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Non-Steady State Heat and Moisture Transfer Problems in Building Physics

Transmission de chaleur et d'humidité en régime variable dans la physique du bâtiment

Instationäre Wärme- und Feuchteübertragungsprobleme der Bauphysik

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SUMMARY
Non-steady state heat and humidity transfer problems in building physics are very significant but have been rarely investigated until now. They are based on the temporarily variable influences of the temperature due to solar radiation in summer and to the non-steady habits of heating of the occupants. The non-steady state phenomena of moisture encompass any kind of moistening or drying of building elements.

RESUME
Les problèmes de la physique des bâtiments concernant la transmission de chaleur et d'humidité dans des régimes variables sont très importants, mais ont été rarement étudiés jusqu'à présent. Ils se basent sur les influences de la température variant dans le temps causées par la radiation du soleil en été et les habitudes de chauffage, à un régime variable, des locataires. Les phénomènes de l'humidité à un régime variable concernent l'humidification ou le séchage des éléments de la construction.

ZUSAMMENFASSUNG
Die instationären Wärme- und Feuchteübertragungsprobleme der Bauphysik sind bedeutungsvoll und bislang zu wenig erforscht. Sie beruhen auf zeitveränderlichen Temperatureinwirkungen bei sommerlicher Sonneneinstrahlung und auf instationären Heizgepflogenheiten der Nutzer. Die instationären Feuchtephänomene umfassen jede Art von Befeuchtung oder Trocknung der Bauteile.

1. BUILDING PHYSICS AND NON-STEADY STATE PHENOMENA

There is no doubt that buildings do not always provide comfortable and healthy conditions for the people who live and work in these buildings [1]. High skyscrapers are often demonstration objects for "grandiose statics or architecture", where problems of building physics have not been recognized or even badly neglected. Since a very short time the call for "more building physics" has become loud and clear.

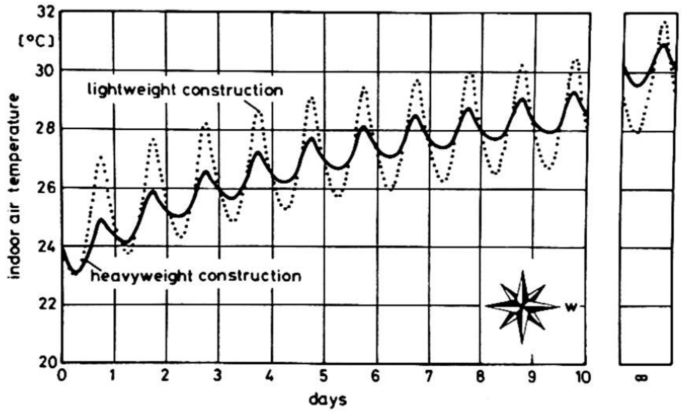
[2] contents a trial of definition about what building physics should include. According to this the building physics examine the transfer phenomena of heat (also regarding higher temperatures in case of fire), the moisture transfer and the sound propagation inside a building, in the building element itself and in the surroundings of a building. Many of these transport phenomena are not constant in time, but are subject to certain short- or long-term changings in time; that means they have a non-steady state character. Especially the phenomena of heat- (energy!) and moisture transfer in buildings follow these non-steady state rules which have been rarely investigated until now but are highly topical. In the following the present introductory report will introduce to the problems of non-steady state heat- and moisture transfer in buildings by means of some examples and it will ask for contributions.

2. NON-STEADY STATE HEAT TRANSFER IN BUILDINGS

The structure of buildings according to non-steady thermal points of view has considerable importance for the practice in three directions: First the building elements and the whole buildings must meet with certain thermal requirements because of the solar radiation in sommer or other time-variable influence of heat, in order to provide a comfortable climate in the room for the inhabitant or user. On the other side, the necessary consumption of energy has to be reduced (which is uncontested since the energy crisis!). The third point is that the heating, due to the radiation, must not be so strong that inavoidable thermal deformations entail damages which endanger the function or the stability of the building elements.

The following examples explain this. Fig. 1 shows that rooms of light construction basically have another thermal behaviour than rooms of heavy construction. The daily temperature amplitudes in rooms, as well as the thermal cyclic behaviour in the course of a period of summerdays have a different expression in these two construction methods. The influence of building elements to the thermal behaviour of buildings relies on their capacity to conduct heat, to emit and to absorb radiation, which primarily influences the niveau of temperature, as well as on their capacity to accumulate heat which damps the fluctuations in indoor air temperature. Indoor building elements primarily have an effect on the storage capacity and outdoor building elements have an effect on the absorption of radiation, as well as on the storage and conductivity. The storage capacity of building elements depends definitely on the structural layers. Inside building elements with heat insulation layers on the inner side of the room prove ineffectual especially in cyclic condition, whereas outside building elements with an insulation on the outside show more favorable results.

For obvious reasons, the non-steady state properties of building elements have an effect on the consumption of energy too. For example the different behaviour of heat in one-family houses of light or heavy construction during the transitional season (spring, autumn) results from their different capability to store heat.



Thermal cyclic behaviour of a west-orientated room of light and heavy construction, according to [3].
Basic data
40 % window surface
clear insulation glazing with outer blind change of air 0,5 h^{-1}

Fig. 1

In view to the heating operation, a structure which is without thermal inertia and less capable to store heat, seems to be more advantageous, because air temperature in rooms can decrease much more during those periods when rooms are not used, so that the losses in heating energy are reduced (decrease of temperature during the night).

As to the behaviour of heat in one-family houses during the transitional seasons, there are two opposite phenomena regarding the influence of building construction, the concurrence of which shows the results indicated in fig. 2 for a wooden house construction - light construction - and a house of heavy structure with a concrete ceiling, interior area ca. 100 qm², window surface of south-orientated façade 41 %. The meteorological basic data have been varied, so that the theoretically possible differences are indicated on one side and the practically arising differences on the other side. The heating is regulated in a way that all rooms have a temperature of 22 °C from 8.00 h to 22.00 h. The heating is put out of operation between 22.00 h and 7.00 h.

Meteorological boundary conditions			Savings of energy (%) light structure	Savings of energy (%) heavy structure
constant weather	solar radiation and outdoor temperature	extremely high	50	44
		high	42	35
		low	28	21
		extremely low	24	18
change of weather	extremely strong		27	33
	medium-strong		29	28

Saving of energy for one-family houses due to non-steady state effects (intermittent heating, solar radiation) according to [4].

The percentages have been indicated for the consumption of energy for constant heating, without solar radiation.

Fig. 2

Fig. 3 shows how much the thermal strain and the behaviour of deformation and stress is influenced by the non-steady state effects. You can see that the colour of the outside surface, that means the absorption of solar radiation, has an important influence on the heating. Whereas a light-coloured wall reaches just 50 °C, a dark-coloured wall comes up to 85 °C. Moreover it is shown how the non-steady state "wave of heat" is transmitted to the inside of the building element. The deeper layers have a decrease of amplitudes and a time lag.

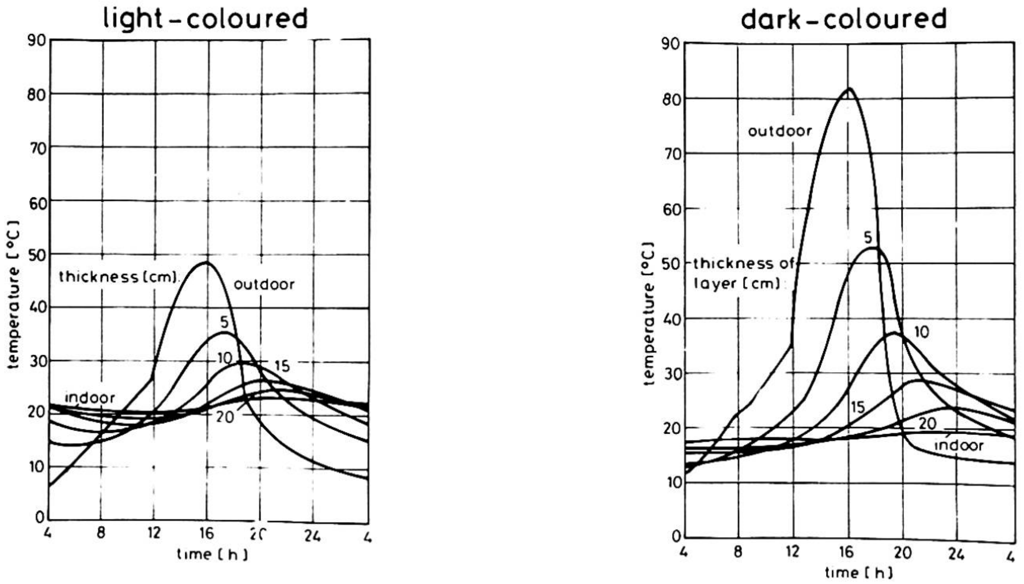
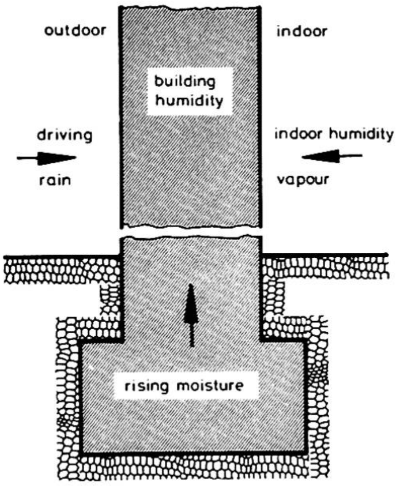


Fig. 3 Thermal stress of outer wall with light and dark colour, according to [5].

Basic data:
west-orientation,
summerday, Central Europe,
cellular concrete material.

3. NON-STEADY STATE TRANSFER OF MOISTURE IN BUILDINGS

The transfer of moisture in buildings is very much spread. Fig. 4 tries to give a schematical review. In the course of time, the moisture coming up from the floor affects the basis of building elements. The building elements have their own moisture, resulting from the production, which dries during a long non-steady state process to the outside or the inside. Temporarily driving rain strikes the outside wall and the inside wall is affected by more or less air humidity, according to the using of the room Whilst the humidity coming from inside the room releases a vaporous water transport (diffusion), the transfer of other kinds of moisture is based on capillary suction in liquid form. Both ways of transport may, according to the structure of pores of the building material, occur at the same time and overlap each other in a very complicated form.



Different kinds of moisture-transport in an outer wall.

Fig. 4

The processes of non-steady state moisture transport urgently need a closer investigation. Fig. 5 shows the possible influence of time for moistening and drying of a wall. The distribution of moisture and its concentration are indicated for several instants for moistening (sucking, rain) and for drying for the cross-section of a 20 cm thick wall. You realize that during the moistening direct "water-fronts" are formed in the body, which constantly advance to the interior. The drying procedure takes about 25 times as long as the moistening.

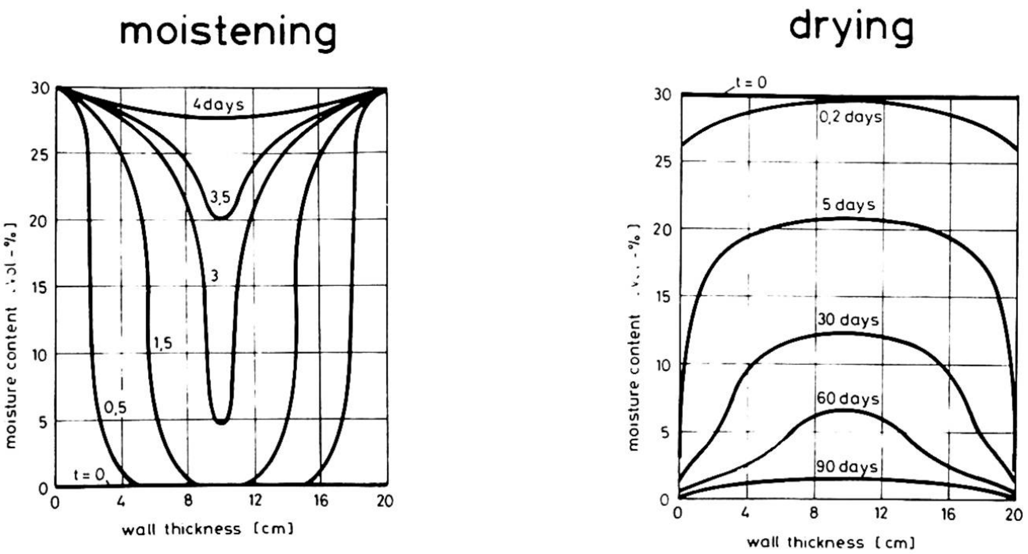


Fig. 5 Distribution of moisture concentrations on a wall of cellular concrete at different instants, according to [6].

On the left: Moistening on both sides (sucking, rain),

On the right: Drying on both sides.

4. CALL FOR PAPERS

The short comments explain that the non-steady state heat- and moisture transfer problems are very important in building physics. A great number of research works has been done in the various countries during the last years concerning this scope of themes. You are therefore kindly asked to present results of such works to the IABSE-Congress. Especially contributions to the following subjects are welcomed:

- Non-steady state heat transfer through outdoor building elements (one-layer and multiple-layer)
- Non-steady state heat behaviour of buildings
- Indoor climate in summer, windows and sun-shading
- Intermittent heating
- Thermal deformations and stress of building elements due to influence of non-steady state temperature
- Basic laws for capillary suction
- Sucking of building material (dates of material
- Driving rain and outdoor building elements
- Vapour diffusion in building elements under non-steady state conditions.

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