) **Thermal images** **- quite lookalike**
2) **Quantitative results** **- differ**
   Temperature ratio's and heat loss

- **Vertically mounted roof system – climate cabinet**
  Horizontal roof system
- **R_c differ: mock-up and simulation**

Questions

Thank you!