Comparing Different Approaches for Moisture Transfer inside Constructions with Air Gaps

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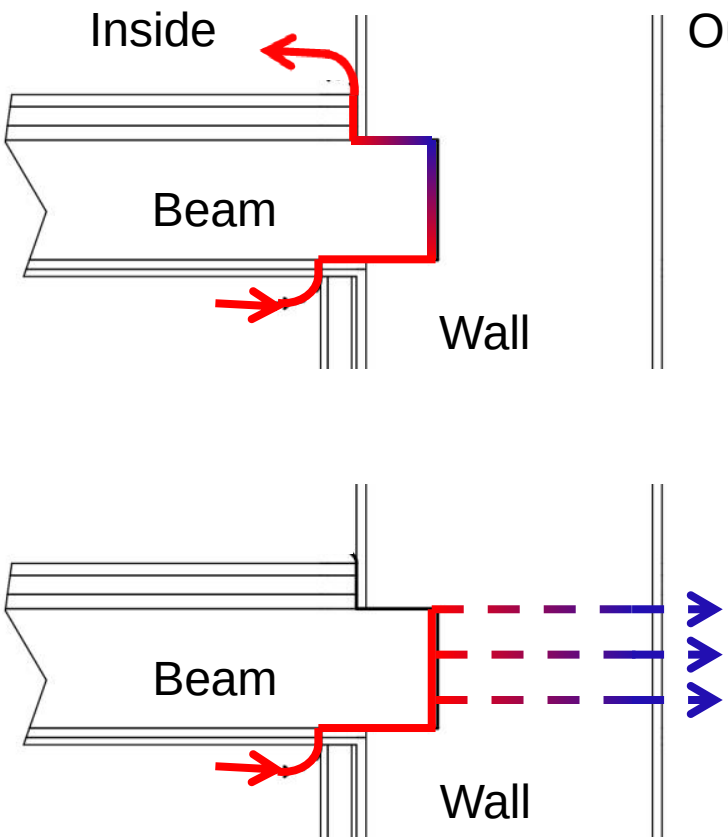
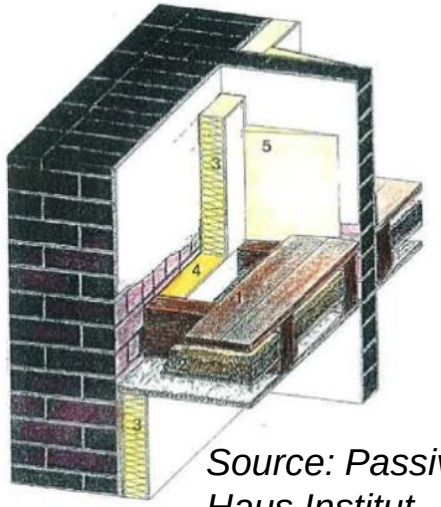
Motivation



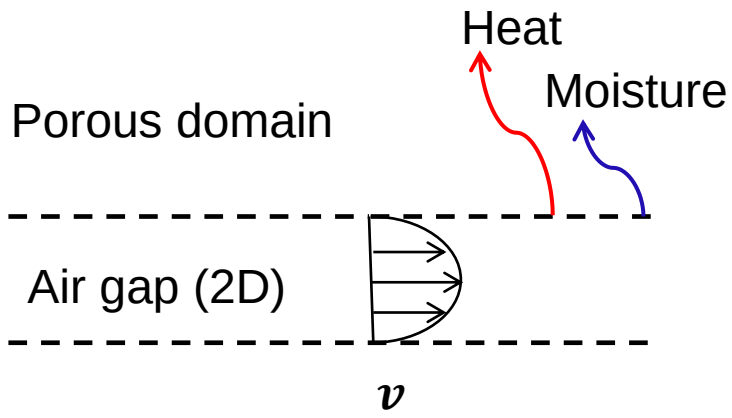


Source: Passiv Haus Institut, Protokollband Nr.32, Architekt Fingerling

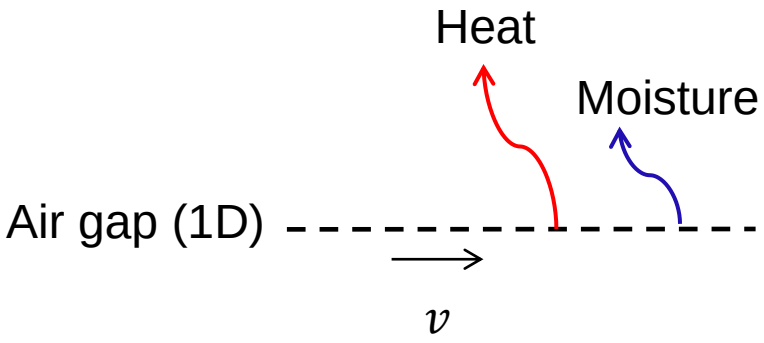
Heat and Moisture Simulation at Beam-Ends

Different coupling approaches

Conjugate Approach (including CFD)



Line-source approach



Porous Domain

$$\frac{\partial u}{\partial \varphi}\frac{\partial \varphi}{\partial t} + \nabla \cdot \left(-D_{m,\varphi}\nabla\varphi - D_{m,T}\nabla T\right) = 0$$

⇦ Moisture balance

$$\frac{\partial h}{\partial T}\frac{\partial T}{\partial t} + \frac{\partial h}{\partial \varphi}\frac{\partial \varphi}{\partial t} + \nabla \cdot \left(-D_{e,\varphi}\nabla\varphi - D_{e,T}\nabla T\right) = 0$$

⇦ Energy balance

⇨ Moisture distribution:
φ(x,y,t)
Temperature distribution:
T(x,y,t)

φ	Relative humidity
T	Temperature
u	Water content
h	Specific enthalpy
$D\ldots$	Non linear transfer coefficients

Air gap: Conjugate approach

$$\frac{\partial \rho_v}{\partial t} + \nabla \cdot (\rho_v \boldsymbol{v} - D_v \nabla \rho_v) = 0$$

⇦ Moisture balance

$$\frac{\partial h}{\partial t} + \nabla \cdot \left((\rho_v \boldsymbol{v} - D_v \nabla \rho_v) h_v + (\rho_a \boldsymbol{v} - D_a \nabla \rho_a) h_a - \lambda \nabla T \right) = 0$$

⇦ Energy balance

$$\frac{\partial \boldsymbol{v}}{\partial t} + \rho \boldsymbol{v} \cdot \nabla \boldsymbol{v} = \nabla \cdot (-p\boldsymbol{I} + \nabla \boldsymbol{\tau})$$

⇦ Momentum balance

$$\frac{\partial \rho}{\partial t} = -\nabla \cdot (\rho \boldsymbol{v})$$

⇦ Continuity

ρ_v	Vapor density
ρ_a	Air density
h	enthalpy
$\boldsymbol{v}$	Air velocity

Air gap: Line-source approach

$$\frac{A}{L}\left(\frac{\partial \rho_v}{\partial t} + v\frac{\partial \rho_v}{\partial s}\right) = \beta\left(p_{v,b} - p_v\right)$$

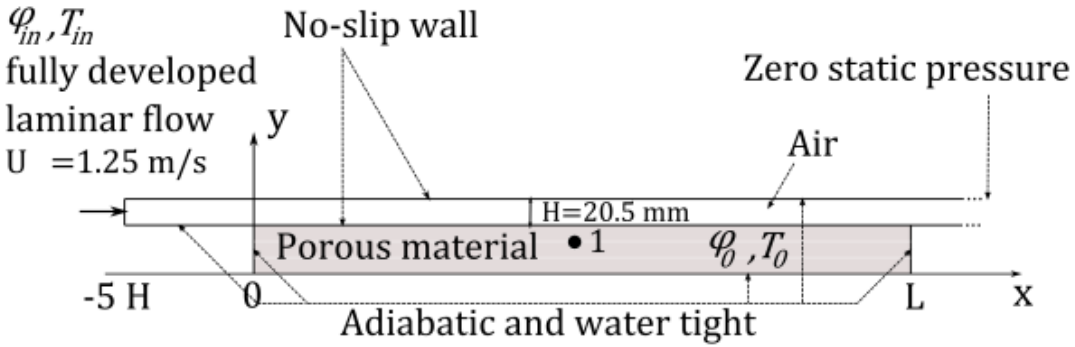
⇦ Moisture balance

$$\frac{A}{L}\left(\frac{\partial h}{\partial t} + v\frac{\partial h}{\partial s}\right) = \alpha\left(T_b - T\right) + \beta\left(p_{v,b} - p_v\right)h_v$$

⇦ Energy balance

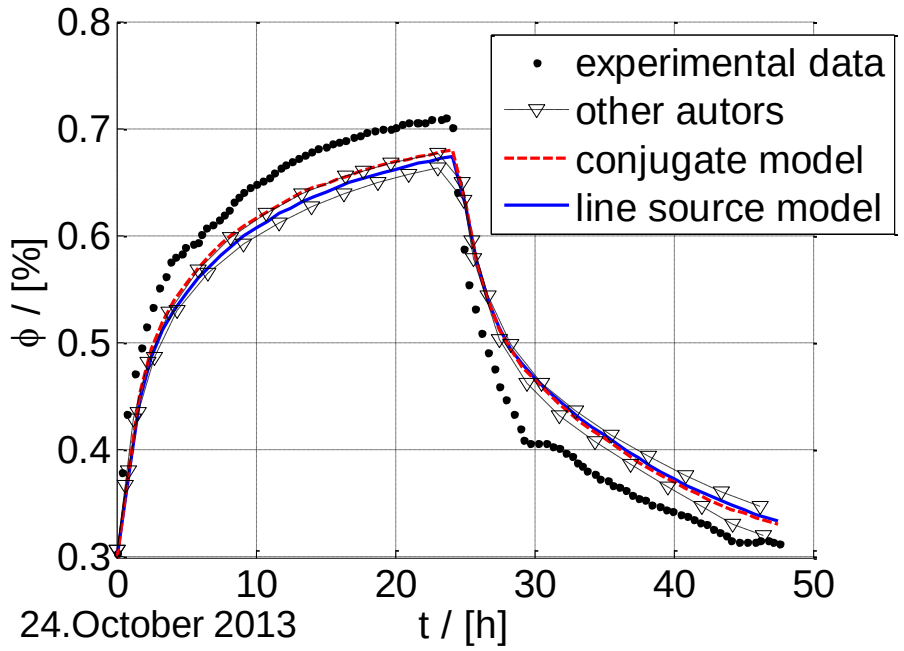
α	Heat transfer coefficient
β	Mass transfer coefficient
A	Cross section area
L	Cross section perimeter
v	Air velocity

Results: Test case A

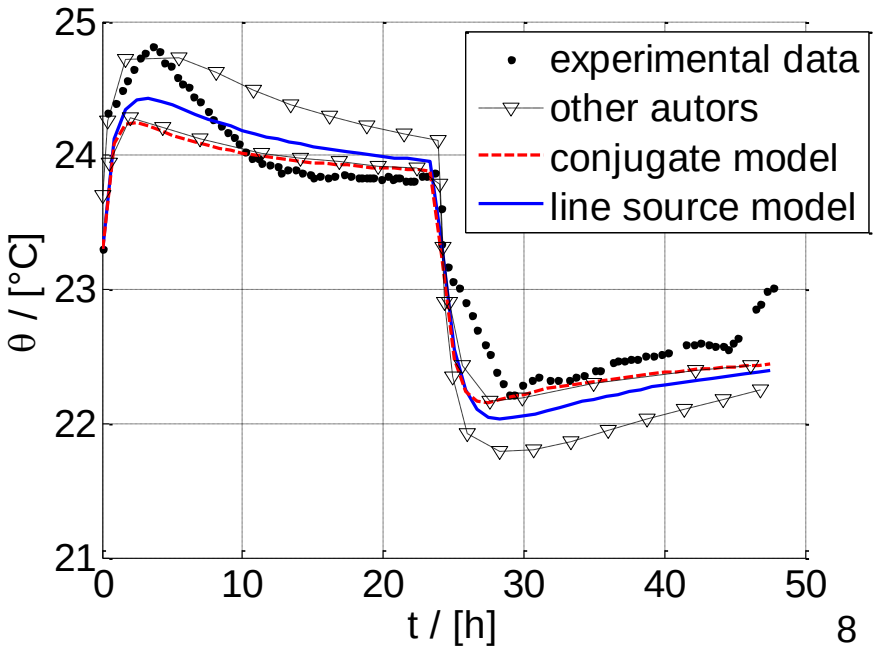


Experimental data from:
C. James, C. J. Simonson, P. Talukdar, and S. Roels, "Numerical and experimental data set for benchmarking hygroscopic buffering models," *Int. J. Heat Mass Transf. 2010*

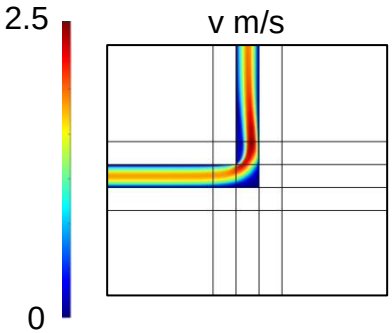
RH evolution at point 1

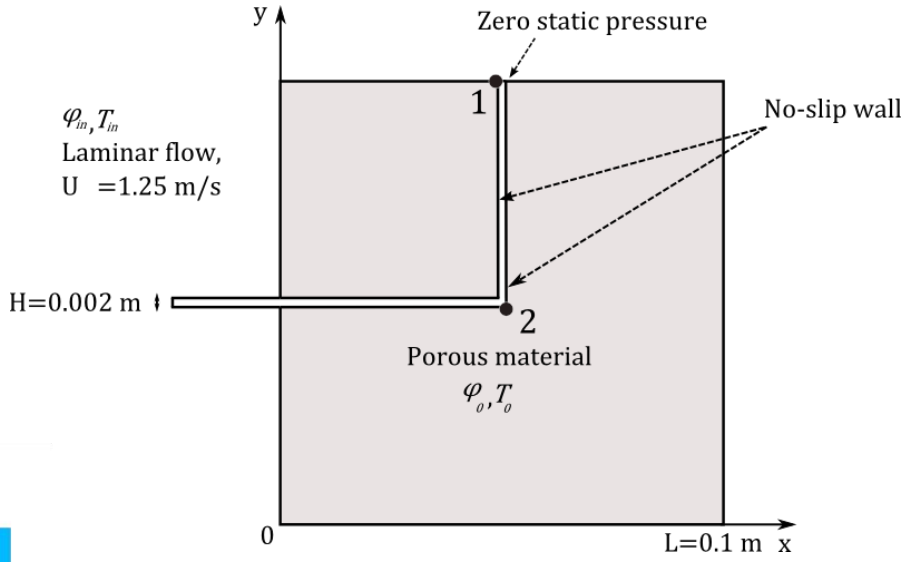


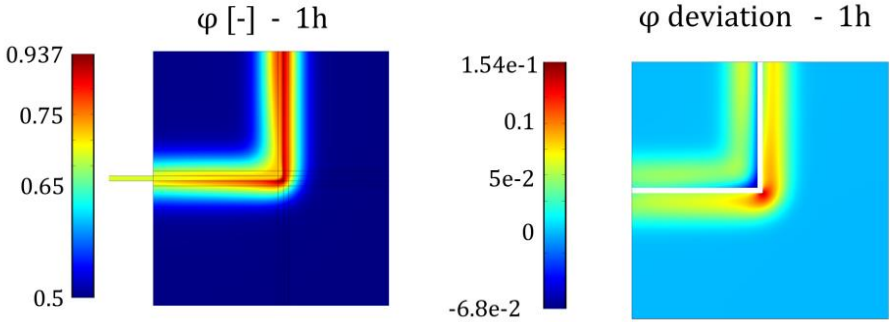
Temp. evolution at point 1

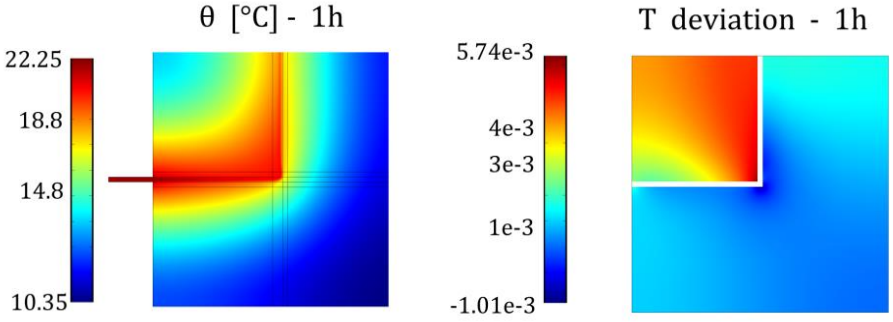


Results: Test case B

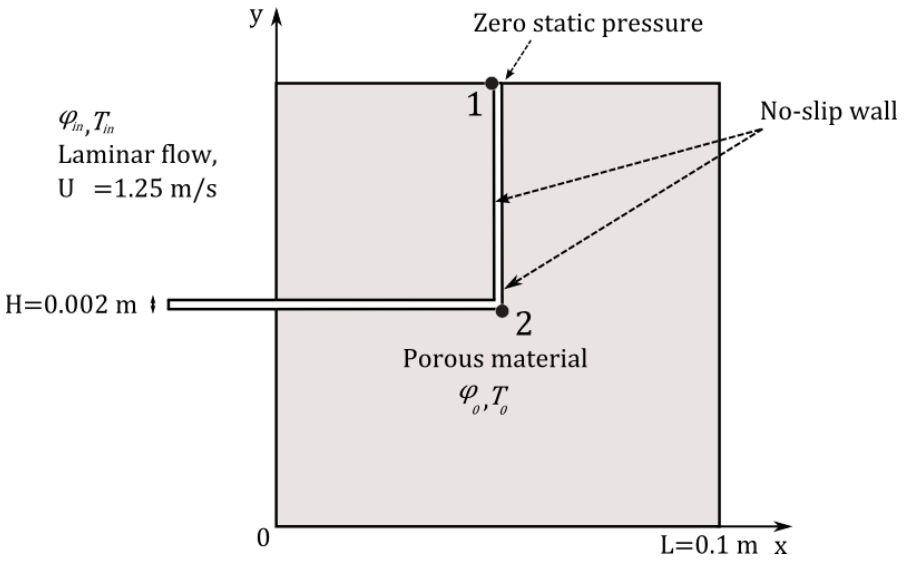


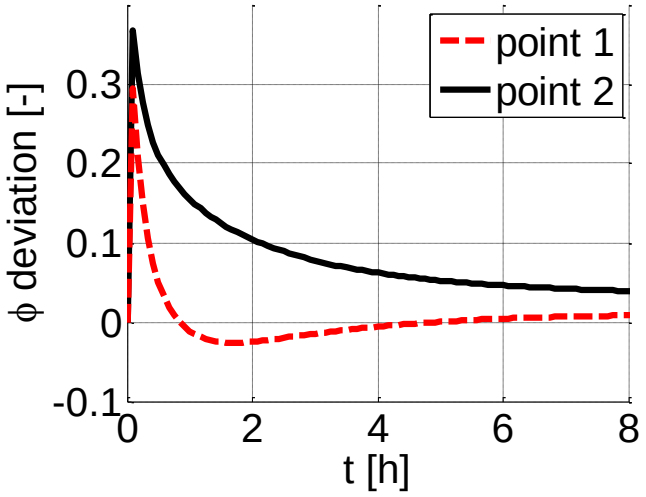


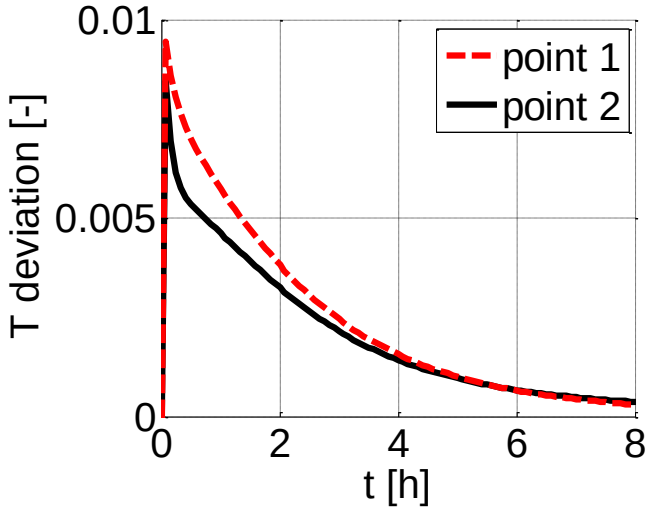




Results: Test case B







Conclusion

Acceptable solution quality employing the line-source approach

Further development

- Further experimental validation
- Variable transfer coefficients

Thank you for your attention!

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