

Building Environment Simulation Project

This 22-month collaborative research project carried out by the UCL Centre for Sustainable Heritage (CSH) and The National Archives (TNA), delivered a computer simulation model of three of the storage repositories at The National Archives, Kew, modelling the energy load and environmental conditions (temperature and relative humidity). The model was used to examine options for maintaining an appropriate preservation environment while reducing building energy loads, in line with TNA's sustainability targets, capital investment strategy and climate change projections.

The building simulation model was developed using open source EnergyPlus software under the combined Heat and Moisture Transfer (HAMT) model algorithm to enable accurate simulation of the hygrothermal behaviour inside the archive building. The model was developed to a desired accuracy level, against which various scenarios were tested in response to:

- changes in external environmental conditions;
- changes in the structure of the building;
- changes in the operation of the HVAC system;
- changes in the quantity (mass) of the content in the repositories; and
- other changes related to occupancy and use of the building.

The model was constructed based on the actual physical dimensions, the material characteristics and the mechanical air conditioning temperature and relative humidity (RH) settings found in the repository. The performance of the model in predicting the repository environment was calibrated to the actual monitored temperature and RH data. The model was designed to produce a range of output variables which included monthly heating and cooling energy loads and hourly predictions in indoor temperature and RH. A satisfactory performance was obtained that can predict the actual temperature and the RH with 2.5% accuracy.

The development of the building environment simulation model was a multi-step iterative process involving model construction and model calibration. At the construction stage, a proof of concept model was developed based on information about the building characteristics: its physical dimensions, material properties, internal loads and air conditioning schedules. At the calibration stage, the final prototype model was developed through a series of calibration exercises involving the adjustment of model performance by comparison with the actual temperature and RH of the archive, until a satisfactory agreement was achieved.

All references to "energy load" are to the energy load normalized per floor area (kWh/m²), which quantifies the total convective and conductive heat loss or gain across the building fabric by taking into account the temperature gradient across the building fabric and the time for which the temperature gradient is maintained. "Energy load" therefore does not include energy required for lighting, equipment and hot water. The energy load is distinguishable from energy consumption in that the latter refers to the amount of energy consumed by the HVAC system in order to deliver the required energy load.

A total of 16 environmental management scenarios were tested, and the important findings are summarized as follows:

1. The average annual energy load of each repository floor under the present environmental management scenario is 33kWh/m²/year; the demand for the cooling load constitutes about 70% of this total load, and the rest is taken up by the heating load.
2. Powering down the HVAC operation over the weekend can achieve a 14% energy load saving if it is turned off until Monday, to a 22% saving if it is turned off until Tuesday (taking advantage of the closure of TNA to the public on Mondays), without affecting the quality of the preservation environment.
3. On the other hand, scenarios designed to increase the energy load saving through longer powering-down strategies did not achieve the desired effect in terms of net energy saving, due to increased demand in the cooling load from increased indoor temperature.
4. By seasonally adjusting the HVAC set point temperature and RH, a 43% energy load saving can be achieved compared to the current environmental management strategy while improving the quality of the preservation environment.
5. Increasing the roof insulation will result in no net change in the energy load because the saving gained in the heating load during the heating season is offset by an increase in the cooling load during the mild season due to heat becoming trapped inside the building.
6. Increasing the archive content is found to have small effect on the RH performance indicating that the capacity of hygroscopic material to moderate the RH in a mechanically controlled storage environment is marginal.
7. The projected climate in the years 2050 and 2080 (UKCP09) under the worst case scenario will result in a 15% and 24% increase in the building operation energy load respectively, mainly from increased cooling load, if the current environmental management strategy is maintained.
8. A stable preservation environment with reasonable thermal comfort conditions can be maintained in the repository space in the months of April, May and December with the HVAC system turned off, while supplying outdoor air at a rate of 1 m³/sec.

Related references

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