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A sound indoor climate for a museum in a monumental building

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Summary. Museums are often housed in monumental buildings. These buildings were originally not built for this purpose. For the preservation of the artefacts in a museum the indoor climate is often restricted to a very narrow interval for temperature, but most of all for relative humidity. This restricted indoor climate originally dates from the 1970-ties. This indoor climate, however, does not fit well into an old building. The indoor surface conditions near cold walls under winter conditions lead to mould building and other deterioration of the wall surfaces. But principally the museum conditions of artefacts near the cold walls are not in line with museum recommendations.

For some typical Dutch museums case studies have been done to show the building physical effects of housing a museum climate in an old building.

A number of well known Dutch museum were selected to be examined. The buildings and their HVAC systems were analysed in a methodical way. For at least a year temperature and relative humidity measurements were recorded in different rooms and at different external wall surfaces of the museums. Additionally outdoor climate, CO\textsubscript{2}, ventilation and infiltration measurements were recorded when needed.

The results of this measurement campaign were a large number of indoor climate conditions in different museums in rooms and near external walls. There was a large contrast between the aimed indoor museum climate and the measured resultant indoor climate in rooms and near external walls.

The aimed indoor climate in museums which are housed in monumental buildings should be reconsidered.

In the Netherlands a multidisciplinary climate network of people involved with the museum climate like conservators, museum-, monumental building- and HVAC consultants and building physicists is formed to formulate new guidelines for the indoor climate in Dutch museums.

1. INTRODUCTION

In 2005 the State Inspectorate for Cultural Heritage asked themselves questions about the quality of the indoor climate in Dutch State museums. Furthermore they were interested in the indoor climate in respect to the original demands on it. The Eindhoven University of Technology started a measurement campaign in three case studies on the indoor climate in three state museums. The results of these case studies were eye opening. Where a lot of afford was used to create an indoor climate with very strict restrictions on the indoor temperature and relative humidity a number of results were very disappointing. The introduction of high tech HVAC systems in old monumental buildings did not automatically lead to the strict museum indoor climate which was aimed for. Furthermore it was concluded that it may not be possible to combine very strict indoor climate conditions with old monumental buildings, without improving the thermal quality of the external envelopes.

It was decided that the recommendations for the indoor climate in Dutch museums and especially state museums should be reconsidered. A museum indoor climate network was formed, a PhD study was started at the Eindhoven University of Eindhoven and recommendations were reformulated.

This paper will start with a number of results from the case studies.

2. RESULTS FROM CASE STUDIES

In the results of the case studies a common problem was that the assumed indoor climate for the preservation of the objects was in conflict with the preservation of the external façade. A number of examples will be shown.
2.1 Museum Our Lord in the Attic Amsterdam

Museum Our Lord in the Attic in Amsterdam is a 17th century building. The museum houses a number of original 17th century authentic rooms and a church shelter. The Eindhoven University of Technology (TUE), together with the Netherlands Institute for Cultural Heritage (ICN) and The Getty Conservation Institute (GCI) have made an extensive analysis of the indoor climate in Maekawa et.al.1. For the conservation of the objects the indoor humidity climate is controlled to about 60 %RH by local humidifiers and dehumidifiers, which are used throughout the building. The combination of this rather high relative humidity in combination with low winter surface temperatures of the glazing most often has lead to condensation. The results of these frequent condensation events are visible at the rotten wooden frames of the glazing. Moreover some of the wooden beams in the building were rotten at the end of the beams where these are connected to the wall. A number of these beams already have been repaired by epoxy.

At the surfaces of the external walls valuable paintings are hanging. During wintertime these surfaces are cold and the relative humidity near these surfaces may be high. In figure 1 one of these paintings can be seen. The middle picture shows an infrared thermal image. What can be seen from this picture is that it is hanging at an external wall, near to an internal wall. The painting is warmed up by the air, and a large temperature gradient can be detected from painting to wall. The right picture is a visualization of the relative humidity. The picture was constructed from the thermal image, in connection with the specific humidity from other measurements. The technique was introduced by Schellen1.

In the future the specific humidity in the museum will be lowered in combination with a lower air temperature during wintertime.

![Fig. 1. left: painting hanging at an exterior wall. Middle: infrared thermal image. Right: relative humidity near the painting.](image)

2.2 Rijksmuseum Amsterdam

The conceptual choice of the Rijksmuseum was to have a choice to display the national collection in an integrated way. The concept of the (control of the) HVAC system was determined by this choice. Very strict museum conditions should therefore be met in every part of the building. In the whole building very stringently indoor climate conditions will be maintained with a small difference between summer and winter indoor climate design conditions. For the summer the indoor design conditions will be 23 °C and 54 %RH and for the winter 20 °C and 50 %RH, with a tolerance of ± 2 °C and 5 %RH a day. To maintain these conditions in the old monumental building the exterior envelope has to be insulated. Because of the monumental exterior the only choice could be inside insulation. In the early design phase the choice was made for foamglass. Building-physical modeling and simulation studies, however, showed that the construction probably would get wetter and wetter during successive years, due to the lack of drying at the inside. A study from Dresden University by Ruisinger2 showed that a thin inside insulation layer of calcium silicate probably would solve this problem. A mockup study confirmed this assumption. Thermal bridges, however, formed at the beginning of the ceilings and near columns, have still to be solved.

2.3 Haunting Lodge St. Hubert

Haunting Lodge St. Hubert was designed by the famous Dutch architect Berlage and was built in the period from 1916 to 1922. The building and its collection are a so called Gesamtkunstwerk. The building is one of the most valuable monuments, with a ditto interior. Because of this valuable interior one was concerned about the indoor climate for preservation. Therefore the indoor climate was measured during a
year. In figure 2 for one of the rooms the results of these measurements during a year are displayed in a Climate Evaluation Chart, introduced by Martens\(^8\). From the graph it can be concluded that during the heating season relative humidities below 20 to 30 %RH were recorded. These are dangerous low values for the preservation of the wooden interior parts, like furniture. Because of the rather unique character of the interior visible ways to improve the indoor climate by show cases, humidifiers or HVAC systems were no alternative. It was decided to do a test by conservation heating. The results of these tests were encouraging (Neuhaus et. al.\(^6\)).

![Climate Evaluation Chart](image)

**Fig. 2. Climate Evaluation Chart of indoor conditions in the living room**

### 2.4 Museum Dordrecht

The museum of Dordrecht will be enlarged by an exhibition room. The new building will have a modern HVAC system, assuring a class A ASHRAE qualified indoor climate (ASHRAE\(^3\)). The old existing monumental building will be upgraded in a building physical way. The idea is to have the same highly qualified indoor climate as was chosen for the whole new building. Therefore the external envelope has to be insulated. Like the Rijksmuseum it is a building with a monumental exterior, so the choice of inside insulation was inevitable. The construction of the floors, however, consists of wooden beams which are supported by the external walls. The suggested thermal insulation layer of mineral wool seems to be dangerous and may result in rotting of the end of the wooden beams.

### 3. DEVELOPMENT OF GUIDELINES

Until now Dutch museums used guidelines from the Netherlands Institute for Cultural Heritage (ICN). These guidelines with recommended values for air temperature and relative humidity were based on the maximum security and lowest risks for humidity sensitive valuable materials. Museums used these values even for rooms where those materials were not exposed.

Most of these guidelines are derived from ‘The Museum Environment’ from Thomson\(^4\) from 1978. In this edition 55%RH is mentioned as a recommended, save mean value for mixed collections, with acceptable deviations from plus or minus 5%RH. Thomson himself indicated that these deviation values were not based on pure research, but that these were values which were feasible for the HVAC systems from that time.

The mean recommended 55%RH value was based on the yearly mean expected indoor RH value in buildings in Northern Europe and the experience that around 55%RH acceptable deviations, without causing damage, around this value were largest.
New recommendations for the indoor museum climate go back to the relation between T and RH and possible damage to objects of value. In these considerations not only the value and sensitivity of objects is important, but also the possible damage to buildings and their exterior envelope. On the basis of these considerations the optimal determined indoor climate not always has to be the most stringently.

Regarding the formulation of the new guidelines next four principles were determined to be most important.

3.1 Determination of value of collection and building

Possible measures to reduce climate risks for collections have to be weighed against the changed values for building and collection. The introduction of an HVAC installation or the use of display cases e.g. may change the historical value of a room.

3.2 Indoor climate and possibilities of the building

As could be seen from the case studies there is a limit to the possibilities old and monumental buildings can stand regarding allowable RH values. To maintain very stringently RH values in these buildings very drastic building physical measures like inside insulation and air tightness have to be taken.

3.3 Risks to collection

For each part of the exposed collection the risks for degradation linked with several climate classes (ASHRAE³) have to be determined. Three degradation mechanisms should be considered: chemical, physical and biological degradation.

3.4 Indoor climate control

An analysis of most efficient measures to maintain a certain recommended climate around objects of value should be carried out. Models like HAMBASE by Wit⁵ may be helpful.

4. CONCLUSION

A sound indoor climate for a museum in an old monumental building is a climate that has lowest risks for the objects of value and the building itself. One recommended very stringently value for a whole building mostly is not possible and gives high risks to the building. Apart from that energy costs may be unacceptable high for these kinds of recommendations. There are a lot of alternatives to preserve objects of value or vulnerable objects, e.g. by means of introducing a locale climate.

5. REFERENCES