Supplement to the Lecture by Professor Künzel, International Honorary Member of SHASE

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Prof. Hartwig Künzel of the Fraunhofer Institute for Building Physics (IBP) in Germany was made an international honorary member of the Society of Air-Conditioning and Sanitary Engineers for 2023.

Professor Künzel gave lectures at Waseda University on May 9 and at Tokyo University on May 12. The contents of the lectures were very similar at both universities, focusing on the development of "building physics" in Germany. Some of the academic terms and definitions used in this field in Germany were difficult for the Japanese audiences. Therefore I would like to explain these more fully.

Introduction

Prof. Hartwig Künzel of the Fraunhofer Institute for Building Physics in Germany was made an international honorary member of the Society of Air-Conditioning and Sanitary Engineers in 2023, and received the award from President Kurabuchi at the general meeting of the Society on May 12, 2023, at the Meiji Memorial Hall. At the time, the reception was not held due to the COVID-19 epidemic. Professor Künzel did not give a lecture at the site of the general meeting. Instead, lectures were given at Waseda University on May 9 and at Tokyo University on May 12. The lectures were very similar at both universities: They were on the development of "building physics" in Germany, and the content was very diverse.

Fig. 1 Prof. Künzel receiving the International Honorary Member certification from SHASE President Kurabuchi

Some of the academic terms and definitions used in this field in Germany were difficult to understand for the Japanese audiences. In this talk, I would like to explain these terms more fully.

Fig. 2 Prof. Künzel giving a lecture at Tokyo University on 12. May 2023

1. Relationship with Prof. Künzel

Professor Hartwig Künzel is the son of Dr. Helmut Künzel, who selected the land for the Fraunhofer Institute for Building Physics in Holzkirchen and devoted himself to building physics research. I worked at the Technical Research Institute of Obayashi Corporation in 1966. At that time, the height limit of 31 meters for buildings was abolished, and high-rise buildings began to be constructed. Conventional heavy buildings were replaced by lightweight buildings. With this change, the conventional thermal load calculation method for air conditioning had to be revised. In addition, small process control computers were gradually coming into practical use. No one was sure whether the results of building calculations made with small process control computers would match the actual heat load. Therefore, a "Revolving Type of Air Conditioning Test Room" was created that could measure the actual thermal load for each direction, and the actual thermal load was measured for different seasons and directions. The author reported the results in the German journal HLH. At the same time, another German journal, Gi, published a paper by Dr. Helmut Künzel. Dr. Künzel used an experimental apparatus that was the same size and had the same research purpose as the rotary air-conditioning test room of the Obayashi Corporation. I was very surprised at the coincidence, because we had not discussed anything at the time. Since there was no fax service in those days, I exchanged opinions with Dr. Künzel by air mail and asked him to teach me.

Fig3 Revolving Type of Air Conditioning Test Room at Obayashi Corporation in Kiyose, Tokyo

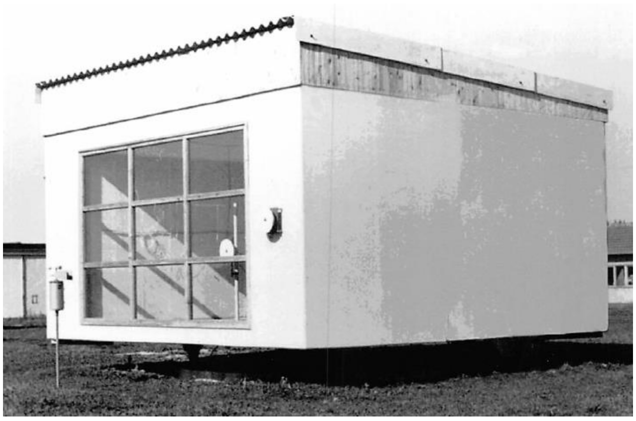

Fig. 4 Revolving Type of Air Conditioning Test Room at Fraunhofer Institute for Building Physics in Holzkirchen

In 2007, Dr. Helmut Künzel's 80th birthday celebration was held at the Fraunhofer Institute for building physics in Holzkirchen. I was invited to the celebration and gave a congratulatory speech. Ten years later, I visited Dr. Helmut Künzel at his home and had an informal chat with him.

Fig 5 I visited Dr. Helmut Künzel at his home and had an informal chat on 19. Jan. 2017.

2.The Supplement to the Lecture of Prof. Künzel

In Prof. Hartwig Künzel's lecture, I would like to explain some technical terms that were difficult for Japanese audiences to understand.

2-1 The coefficient of water vapor diffusion resistance μ (−)

Calculation Method of Water Vapor Diffusion Resistance Coefficient

The coefficient of water vapor diffusion resistance μ (−) is the number obtained by dividing the moisture permeability of a static air layer by the moisture permeability of the material, and indicates the water vapor diffusion resistance of the material relative to that of a static air layer of the same thickness and at the same temperature. In Japan, the moisture conductivity or moisture permeability (kg/mhPa) is sometimes used to indicate the ease of moisture permeability because the physical properties of building materials related to moisture are not well organized. The calculation of μ is shown in Equation (1)

$$\mu = \frac{\frac{1}{p}}{\frac{1}{\delta}} = \frac{\delta}{p} \qquad (1)$$

Where,

μ = The coefficient of water vapor diffusion resistance (−)

p = Moisture permeability of the material [kg/mhPa]

δ = Moisture permeability of a static air layer [kg/msPa]

$$\delta = \frac{2.0 \cdot 10^{-7} \cdot T^{0.81}}{p} \qquad (2)$$

Where,

T = air temperature [˚K]

p = Atmospheric pressure [Pa]

(Note: Example of test conditions: 23°C, 50% RH, etc., see JIS A 1324)

In Japan, "moisture permeability" and "moisture conductivity" were used to express the ease of passage of water vapor through building materials. In addition, when the thickness of the material is taken into consideration, the "moisture permeability" was used. The catalogs of building material manufacturers are not consistent. Internationally, the moisture vapor diffusion resistance coefficient μ value is used in the ISO standard. The water vapor diffusion resistance coefficient is not affected by temperature and pressure, while the moisture permeability (moisture conductivity) is affected by these factors, so it is more reasonable to use the water vapor diffusion resistance coefficient in the international unit system.
The μ values of some building materials that have been measured at the Fraunhofer Institute and are in public use are given below.

Perlite sheet	5
Expanded cork	5
Wood wool + lightweight boards	3
Wood fiber insulation boards	5
Beech	12.4
Pine	19.1
Mineral fiber boards	2.4
Standard Concrete	17.8

2-2 Air thickness equivalent to water vapor diffusion Sd

The air thickness equivalent to water vapor diffusion, Sd [m], is the thickness of the stationary air layer corresponding to the water vapor diffusion resistance of the test specimen. It is used in cases such as paints and sheets, which have little influence on heat transfer but are involved in water vapor transfer. This property is often used for airtight sheets and heat insulators in Europe.

$Sd = \mu \cdot s$

where, Sd = water vapor diffusion resistance air thickness (m)
μ = Water vapor diffusion resistance coefficient of the material [－]
s = Thickness of the material [m]

The Sd values of some building materials that have been measured at the Fraunhofer Institute and are in public use are given below.

Polyethylene film 0.15mm	50.0m
Polyethylene film 0.25mm	100.0m
Polyester film 0.2mm	50.0m
PVC film	30.0m

An exterior plaster receives the predicate water-repellent when the following relationship between the water absorption w and the drying capability Sd of the plaster is satisfied:

$w \cdot Sd \leq 0.1$ kg/m・$h^{0.5}$

with the boundary conditions $w \leq 0.5$ kg/m^2・$h^{0.5}$ and $Sd \leq 2.0$ m.

The limitation of these measured variables was based on the following condition:

$w \leq 0.5$ kg/m^2・$h^{0.5}$

The water absorption coefficient should not exceed this value, even if drying would be ensured in the long term in order to limit a short-term increase in moisture (influence of increased moisture on the thermal insulation).

$Sd \leq 2.0$m: The value should be limited, even if the w-value is very small, in order to avoid large increases in moisture in the area of possible defects in the plaster.

The hyperbolic function $w \cdot Sd = 0.1$ means w and Sd vary inversely. So, with high water absorption, there must be a correspondingly good drying possibility (small Sd value) and with low water absorption, the Sd value is large. As the weather conditions on the test site near Holzkirchen are extreme compared to other locations in Germany, these results can generally be considered to be applicable for both heavy and driving rain exposure in Germany.

3. Prof. Hartwig Künzel explained computer program "WUFI".

The Department of Hygrothermics at Fraunhofer Institute for Building Physics (IBP) has developed the WUFI® software package for state-of-the-art hygrothermic analysis.
WUFI is an unsteady heat and moisture simultaneous transfer analysis program that can accurately predict the heat and moisture behavior of individual building materials comprising a wall or roof under a variety of climatic conditions. The name WUFI is an acronym for *Wärme und Feuchte instationär,* (transient heat and moisture) and is widely used in the United States and Europe by researchers, building materials manufacturers, planners, design firms, contractors, construction companies, house builders, and equipment suppliers.

In addition to accounting for the thermal response of buildings and building components it is necessary to also understand the moisture conditions and the effects of humidity. Long-term exposure to high moisture conditions can cause damage in building components, and significant health problems result from mold growth on surfaces that are exposed to high moisture conditions.The thermal and moisture conditions and transport in buildings and building components are coupled. It is well known that high moisture levels result in higher heat losses, and the temperature conditions in building components influence the moisture transport. Analysis of the coupling of heat and moisture is known as "hygrothermics."

4. The former method: Glaser

The traditional method for assessing the moisture balance of a building component was the Glaser method (described in the DIN 4108 standard) which analyzes the vapor diffusion transport in the component. However, this method does not account for the capillary transport of moisture and for the sorption capacity of the component, both of which reduce the risk of damage from condensation. Furthermore, since the Glaser method only considers steady-state transport under simplified steady-state boundary conditions, it cannot reproduce individual short-term events or allow for rain and solar radiation. It was meant to provide a general assessment of the hygrothermal suitability of a component, not to produce a simulation of realistic heat and moisture conditions in a component exposed to the weather prevailing at its individual location.

5. The current method: WUFI®

WUFI continues to be further improved. It is commonly used to analyze in one dimension. Today, WUFIs that analyze in two dimensions are also available. There are also WUFIs that can determine if mold is present in building materials and construction areas. The beauty of WUFI is that it includes the physical properties of almost all building materials. Even the physical properties of building materials that are unique to Japan, such as tatami mats, are measured at the Building Materials Testing Center in Japan. Building materials newly developed by Japanese manufacturers are also tested for physical properties at the Fraunhofer Institute and included in WUFI.

WUFI performs dynamic simulations of coupled heat and moisture transfer. The methods have been validated world wide and provide realistic simulation of hygrothermal conditions in building components and buildings under actual climate conditions.

WUFI is based on the latest knowledge in vapor diffusion and liquid transport in building materials. Nonetheless, the WUFI software requires only standard material properties and easy-to-determine moisture storage and liquid transport functions. For boundary conditions, measured outdoor climates – including driving rain and solar radiation – are used. Various types of models thus allow the analysis of multi-layer materials, component connections, and even multi-zone buildings under realistic exposure to natural weather conditions.

6. Conclusion

The 28th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 28) in 2023 set a policy of 60% reduction in greenhouse gas emissions by 2035 compared to 2019 levels in order to limit temperature rise to 1.5°C. The development of global warming gas reduction targets is important. Japan is affected by international energy market instability due to the crisis in Ukraine. It is important to achieve energy security and decarbonization at minimum cost.

It is also important to develop technologies for the use of natural energy sources such as solar energy and hydrogen energy. However, even more important is energy conservation in Japan. In Japan, energy conservation in buildings, especially insulation, has not progressed well. Japanese buildings have been built to provide shelter from the summer heat and humidity. In other words, large roofs and eaves were used to block the sun's rays and large openings were used to improve ventilation and cooling. However, these days, due to global warming, outside air temperatures in summer often exceed body temperature. In such cases, it is impossible to perform cooling by opening windows. Therefore, it is important to change the way of thinking about architecture and maintain airtightness and air harmony in buildings. Conventional Japanese buildings are not insulated, so the energy consumption of air conditioning is high. In the future, it will be important to insulate buildings and make them airtight.

The increased insulation thickness of Japanese buildings can thus cause problems of condensation within the external walls. WUFI is an excellent help in dealing with these problems.

References

1. Helmut Künzel, "Bautradition auf dem Prüfstand, Die Entwicklung der Bauphysik im Spannungsfeld zwischen Tradition und Forschung", *Fraunhofer IRB Verlag*
2. Helmut Künzel, "Außenputz Untersuchungen Erfahrungen Überlegungen", *Fraunhofer IRB Verlag*
3. Helmut Künzel, Bauphysik und Denkmalpflege *Fraunhofer IRB Verlag*
4. Helmut Künzel, Richtiges Heizen und Lüften in Wohnungen *Fraunhofer IRB Verlag*
5. Helmut Künzel, Fensterlüftung und Raumklima, *Fraunhofer IRB Verlag*
6. Richard Jenisch, Tauwasserschäden, *Fraunhofer IRB Verlag*
7. Erich Cziesielski, Frank Ulrich Vogdt, Schäden an Wärmedämmverbubdsystemen, *Fraunhofer IRB Verlag*