Hygrothermal response of highly insulated timber frame walls with an exterior air barrier system: laboratory investigation

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Introduction – problem statement

Tendency towards low-energy-buildings, makes light-weight constructions more and more popular also in countries with masonry tradition.
Introduction – problem statement

Complex details of interior air barriers
Introduction – problem statement

Complex details of interior air barriers
Case Study: exterior air barrier


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Introduction – problem statement

Total air pressure difference

\[ \Delta P \]

Exterior

\[ \rightarrow \]

Interior
Introduction – problem statement

Total air pressure difference

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Introduction – problem statement

Vapour pressure difference

\[ \Delta P_v \]

Exterior

Interior
Introduction – problem statement

Vapour pressure difference

Exterior

\[ \Delta P_v \]

Interior

Exterior

\[ \Delta P_v \]
Introduction – problem statement

Temperature difference

\[ \Delta T \]

Exterior \hspace{2cm} Interior
Introduction – problem statement

Temperature difference

1. ΔT
2. Exterior
3. Interior
4. Exterior
5. Interior

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Test Set-up
Test Set-up
### Test Set-up

<table>
<thead>
<tr>
<th>Air barrier</th>
<th>$K_a$ (m³/m²/h/Pa)</th>
<th>$R$ (m²K/W)</th>
<th>Buffering</th>
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<tbody>
<tr>
<td>Foil</td>
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- **Air barrier Ka (m³/m²/h/Pa)**
- **$R$ (m²K/W)**
- **Buffering**

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## Test Set-up

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Reference wall
## Test Set-up

### Air barrier

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<tr>
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![Reference wall](image)

### Hygrothermal

![Graph showing diffusion permeability vs. relative humidity](image)
Test Set-up
Test Set-up

Insulation: 30 cm mineral wool
Test Set-up

Vapour resistance OSB

Interior: OSB gap on top and bottom of OSB
Test Set-up

Exterior: Vented cavity 6 cm
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Thermal
Hygrothermal
Conclusions

Test Set-up

Exterior climate: cold box

Interior climate: hot box

Temperature
Test Set-up

Exterior climate: cold box

Interior climate: hot box

Temperature

RH
Test Set-up

Exterior climate: cold box

Interior climate: hot box

Temperature
RH
Air pressure
Test Set-up

- Exterior climate: cold box
  - Temperature
  - RH
- Interior climate: hot box
  - Air Pressure
  - Heat Flux

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Results: thermal

- **Boundary conditions**
  - $T_{in} = 20^\circ\text{C}$ and $T_{ex} = 3^\circ\text{C}$
  - $RH_{in} = 54\%$ and $RH_{ex} = 86\%$

- **3 steps**
  1. Intact interior and exterior sheathing
  2. Openings in interior sheathing (top/bottom)
  3. Total pressure difference
Results: thermal

2 steps

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Results: thermal

2 steps
1. Intact interior and exterior sheathing
Results: thermal

2 steps
1. Intact interior and exterior sheathing
2. Openings in interior sheathing (top/bottom)
Results: thermal

Reference

Fibreboard 1

Fibreboard 2

Foil

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Introduction

Content

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Thermal

Hygrothermal

Conclusions

Reference

STEP 1

Reference

STEP 2

Reference

Fibreboard 1

Fibreboard 1

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STEP 1

Fibreboard 2

Temperature (°C)

0 15 105 315

Foil

Temperature (°C)

0 15 165 315
Results: thermal

STEP 1

REFERENCE  FIBREBOARD 1  FIBREBOARD 2  FOIL

Warm Top  Warm Middle  Warm Bottom
Results: thermal

STEP 2

REFERENCE  FIBREBOARD 1  FIBREBOARD 2  FOIL

Warm Top  Warm Middle  Warm Bottom

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Results: thermal

3 steps
1. Intact interior and exterior sheathing
2. Openings in interior sheathing (top/bottom)
Results: thermal

3 steps
1. Intact interior and exterior sheathing
2. Openings in interior sheathing (top/bottom)
   • +/- 3 Pa over pressure (ventilation in cold box)
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Results: thermal

STEP 2

- Warm Top
- Warm Middle
- Warm Bottom

Categories:
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- Test Set-up
- Thermal
- Hygrothermal
- Conclusions

Graph showing thermal properties with various materials.
Results: hygrothermal

[Graph showing relative humidity over time for interior and exterior conditions.]
Results: hygrothermal
Results: hygrothermal

- Exterior Humidity
- Interior Humidity
- Weight process

- Interior
- Exterior
- Ref. Middle
- Ref. Top
- Ref. Bottom
- FB 1 Bottom
- FB 1 Middle
- FB 1 Top

Time (h): 400 to 2000
Results: hygrothermal

[Graph showing relative humidity over time for different locations: interior, exterior, reference top, etc.]
Results: hygrothermal
Conclusions

- Preliminary results of hygrothermal impact of exterior air barrier are given
- Small effect of natural convection in mineral wool if placed carefully
- Interior openings increase the moisture load at the top position
- Exterior air barriers without thermal resistance and moisture buffer immediately shows condensation
- Valuable set of validation data for HAM-models
Test Set-up

Problems in first test round (2010)

- 3 layers of insulation: gaps in between + uncertain position of sensors
- Very small air leakage dominated the system
  - Weight samples
  - Sensors
- Flux sensors on cold side: condensation
- Condensation on boundary of weight samples
Test Set-up

Changes in second test (2011)

- Two insulation layers (2x16cm in cavity of 30 cm)
- Only flux sensors on interior sheathing
- New design weight monsters
- Smoke test: extra sealing of exterior sheathing
Test Set-up

Exterior: Finished with fly screen (to avoid vortices)
Results: hygrothermal

Weight samples

Date

Water content (%)


W1 Boven
W1 midden
W1 Onder
W2 Boven
W2 Midden
W2 Onder
W3 Boven
W3 Midden
W3 Onder

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