A Brief Journey Through Building Physics / Science: Research, Standards, and Education

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NEITHER

HERE

NOR

THERE
## What is Building Science / Physics?

### Building Science

#### Building Physics (Bauphysik)
- Energy
- Heat
- Moisture
- Air
- Light
- Acoustic
- Fire Safety

#### Building Technologies (Gebäudetechnik)
- Electrical
- Lighting
- Mechanical
- Heating
- Cooling
- Ventilation
- Water

#### Environment (Umwelt)
- Climate
- Biology
- Hygiene

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Shelter from …

- Storm
- Temperatures
- Enemies
  - Animals
  - Humans
  - …
Building Physics in History

- **Vitruvius – Roman Master Builder (33 B.C.)**
  - De Architektura libri decem (10 books about architecture)
  - *Book V*: Acoustic design of theaters
  - *Book VI*: Climatic control and design of private buildings

- **Middle Ages**
  - Urbanization required double walls as fire walls for safety zoning
  - Improved acoustics (noise protection) between buildings

- **Research**
  - 18th century: Fourier (Mathematics, Physics)
  - 19th century: Laplace, Joule, Helmholtz (Energy)
Building Physics in History

- **G.A. Breymann, Baurat**
  - Professor an der Königlich Polytechnischen Schule in Stuttgart.
  - Deals with moisture and temperature control in building enclosures

- **Dr.-Ing. Heinrich Gröber**
  - "Einführung in die Lehre von der Wärmeübertragung“, 1926 (Introduction to thermal transfer in materials)

- **J.S. Cammerer**
  - "Gesamt-Wärmeverlust von Wärmespeichern", 1925 (Total Heat Loss of Thermal Capacitors)
  - "Hilfstafel zur Berechnung des Wärmeschutzes im Bauwesen", 1925 (Tables for Calculating Thermal Resistance in Building Construction)
  - „Der Wärme- und Kälteschutz in der Industrie“ (Springer, 1928)
  - Table 12: Impact of humidity ratio on thermal conductivity in building materials of walls
  - „Tabellarium aller wichtigen Größen für Wärme-, Kälte- und Schallschutz“ (1936) (Table of important properties for thermal and noise protection)
“Reflex Patterns” in Addressing Issues

Europe – Government Fix

- Design and Construction Progress
- Building Issues and Failures
- Call for Standard Development
- Implementation in National Building Codes

United States – Trade Fix

- Building Issues and Failures
- Risk = $$$
- Involvement of Trades, Lobbies
- Litigation, Lawsuits, Class Action, ...
- Call for Standard Development
- Implementation in National Building Codes

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The 50ies – Emerging Standards

- **Rain/Storm Protection**

- **Minimum Thermal Insulation**
  - 1952: 1st Edition of DIN 4108
    - DIN 4108-1: Wärmeschutz im Hochbau; (Thermal insulation)
    - DIN 4108-2: Mindestanforderungen (Thermal performance requirements)
    - Only walls and roof; windows or doors were not covered
  - 1959: 1st Edition of ON B 8110

- **Thermal Capacity**
  - Intermittent heating
  - No central heating → heating of selected rooms
The 60ies – Emerging Technologies

- **First Problems with Interstitial Condensation**
  - More Timber-framed Construction
  - Emerging Flat roofs
  - DIN 4108-3: Klimabedingter Feuchteschutz; Anforderungen, Berechnungsverfahren und Hinweise für Planung und Ausführung (Moisture control in buildings; requirements and calculation model)

- **New Heating Systems**
  - Emerging central heating

- **Temperature Control**
  - Through (over-)ventilation → no thermostats
  - Few mold problems (mostly too dry indoor air)

- **Term “Bauphysik” emerges**

- **Austria: Individual State Building Codes**
  - Now require minimum levels of thermal and acoustic insulation
The 70ies – The First Energy Crises

□ Energy Crises

 Leads to Increased Energy Cost
 Improved thermal performance requirements
  ➢ Revision of DIN 4108-2: (Thermal performance requirements)
  ➢ 1. Wärmeschutzverordnung 1977
 Airtightness of windows
  ➢ DIN 4108-7: Luftdichtheit von Gebäuden
    (Air tightness of buildings)
 Thermostat valves for temperature control

□ Mold Problems

 Lower air change rates
 Despite insulation efforts still comparatively low surface temperatures

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The 80ies – Emerging Architecture

- **Increased Thermal Performance Requirements**
  - 2. Wärmeschutzverordnung 1984

- **New Façade Systems**
  - Larger window/wall ratios with improved glazing performance
  - Summer over-heating control (architectural, mechanical)
    - Expansion of DIN 4108-2: Section “Sommerlicher Wärmeschutz”

- **Alternative Energy Systems**
  - Solar thermal systems
  - Passive solar systems

- **Urbanization**
  - Acoustic performance requirements

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The 90ies – Environmental Issues

☐ Increased Thermal Performance Requirements
  ▪ 3. Wärmeschutzverordnung 1995

☐ Health Issues
  ▪ Building product related (asbestos, formaldehyde, …)

☐ Discussion on Ecological Impact
  ▪ Building Products
  ▪ Building Developments

☐ EU Opens Market
  ▪ EU wide product directives
The 21st Century – A Shift in Scale

- **Microbial Issues**
  - From exterior environment
  - Odor issues

- **Energy Efficiency of Industrial Facilities**
  - Integration with energy efficient manufacturing
  - Facility development integration with transportation infrastructure

- **Building Physics in Mobile “Facilities”**
  - Airplane design and construction
  - Automobile designs and construction

- **Sustainability (“Nachhaltigkeit”)**
Recap of (European) Development

Why did it take two decades for building physics to emerge as a recognized profession?

- Missing of theoretical fundamentals and methods
  - Academic research
- Missing best practice and application in construction
  - Development of standards
- Knowledge deficit in practice
  - Continuing education
- Missing professional engineers for building physics
  - New academic programs and professionals
- Missing governmental requirements
  - Code requirements implementing existing standards
  - Incentives driving better building practice
    (e.g. subsidized loans for “correct” or better building practice)
- Missing advanced building products, test instruments and protocols
Common Educational Program Layout

Civil Engineering

- Geotechnics + Water
- Transportation + Environment
- Construction
- Structural
- Building Construction
- Construction Management

Architecture

- Design + Practice
- Urban Affairs + Planning
- History and Theory
- Construction Technologies
- Building Technologies
- Visualization and Practice
- City Planning
- Landscape Planning
- Development

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Degree Programs with Building Physics Focus

Interactive map with tagged departments and website URLs.

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Close Up View – Graz University of Technology

☐ Civil Engineering
  ▪ Department of Building Construction
    ➢ Building Construction Principles (2)
    ➢ Building Physics (3)
  ▪ Building Construction Laboratory
    ➢ Building Physics Research
    ➢ Accreditation Laboratory

☐ Architecture
  ▪ Department of Buildings & Energy
    ➢ Building Technologies (4)
    ➢ Building Physics (3)
    ➢ Architecture and Energy (4)

☐ Mechanical Engineering
  ▪ Master Program Energy Technologies
    ➢ HVAC Technologies (3)
    ➢ Energy Technologies (4)
    ➢ Energy Measurements and Technologies (4)
Performance Tools

- Thermal Performance
  - U-Value
  - Thermal Lag Times

- Hygrothermal Performance
  - Condensation Risk
  - Mold Mitigation
  - Durability

- Acoustic Performance
  - Transmission Loss

BEST-Lab Research Group, Sept 2012

Building Science Research / Myers-Lawson School
Interstitielle Konденstation

Kondensationsberechnung

Kondensatmengen $G_{K_i}$ nach ÖNORM B1100-2 (Punkt 5.2.5)

<table>
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<th>$G_{K_i}$</th>
<th>$G_{K_{E}}$</th>
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Bauphysikalische Beurteilung des Bauteilbereichs:

Die anfallende KONDENSATMENGE KANN in der Verdunstungsperiode weder VOLLSTÄNDIG AUSTROCKEN, sodaß keine fortschreitende Feuchteanhäufung im Bauteil auftritt ( $G_{K} < G_{K_{E}}$ ).

---- Beginn Schicht 1: Innenputz

Berechnung starten
Educational Sites with “Building Science”  (site:.edu)
http://www.maptive.com/ver3/building-science
Close Up View – Virginia Tech

- Architecture
  - Architecture + Design
    - Building Construction Principles (2)
    - Building Physics (3)
  - Building Construction
    - Building Physics
    - Applied Building Sciences
    - Building Science Modeling & Simulation (Grad)
  - Research & Demonstration Facilities
    - Building Science Research

- Civil Engineering
  - ...

- Mechanical Engineering
  - HVAC Technologies (3)

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Co-taught with BC 5314
Applied Building Sciences
Where are we today on either side?

Neither Here Nor There

☐ European nations may be closer, but still not “There”
  - Highly fragmented education system
  - Still territorial academic silos

☐ North American institutions have left the “Here”
  - Quite a way ahead to get “There”
  - Use existing roads – (internet) highway?
    - Potential to catch up by building on existing knowledge and practice
    - Learn from mistakes (still existing) in Europe
  - Potential to surpass European peer institutions by addressing building science through integrated program models
The New Master-Builder?

Building Science Professional

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