

Dynamic Heat and Moisture Transport Modeling of Industrial Floors on Different Climates

Dóra SZAGRI
Civil Engineer Student

Balázs NAGY
PhD Student
Structural Engineer MSc
Building Energetics Spec. Eng.

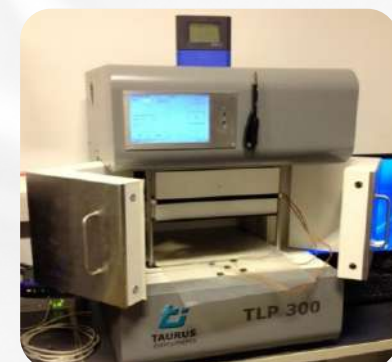
Budapest University of Technology and Economics (BME), Hungary
Faculty of Civil Engineering, Department of Construction Materials and Technologies, Laboratory of Building Physics

Content

- I. Introduction
- II. Dynamic heat and moisture simulation
- III. Base models
- IV. Thermal design of the floor
- V. Boundary conditions
- VI. Results
 - a) Heat flux densities of insulated floors on different climates
 - b) Relative humidities in the floor and wall components
 - c) Heat flux densities on internal faces of floors with different insulations
 - d) Relative humidity in floors with different insulations
 - e) Heat flux densities on internal faces of plinth walls with different insulations
 - f) Heat flux densities of floors with different insulations
 - g) Heat flux densities of floors with diff. insulations and diff. soils
- VII. Conclusion and application of the results

Introduction

- Hygrothermal aspects of a structure are essential in building energy calculations.
- There were no material properties measured of industrial applied steel fibre reinforced concretes for HAM simulations.
- Last year we have measured these important properties (moisture and temperature dependent thermal conductivity, specific heat capacity, vapor diffusion coefficient and resistance, moisture storage functions, water absorption coefficient and liquid transport coefficient) [3, 4]
- With these measurements we are able to make simulations closer to reality.



Dynamic heat and moisture simulation

- We have analyzed 126 combinations of a general segment of wall and foundations connection of a heated industrial hall.
- We used WUFI 2D simulation tool for the conjugated heat and moisture transport analyses.

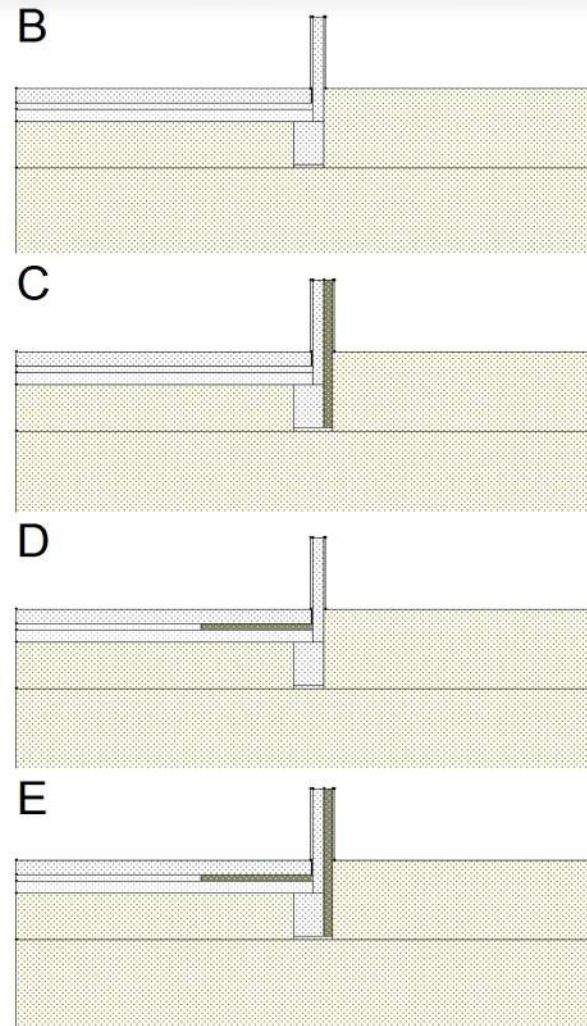
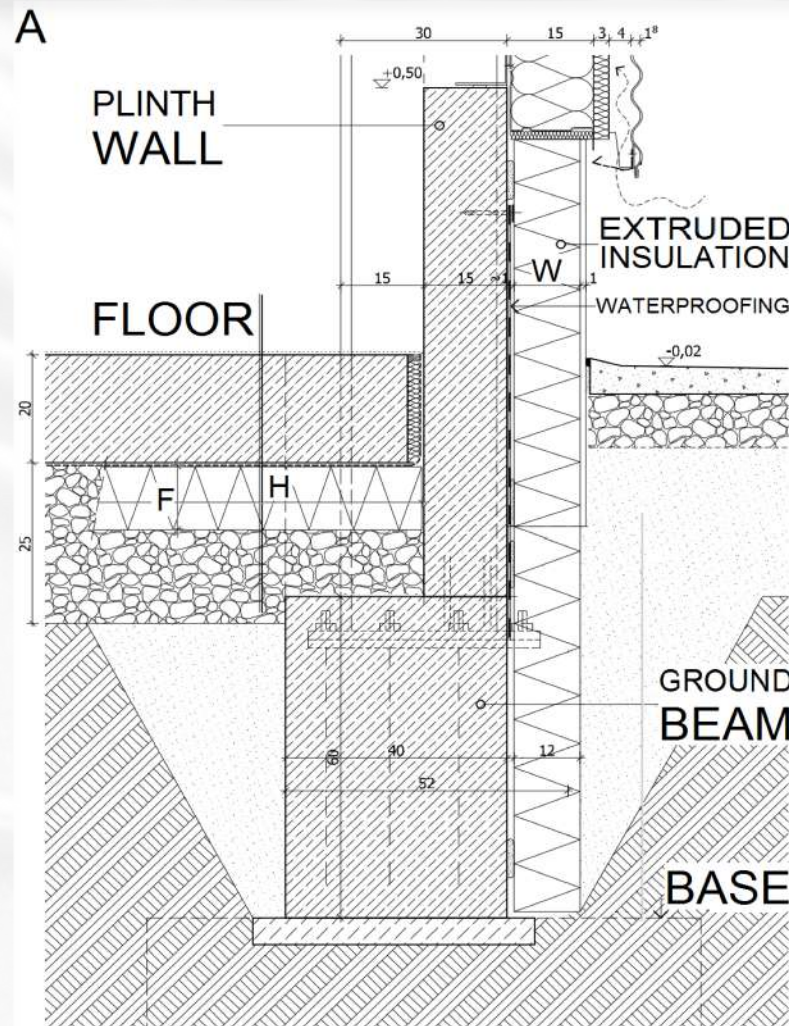
$$\frac{dH}{d\vartheta} \cdot \frac{\partial \vartheta}{\partial t} = \nabla \cdot (\lambda \nabla \vartheta) + h_v \nabla \cdot (\delta_p \nabla (\varphi p_{sat}))$$

$$\frac{dw}{d\varphi} \cdot \frac{\partial \varphi}{\partial t} = \nabla \cdot (D_\varphi \nabla \varphi + \delta_p \nabla (\varphi p_{sat}))$$



Our goal: Temperature and RH changes inside the structure

Base models



without
insulation

with vertical plinth
wall insulation

with horizontal floor
insulation

insulated plinth wall
and floor

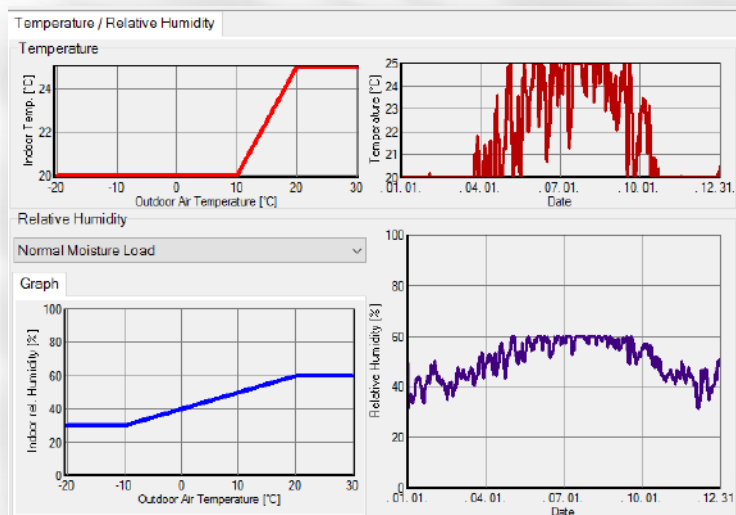
Thermal design of the floor

TMN Decree No. 7/2006

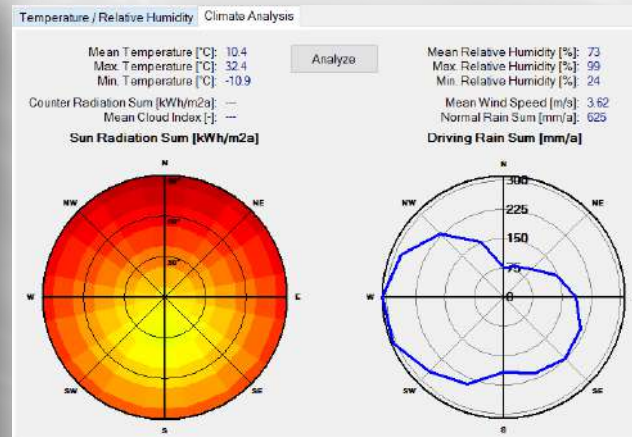
Regulation	Component	Prescribed U-value [W/m ² K]	Designed U-value [W/m ² K]	Insulation thickness
General	wall	0.45	0.431	6 cm
	floor	0.5	0.458	5 cm
“Cost optimized”	wall	0.24	0.232	12 cm
	floor	0.3	0.285	10 cm

Parameters	Values
“F” Thickness of underfloor insulation	0 cm, 5 cm, 10 cm
“H” Length of underfloor insulation	0 cm, 50 cm, 100 cm, 150 cm
“W” Thickness of wall & beam insulation	0 cm, 6 cm, 12 cm
Soil	Sandy Clay (SC), Loamy Sand (LS)
Climate	Budapest, Hungary (B), Espoo, Finland (E), Lisbon, Portugal (L)

Boundary conditions

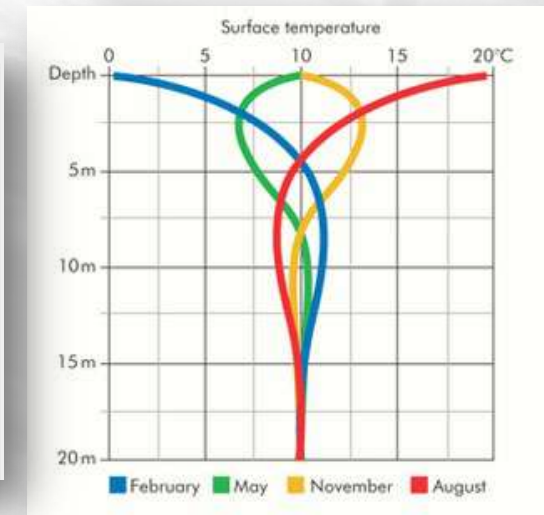


Inner conditions according to
MSZ EN 15026:2007
- normal moisture load



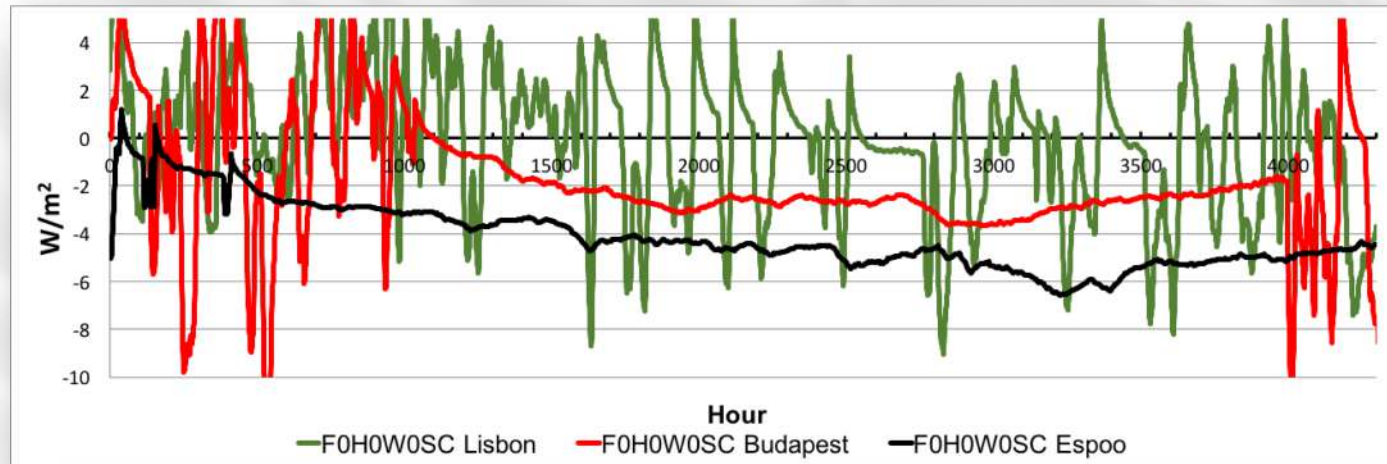
Detailed meteorological data:

- temperature
- solar radiation
- rainfall
- atmospheric pressure



During the simulations,
the soil temperature was
set to constant 10 °C in
the depth of 20 m.

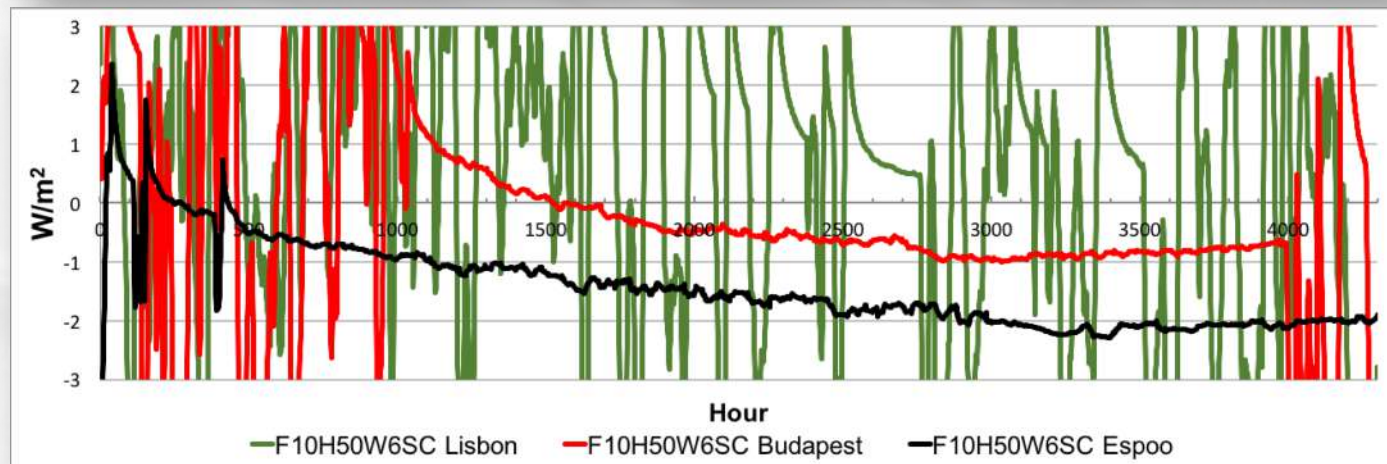
Heat flux densities of insulated floors on different climates



uninsulated floors

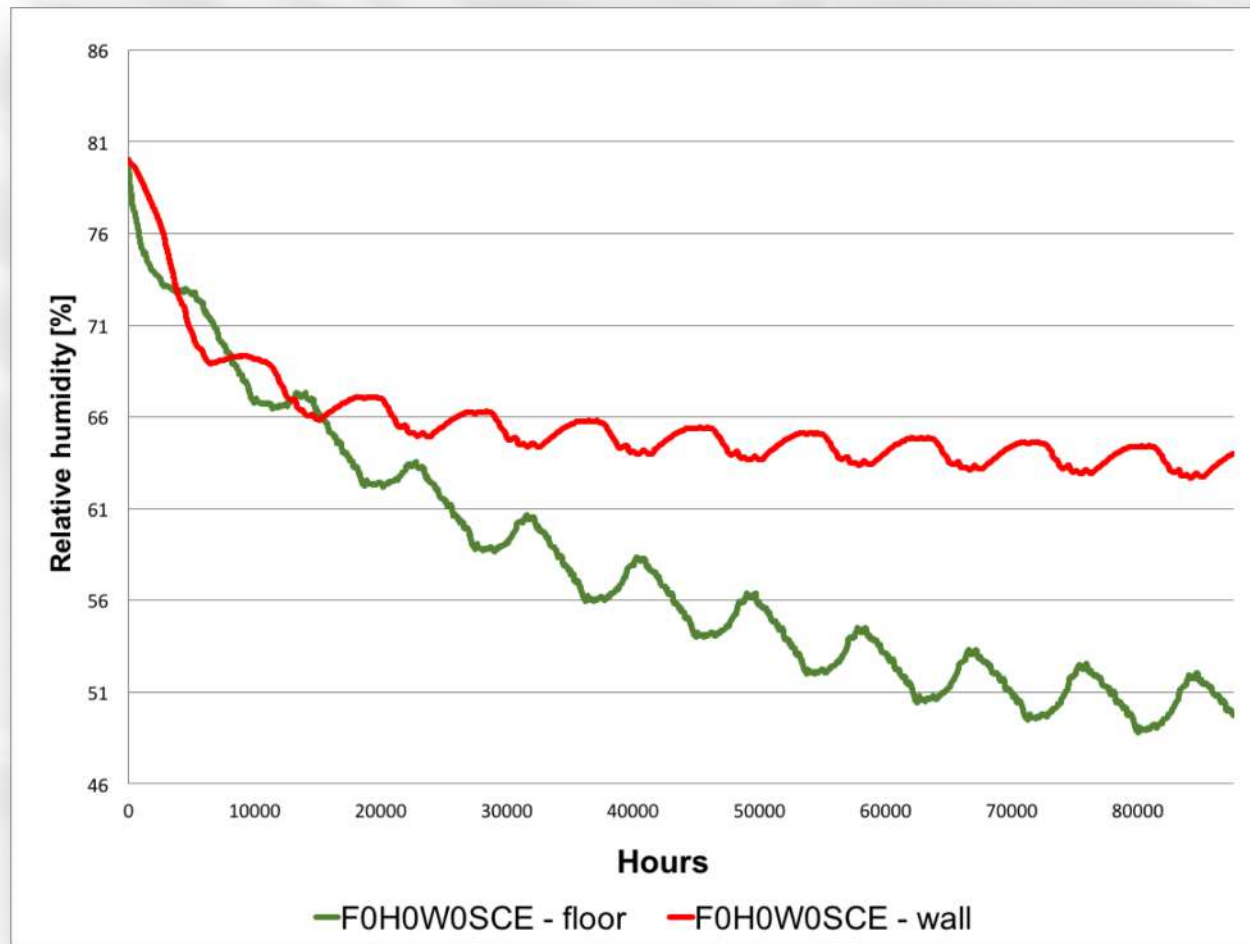


larger heat fluxes in
Budapest or Espoo



insulating the floor
can reduce heating
season length

Relative humidities in the floor and wall components



initial relative humidity: 80%



more than 10 year
long simulation time

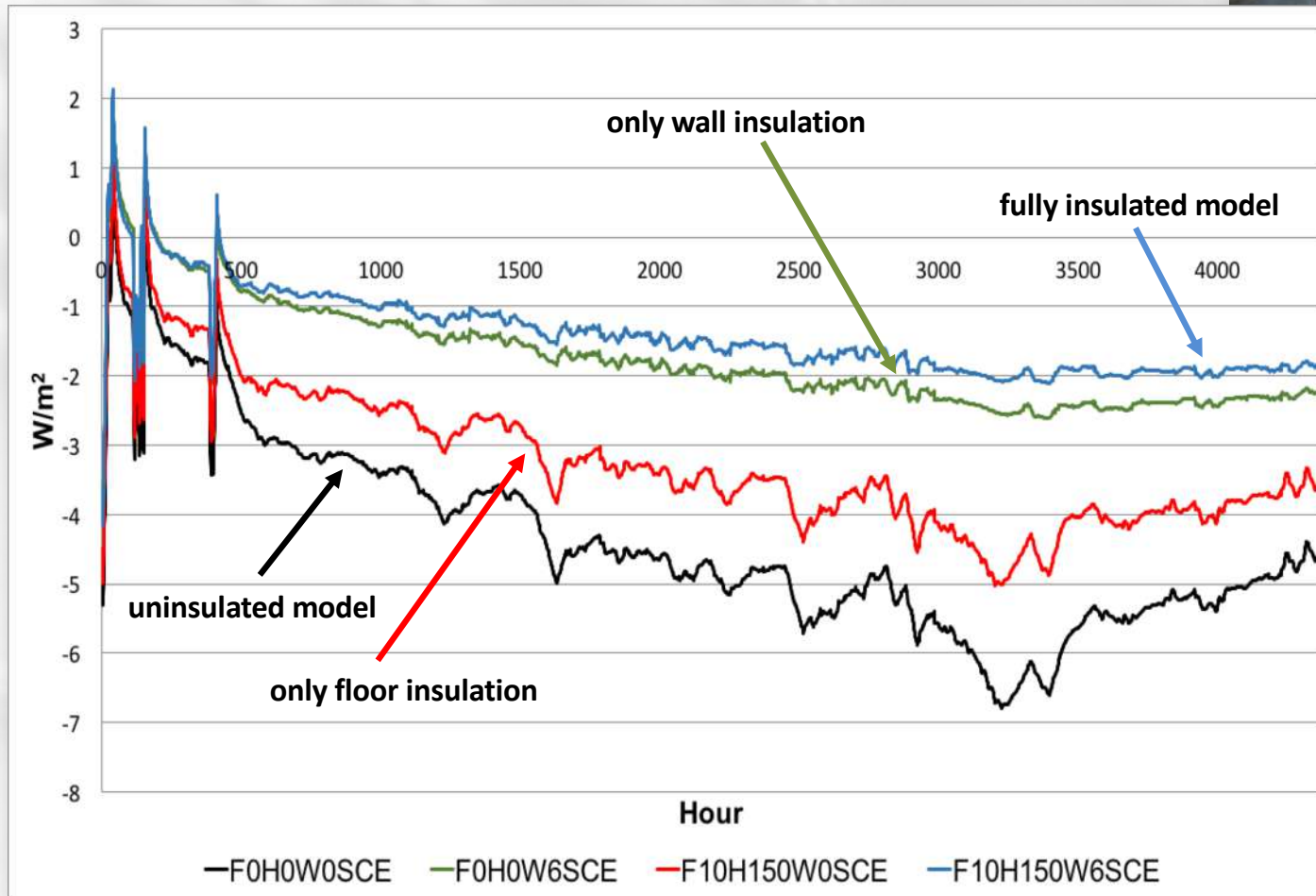
walls: 63%
floors: 50%



reduced simulation
time (5 years)

Heat flux densities on internal faces of floors with different insulations

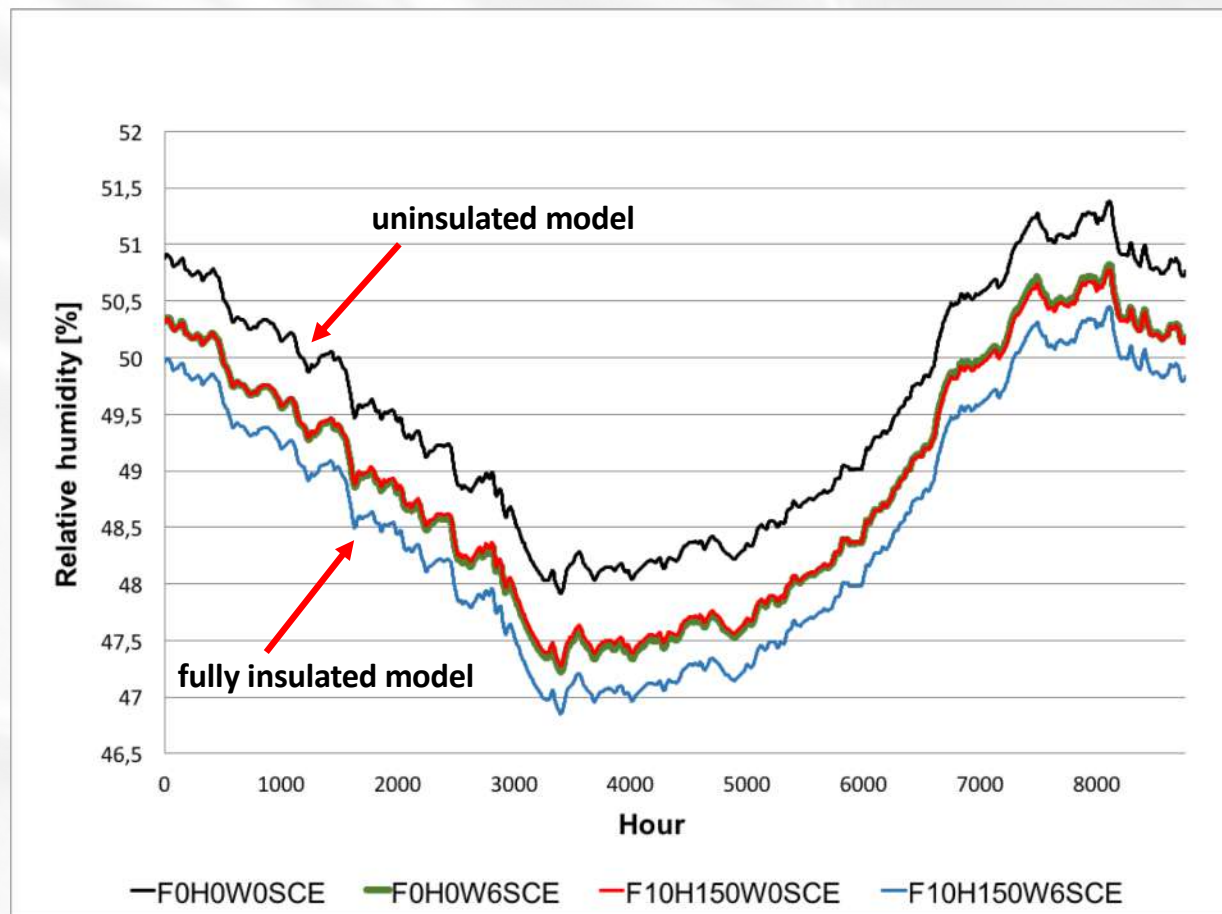
Simulations with sandy clay soil and Espoo climate



insulation next to the
plinth wall and the
ground beam are more
efficient than insulating
horizontally under the
industrial floor

Relative humidity in floors with different insulations

If we are using insulation under the layer, we separate it from dynamic conditions.

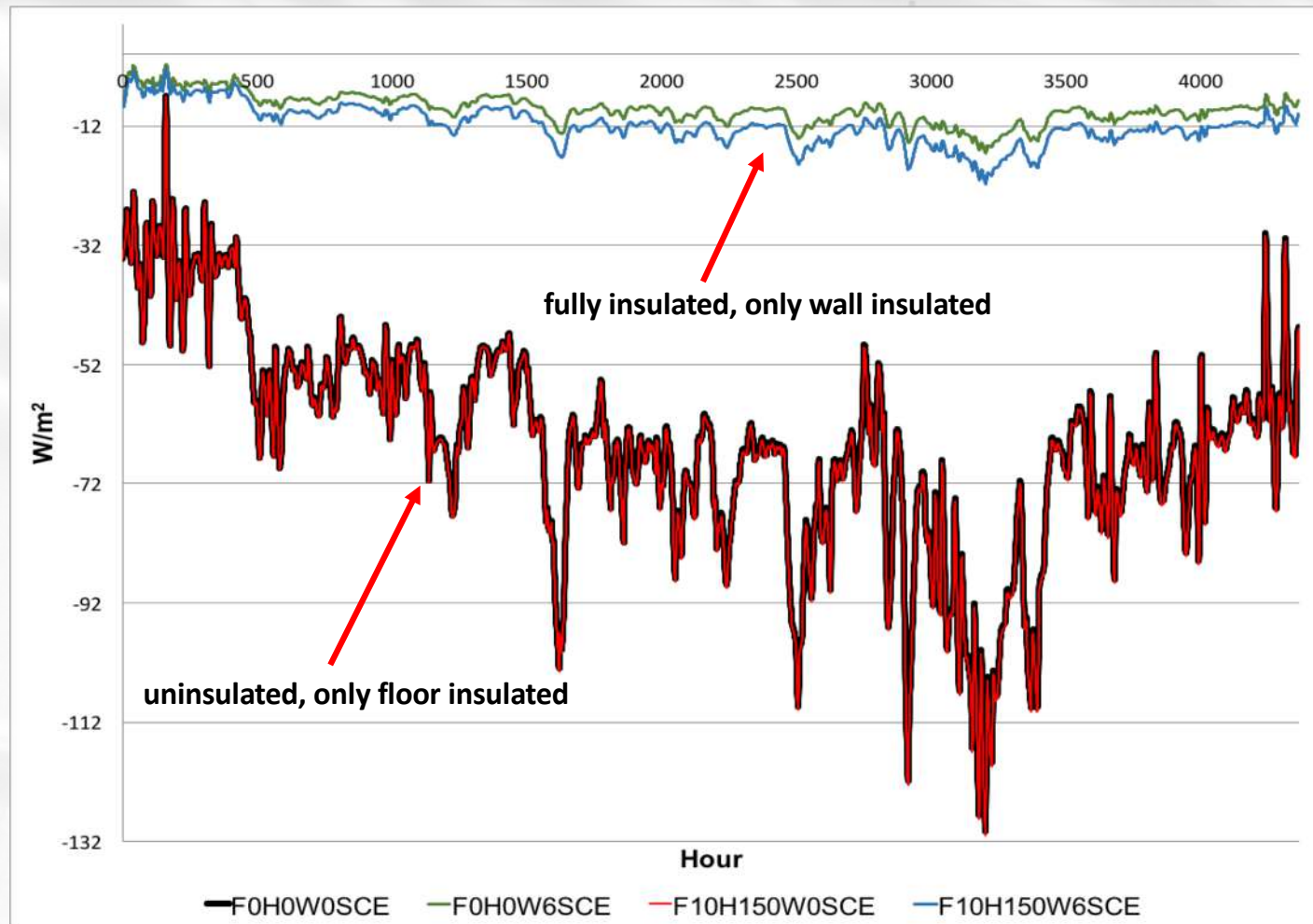


better insulated section



relative humidity of the
fibre reinforced concrete
layer decrease

Heat flux densities on internal faces of plinth walls with different insulations



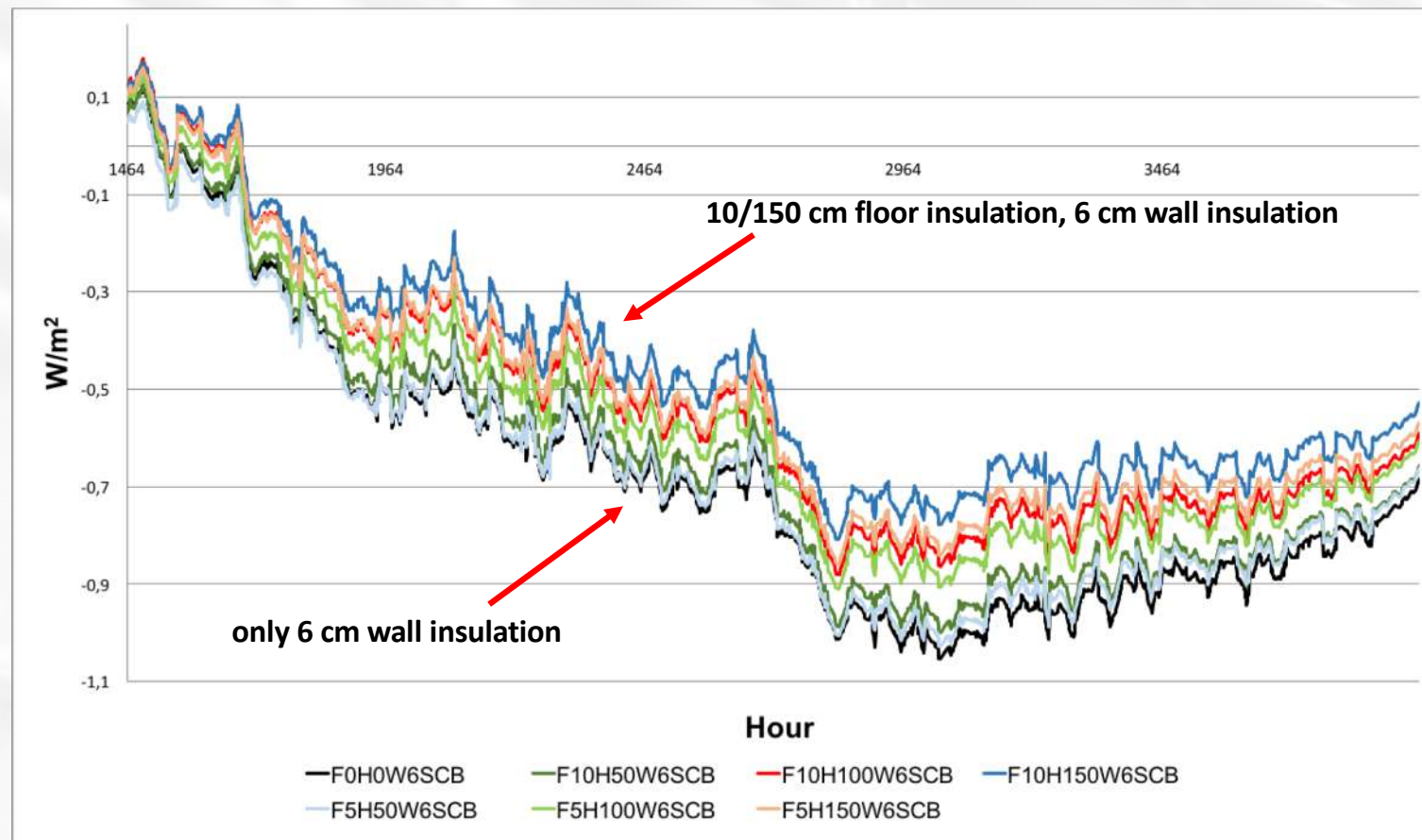
insulating only the wall
can cause the least heat
loss, but we should
consider, that in this case
there is much more heat
loss through the floors

in a fully insulated model
the heat losses reduced
by an observable quantity

insulating only the floor
have almost no effect

dramatically big heat
losses, when we not
insulate the walls

Heat flux densities of floors with different insulations

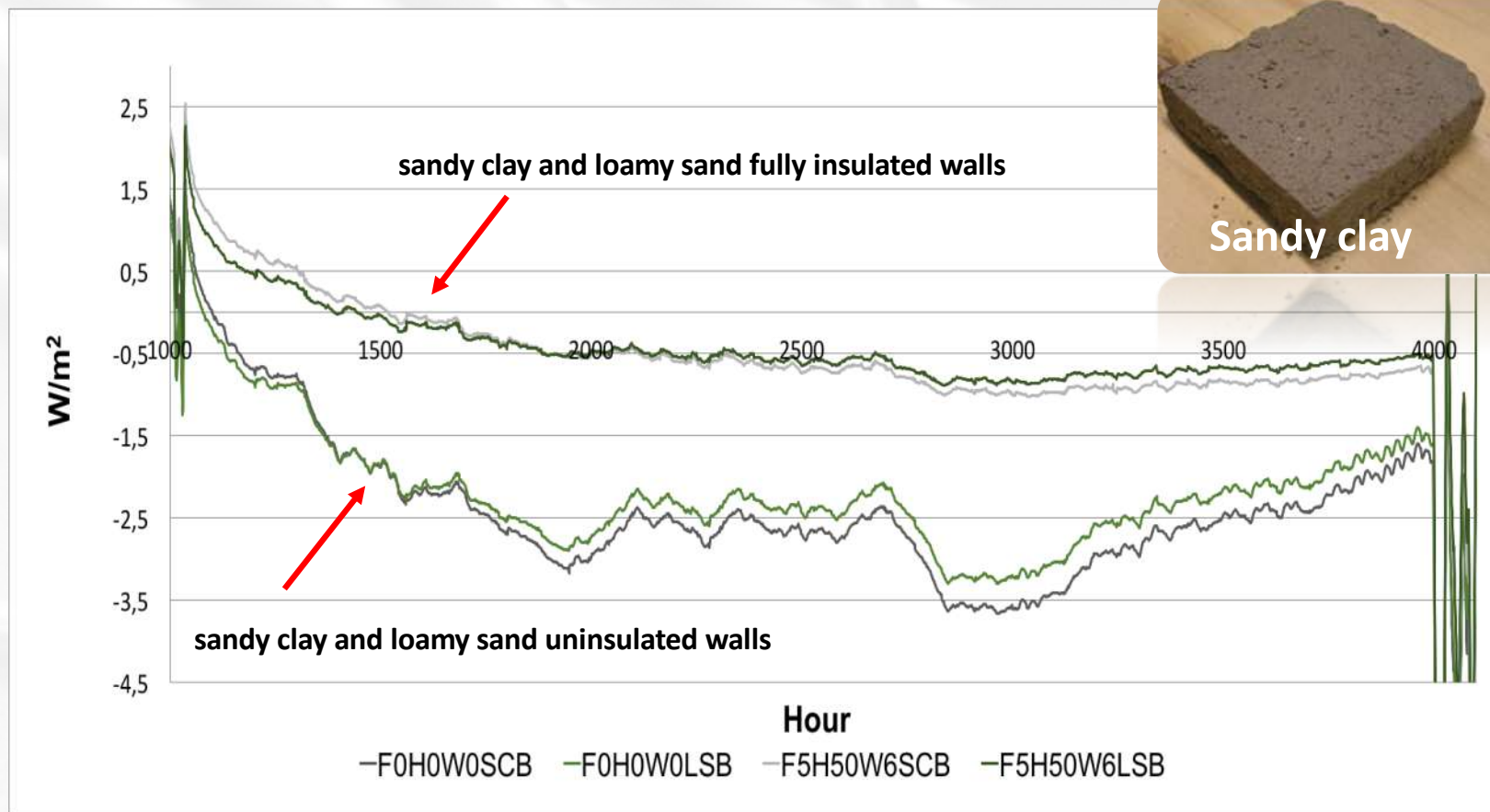


Using thicker insulation with smaller width (10 cm/50 cm) next to the base wall than thinner insulation with longer width (5 cm/150 cm) leads to higher heat losses.

50 cm insulation length gives significantly less heat loss reduction, than 100 cm or 150 cm, even if it will be 10 cm thick.

Heat flux densities of floors with diff. insulations and diff. soils

There is a visible connection between different soils and heat losses



insulated floors
and walls



effect of different
soil types reduced

Conclusion

- Using thicker insulation with smaller width (10 cm/50 cm) next to the base wall than thinner insulation with longer width (5 cm/150 cm) leads to higher heat losses. 50 cm insulation length gives significantly less heat loss reduction, than 100 cm or 150 cm, even if it will be 10 cm thick.
- There is a visible connection between different soils and heat losses, but the effects of different soil types reduced when we used insulated floors and walls.
- We showed that climate differences across Europe should result different insulation techniques as well, insulating the plinth walls could be very effective, floors should be insulated at least 1 m from their edge.
- In short, the conclusion is that keeping in mind the presented results can improve the energy efficiency of industrial buildings across Europe.



References in paper

- [1] L. Horka, O. Sikula, J. Weyr, Numerical Simulation of Subsoil Freezing Risk under the Freezer Room, Appl. Mech. Mater. 797 (2015) pp. 225-230.
- [2] MSZ 04-140-2:1991, Power Engineering Dimensioning Calculuses of Buildings and Building Envelope Structures, KTM, Budapest, 1991.
- [3] B. Nagy, S.G. Nehme, D. Szagri, Thermal Properties and Modeling of Fiber Reinforced Concretes, Energ. Procedia 78 (2015) pp. 2742–2747.
- [4] B. Nagy, D. Szagri, Hygrothermal Properties of Steel Fiber Reinforced Concretes, Appl. Mechan. Mater. 824 (2016) pp. 579-588.
- [5] W. Robert, P. Kosiński, Seeming Air Tightness of Construction Partitions, Energ. Procedia 78 (2015) pp. 1519-1524.
- [6] B. Nagy, Thermal Calculation of Ground Contact Structures: New Methods Based on Parametrized Transient Finite Element Thermal Modeling, Acta Physica Polonica A 128 (2015) pp. 164-166.
- [7] H.M. Künzeli, Temperature and Moisture Dependence of the Thermal Conductivity of Insulation Materials, Fraunhofer IRB Verlag, Stuttgart, 1995.
- [8] M. Krus, Moisture Transport and Storage Coefficients of Porous Mineral Building Materials. Fraunhofer IRB Verlag, Stuttgart, 1996.
- [9] B. Nagy, Comparison of Approximate Soil Thermal Conductivity Calculations with Laboratory Measurements and New Estimation Methods for Sandy Clayey Silt, Adv. Mat. Res. 1041 (2014) pp. 285-291.



Thank you for the attention!

email: nagy.balazs@epito.bme.hu

szagridora@edu.bme.hu

Dóra SZAGRI
Civil Engineer Student

Balázs NAGY
PhD Student
Structural Engineer MSc
Building Energetics Spec. Eng.

Budapest University of Technology and Economics (BME), Hungary
Faculty of Civil Engineering, Department of Construction Materials and Technologies