

Shading of flat roofs

Christian Bludau ^a

a Fraunhofer Institute for Building Physics (IBP) Department Hygrothermics, Valley, Germany

Abstract

Shading of the roof surface directly influences the thermal conditions and thus also the hygrothermal behaviour of the roof construction. Especially in the case of wooden flat roofs, shading can lead to a reduction in drying and therefore taking in account the effects of shading is essential for a moisture-safe design of such roofs. In this paper, possibilities to account for different shading situations in hygrothermal simulations are shown and their influence on the roof structure are discussed.

Peer-review under the responsibility of the organizing committee of the ICMB23.

Keywords: shading; flat roof; transient simulation; hygrothermal risk assessment; moisture-safe design

Nomenclature

a	short-wave absorptivity of surface	AVCL	Air and vapour control layer
ϵ	long-wave emissivity of surface	k	reduction factor
IBP	Fraunhofer Institute for Building Physics (IBP)	PV	photovoltaic

1. Introduction/Background

The increasing population density in large cities as well as the expansion of renewable energies are steadily leading to the use of free areas on flat roofs as living space or for energy production. This inevitably impacts the roof surface and cause changes in the boundary conditions on the roof by shading, which in turn results in a change in the surface temperature. Especially for wooden structures, where the drying potential is largely responsible for its functionality, such influences must be considered in the moisture-safety design. Thus, different shading situations on flat roofs, such as PV modules, wooden terraces and neighbouring higher building parts, are investigated and approaches for taking them into account in hygrothermal simulations are presented. Furthermore, the effects on the moisture behaviour of the roof structure are studied.

2. Approaches to account for shading in hygrothermal simulations

There are different ways of taking the shading of the roof surface into account. The most common is the adaption of radiation gains by reduced absorption and emission coefficients, which can be used directly in hygrothermal simulation software. Another way is calculating the radiation load by determining the position and size of the shading object in the field of view to the receiving surface. Both methods were used to investigate the shading effects on wooden flat roof constructions and to gain general reduction factors for calculating the effect of shading [1].

2.1. Determination of shading by constant reduction of absorption and emission coefficients

Hygrothermal simulation software usually use hourly values of solar irradiance and atmospheric counter-radiation with the corresponding surfaces short-wave absorptivity (a_s) and long-wave emissivity (ϵ). Since these values can be changed directly by the user, taking into account shading via a reduction of these coefficients is a simple method that does not require any modification of the climate file or simulation software itself. The reduction factors (k) were generated by recalculating long-term measurements of the surface temperature and adapting the absorptivity and emissivity to critically reflect the average values and also represent the moisture behaviour of the structure below on the safe side. Fig.1(a) shows an exemplary test bench for measuring the temperatures on the roof surface under a PV module as well as on the modules back. The corresponding climate data were gathered from the weather station on the field test side of the IBP. The radiation exchange of the surface reduced by shading can be calculated according to $a_{\text{shaded}} = k_a \cdot a_{\text{surface}}$ and $\epsilon_{\text{shaded}} = k_\epsilon \cdot \epsilon_{\text{surface}}$. An overview of the reduction factors on the radiation parameters of the surface determined based on comparisons between simulation and measurements for different shading situations is given in Table 1.

Table 1. Overview of the determined reduction factors on the radiation parameters of the surface for different shading situations [1].

Shading by	Reduction factor k_a	Reduction factor k_e
PV modules	0.3	0.5
Wooden terrace	0.6	1.0
Vertical object, south	0.35	1.0
Vertical object, east / west	0.65	1.0

2.2. Determination of shading by calculating the radiation load on a receiving surface

A more accurate method of accounting for shading is to calculate the radiation load on the receiving roof surface reduced by the shading object. Position and size of the object between the sun and the roof is defined and, depending on this, the remaining short-wave and long-wave radiation is determined according to the position of the sun. Hereby the long-wave radiation of the object is also included. For this purpose, a software tool was developed that allows to adjust the radiation values in a climate file according to a given shading object and its surface temperature and thus to generate a modified climate file with shaded values for radiation, which can then be used for the hygrothermal risk analysis. A screenshot of the software tool is shown for a vertical object in the West in Fig.1(b). The blue circle is the field of view to the sky, the ribbons represent the hourly position of the sun over the course of the year (visible in yellow, hidden in brown, ribbons outside the circle are below the horizon).

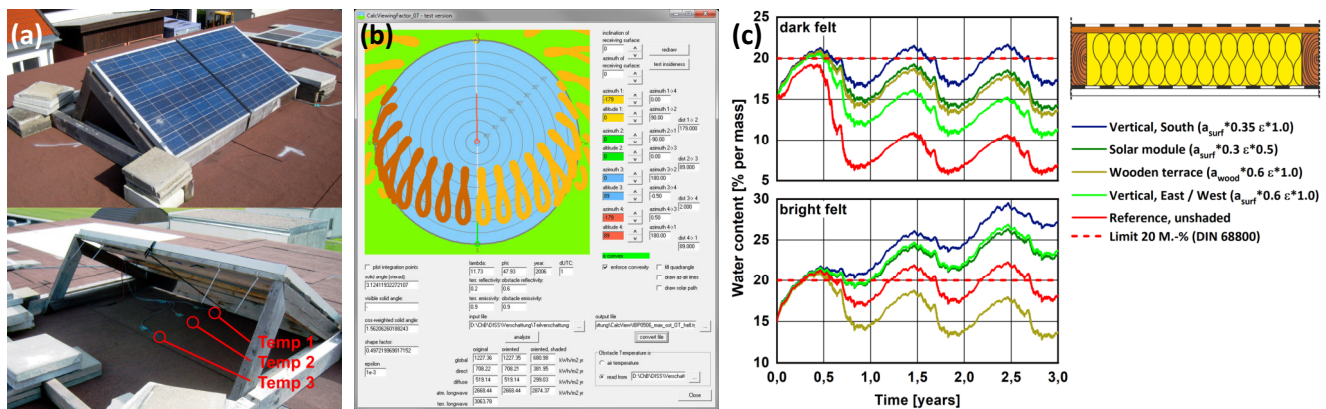


Figure 1. (a) PV module test bench; (b) tool for modifying the radiation in a climate file; (c) moisture content in wooden sheathing

3. Effects of shading on the moisture behaviour of flat wooden roofs

The moisture behaviour of the roof assembly was assessed using the transient simulation modelling tool, WUFI® Pro [2], which is developed at the IBP and complies with the requirements of the European standard EN 15026 [3] for hygrothermal simulations and the German standard DIN 4108-3 Annex D [4]. The calculations were performed for a single layer flat roof construction build up from outside to inside with a bituminous roofing felt, softwood sheathing, fibre insulation between rafters, variable AVCL and gypsum board for the location Holzkirchen, Germany with an interior climate according to [4].

Fig.1(c) shows the courses of the moisture content in percent by mass for the wooden sheathing which occur under the shading situations shown in Table 1. Whereas, with a dark surface, the limit value is only exceeded with a full area shading in the south. With a light surface, all courses exceed the limit value except for the wooden terrace, which makes the situation somewhat more favourable. These results also show how sensitively such flat roof constructions react with regard to shading.

4. Conclusions

The models presented here allow the shading to be taken into account in hygrothermal simulations with good accuracy. These make it possible to carry out moisture-safe design in new constructions and for renovation purposes of such structures.

References

- [1] Bludau, Ch. (2021). Spezielle Randbedingungen für die hygrothermische Simulation von Flachdächern in Holzbauweise. *Forschungsergebnisse aus der Bauphysik*, Band 47. Dissertation Uni Stuttgart. ISBN 978-3-8396-1751-9. <http://publica.fraunhofer.de/dokumente/N-640386.html>
- [2] <https://www.wufi.de>
- [3] Anon. (2018) DIN 4108-3: Wärmeschutz und Energie-Einsparung in Gebäuden - Teil 3: Klimabedingter Feuchteschutz - Anforderungen, Berechnungsverfahren und Hinweise für Planung und Ausführung. Beuth Verlag, Berlin.
- [4] Anon. (2007). EN 15026 Hygrothermal performance of building components and building elements - Assessment of moisture transfer by numerical simulation. Beuth Verlag, Berlin