Biological Growth on Stucco

Hartwig M. Kuenzel, Dr-Ing.
Member ASHRAE

Klaus Sedlbauer

ABSTRACT

In recent years, microbial growth on stucco facades has become an increasing problem in Central Europe. Apart from the effect of a cleaner environment and less poisonous additives in the stucco, this is mainly due to better hygrothermal growing conditions for algae and fungi. Essentially, this means that the facade surface retains enough moisture throughout a certain period of time to allow the formation of vegetation. The increase in surface humidity of exterior walls can be largely attributed to better thermal insulation and lower thermal capacitance of the facade, which leads to frequent condensation of moisture from outdoor air caused by longwave sky radiation. Another effect is the slower drying of precipitation moisture due to the diminished exterior surface temperature of energy-efficient buildings with high thermal insulation.

In order to prevent or at least reduce algae and fungi growth without polluting the environment, methods have to be devised to improve the hygrothermal surface conditions. These methods include a reduction of the water absorption of the stucco by innovative water repellents that rely on the lotus effect and exterior coatings with a low longwave emissivity. Both methods are supposed to reduce the wetting of the facade resulting from precipitation and condensation. Another method would be the staining of the stucco, which leads to a higher surface temperature and better drying during daytime. Alternatively, increasing the suction tension of the stucco substrate could also result in a faster reduction of the stucco surface humidity. The different methods described are currently being examined at a test site in Germany. First results should be available by the end of 2001.

INTRODUCTION

Staining or degradation of stucco due to algae or fungi growth is becoming a problem in many parts of the world. While there is a great variety of species found in different rural and urban locations (Gaylarde and Gaylarde 2000), the basis for growth appears to be an elevated surface humidity of the stucco. There are several moisture sources that can lead to prolonged elevated surface humidity: precipitation, splash water, and condensation of outdoor air humidity. In the last decade, a rising number of algae growth problems on exterior insulation finish systems (EIFS), also called exterior thermal insulation composite systems (ETICS), have been reported in Germany. Blaich (1999) from the EMPA in Switzerland has shown that the increasing insulation thickness of EIFS contributes to the problem. Figure 1 shows a photograph of a northeast-facing wall with 10 cm exterior insulation ($U = 0.3$ W/m²K). There is microbial growth all over the facade except for some clear spots of about 5 cm diameter. The infrared thermograph below the photograph indicates "hot" spots at the locations where no algae are visible. These hot spots result from the thermal bridging of the fixing anchors beneath the stucco. Their temperature exceeds the rest of the facade by about 1.5 K. The surface temperature plotted at the bottom of Figure 1 for the horizontal line in the thermograph shows that a difference of less than 1 K during the test conditions is enough to inhibit biological growth. This phenomenon can be explained by radiative cooling. If the facade cools below ambient conditions due to sky radiation, a small difference in surface temperature can result in the dew point being reached and then condensation occurs.

Hartwig M. Kuenzel is head of the hygrothermal division and **Klaus Sedlbauer** is deputy director of the Fraunhofer Institute of Building Physics, Holzkirchen, Germany.

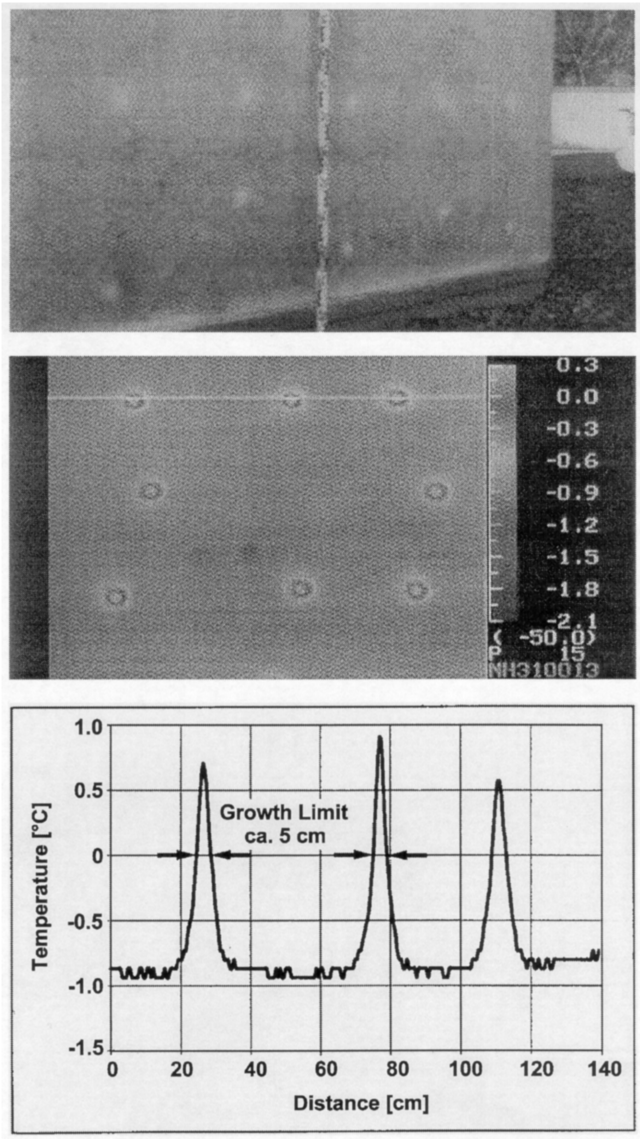

Figure 1 *Photograph and thermograph of an EIFS attached with anchors. There is no algae growth in the vicinity of the anchors due to the slightly higher surface temperature there (Blaich 1999).*

The anchors cause a higher heat flux to the surface than the insulation, thus preventing the moisture supply for biological growth. Therefore, the temperature drop of the wall surface below the temperature of the ambient air seems to be a prerequisite for a surface humidity high enough for algae or fungi growth. In this paper, continuous temperature measurements at test walls are analyzed concerning the probability of biological growth and remedial measures will be indicated.

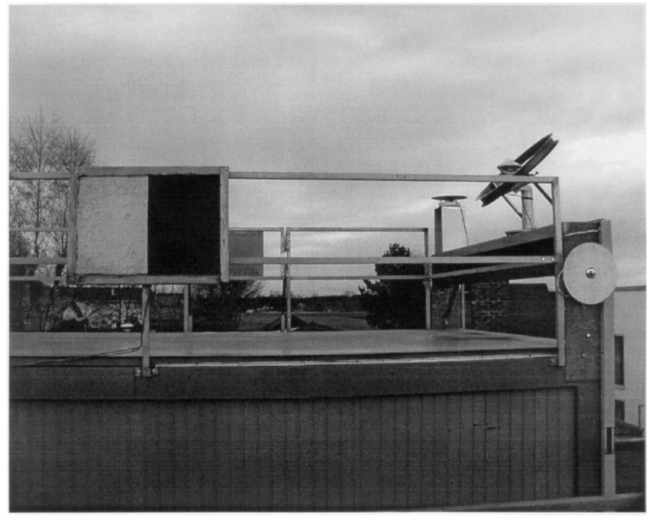

Figure 2 *White and black stucco samples exposed to the west on top of meteorological station with insulation at the backside and temperature sensors located beneath the stucco surface in the middle of each sample.*

EVALUATION PROCEDURE AND MEASUREMENT ANALYSIS

The humidity conditions at the exterior surface of walls are assumed to be the predominant growth factor. For an inert surface (no significant storage of moisture), the surface humidity can be determined from the dew point of the ambient air and the surface temperature. Microbial growth requires some time to develop; therefore, the surface conditions have to be investigated over a certain period of time. Similar to the assumption for mold growth in the guidelines of IEA Annex 14 (1990) the average conditions over a period of at least one month will be considered. However, because of the diurnal wetting and drying cycle of a facade due to sky radiation and insolation, it makes sense to determine a mean cycle by averaging the conditions for every hour of the day. From that mean cycle, the probability of biological growth may be deduced by comparison with measurements carried out at different building assemblies and locations.

EXPERIMENTAL INVESTIGATION

At a building science open-air test site in Germany, close to the Bavarian Alps (altitude 680 m), the surface temperature of the freestanding white stucco sample in Figure 2, which is exposed to the west and insulated on the east-facing side, is continuously monitored together with other meteorological data. Figure 3 shows the average diurnal cycle of the temperature and humidity conditions at the stucco surface and in the ambient air determined for the four seasons from hourly data of three consecutive years (1997-1999). The highest average surface humidity can be detected in the fall with the average

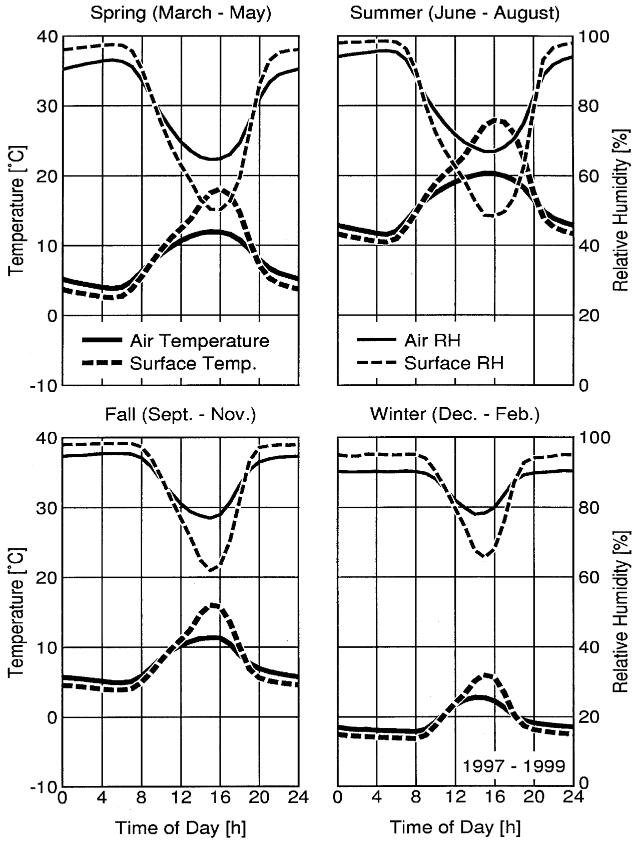

Figure 3 *Average diurnal cycles of temperature and relative humidity of the outdoor air and the surface of an exposed stucco sample determined from hourly data recorded between 1997 and 1999.*

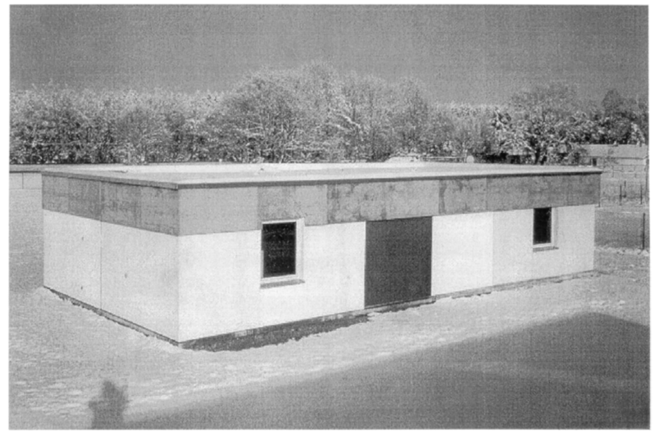

Figure 4 *West facade with EIFS (left) and monolithic brick wall sections with red and white stucco facing south of the test house.*

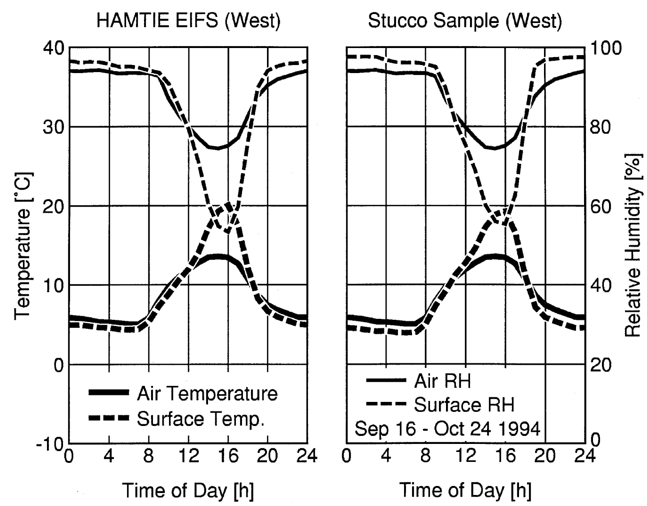

Figure 5 *Diurnal cycles of surface and ambient air conditions of the west-facing EIFS at the test house compared to the exposed freestanding stucco sample during the same period of time.*

temperature being well above freezing, i.e., in a range where biological growth is likely to occur. In winter, the temperatures are probably too low to promote growth, and in spring and summer, the average surface humidity falls below 60% RH during daytime, indicating better drying conditions than in the fall. Since the period between September and November appears to be the most favorable season for biological growth, the following investigations will be limited to these months.

At the test building shown in Figure 4, which was erected within the framework of the IEA project Annex 24, the facade temperature in the stucco of different wall systems was continuously monitored during the test period. Compared to the ambient air conditions, the average temperature cycles and the resulting relative humidity for the period from September 16 to October 24, 1994, are shown in Figure 5 (left side) for a west-facing 24 cm calcium silica brick (CSB) wall with 8 cm of EIFS. In relation to the results from the freestanding stucco sample (Figure 5, right side), the surface temperature of the EIFS on the test house is only marginally higher. This means that the heat flow from the interior of the building has only a minor effect on the surface temperature, despite the moderate insulation thickness of 8 cm (the thermal insulation of the CSB masonry is almost negligible).

The north- and south-facing walls of the test house consist of monolithic brick walls (36 cm) without additional insulation. These masonry wall sections are covered with stucco painted white or red and have U-factors similar to the insulated CSB wall. The red stucco coat simulates the situation of brick veneer on the wall. In Figure 6, the surface temperature and humidity cycles are plotted for the monolithic wall section (same period as above). Due to the high thermal capacity of the walls, there is no nighttime overcooling of the exterior surface. The south-oriented surfaces are warmer throughout the whole day and, therefore, also dryer (max. 90%, res. 82% RH) than the ambient air. The same is true to a lesser extent for the north-facing red surface. The north-facing white surface is cooler

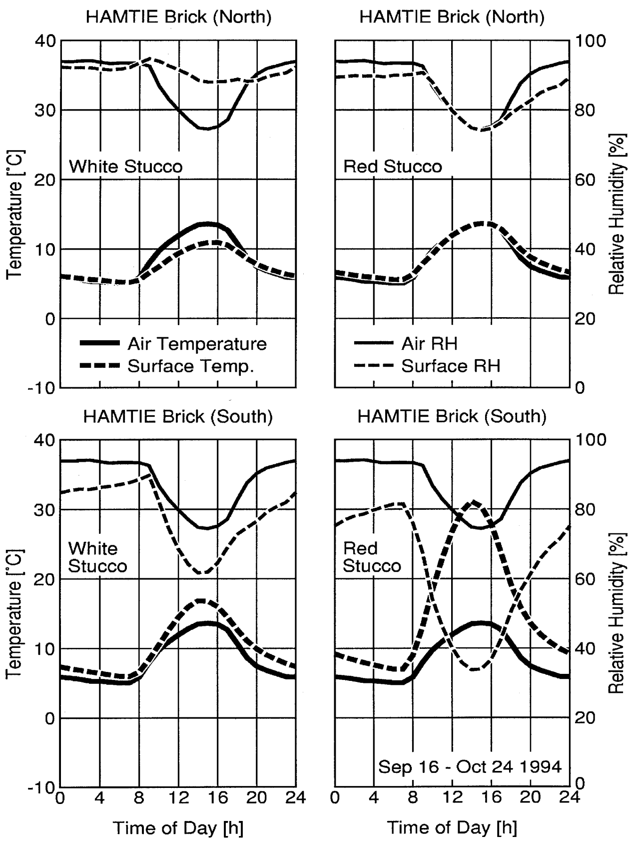

Figure 6 *Diurnal cycles of surface and ambient air conditions of the north- and south-facing monolithic brick walls of the test house.*

than the ambient air during daytime. However, this does not lead to a rise in surface humidity because the ambient air becomes dryer with increasing temperature. Compared to the west-facing EIFS covered wall with an average nighttime humidity reaching 97% RH, the white painted north-facing brick wall shows only little fluctuation in surface humidity with peaks around 95% RH. The red color reduces this peak to 91% RH by absorbing more solar radiation during daytime.

At another test building with a south-oriented facade, shown in Figure 7, the surface temperature of differently painted EIFS (6 cm) applied on solid brick masonry was recorded during the fall of 2000. Figure 8 shows the mean temperature and humidity cycles for two test sections painted in gray. While both sections had the same optical appearance, one had a special infrared reflecting coat with an IR emissivity of 0.6 and the other had a standard paint (IR emissivity 0.9). The lower IR emissivity does not have a great effect on the peak temperature, but it significantly diminishes the radiative overcooling of the facade. This leads to a reduction of the average surface humidity from 95% to 92% RH during the night.

Condensation is not the only moisture source on exterior building envelopes. At the test site, staining occurs mainly on west-facing walls, indicating that driving rain may contribute

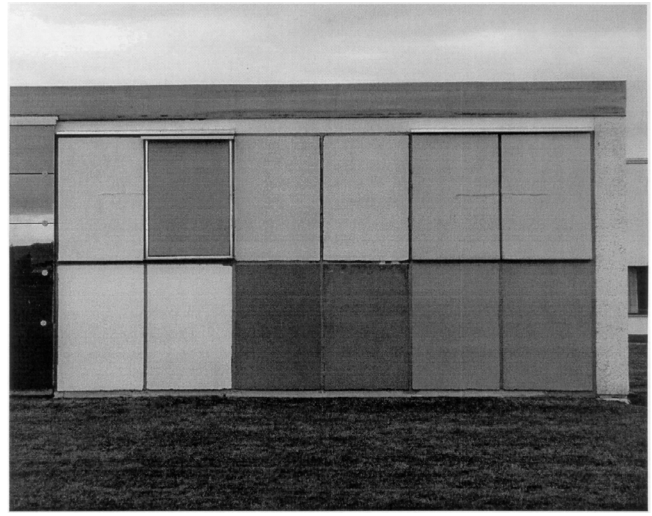

Figure 7 *Test facade oriented to the south for solar energy related examinations with different wall sections. The colored twin fields were designed to compare the thermal performance of infrared reflecting coatings to standard paints. The gray sections on the right are the EIFS test fields considered here.*

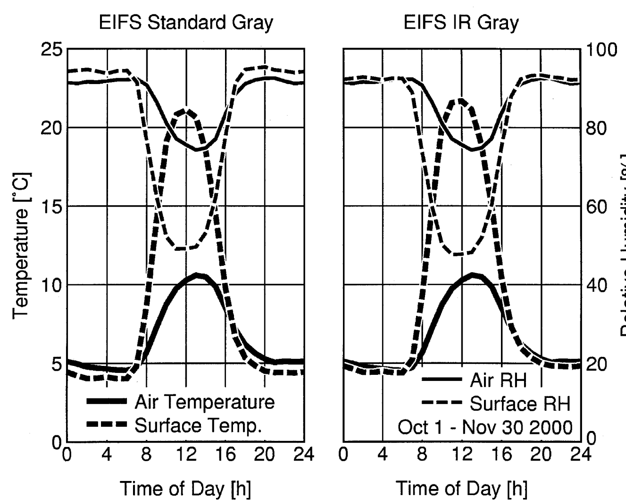

Figure 8 *Diurnal cycles of surface and ambient air conditions of a south-facing EIFS on a solid brick wall with standard and infrared reflecting gray coating.*

considerably to algae or fungi growth. Especially finish materials with a high water absorption, such as untreated stucco, are prone to biological growth. Problem areas are also those that suffer from unfavorable drying conditions, e.g., the north-oriented jamb of a west-facing door or window. The photograph of such a window (see Figure 9) shows severe staining at the bottom of the right jamb due to splash water from the sill. Compared to the reduced drying potential of the north-facing

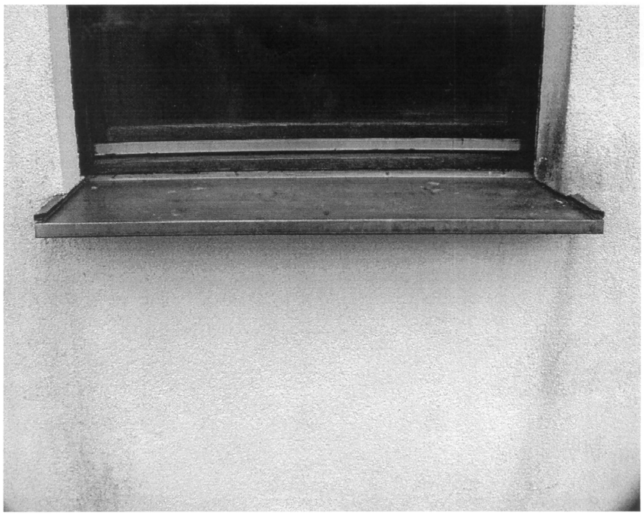

Figure 9 *West-facing window of a test house with severe algae growth at the bottom of the north-oriented jamb on the right.*

jamb, the left jamb, which is oriented to the south, receives enough solar radiation to handle the splash water. Similar staining patterns can be found at many envelope parts that are exposed to precipitation but shaded from direct insolation.

DISCUSSION AND CONCLUSION

The authors have not yet fed the measured data into biological models able to predict the growth probability from transient temperature and humidity conditions. However, they intend to apply a model based on the findings of Block (1953), Grant et al. (1989), and Viitanen (1996) on the hourly mean values of the surface conditions recorded during the reported investigations. For the time being, the experimental results can only indicate which situation might cause problems by comparison with observations. The surfaces of EIFS are known to be more prone to biological growth than monolithic walls. The tests have shown that the higher thermal capacity of monolithic facades protects them from radiative overcooling and dampens the surface humidity changes. This situation seems to be less favorable for algae or fungi growth than the humidity fluctuations, including condensation, with respect to elevated humidity conditions at the surfaces of EIFS. Currently, the algae problem of EIFS is solved with biocides. Especially for exposed facades, this is only a temporary solution because the chemical growth inhibitors will be washed away by driving rain. A more ecological solution could be the application of infrared reflecting paints. However, the durability and long-term efficiency of these paints is still unknown.

The contribution of precipitation to biological growth is still largely unknown. The exposure of roofing tiles (Kuenzel 2000) has shown that concrete tiles are more prone to growth than brick tiles. This indicates more favorable conditions on substrate with high sorption capacity. The lower water absorption of concrete compared to brick tiles appears to be outweighed by the sorption properties. The same seems to be true for inherently water-repellent stuccos. Despite a very limited water absorption, they are not immune to biological growth. In some cases, the compounds leading to water repellency appear to promote growth either by being nutrients or by attracting dirt and organic material from the air. A recent innovation claims to provide a water and dirt repellent effect by applying a coat to the stucco with a microstructure similar to that of a lotus plant. Even if this lotus effect were genuine, it does not prove that biological growth cannot occur. It may be concluded that despite an increasing number of staining problems reported, there is a severe lack of thorough investigations or durable solutions.

ACKNOWLEDGMENT

This investigation was supported by the director of the Fraunhofer-Institute of Building Physics (IBP) Prof. Dr.-Ing. habil. Dr. h.c. mult. Dr. E.h. mult. Karl Gertis.

REFERENCES

Blaich, J. 1999. Aussenwaende mit Waermedaemm-Verbundsystem, Algen- und Pilzbewuchs. *Deutsches Architektenblatt* 31(10): 1393-1394.

Block, S.S. 1953. Humidity requirements for mold growth. *Applied Microbiology* 1: 287-293.

Gaylarde, P.M., and C.C. Gaylarde. 2000. Algae and cyanobacteria on painted buildings in Latin America. *Int. Biodeterioration & Biodegradation* 46: 93-97.

Grant, C., et al. 1989. The moisture requirements of moulds isolated from domestic dwellings. *Int. Biodeterioration* 25: 259-284.

IEA. 1990. Annex 14, Condensation and energy. *Guidelines & Practice*, vol. 2, KU Leuven.

Kuenzel, H. 2000. Heutige Beanspruchung von Tondachziegeln und Betondachsteinen bei Dachdeckungen. IBP-Mitteilung 27, n. 371.

Viitanen, H. 1996. Factors affecting the development of mould and brown rot decay in wooden material and wooden structures. Dissertation, Uppsala.