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Reducing the risk of microbial growth on insulated walls by PCM enhanced renders and IR reflecting paints

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ABSTRACT

Staining of façades due to microbial growth has been on the rise in recent years. Especially walls with external insulation systems are affected because low thermal mass of the exterior render combined with high thermal resistance of the insulation layer leads to frequent overcooling of the render's surface by long-wave radiation exchange with the sky. Condensation forming on the overcooled façade is of major importance for microbial growth. Therefore, the best way to prevent growth is to reduce the frequency of condensation by limiting the periods of overcooling. This could be achieved by increasing the thermal inertia of the exterior render through the addition of phase change materials (PCM) or by applying low IR emissivity (Low-E) paint coats. The performance of novel rendering systems including PCM additives and/or Low-E coating has been investigated by field tests as well hygrothermal simulations. The results show that Low-E coats may be more effective than PCM additives because the latent heat of phase change is only beneficial when the surface temperature coincides with PCM's melting temperature range.

KEYWORDS

Microbial growth, phase change materials, low-E coating, exterior condensation.

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1 INTRODUCTION

Due to the enhancement of the thermal insulation of external building components the probability is increased that higher surface humidity, even condensation, can occur on the external surfaces of façades. As a result, humidity being the most important basis for microbial growth on walls has increased [Blaich 1999], [Venzmer 2001]. The consequences are most severe for external thermal insulation composite systems (ETICS), since they possess only a low thermal storage capacity compared to monolithic constructions. Only a small part of the energy of the solar radiation during daytime can be stored so that the long-wave radiation during the night frequently causes a reduction of the surface temperature below the dew point temperature of the ambient air. Fig. 1 shows a façade with the typical microbial growth of fungi and algae. The surface above the tilted window clearly shows that even the ventilation behaviour of the residents can have an influence on the microbial growth. The effect of thermal bridges is also clearly visible. The slightly higher surface temperature causes an interruption of the massive fungal growth above the window. The surface below the window shows predominantly the growth of algae.

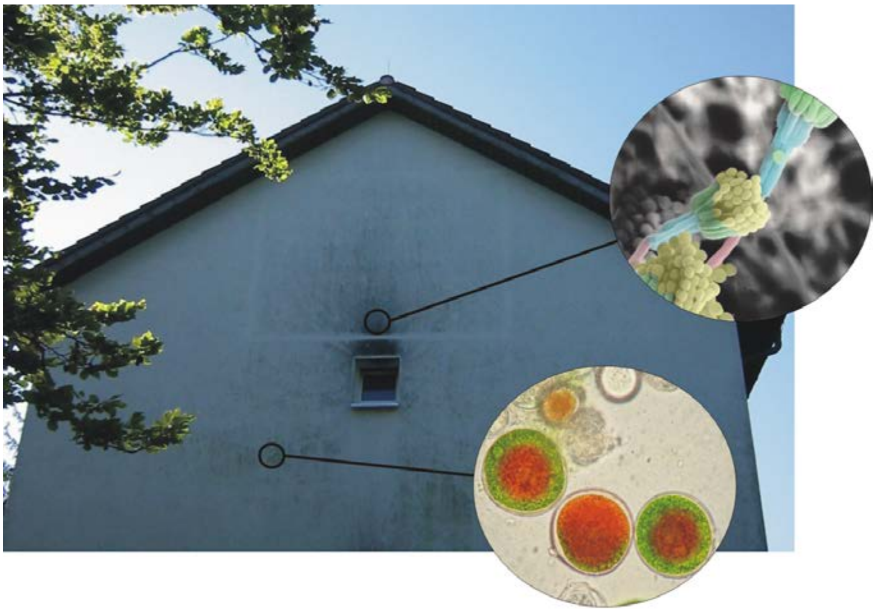

Figure 1. Growth of algae on a façade with external thermal insulation composite system (ETICS) and fungal growth above the window.

Since biocidal finishing of surfaces should be an extraordinary solution for environmental reasons and due to the temporary efficiency, new possibilities must be found to avoid the growth of algae or fungi preferably by physical measures. For this purpose, comprehensive analyses of façade surfaces are conducted on the outdoor testing site of the Fraunhofer Institute for Building Physics (IBP). The whole variety of interesting variations, however, cannot be studied by field tests. Calculations can be carried out by the hygrothermal programme WUFI® modified for this purpose. It allows after validation the rapid and cost-efficient assessment of numerous further variations to evaluate the influence of different factors, e.g. orientation, thickness of thermal insulation layers or enhancement of the thermal storage capacity by using phase change material (PCM) effects.

2 COMPUTATIONS OF PREVENTION STRATEGIES

Computations are carried out by means of the computation programme WUFI® [Künzel H.M. 1994], which was developed by IBP and meanwhile received multiple validations. To allow the comparison of the computed results (surface temperature and surface humidity) of individual wall constructions with measured data, calculations are carried out on the basis of the boundary conditions of the exterior climate recorded in the same period of time. Therefore all following results refer to the climate in Holzkirchen. The most critical season for biological growth on external walls are autumn and spring. Winter and summer do not offer any optimal climate for the growth of algae and fungi [Hofbauer et al. 2006].

There are principally two different physical approaches to reduce condensation on the external surfaces of ETICS. By enhancing the thermal storage capacity close to the exterior surface for example with phase change materials (PCM), it is possible to store the heat from the daily solar warming of the building component to avoid the lowering of temperature below the dew point temperature. In addition, the daily warming of the façade can be enhanced by applying paint with a short wave-higher absorption factor. The drop in temperature at night can be reduced by means of applying paint with a reduced long-wave emissivity (IR paints). A possible criterion to assess the results and the risk of growth is the duration of condensation and the intensity of the dew point temperature undercut.

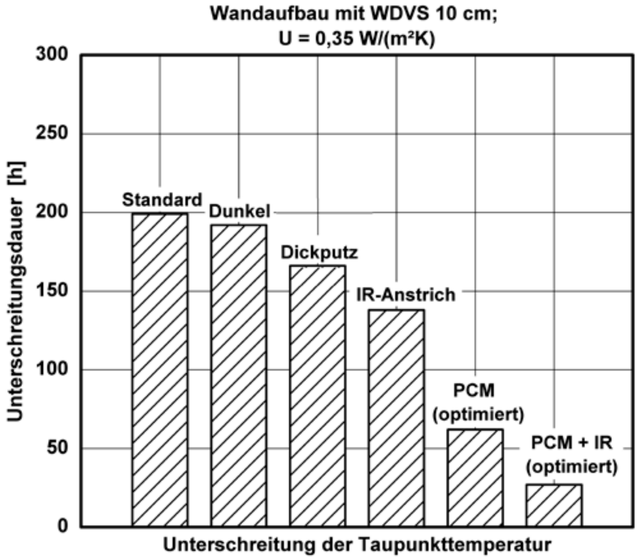

Figure 2. effects of various measures on the duration of the dew point temperature undercut in the period from September to October.

Figure 2 shows the diagram, which summarizes the effects to be expected of different measures. It can be clearly seen that the application of darker façade paint with regard to avoiding condensation does not yield any noteworthy result. Nevertheless, a tinted paint can be advantageous, since it conceals slight growth as well as entails higher temperatures from time to time, which may be lethal to micro-organisms. A thicker external plaster with a high thermal mass can reduce dew point temperature undercut by a maximum of 20 %, IR paint by almost 30 %, and a latent thermal storage layer even by 70 %. The combination of both measures (PCM + IR) can further reduce the duration of dew point temperature undercut, as an extreme case. It must, however, be taken into consideration that in case of applying phase change materials (PCM) the desired effect will only occur, if the melting point of the PCM is adjusted to the climate boundary conditions, which is expressed by the additional term "optimized" in Fig. 2. Microcapsules filled with paraffin as phase change material is mostly used, which is available for this purpose with different melting point between 5 °C and 15 °C. The melting heat amounts to about 200 kJ per kg paraffin.

3. FIELD TESTS

Temperature profiles on the external surfaces of the wall assemblies were measured during outdoor tests to determine by comparison with the measured ambient air dew point temperature the duration and intensity of condensation. Fig. 3 shows western oriented (right) and a northern oriented (left) façade being tested.

Figure 3. Photos with the view of the western oriented (right) and the northern oriented (left) façade.

To show that the impact of condensation is lower on monolithic systems, the measured results of massive walls are also taken into consideration (Fig. 4). Compared to ETICS they clearly show shorter condensation times. As the calculations already showed, the grey colour only yielded a negligible improvement.

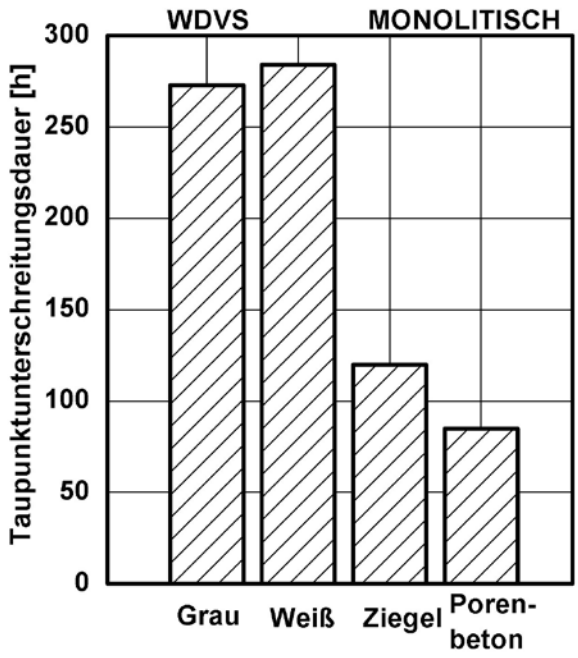

Figure 4. Summarized condensation times for various wall constructions and paints for the most important period of growth in autumn.

The advantage of innovative materials, e.g. IR paints, PCM plasters and the combination of PCM and IR paint can be proven by measurement (see Fig. 5, from the northern façade of Fig. 3). Since temperatures are too low for microbial growth in winter, autumn (as general observations confirm) is the main period of microbial growth. If the measured condensation times are observed for this period of time, the effectiveness of PCM is clearly visible in the first autumn, although measurements could only be started in October. In comparison to a white thin plaster duration of condensation was reduced by approx. 30 % for thick plaster with PCM additives. When comparing with the calculated results for PCM in Fig. 2 it must be taken into consideration that only half the quantity of PCM was added so that the measured duration of condensation tends to show good compliance with the calculation result.

The façade with IR paint, which only achieved a emissivity value of 0.74 instead of 0.6 in contrast to the calculations, shows a decrease of the condensation times by approx. 15 %. As was expected, the combination of PCM plaster and IR paint achieves a reduction of the exterior condensation of almost 50 %, clearly a higher reduction than the results with PCM additive and IR paint alone.

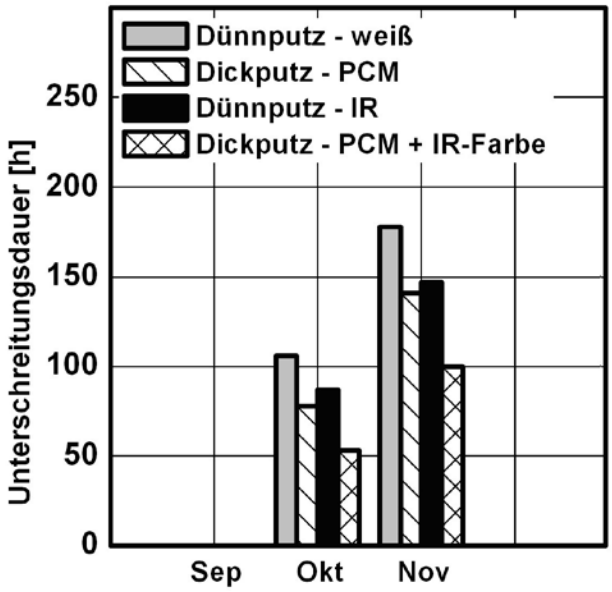

Figure 5. Duration of condensation for the ETICS without and with PCM and IR paint for the first autumn of the measurement period.

Besides the duration and quantity of condensation the actual amount of surface water is decisive to assess the risk of microbial growth, since only the water on the surface of a façade is available for micro-organisms. Therefore, the surface humidity on a western façade without PCM plaster was determined by dabbing. Fig. 6 shows the results of a morning after a clear night. Almost double the amount of water was measured on the surface of a standard ETICS with white paint than on the surface of a white thick plaster. It must, however, be taken into consideration that these results are dependent on the hygric material properties of the plaster and paint to a very large extent. More condensation is penetrating through the thick plaster beneath the surface. The best result is achieved by the surface with IR paint (variant with an emission coefficient of approx. 0.6). Almost no water could be measured on the surface this morning. Unfortunately, the IR paints available at present are not yet sufficiently weather resistant. This could be seen by the fact that for the investigated paints aluminium flakes, which were used to reduce long-wave emission, appeared on the surface due to the impact of weathering after a relative short period. The result is a metallic glaze of the paint. The measurements, however, show that it would be beneficial to further develop IR paints to adjust weathering resistance to present requirements.

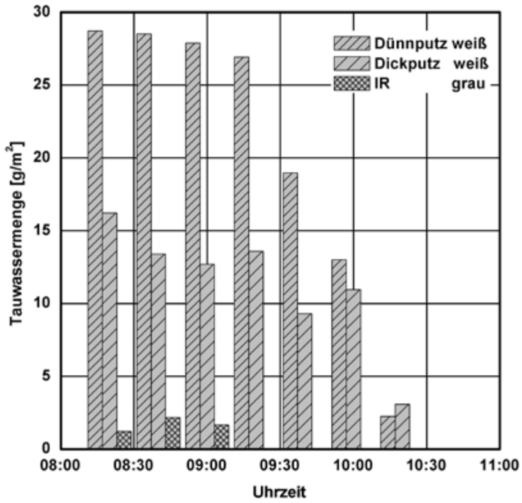

Figure 6. Courses of surface humidity of western oriented walls with various ETICS.

The measurements on the northern façade of Fig. 3 were continued. Fig. 7 shows the results for the successive 2 periods in autumn. Surprisingly, the façade with PCM additives shows no or only a slight reduction of the condensation times in contrast to the first period in autumn. The reason is not the stability but the melting temperature of the PCM used, which amounts to 6 °C. Whereas the mean ambient air temperature was 5 °C in the autumn of the first year of investigations, it amounted to approx. 10 °C in the following years. Therefore, no latent heat could be released. The façade with IR paint, however, shows a continuous and constant lowering of condensation times. An interesting aspect is the fact that the combination of PCM plaster and IR paint shows a clearly higher reduction of the condensation production during the total period of measurements than the IR paint alone, although the PCM additive alone did not yield any improvement from time to time.

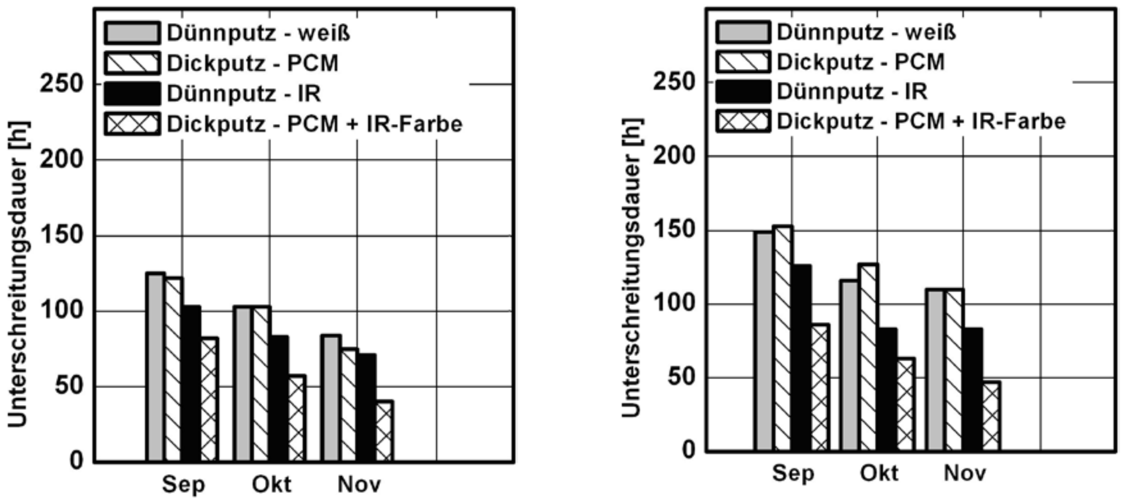

Figure 7. Duration of condensation on the surface of the ETICS without and with PCM and IR paint of the second autumn (left) and the third autumn (right) of the period of measurements.

4 SUMMARY

In the last decades, the level of thermal insulation was clearly increased especially for new buildings. The improvement of the standard of thermal insulation resulted in a clearly higher risk of microbial growth on external façades by mould and algae. The essential criterion for the risk of microbial growth on façades is the availability of sufficient humidity. Condensation at night caused by nocturnal long-wave emission is of special importance, since it is the only explanation for the observed increase in microbial growth on the northern façade with only little driving rain. To assess the risk of microbial growth condensation on the surface is thus a good criterion. The direct comparison of monolithic walls e.g. made of aerated concrete or bricks, with walls with ETICS shows that they are more at risk. But to improve the thermal insulation of already existing buildings the application of ETICS is the most practicable way in most cases. Therefore possible solutions against microbial growth are investigated for these systems. Calculations as well as field test measurements were conducted for this purpose. If we consider the problem of undesired microbial growth on façades, we must notice that the majority of ETICS is without any damage. Only a minor percentage shows microbial growth. This is the reason why the authors suggest that already the reduction of the time of condensation by 25 % could avoid most problems. But there are always special circumstances, for example a shaded wall in the vicinity of a forest or water, where the application of chemical agents is inevitable.

A possible solution to reduce nocturnal condensation is to use latent heat effects by adding so-called PCM (phase change materials) in external façades. Paraffin for example, which is available with various melting point ranges, can serve as PCM. The optimization of the temperature for the phase change is essential to reduce the condensation by applying PCM. The problem, however, is its application. The optimization of the phase change point is calculated by applying test reference years. Yet, the differences of the climate conditions in successive years are so immense that not even this kind of optimized PCM can be continuously effective. This example, however, also shows that calculations alone do not reflect practical reality despite correct calculation results, since parameters are neglected from time to time, which can only be revealed by outdoor testing, in this case over a period of several years.

In case of IR paints the emission coefficient for long-wave radiation could be reduced from more than 90 % to approx. 60 %. Higher maximum temperatures during the day as well as a reduction condensation are achieved by reduced thermal emission. This is the method, which is most simply practicable in already existing buildings. Unfortunately, IR paints, which are sufficiently resistant to weathering, are not yet available.

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