The first Passivhaus Archive in the UK

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1 Introduction

Architects Architype worked with Elemental Solutions to design an Archive repository for Herefordshire Council. The attached offices and public records building follows the now familiar Passivhaus approach and will not be covered here. The archive repository building was considered from first principles and draws heavily on the passive approach championed by Tim Padfield's group in Denmark. The repository has a Treated Floor Area by Passivhaus Institut methodology (TFA) of 1130m^2 located on 3 floors. The form factor (heat loss area divided by TFA) is 1.5. Passivhaus was priced against the BREEAM environmental standard and was found to be about 5% cheaper to build. The whole project has been written up in detail elsewhere [de Selincourt].

Figure 1: Hereford Archive and Repository, West elevation.

2 General design strategy

A number of the archive buildings that we visited placed the storage rooms above a ground level office space. The need for a structural connection does however make it difficult to create thermal separation between the office and repository spaces which will be at different temperatures all year. By placing the repository behind the office building it was possible to provide excellent thermal separation using a fully filled cavity wall with no structural penetrations. This layout fitted the site well and allows for possible expansion in the future by adding a bay to the North.

The repository construction is load bearing concrete block with precast plank floors. Larsen trusses support a cedar shingle rain-screen with 300mm of cellulose insulation. The party wall has 300mm of mineral wool. The first blower door test with the doors to the service core temporarily sealed indicated <0.04ach @ 100Pa but the (domestic) fan was too large to complete the test. The final test included the significant leakage around the doors (into the adjacent office spaces) and achieved 0.4 ach at 50Pa.

A cooled and dehumidified storage room for photographs is located on the middle floor (figure 2). This room has a vapour control layer on the walls, floor and ceiling under a continuous layer of internal insulation with a U value of 0.19W/m^2.K to isolate it from the other storerooms. The photo-store is close conditioned to 12°C and 30% RH whilst the adjacent general storage rooms are allowed to vary between 13 and 20°C.

Figure 2: First floor plan of repository and offices. Drawing courtesy Architype.

3 Energy strategy

The authors had visited the Passivhaus Archive in Dresden in 2010 but decided to pursue a simpler passive strategy inspired by the work of Tim Padfield and his colleagues in Denmark. During the design process the brief changed to accommodate the new guide for the storage of archival documents, PD5454 2012 [BSI]. This standard allows for a slow seasonal drift in temperature and RH with the intention of avoiding the need for air conditioning.

PHPP (Passivhaus Planning Package 2007) was used to model the building as two zones with the following boundary conditions for the repository:

TFA	1130m^2
Temperature range	13-20°C
Relative Humidity	35-60%
Internal heat gains (net)	0.4W/m^2
Airtightness	0.4h^{-1} @ 50Pa see text.
Vent rate	c.a. 250m^3/h (may be reduced in future)
Heat recovery	none, supply air ventilation only
Target cooling load	no cooling of general repository stores.
Calculated heat load	4 W/m^2
Calculated heat demand	c.a. 5 kWh/(m^2.a) very sensitive to occupancy assumptions.

The PHPP suggested that the general archive storage rooms should achieve the required environmental conditions with minimal heating and no cooling. The decision was made to only use supply air with no heat recovery. This was to avoid infiltration of unconditioned external air by achieving a slight pressurization of the repository. The secure fire doors that allow access from the service corridors have imperfect seals and provide an exit path for the ventilation air into the rest of the building.

The archived materials provide a considerable moisture buffer but our simple monthly mass balance calculations indicated that air in the repository could possibly exceed the 60% maximum RH target in summer. In addition the masonry building will take many years to fully dry. The solution, following the lead of Padfield, was to provide the option to dehumidify the small volume of fresh air supplied to the repository.

A small photo store with lower temperature requirements is insulated from the adjacent general store room and employs active cooling and adsorption dehumidification.

Heating

Although, in such an airtight building, RH can be controlled by conditioning the supply air, the flow rate is far too low to deliver useful heating or cooling. For archives there is a presumption against wet heating systems within the stores because of the risk of leaks. As the heat requirement (if any) is expected to be so low, consideration was given to electric heating or even the use of the lighting as a heat source (e.g. overriding the movement sensors when the temperature drops below the set point). However, archive guidance requires the power to the store rooms to be shut off when unoccupied to reduce fire risk so these options were rejected.

The system installed uses a recirculating fan coil heater for each of the three stores connected to the main gas boiler heating system. Given the very low heat load of under 5kW for the three floors we might in future propose radiators within the service core where the fan coil units are installed. Alternatively intrinsically safe, low temperature electric panel heaters or electric fan heaters could be used.

4 Results

Whilst confident that the RH would be within limits once the building had dried out, we had some concern that the slow release of residual moisture would lead to elevated RH within the repository space. Portable dehumidifiers were used to dry the building before handover but after initial rapid drying, moisture transfer from the core of the concrete was very slow and the dehumidifiers removed very little water. Whilst construction activity on site precluded a properly controlled experiment, we monitored changes in room air RH as well as the RH in pockets drilled into the walls and floor slab as indicators of fabric moisture content. Once the building was handed over we monitored the RH and temperature in the repository and were happy to find that supplying air at around 50% RH, 12°C and 2 air changes per day was sufficient to stabilise the RH as the building continues to dry out.

The control strategy for the supply air will be revisited after a year of operation. It is expected that once the building is sufficiently dry, supply air dehumidification will only be required during the summer when the external air absolute humidity is too high. This could have been achieved using a cooling coil rather than the desiccant dehumidifier which adds heat.

In time we expect the RH to decrease in winter but the low ventilation rate means that any changes are heavily buffered by the large mass of paper and fabric material in the stores.

Childhood illnesses

The graph in figure 3 shows the RH and temperature of the middle floor store room for the last 8 months. From point A to C on the graph the temperature rose from 13.5°C to 17.5°C in 2 months. Initially we suspected the temperature rise to be due to lighting as staff were working in the store rooms. On inspection we discovered that the heating circuit was allowing a backflow through the heating pipes in the repository service core even though no heat was required. At some point between B and C on the graph, a Building Management System (BMS) fault caused the heating to come on in the repository. We also spotted that the desiccant dehumidifier for the photo store had been installed backwards. This meant that it was operating very inefficiently leading to additional heat gains in the repository building.

From B to D on the graph we can see the impact of moving the collection into the building. Over this period the lighting was on during the day and staff moved in and out of the stores leading to fluctuation in temperature and RH. The move was complete by the 17th July 2015 from which point conditions can be seen to stabilise.

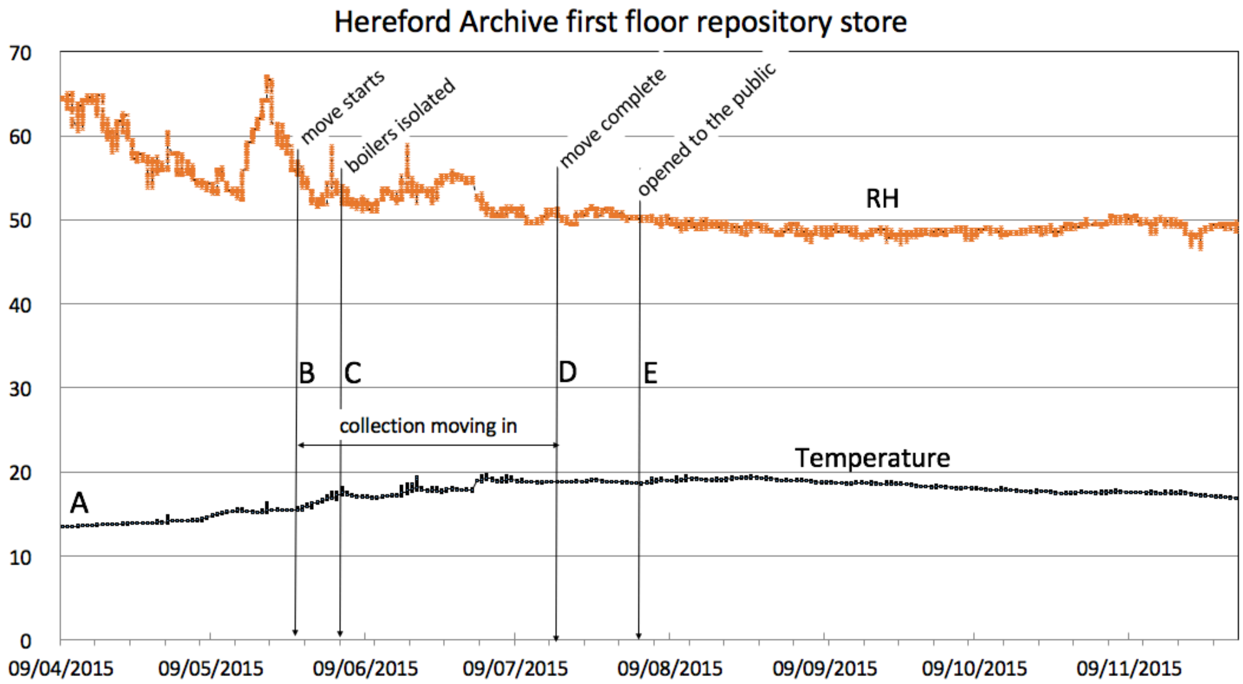

Figure 3: Graph of temperature & RH for first (middle) floor store.

Whilst the monthly temperature and humidity logs are reassuringly boring, we are very interested to see how conditions change over a number of years.

Stratification

During the design process concern was raised that conditions would vary throughout each storeroom unless continuous air circulation was employed. This would of course add heat from the fans and lead to the need for cooling. Thanks to very low heat transfer through external walls, conditions are very constant within each store and between floors. The one off readings below were taken when checking the accuracy of the room sensors but are confirmed by ongoing monitoring. The authors argued against the need for mixing but were surprised just how even temperatures are. This also suggests that if heat is required, this could be supplied to the corridors rather than into the actual secure store rooms.

Ground floor	17.00°C	50% RH
First floor	17.86°C	46% RH
Top floor	17.87°C	49% RH

One concern we had was that the very low air change rate of around 1-2 air changes per day might mean that the stores, being full of old documents, would smell fusty like a second hand bookshop. This has not been the case.

5 Lessons learnt

It is clear from initial monitoring that the combination of Passivhaus details and quality assurance combined with low level supply air ventilation is enough to ensure very stable environmental conditions beyond the requirements of PD 5454 in the UK climate. This stability means that adding fast response automatic control systems is counter productive and undermine the inherent stability of the passive approach.

As an example, following a sensor fault, the BMS reported a low temperature in one of the stores and automatically switched the heating on. This resulted in a small but unwanted rise in temperature (B to C on graph). To prevent a recurrence, the heating system was then isolated. Having seen the very slow cooling of the building without heat input, the archive management agreed that manual control of the heating would be more reliable but this needed to be experienced to be believed.

Based on the experience of this building the authors would strongly recommend a very simple control system combined with a simple low power heating system. Similarly, limiting humidity conditioning to the supply air rather than recirculated air cannot result in rapid changes in conditions when the system fails in any way.

6 Summary

Overall the performance has exceeded our expectations and the repositories have remained well within the required range of temperature and RH. This is in spite of the intense activity during the move and a number of teething problems with the building services and BMS. The operation of the building will be closely observed over the coming years. We hope that the performance will inspire confidence in even simpler approaches and further questioning of rigid standards, as advocated by Tim Padfield [Padfield].

7 Acknowledgements

Architect: Architype Ltd, Contractor: Kier Construction, Passivhaus Consultants Alan Clarke & Nick Grant, M&E: E3 Consulting Engineers, Structural Engineers: Eastwood & Partners, Passivhaus Certifier: WARM Low Energy Building Practice, Client: Herefordshire Council.

8 References

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