Frost Damage of Masonry Walls – A hygrothermal Analysis by Computer Simulations

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INTRODUCTION AND OBJECTIVES

Frost damage occurs especially if damp building elements are subjected to frequent freeze-thaw cycles. The observation that frost damage can also be frequently observed in warmer winters – for example in the winter of 98/99 (see Figure 1) confirms that one cannot use the outside air temperature level as the only criterion, but that the combination of the number of freeze-thaw cycles in the building element's interior and the moisture content in the material at those times must also be considered. The number of zero crossings on a Celsius scale during each half year of the winter, and the corresponding moisture content profiles were calculated using the PC program WUFI [1] for the example of a calcium silica brick (csb) wall construction. The effect of different meteorological conditions on zero crossings and material moisture has been determined using meteorological data measured during several years at the Fraunhofer-Institute for Building Physics (IBP) outdoor testing field. From the results, it is possible to assess the frost damage risk.

CONSTRUCTIONS EXAMINED

To calculate the number of zero crossings in the building material as well as the corresponding moisture profiles, the calculations are conducted with WUFI for a west-facing csb-wall construction with a coat of paint which has become defect over the course of the winter (Figure 1). The permeability of the paint coat is assumed to be 6.5 perm in the calculation. At the same time the water absorption coefficient (A-value) in the outermost layer is assumed to be reduced by some 30 % in comparison with the non-coated csb, because the coating still reduces the water absorption despite the imperfections. The remaining material parameter for csb required for the calculation are obtained from the WUFI database.

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FIGURE 1: Photograph of frost damage on a west-facing calcium silica brick wall at the outdoor testing field at the Holzkirchen IBP site following the 1998/99 winter.

RESULTS OF THE CALCULATIONS

Figure 2 shows the daily totals of wind-driven rain measured in winter 1998/99 (centre diagram) as well as the minimum outdoor air temperatures occurring in the same period (bottom diagram). The moisture content courses calculated for these conditions in the outer 5 cm for a non-coated csb wall are depicted in diagram 2 at the top, as are those for a defect coating of paint. The coated wall dries out far less as a result of the paint coating's diffusion resistance; the moisture content of the outer 5 cm varies between 11 and 13 M-%. This means that freezing there often occurs while the water content is close to capillary saturation. Frost damage in csb-walls is known to occur from a moisture content of approximately 12 M-% on upwards [2]. The uncoated wall, on the other hand, absorbs a lot of moisture if exposed to wind-driven rain, but subsequently can quickly dry out again. This means that the moisture content has usually sunk to a non-critical level by the time the temperature has fallen below freezing point. However, if frost occurs immediately after the wind-driven rain then damage cannot be excluded for non-coated walls, too.

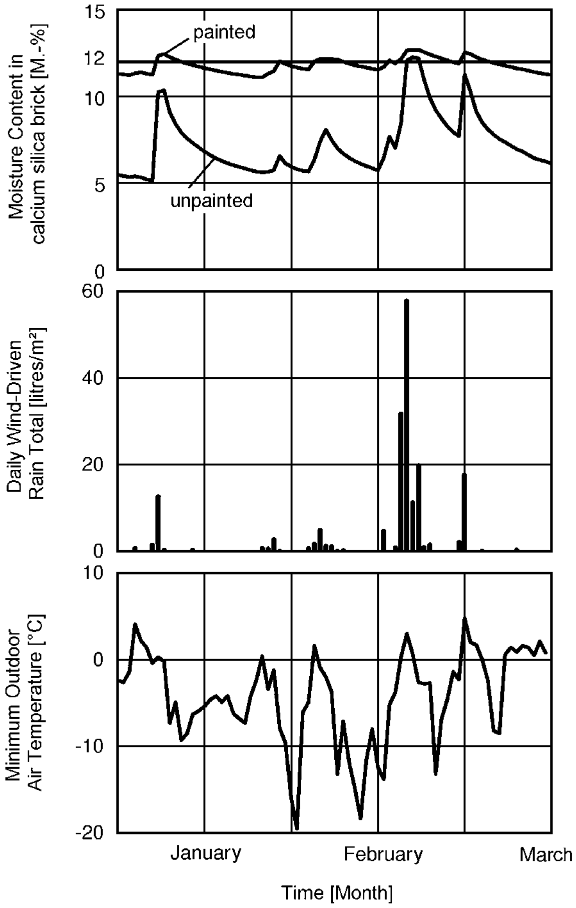

FIGURE 2: Course in time for the moisture content of the 5 cm thick outer surface zone of a calcium silica brick wall with defect paint coating as well as on a non-coated example, with specifications of the daily total of wind-driven rain and the minimum daily outdoor air temperature.

The number of zero crossings as distributed over the csb wall cross-section and calculated for the case of a damaged coating are shown in Figure 3 (top) for two of the examined Holzkirchen weather data sets: The winter 1998/99 as the period under investigation and the year 1991 as an example of the other years used for comparison. Figure 3 (bottom) represents the mean moisture content during zero crossings, plotted over the wall cross section and expressed as a fraction of maximum water content (saturation ratio). Evidently, there are differences depending upon the selected climatic data sets, with the 1991 data resulting in a somewhat higher number of zero crossings than those of 1998/99. However, if one considers the saturation ratio (Figure 3, bottom), then one can see that the 1998/99 winter resulted in higher moisture levels than all other years (Figure 3 displays only 1991 as an example).

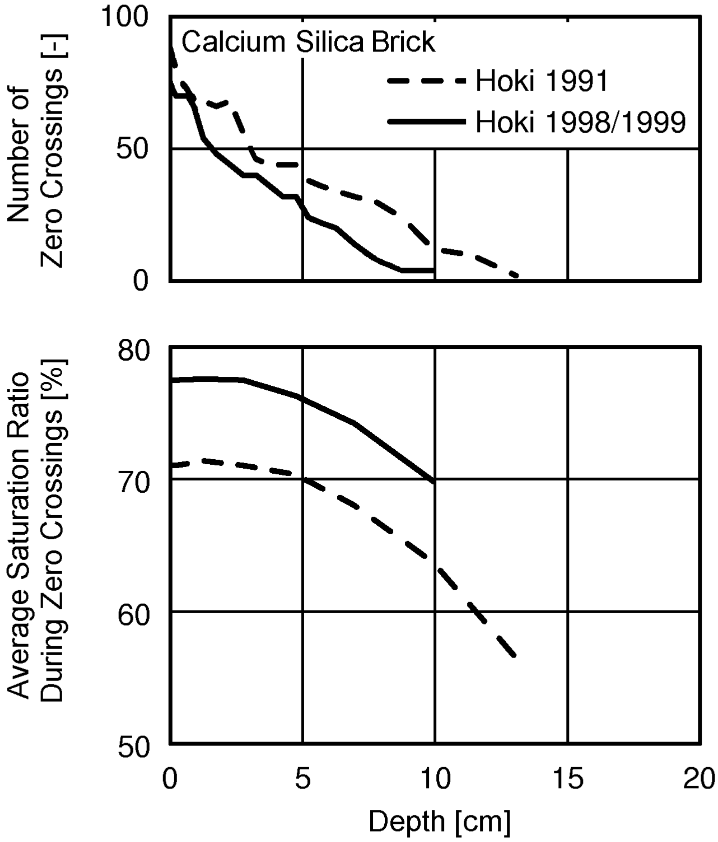

FIGURE 3: Number of zero crossings in calcium silica brick with defect paint coating as distributed over the building element's cross-section (top) and the resulting average saturation ratio (bottom).

CONCLUSION AND OUTLOOK

The conclusion from the above results is that large differences in the number of zero crossings as well as in the corresponding moisture levels in the building element arise depending upon the climate acting on the element. Weather periods with wind-driven rain followed immediately by frost have a considerable influence. The 1998/99 winter was especially extreme for frost damage risk, which means that further analyses of these weather data should be conducted in the future.

Literature

[1] Künzel, H.M.: Simultaneous Heat and Moisture Transport in Building Components. One- and two-dimensional calculation using simple parameters. IRB-Verlag Stuttgart 1995, ISBN-............

[2] Prepens, M.: Der Einfluß von Beschichtungen und Imprägnierungen auf die Frost- und Witterungsbeständigkeit von Verblendmauerwerk aus Kalksandsteinen. Dissertation Universität Hannover 1991.