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Holzkirchen, July 10, 2019

Review Report for the dissertation of Magnus Wessberg

Dear Prof. Jirout

Thank you very much for the offer to be part of the dissertation process of Magnus Wessberg. I have read the thesis with interest and include my comments in this document. Also, you will find some questions for the defense presentation at the end of this document.

Best regards

Dr. Ralf Kilian

Fraunhofer Institute for Building Physics

Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V., München
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*Review Report for the dissertation of Magnus Wessberg
by Dr. Ralf Kilian*

“Design and analysis of energy efficient indoorclimate control methods for historic buildings”

The thesis by Magnus Wessberg “Design and analysis of energy efficient indoor-climate control methods for historic buildings” for the first time assesses control strategies and algorithms for preventive conservation of cultural heritage objects and of historic buildings that take into account cost effectiveness, energy efficiency, and sustainability. The aims of the thesis have been widely achieved. A new control method to heat up massive buildings intermittently to prevent damages to valuable works of art has been developed via experiments and simulation. In a next step it can be validated and put into conservation practice. This has a high relevance to applied conservation.

The main challenge of the thesis is connected to the task and the subject as all research in the field of climate control for preventive conservation has to be interdisciplinary and needs to refer to the state of the art in damage risk assessment of artworks as well as to control engineering and simulation. Both fields are explained in a short and concise manner and the relevant literature is mentioned. At some points a deeper discussion of certain aspects could have added extra value

As one central aspect the thesis addresses intermittent heating of massive historic buildings, e.g. the brief time of heating of a church during a service. This is a much debated question in heritage preservation with different opinions on the correct procedure.

The second central technology investigated in the thesis is adaptive ventilation.

The aspects of limiting the risk for mould growth, the influence on the stability in relative humidity, and energy efficiency are addressed.

Also adaptive (or controlled) ventilation is widely debated, especially concerning the efficiency of the method. Therefore the results from these studies is actually very relevant for the preventive conservation community and stakeholders.

The PhD from Magnus Wessberg shows that it is energy efficient, but however very limited in its effect on mould prevention, because it cannot prevent the influence of certain longer periods of higher humidity

which are likely to increase with global warming. Also the thesis states the risk of increasing short term fluctuations of relative humidity and thereby the risk for mechanical damages.

In a case study of Skokloster Castle the methods of conservation heating, dehumidification and adaptive ventilation were applied and successfully compared in terms of risk for mould growth, energy efficiency and indoor climate stability. Here dehumidification worked best for areas without extra moisture sources. This result supports results by other research groups, esp. for churches in Denmark. In this study focus is also put on building physics parameters like the air exchange rate which has high importance on the efficiency of any dehumidification measure.

The analysis of the possibilities of the different climatization methods to prevent mould growth revealed, that considerable energy savings can be achieved when the mould growth dependence on a combination of RH and temperature is taken into account when determining the RH set-point, compared to the common RH control using a fixed set-point value. Here also the bio-hygrothermal model by Krus and Sedlbauer should be considered in the future in a next step as it could mean even further energy savings for climate control to prevent mould.

The thesis is well written and the argumentation is stringent. The overall layout is well done and also the illustrations very well highlight the overall argumentation and development of the ideas.

Taking all aspects above into account I recommend the dissertation for defense. .

Dr. Ralf Kilian

Munich, July 7th 2019

Questions for the defense:

Can you please explain, how you chose the limits for mould growth in the risk assessment?

Can you please explain, about the safety margin you used at Skokloster for the Isopleths LIM1? How was that decided?

In your thesis you used the isopleths for mould growth that were developed by Sedlbauer. Did you also consider using the WUFI Bio Model which includes periods of drying out of mould and spores and predicts therefor delayed mould growth?

Is it better to heat up a massive stone church fast or slow and why?

Dr. Ralf Kilian

Munich, July 7th 2019