Whole-Building Hygrothermal Modeling in IEA Annex 41
Towards a new Annex?

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Whole-Building Hygrothermal Modeling in IEA Annex 41

→ Towards a new Annex?

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Whole BEE
Whole building Environmental Engineering

• Proposal for a new IEA Annex
• - or other international cooperative project
A New Annex?

Ongoing discussions:

- IBPSA, Beijing (Sept. 07)
- IEA Annex 41, Porto (Oct. 07)
- Buildings X, Clearwater (Dec. 07)
- Nordic Building Physics, Copenhagen (June 08)
- Indoor Air, Copenhagen (Aug. 2008)

Presentation Outline

- IEA Annex 41 – the history
- Modeling whole building HAM
- What comes after IEA Annex 41?
IEA Annex 41

Whole Building Heat, Air and Moisture Response (MOIST-ENG)
Nov. 2003 – Nov. 2007

Subtasks:
1. Modeling principles and common exercises
2. Experimental Investigations
3. Boundary Conditions
4. Long Term Performance and technology transfer

Past Progress

Past IEA HAM Activities:

• IEA Annex 14
  - Mould criteria, analysis

• IEA Annex 24
  - HAM theory, material properties, Environmental conditions, Durability & energy.

• IEA Annex 32
  - System approach

• IEA Annex 41
  - Whole building analysis
Annex Participants

- British Columbia Institute of Technology Canada
- Building Research Establishment Canada
- Grenoble University France
- CEA Centre d’Études et Technique du Bâtiment France
- Danmarks Tekniske Universitet Denmark
- Eidgenössische Materialprüfungs- und Forschungsanstalt Switzerland
- Fraunhofer Gesellschaft Germany
- Chalmers Tekniska Högskola Sweden
- Danish Building Research Institute Denmark
- Kungliga Tekniska Högskolan Sweden
- Katholieke Universiteit Leuven Belgium
- Technische Universität Wien Austria
- Oak Ridge National Laboratory United States
- Technical Research Center Finland
- Università di Genova Italy
- Universidade da Coruña Spain
- Technical Research Center Finland
- Technical Research Center Finland
- Universidade Federal de Santa Catarina Brasil
- Technische Universität Wien Austria
- National Research Council Canada
- Technical University of Denmark
- Technical University of Denmark
- University College London United Kingdom
- Technical University of Denmark
- Tallinna Technikaüliool Estonia
- Tampereen Teknillinen Yliopisto Finland
- Technische Universität Dresden Germany
- Technische Universiteit Eindhoven The Netherlands
- Tohoku University Japan
- Université de La Rochelle France
- Universidade do Porto Portugal

39 institutions
19 countries

Objectives have been met by:

- Theoretical analysis
- Computer model development
- Application of engineering tools
- Benchmarking and Common Exercises
- Parameter analysis and making considerations about which details are important (and which not)

Extension of building component simulation tools

Improving existing building simulation tools (transfer in the envelope)

Combination of both

IEA Annex 41 / Subtask 1 should not develop one common tool
### Software used/developed

<table>
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<tr>
<th>Name</th>
<th>Developer</th>
<th>Main user in Annex 41</th>
<th>Availability</th>
<th>Origin</th>
<th>Possibility of adding new components</th>
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<td>CHAMPS Seminar</td>
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<td>Chaire de Thermique de Lyon - CETHL, (France)</td>
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<td>Provisioner</td>
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### Common Exercises

- **CE0** | CETHIL, France | Validation of thermal aspects of the employed models by repeating BESTEST.
- **CE1** | DTU, Denmark | Experimental data from climate chamber tests (cortec) and indoor climate.
- **CE2** | Tohoku University, Japan | Extension of CE3 with focus on energy efficient moisture management.
- **CE3** | KUL, Belgium | Double chamber test under real conditions.
- **CE4** | CETHIL, ENSA-Lyon, France | Extension of CE3 with focus on energy efficient moisture management.
- **CE5** | KUL, Belgium | Double chamber test under real conditions.
**Common Exercises**

- **CE0**: Cethil, France
  - Validation of *thermal* aspects of the employed models by repeating BESTEST.

- **CE1**: DTU, Denmark
  - Moisture interactions between constructions and indoor climate.
  - Experimental data from climate chamber tests (airflow).
  - IEA SHC Task 12 & ECBCS Annex 21

- **CE2**: Tohoku University, Japan
  - Double chamber test under real condition.

- **CE3**: FhG, Germany
  - Experimental setup.

- **CE4**: CETHIL, INSA-Lyon, France
  - Extension of CE3 with focus on energy efficient moisture management.

- **CE5**: KUL, Belgium
  - Case study of a real life row house - growing complexity.

**RESULTS: CE1A**

- **CE1A Case 0B**: open indoor surface

**NUMERICAL RESULTS**

- Indoor Relative Humidity

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Numerical vs. analytical calculations. Isothermal. Monolithic construction with open surfaces.
RESULTS: CE1 600_0B (RH indoor)

**Case 600_0B**
Indoor Relative Humidity

- # 1
- # 2
- # 3
- # 4
- # 5
- # 7
- # 8
- # 9
- # 10
- # 11
- # 12
- # 13
- # 14

**CHAMPS Seminar, La Rochelle, July 6-8, 2008**

Analytical calculations. Isothermal. Construction surfaces are open.

RESULTS: CE1B Case 3 (indoor RH)

**CE1B Case 3: Varying indoor Temperature, with radiation**
Indoor relative humidity
A day in July

- # 1
- # 2
- # 3
- # 4
- # 5
- # 6
- # 7
- # 8
- # 9
- # 10
- # 11
- # 12
- # 13A
- # 13B

**CHAMPS Seminar, La Rochelle, July 6-8, 2008**

Analytical solutions
- Moisture in rooms

Solution without moisture transfer to the construction
\[ c_i(t) = \frac{G}{n \cdot V} \left( c_e - c_a - \frac{G}{n \cdot V} \right) \cdot e^{-\left(t - t_0\right)} \quad t \geq t_0 \]

Solution with moisture transfer to the construction
\[ c_n(t) = \frac{G_{in}}{R_e} \left( 1 - \frac{d_0}{d_2} \right) \cdot e^{t} \cdot \text{erfc}\left(\sqrt{t}\right) \]

Bednar & Hagentoft

Common Exercise 2

Based on experimental data from climate chamber tests at Tohoku University, Japan. The tests had known wall claddings and air flow conditions.
CE2 - Some Results

![Temperature and Absolute Humidity Graphs](image)

Figure 4.4.8 Comparison between measured values and simulation results (Case 2-3)

Common Exercise 3

Based on double climatic chamber tests carried out by the Fraunhofer Institut für Bauphysik, Germany, using two identical chambers with different cladding materials.

foil faced test room  reference room
Common Exercise 4

CE3 with RH controlled ventilation

\[
\text{RH1} = 25\%, \; Q1 = 10 \text{ m}^3/\text{h}, \; \text{RH2} = 60\%, \; Q2 = 40 \text{ m}^3/\text{h}.
\]
CE 4 - Power Demand

Common Exercise 5

CE 5. Based on data from a real life row house located in Belgium. With some known indoor climate/moisture problems which also involve effects of adventitious airflow.
CE 2. Based on experimental data from climate chamber tests at Tohoku University, Japan. The tests have known wall claddings and air flow conditions.

CE 3. Based on double climatic chamber tests carried out by the Fraunhofer Institut für Bauphysik, Germany, using two identical chambers with different cladding materials.

CE 6. A two-storey climatic chamber test carried out at Concordia University, Canada, has served as basis for this exercise.

Objective of the experimental study:

- to generate reliable datasets to advance the understanding of the whole building response to heat, air, and moisture (HAM),
- to validate ongoing and future numerical models
Final Report:
A critical review of past/recent activity

- Good in 1D diffusion modeling
- Now getting better in capillary moisture analysis
- Very limited in air flow modeling (Fundamentals, System, and Sub-system effects)
- Very crude in whole building
- Crude in IAQ modeling

Relation to Energy & Durability Limited
A New Annex?

What’s next?

More of the same...

- Emission & IAQ modelling
- Surface chemistry
- Durability
- Stochastic analysis
- Risk assessment
- Generation of “damage functions”
- Impact of climate change
- Buildings for developing countries & their climates

A New IEA Annex?

- Energy!
  - Internationally coordinated national initiatives (e.g. national centres of excellence)
  - Industry funded activities
  - EU-funded
  - Combinations...
Background of New Annex

- Existing models allow for the prediction of several aspects related to climatization of buildings including energy performance, building physics, thermal indoor climate, and to a limited extent indoor air quality.

- IEA Annex 41 on Whole Building Heat, Air and Moisture Transfer is coming to an end by the end of 2007. The project has been successful in stimulating a lot of new integrated model development on the building physics side.

- New endeavours in indoor environmental research and knowledge on the impact of materials (emissions) on the IAQ.

- There is a strong need to link the building physics activities to the IEQ activities.

- Prospect (in terms of energy and sustainability issues):
  It is necessary to tie in this knowledge in order to reach towards future goals of passive / near zero energy consuming buildings while still maintaining good indoor climates for human activity, well-being and high productivity and learning.

Combined Heat, Air, Moisture & “Something”

- State of the art
  - HAM
  - VOC emissions
  - Durability
  - Energy
  - Sustainability
  - Impact of climate change

- Further research needs
  - Refinement of mechanistic models
  - Integration of current knowledge
  - Data
  - ...

- Scope for research
  - Application, modelling tool and targeted fundamentals
Whole Building Environmental Modelling (Whole BEE)
Whole Building Environmental Modelling (Whole BEE)

Applications

Whole Building HAM models

VOC emissions & IAQ modelling
Surface chemistry emissions
Durability
Energy

Whole Building HAM models
Whole Building Environmental Modelling (Whole BEE)

Applications

Whole Building HAM models

Need Multiple Annexes

- Statistical Analysis
- Risk Assessment
- Fill in the gaps

ENERGY

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Input coordinated by:
Prof. Carl-Eric Hagentoft,
Chalmers Univ., Sweden

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ENERGY

Input coordinated by:
Assoc. Prof. Carsten Rode,
Techn. University of Denmark
Possible Funding / Framework

- IEA (nationally funded)
- EU
- National research foundations