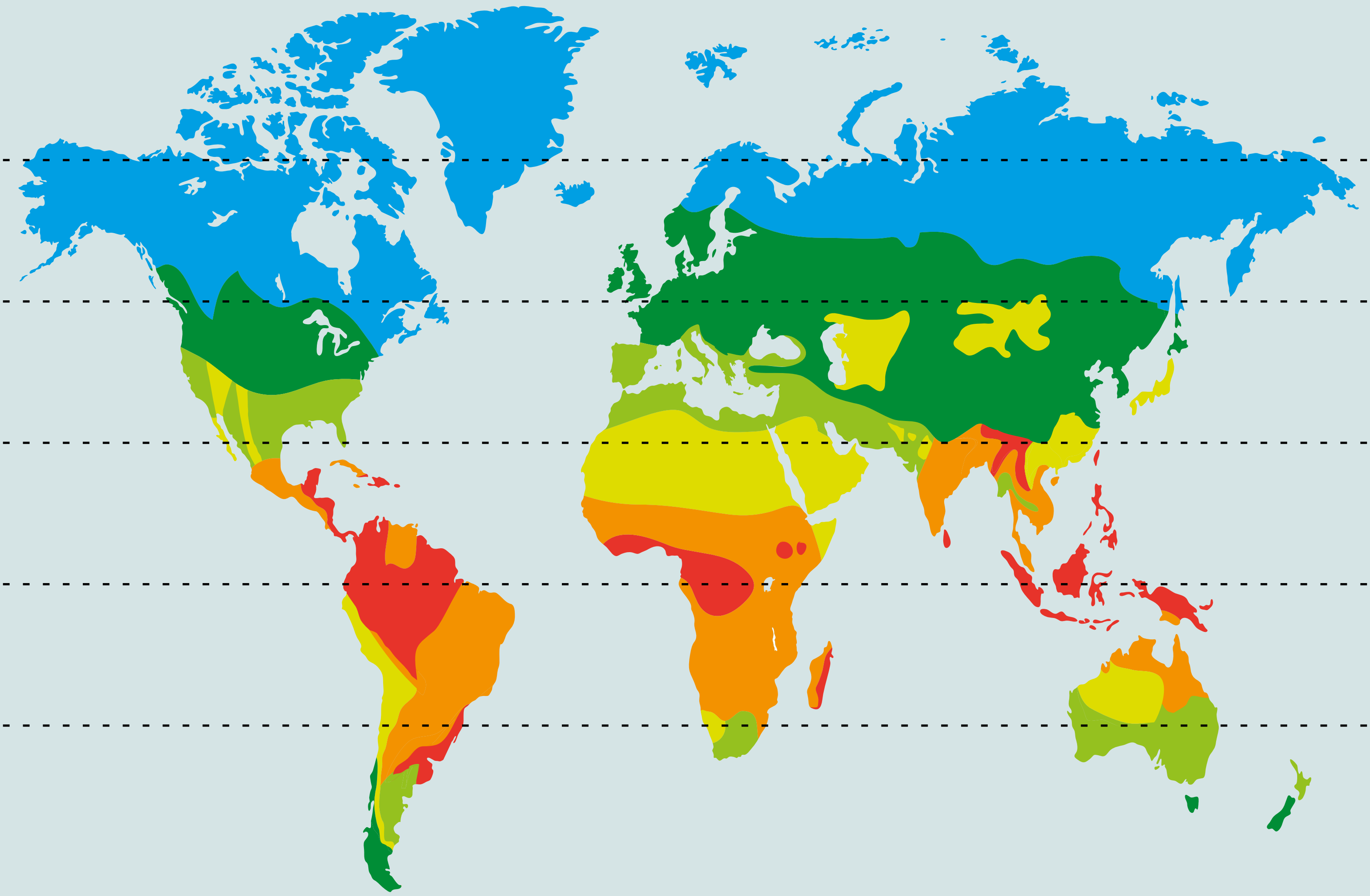
IBP

FRAUNHOFER INSTITUTE FOR BUILDING PHYSICS IBP

HYGROTHERMICS



ENHANCED ENERGY EFFICIENCY AND COMFORT WITHOUT MOISTURE DAMAGE

HYGROTHERMICS

FIELDS OF RESEARCH

- Thermal parameters and climate simulation in the laboratory
- Outdoor testing and climate data recording
- Moisture testing and climate-related material behavior
- Moisture protection assessment and hygrothermal model development
- Hygrothermal building analysis
- Bio-hygrothermics: Preventing mold formation and unwanted growth on façades
- Conserving historic structures and renovating old buildings
- Building in other climate zones

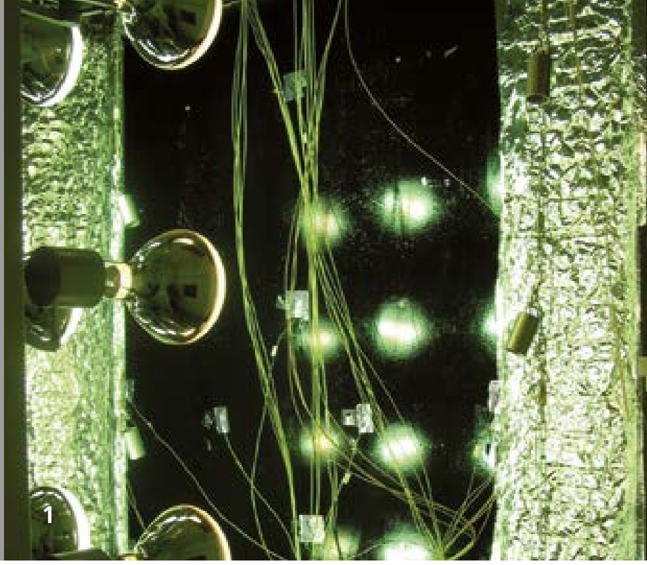
The Hygrothermics department is specialized in analyzing the dynamic heat and moisture behavior of building materials and components and whole building complexes. This includes analyzing the energy and moisture behavior of ventilation and air-conditioning systems and their interaction with the building envelope and other hygrothermal storage capacities. Such analyses form the basis for optimized systems technology that is adapted to the planned function of a building.

Material tests are conducted alongside the laboratory analysis of complete building and system components which are modified as required. All-important practical tests include those conducted outdoors under defined boundary conditions, climate simulations in suitable differential climate chambers, and new testing methods specially developed at Fraunhofer IBP.

A large part of the department's work is also devoted to the development and application of numerical simulation models. Many years of experience with both experimental and computational research methods, enable researchers to comprehensively evaluate energy-related building and systems behavior as well as the climate-related moisture protection of building structures. This experience also leads to their targeted improvement and optimization of building products and the development of innovative building equipment, materials and construction systems.

Architects and construction firms are faced with new challenges resulting from the need to save energy while meeting the growing demands for more comfort, which are both accompanied by the desire to ensure sustainable development in the building sector. These challenges cannot be met without an in-depth understanding of hygrothermal interactions.

The department's core areas of expertise, supported by its constant expansion of testing facilities and new hygrothermal simulation tools, form the basis for innovative product development. The humidity-controlled vapor retarder now being marketed in many countries is exemplary of the department's achievements in development, while considerable potential has also been identified for the researchers' novel cooling fountain **(see picture on the left)**. In contrast to conventional decorative fountains, it uses a chilled film of water. In addition to conditioning the air inside the room, this also cools people and objects in the room through the exchange of long-wave radiation. The water film's low temperature not only leads to effective cooling, but also dehumidifies the air in the room at the same time, creating a pleasant indoor climate even on hot and humid days. It may appear counter-intuitive that air can be dried with water but this happens every time when condensation takes place on cold surfaces. If the temperature of a water film drops below the dew-point of the ambient air vapor condenses on it.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THERMAL PARAMETERS – CLIMATE SIMULATION IN THE LABORATORY

The thermal research laboratory at the Stuttgart site is officially recognized by the German building technology institute DIBt as a test center in accordance with the federal state building code (Landesbauordnung) and construction products lists (Bauregellisten) and as a Notified Body (no. 1004) for windows, façades and insulation materials in accordance with the EU Construction Products Regulation. The laboratory also has flexible accreditation from Germany's national accreditation body DAkkS (Deutsche Akkreditierungsstelle GmbH) in accordance with DIN EN ISO/IEC 17025. Numerous parameters are used to determine the characteristics of building components and materials, including the following:

- Thermal conductivity
- Thermal resistance
- U-value
- Heat dissipation
- Dimensional stability under the effects of heat
- Compressive stress and tensile strength, adhesive strength
- Freeze-thaw resistance
- Moisture absorption via vapor diffusion in temperature gradient
- Flow resistivity
- Air permeability
- Resistance to rainwater penetration
- Resistance to wind load

Integral radiation-technology methods are also employed, including the following:

- Emissivity and solar reflectance index (SRI) of surfaces (thermal principle)
- Solar heat gain coefficient (calorimetric principle)
- Thermography of components

In addition, various solar simulation facilities are available to test building component surfaces of up to 8 m^2 under radiation loads.

OUTDOOR TESTING AND CLIMATE DATA RECORDING

Outdoor testing under realistic transient boundary conditions ultimately delivers the most convincing results. Further advantages are gained when outdoor tests are combined with simulations, which can then be validated while keeping outdoor testing costs down to reasonable levels at the same time. Fraunhofer IBP's site in Holzkirchen is home to the world's largest full-scale outdoor testing ground for building structures and components, building materials and building system components. The local climate is characterized by extremes of weather that make it perfectly suited to this task, including strong sunshine in summer, cold winters and driving rain.

One large and several small meteorological stations are situated on the outdoor testing ground and in the immediate vicinity. A number of these stations have continuously recorded all key climate parameters since the 1980s. They provide the data needed for a precise analysis of weather conditions and their local dependencies (microclimate analyses). The collected data also serve to establish the boundary conditions for hygrothermal and energy simulations and to facilitate more precise interpretation of outdoor test results.

MOISTURE TESTING – CLIMATE-RELATED MATERIAL BEHAVIOR

The moisture research laboratory has been granted flexible accreditation by Germany's national accreditation body DAkkS (Deutsche Akkreditierungsstelle GmbH) in accordance with DIN EN ISO/IEC 17025. Its testing portfolio enables determination of the following characteristics:

- Water vapor diffusion parameters (μ-value, s_d-value)
- Capillary water absorption (A-value)
- Reference moisture content (U_{80})
- Sorption isotherm and moisture retention curve
- Capillary transport coefficients
- Bulk density and porosity
- Thermal and hygric length variations

The entire range of hygric parameters required for hygrothermal simulations relating to materials can therefore be determined by the laboratory. Work on a standardized method for evaluating


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1 *Testing a roof component's insulation against summer heat using a modified U-value test bench.*

2 *Solar simulator for large-area transparent, translucent or opaque roof and façade components, particularly those with light-directing features.*

3 *Rig for testing the air seal of windows and impermeability against driving rain.*

4 *Removing wall test specimens exposed to natural weather conditions in a climate-controlled test hall in order to determine the moisture content by weighing.*

5 *Measuring apparatus for determining moisture distribution in porous building materials by means of nuclear magnetic resonance.*

6 *In-situ measurements of the adhesive tensile strength of external insulation systems.*

7 *Building physics research into microbial growth on façades depending on microclimate and material characteristics.*

8 *Measurement of airflow resistance on half-timbered house at Fraunhofer IBP's outdoor testing site in Holzkirchen.*

the drying behavior of building materials, or to determine the surface moisture of façades, illustrate how methods are modified or newly developed during research projects. Outdoor test walls and small-scale test specimens are used to obtain valuable information about the ageing behavior and durability of materials. The tendency of façade coatings and roofing tiles to become soiled is also evaluated outdoors, as is comparative analyses of moisture balance under natural climatic conditions using wall sections exposed to natural weather on an east-west-aligned test rig.

MOISTURE PROTECTION ASSESSMENT AND HYGROTHERMAL MODEL DEVELOPMENT

Although energy-saving initiatives have led to significant improvements in heat insulation and sealing off building interiors, these improvements are associated with an increased risk of moisture damage arising from higher indoor air humidity, which in turn condensates due to greater temperature differences between the inside and the outside of the building. Adding to this problem, there is less heat available overall to evaporate moisture accumulated in construction components, with the result that other moisture issues such as rainwater, condensation water from outside and trapped humidity pose a greater problem than in the past.

This makes a precise appraisal of hygrothermal conditions and targeted moisture control design more important than ever, accompanied by the search for new solutions and approaches. Most damage can be avoided by careful planning and implementation of moisture protection measures and by choosing the right materials. A traditional means of moisture protection assessment is the Glaser method. However, this method only takes into account condensation formed as a result of diffusion from the interior such as commonly occurs in winter – it cannot evaluate other important factors for many buildings, such as trapped moisture, driving rain and summer condensation.

Today's hygrothermal simulation software is capable of delivering realistic calculations of all relevant hygrothermal storage and transport processes in components under real climatic conditions. As well as allowing comprehensive moisture moisture control design, this also makes it possible to factor in the energy effects of moisture. Demand for the WUFI® software family first licensed by Fraunhofer IBP in 1995 is growing around the world. Intensive program maintenance ensures that new discoveries in building physics are swiftly implemented and that material and climate databases are continuously updated with new information. In collaboration with many international partners, new functions are being added to the programs all the time, including tools for evaluating leaks, damage mechanisms and ageing processes.

HYGROTHERMAL BUILDING ANALYSIS

The interaction between building envelope and the rooms it encloses is the main factor determining the hygrothermal behavior of

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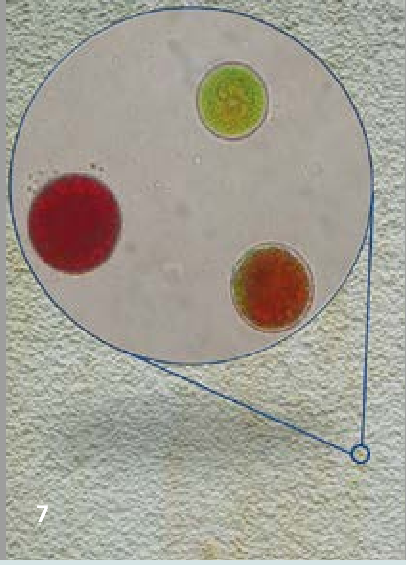

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a building. A comprehensive view of all boundary conditions that affect this interaction enables a detailed analysis of energy demands, indoor climate and hygrothermal conditions inside the building envelope. This view is derived from both experimental sampling and the evaluation of boundary conditions, including inner sources of heat and moisture, air exchange, measured and simulated weather data sets, as well as from user preferences regarding temperature and humidity set-points, or window opening patterns in different climate zones. The research findings flow into the development and application of hygrothermal building simulation tools.

Hygrothermal building monitoring paves the way to new solutions that are developed to avoid critical conditions, improve hygrothermal comfort and to reduce energy consumption. Models are developed based on measurements derived from monitoring under real conditions and in the lab, as well as on theoretical relationships. Once these models have been validated, they are implemented in the WUFI® Plus software. By combining hygrothermal building component simulation and energy building simulation, integral solutions are developed that take into account conditions in the room and in the component, as well as how these interact – while not neglecting the influence different approaches have on energy consumption. This not only leads to strategies that can be adapted to best serve homes and offices, but also to recommendations on passive measures that can, for example, enhance climate stability in historic buildings. The existing simulation environment makes it possible to quantify the influence of different climate zones, usages, component assemblies, geometries, alignments and building operation strategies on indoor climate, energy consumption and the extent to which the building envelope remains damage-free.

BIO-HYGROTHERMICS: PREVENTING MOLD FORMATION AND UNWANTED GROWTH ON FAÇADES

Mold growth represents a potential health hazard due to its production and spread of pathogenic substances. To avoid mold, it is important to develop prevention strategies that take into account both the preconditions for mold growth and the actual transient boundary conditions. WUFI® Bio is a bio-hygrothermal calculation method based on known climatic boundary conditions. It is used to assess the risk of mold formation and devise strategies that avoid its occurrence.

In contrast to the situation in building interiors, microbial growth on façades is usually a mere esthetic problem. The improved heat insulation of exterior components increases surface moisture and therefore the risk of algal and fungal growth. Fraunhofer IBP experts carry out chemical, biological and building physics research into ways of curbing and eliminating this growth.

CONSERVING HISTORIC STRUCTURES AND RENOVATING OLD BUILDINGS

The long-term conservation of historic buildings is entirely dependent on their being used and their ability to meet today's standards of comfort and energy efficiency. Refurbishments designed to make buildings more energy efficient must take historic conservation concerns into account. In cooperation with working groups dealing with preservation of heritage buildings and rehabilitation of existing structures specific solutions adapted to individual old buildings are explored.

Wherever possible, the restoration of old buildings should be accompanied by energy-efficiency improvements to the building envelope. When external insulation is not viable, fitting internal insulation is usually the only alternative. However, this poses special structural challenges with respect to moisture balance. Cramped space where insulation components are joined and elevated humidity levels in rooms demand particular care when planning and implementing insulation measures. Using hygrothermal simulations and lab-based and on-site

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research, internal insulation solutions are analyzed and optimized based on actual building occupancy and operation.

BUILDING IN OTHER CLIMATE ZONES

Although the laws of nature are the same wherever you go, building regulations and traditions can vary hugely between countries. This is often due to differences in climate. Whereas fire protection and noise insulation systems work pretty much the same across different climates, it is generally not so easy to transfer experience and specifications when it comes to heat and moisture protection. Thanks to the numerous international projects and product development work it has undertaken together with its cooperation partners across the globe, the Hygrothermics department has comprehensive know-how and tools for scientifically evaluating energy and moisture issues in buildings located in any climate zone. Routine analyses carried out by the department include:

- assessing the condensation risk caused by vapor diffusion from inside (e.g. buildings in cold regions and mountainous areas) or from outside (e.g. buildings in tropical and subtropical regions)
- forecasting the service life and evaluating the durability of building structures for other climate zones by comparing hygrothermal loads in the target region with conditions in the home country
- analyzing climate data or creating/reviewing meteorological data records for hygrothermal simulation.

In this way, energy-efficient building concepts are developed for growth markets such as Asia and are specifically tailored to the compact urban architecture and climate there. In addition, collaborations with industrial partners result in new building products and systems that are cost-efficient, of good technical quality, and also offer users in these countries added value through improved indoor climates.

WUFI® SOFTWARE

Since 1995, the Hygrothermics department has been developing hygrothermal simulation tools for the energy and moisture performance evaluation and control design of building structures for use by scientists and construction professionals.

WUFI® Pro, WUFI® 2D: One- and two-dimensional transient component analysis based on the relevant hygrothermal storage and transport phenomena, such as thermal conduction, latent heat effects, vapor diffusion and liquid transport.

WUFI® Plus: Hygrothermal building simulation that takes into account transient heat and moisture exchange processes between the building envelope and the rooms it encloses, enabling the integral evaluation of energy energy demands, comfort and the extent to which the building envelope is damage-free.

WUFI® Passive: Monthly heating energy balance calculations combined with dynamic building simulation as per WUFI® Plus for passive house planning.

WUFI® Bio, WUFI® Corr: Post-process models for evaluating the risk of mold growth on component surfaces and the progress of corrosion of metallic parts in the masonry or in wooden components depending on the microclimate in the observed area.

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