HYGROTERMICS
The Hygrothermics Department specializes in the analysis of transient hygrothermal behavior of building materials, building components and constructions. This work also includes the conduct of laboratory materials testing and outdoor tests under defined conditions, along with creation and trials of new test procedures. A considerable portion of the activities in hygrothermics also consists of developing and applying numerical simulation models. The department’s long-standing experience with experimental and computational investigative methods permits a comprehensive assessment of ways of protecting building structures from moisture due to climatic impacts. It also permits targeted optimization of construction products, including development of new construction materials and building systems.

Assessing thermal and moisture protection of building structures involves analysis of the transient hygrothermal conditions in and on building materials and building components, and analysis of how these conditions affect usability. Assessment criteria include thermal and hygienic requirements (e.g., thermal insulation unimpaired by moisture, prevention of mold growth) and freedom of damage to building components (e.g., elimination of moisture accumulation, corrosion, frost damage or loss of strength). Along with hygrothermal material properties, ambient weather conditions and indoor air conditions play a major role as well. Accordingly, to ensure that a building is in proper working order, both the construction design and the selection of materials must be analyzed as a function of the respective climate zone and conditions of use.

The main goal of product development is to improve economic efficiency and durability while optimizing the thermal and moisture performance of construction products. The department’s core competence areas provide the foundation for this, aided by experimental facilities and hygrothermal simulation tools that are kept updated on an ongoing basis. An outstanding example of this kind of product development is the humidity controlled vapor retarder now available for sale in many countries.

Knowledge transfer includes worldwide seminars and the preparation of materials and documentation for the training of craftsmen, architects and engineers. Additional building blocks are participation in national and international standardization bodies (DIN, CEN, WTA, ASHRAE, ASTM) and involvement in international standard reference works for engineers such as e.g. the ASHRAE Handbook of Fundamentals. The immediate transfer of research findings to practical applications in the field usually takes place through lectures and publications held and presented in both German and English.

The need to save energy has led to a significant improvement in building insulation and air-tightness. At the same time, though, these improvements also involve greater risk of damage due to moisture. Firstly, this is because improved air-tightness causes higher indoor humidity, and secondly, because more insulation results in greater differentials between internal and external surface temperatures which also increases the risk of interstitial and surface condensation. With less heat available to evaporate moisture on and within building components, other moisture-related effects such as e.g. precipitation, condensation water or construction moisture also pose greater problems than they did in the past. Today, close consideration of hygrothermal conditions, targeted moisture control design and the ongoing search for new solution approaches are all more important than ever before.
The accredited testing laboratory at our location in Holzkirchen measures the moisture-proofing qualities of materials in accordance with international product standards or technical approvals. The lab is also where all of the hygric material parameters are measured for computer simulations. It offers an opportunity to investigate climate-related moisture transfer and natural aging of construction materials, taking outdoor climate conditions into effect.

The WUFI® software family is a major asset to the department. In cooperation with partner institutions in Europe, North America and the Far East, models are developed to explain the hygrothermal behavior of building structures and prepared for use in a practical setting. This work also includes providing worldwide user seminars and specialized workshops.

Thanks to globalization, construction products native to one country are increasingly put to use in other climatic zones. Accordingly, a growing area of responsibility for the department is to provide moisture control assessments and to tailor these products to new climates. The same applies to the transfer of hygrothermal models to business areas beyond construction.

### THERMAL PARAMETERS – CLIMATE SIMULATION

The thermal laboratory at the location in Stuttgart is recognized by the Deutsches Institut für Bautechnik (DIBt) as a testing facility under applicable building regulations (LBO / BRL) and is recognized as Notified Body No. 1004 for products under EN 14351-1 to the terms of the Construction Products Law (BauPG). It has been granted flexible accreditation under DIN EN ISO/IEC 17025 by the German Accreditation System for Testing (DAP) under accreditation no. DAP-PL-3743.27. Numerous parameters are identified for the characterization of insulation and construction materials, such as:

- Thermal conductivity
- Heat transfer resistance (R-value)
- Tensile transmittance (U-value)
- Heat dissipation
- Dimensional stability under thermal load conditions
- Compressive stress and tensile strength, adhesive strength
- Freeze-thaw cycle resistance
- Moisture absorption through vapor diffusion in temperature gradients
- Linear drag
- Air permeability
- Driving rain resistance
- Wind resistance.

Other measurements carried out there include radiation-based, integral methods such as:

- Surface emissivity (thermal principle)
- Total energy transmission (calorimetric principle)
- Thermography of building components. Also available are a variety of pieces of solar equipment for the measurement of usability of construction elements under exposure to the sun.

### HYGROTHERMAL PROPERTIES – MATERIAL BEHAVIOR UNDER MOISTURE LOAD CONDITIONS

The hygrothermal laboratory has been granted flexible accreditation by the German Council of Accreditation (DAkkS) under DIN EN ISO 17025. The testing includes determination of:

- Water vapor diffusion parameters (μ-value, s_value)
- Capillary water absorption (A-value)
- Reference moisture content (U80)
- Sorption isotherms and moisture retention functions
- Capillary transport coefficients
- Apparent density and porosity
- Thermal and hygric material expansion.

Methods are modified or developed in the context, for instance, of research projects to determine surface moisture on façades, or to develop standardized methods to identify the drying behavior of building materials. Outdoor experiments are also conducted on test walls and small-sized material specimens to investigate the aging behavior and durability of materials. Outdoor experiments are also used to identify the potential pollution of façade coatings and roofing tiles. Wall panels subjected to the elements on a east-west-oriented test stand can also be investigated and compared in terms of the moisture content under natural-climate conditions.
DEVELOPMENT OF HYGROTHERMAL MODELS AND USER SOFTWARE (WUFI® FAMILY)

Often, inadequate moisture protection leads to increased heat loss through transmission; but it can also cause damage to the building shell due to mold, frost, corrosion or decay. Most damage can be prevented, though, through careful planning and execution of moisture control design and the right choice of materials. Until now, moisture control has typically been thought of as protection against condensation in the winter. The traditional assessment method for condensation is the steady-state diffusion calculation commonly called Glaser method (EN ISO 13788). Yet this method is limited to winter-time condensation resulting from the diffusion of moisture from the interior space – while other factors such as the effects of driving rain or construction moisture are not considered.

Today, thanks to years of work spent developing hygrothermal simulation software, we can arrive at a realistic application has quickly grown worldwide. Intensive program maintenance ensures that the latest findings in the physics of construction are implemented, with material and climate databases updated on an ongoing basis. In cooperation with international research institutes, new models are also being developed, e.g. for the simulation of aging, corrosion or convection. In the future, these models hold promise to permit improved evaluation and assessment of hygrothermal simulation results.

MOISTURE CONTROL AND CONSTRUCTION IN OTHER CLIMATIC ZONES

The laws of nature may be the same everywhere, but building regulations and traditions in other countries vary considerably from those here in Germany. Often, the variations are a function of different climate conditions. While fireproofing and soundproofing function more or less the same regardless of climate, usually the specifica-

- Drying of building moisture
- Absorption of driving rain
- Summertime condensation
- Condensation on exterior building components due to night-time over-cooling
- Rising damp
- Energetic impacts of moisture.

Ever since licensing of the WUFI® software family began for external users in 1995, demand for this application has quickly grown worldwide. Intensive program maintenance ensures that the latest findings in the physics of construction are implemented, with material and climate databases updated on an ongoing basis. In cooperation with international research institutes, new models are also being developed, e.g. for the simulation of aging, corrosion or convection. In the future, these models hold promise to permit improved evaluation and assessment of hygrothermal simulation results.

Its routine investigations include:
- Analysis of climate data and creation or review of meteorological data records for hygrothermal simulation
- Assessment of the risk of condensation through vapor diffusion from inside (e.g. cold regions and mountains) or from outside (e.g. tropical or subtropical areas) a structure
- Determination of the moisture load caused by drying building moisture and planning of measures to remedy this
- Assessment of the hygrothermal loads on the building shell due to precipitation and wind (e.g. driving rain) and the radiation of the sun
- Lifespan forecasting and durability assessments for building structures for other climate zones through comparison of hygrothermal loads in the target region with conditions in the country of origin.

Sample projects
- Development of a physical, regulatory and cultural guideline for use by German companies entering the Japanese market
- Planning of timber frame buildings optimized for climate conditions in Japan
- Investigation of the suitability and adaptability of insulated composite systems to climate conditions in India
- Measurement of vapor barriers for industrial halls in Russia
- Assessment and improvement of hygrothermal conditions in membrane roof construction of the airport building in Bangkok
- Hygrothermal optimization of wall panels for residential buildings in Dubai
- Review of the durability of façade systems under Irish climate conditions

HYGROTHERMAL BUILDING ANALYSIS

The interaction between building envelope and enclosed space mainly determines the hygrothermal performance of buildings. An integral assessment of all influencing boundary conditions allows a detailed analysis with regard to energy demand, indoor environment and hygrothermal conditions in the building components.

This includes the experimental gathering and evaluation of boundary conditions like interior heat and moisture sources, air change rate, measured and modelled weather data sets but also the user behaviour regarding set-points or window opening in different climate zones. The achieved know-how is used for the development and application of a hygrothermal whole building simulation tool.

Hygrothermal building monitoring allows the development of solutions to avoid critical conditions, improve the hygrothermal comfort and reduce the energy demand. New models are developed based on measurements under real conditions and in the laboratory as well as on theoretical principles. After validation these models are implemented in the software WUFI®Plus.

Integral solutions are developed by connecting hygrothermal building component simulation and whole building energy simulation. They take the conditions in the room and in the component and their interaction into account so that the influence of different approaches on the energy use is not neglected. Adjusted strategies are developed not only for residential and office spaces, but for example also measures for passive climate stabilization in historic buildings. The existing simulation environment allows quantifying the influence of different climate zones, uses, component assemblies, geometries and orientations as well as different building operation strategies on indoor environment, energy use and damage free constructions.

Energy efficient building concepts for growth markets in e.g. Asia are adapted to compact urban building techniques and different climatic boundary conditions. Furthermore building products and systems are developed together with industrial partners, which are cost-effective and provide beside technical quality also an added value by better service for the users and improved standard of living.

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