Passive hygrothermal control of a museum storage building in Vejle - DTU Orbit

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For optimal conservation of the stored objects, museum storage buildings require a very stable interior climate, with only minimal and slow variations in temperature and relative humidity. Often extensive HVAC is installed to provide such stable indoor conditions. The resultantly significant energy and maintenance costs are currently motivating a paradigm change toward passive control. Passive control, via the thermal and hygric inertia of the building, is gaining a foothold in the museum conservation and building physical community. In this report we document the hygrothermal performance optimisation of a museum storage building, related to an existing storage centre in Vejle (Denmark). The current building design already incorporates passive control concepts: thermal inertia is provided by the thick walls, the ground floor and its underlying soil volume, while hygric inertia is provided by the thick walls of light-weight concrete. The design promise stated that a few years of dehumidification would bring down the moisture contained in the fresh constructions to a level corresponding with the desired interior climate. After this initial stage, the passive control would eliminate all further need for dehumidification. Four years after completing the construction however, continuous dehumidification remains necessary to maintain acceptable humidity levels. Analysis of the current situation: A thorough investigation of the current building design and management shows that the original design promise of ‘a fully passively conditioned storage building’ is an illusion. With the yearly average exterior temperature and vapour pressure in Denmark at 7.8 °C and 930 Pa, a fully passively conditioned building would reach a yearly average temperature and vapour pressure of 10.2 °C and 930 Pa. The interior temperature is somewhat higher than the exterior, due to interior heat sources (lights and humans); since no significant interior moisture sources are present, the interior vapour pressure is similar to the average exterior vapour pressure. Such interior conditions translate to a yearly average relative humidity of 75 %, which is far above the desired levels. It should be finally stated that similar conclusions would be reached for many other European climates.

Conservation heating or dehumidification are hence required, to maintain acceptable relative humidities in the storage. Conservation heating raises the temperature and lowers the relatively humidity; dehumidification decreases the vapour pressure and thus the relative humidity. For the low air change rates of storage buildings, dehumidification is the most economical option. Moreover, it allows for lower temperature levels, beneficial to the conservation purposes. Reduction of dehumidification load: In an effort to reduce the necessary dehumidification, a number of thermal measures are investigated first. This primarily focuses on the influences of additional insulation in walls, roof and floor. Overall, the effects of extra insulation on the average temperature level are very limited. The effects on the temperature variation differ for the floor and for the walls & roof: • walls & roof: more insulation gives less heat exchange with the exterior, and thus a lower interior temperature variation; • floor: more insulation in the floor breaks the connection with the thermal inertia of the ground and thus a higher temperature variation; For those reasons, more heavily insulated walls and roofs could be considered. Their effects on the interior climate and dehumidification load are however not that large. For the floor, no insulation should be added, and it could be considered to replace the leca layer with standard gravel. This will visibly reduce the temperature variations over the year. All in all however, none of these thermal measures have a great impact on the dehumidification load. To reduce the dehumidification load, only one strong solution exists: a more airtight building. The focus in the new design should therefore go to a construction method allowing for a very airtight building. The original design scored well there (continuous concrete walls), except for the wall-roof joints (and perhaps the perimeter of the big gates). Given the importance of this issue, the air tightness of the new building should be confirmed with a blower door test. Finally, the currently thick walls (24 cm lightweight concrete, providing thermal and hygric inertia) are not really necessary. Such a large hygric buffer is no longer required, as continuous dehumidification shortcuts the buffering behaviour; unpainted walls are still suggested though since they act as a primary hygric buffer. For the thermal behaviour, the thermal inertia of the soil is already quite large, allowing for less massive walls and roofs. Moreover, the thermal and hygric inertia of the stored objects is quite significant, also contributing to a stable interior climate. If ‘superlight structures’ are the construction method of choice, this relaxation of the need for hygrothermal inertia may be beneficial. Reduction of dehumidification cost: Year-round dehumidification is necessary to maintain acceptable interior humidity levels. The large interior mass of the storage (made up by stored objects and unpainted walls) would thought allow concentrating the dehumidification during a part of the day, while leaving the storage ‘free-running’ during the remainder of the day. The large interior hygric inertia would limit the variation in relative humidity to acceptable levels. This concept could be used to use cheap wind electricity during the night (where an excess of wind electricity is produced), or to couple solar collectors to absorption wheel dehumidifiers. Both measures would drastically reduce the dehumidification’s economic and ecologic costs. Conclusion: The effect of further insulation of the building is limited, except for the floor: no further insulation should be provided there. The main target for the new design should be its air tightness: the more airtight the building, the lower the required dehumidification will be. It is therefore advisable to have the contractor make a blower door test after completion of the building, to confirm the desired targets. Apart from that, concentrated dehumidification would allow making use of cheap wind electricity during the night or solar collectors during the day.

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