Developing Sustainable Storage for Big Stuff

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ABSTRACT

The Science Museum has more than 95% of its large objects, from the science, technology, industry, communications, transport, space and medicine collections, in storage. Not all are robust, of single material construction; many are susceptible to environmental changes or are fragile; many are composed of materials which have different preservation requirements

Large objects are stored on a repurposed airfield near Swindon, Wiltshire, in seven 1930's hangars and one 1990's purpose-built store (the A-store), spread across the 545 acre site. A site based team, part of the Science Museum's Conservation & Collections Care section, is responsible for their preservation, treatment, movement and storage.

Environmental conditions on site vary with the hangars at Wroughton, uninsulated and unheated, having excessively high relative humidities for much of the year but the purpose-built store maintaining reasonably stable conditions through low-level heating. Performance indicators developed by the museum are used to assess storage conditions as good, adequate, poor or unacceptable. These are based on the **10 Agents of Deterioration** (Robert Waller 1994), and updated environmental standards using seasonal drift parameters for each type of material found in the collections.

Storage areas are graded for the types of collections they house. Goals are set for each area based on materials and types of object; thus, a storage area which houses fragile and reactive objects is expected to perform at 100% in order to achieve best practice (Science Museum Grade 4) while another which holds robust agricultural equipment and buses needs to achieve only 50% overall (Grade 2). Rehousing large objects based on this system enables many of the more fragile or susceptible objects to be stored in more suitable conditions but also reduces reliance on air conditioning and mechanical systems. Resources can be directed at targeted areas, saving money without reducing standards of care.

However, upgrading and developing new storage spaces on site has become essential as, in 2009, it was decided to move the reserve collections of the National Railway Museum at York and National Media Museum at Bradford to the Wroughton site in order to reduce the Science Museum Group's operating and storage costs. Suitable storage space was also needed for eighty or so large wooden ship models and other objects coming off a Science Museum gallery and twenty-five horse-drawn carriages temporarily housed in an area now destined for conservation work space.

Two projects have been completed to date; a refurbishment of a C-type (MoD steel-framed and concrete) hangar and a new build inside a D-type (concrete) hangar.
The refurbishment is a conventional treatment, the new build is an innovative use of traditional building materials. The building treatments will be discussed and compared, based on a year's worth of data collected by September 2013. Our conclusions and future plans for the Wroughton site and for the storage of the large object collections will be presented at the conference.

The Science Museum is part of a group of five museums in the UK devoted to the history and contemporary practice of science, medicine, technology, industry and media. Science Museum Group incorporates the Science Museum and the Wellcome collections of the history of medicine at South Kensington; the Science Museum Library and Archives at South Kensington and Wroughton, the National Railway Museum (NRM) at York; the National Media Museum (NMeM) at Bradford; Locomotion: the National Railway Museum at Shildon; Concorde 002 with its associated exhibition at Yeovilton; and the Museum of Science and Industry (MOSI) in Manchester. Although efforts are made to exhibit as many of the collections either at the SMG museums or through loan to other institutions, over 95% of the large objects are held in storage.

While MOSI presently retains its own off-site store and Shildon provides open storage for locomotives and other rolling stock, large object storage for the rest of the goup is now at Wroughton near Swindon in Wiltshire, on a former military airfield purchased from the Ministry of Defence in 1979 for use as a collections store for the Science Museum. The repurposed airfield, an hour west of London, has ten 1930s hangars[1] (and one purpose-built store, built between 1993-4, spread across the 545-acre site.

FIRST STORAGE PROJECT – HANGAR C1

The decision to store collections from the other Science Museum Group museums at Wroughton started in 2008 as a way to resolve NRM's long term storage issues at York. Then in 2009-10, with a major internal financial review aimed at reducing running costs , the estate held and used by the group was assessed to see where specific savings could be made. This developed into a wider collections storage rationalisation project in which collections preservation was flagged as being as important as financial savings.

The objectives and needs of the rationalisation project were established:

- To review the number of separate stores used within the organisation with a view to reducing overheads;
- To improve storage conditions for some objects: reducing the deterioration rate of those items currently stored in inadequate environmental conditions;
- To rationalise the collection;
- To allow for new acquisitions;
- To facilitate improved access for collections teams, particularly with regard to selecting objects for future galleries;
- To Improve public access through documentation;
- To explore new ways of documenting;
- To open up new loan opportunities;
- To explore possible commercial opportunities;
- To align with other financial review projects.

The collections storage rationalisation project identified that the reserve stores of both York and Bradford were expensive to run and required significant investment to bring them up to museum standards for holding collections. In Bradford, space was leased in a shared occupancy building, on a site difficult for staff to access, with security and operational issues and environmental conditions unsuitable for some of the materials. At York, the storage buildings were in a poor state of repair with environmental conditions contributing to the deterioration of some of the collections. The site was also identified as a potential lease to external tenants so could generate some much needed income. Documentation for many of the objects was poor or non-existent and there was significant duplication within many of the collections.

In April 2010, the transfer of the reserve collections from NMeM and NRM to Wroughton was initiated. One hangar needed to be vacated to provide sufficient space for the objects from

[1] Four parabolic concrete with steel ribs- L-type; four cast concrete with bow-strung roof trusses- D-type; two steel framework with concrete block infill and multi-pitch roof- C-type; Defence Estates, 'World War II Hangars - Guide to Hangar Identification*', Technical Bulletin 02/02***,** Ministry of Defence.

the northern stores. As none of the hangars had received sufficient maintenance in the past 40 years, refurbishment would be required to eliminate problems such as pest and water ingress, hazardous materials, old wiring, poor lighting, blocked or inadequate drainage and structural deterioration such as spalling concrete and corroding ironwork. Limited funding was available for the project as a whole and had to include collections management procedures such as audit and photography, hazard mitigation and packing and transport of collections as well as refurbishment in order to fulfil as many of the project objectives as possible.

Initially senior management preference was to refurbish a D-type hangar which had received some upgrade work in the early 1990s as this seemed the cheapest option. However, this building contains over 60 large objects including three airliners (a Constellation, a DC3 and a Boeing 24D) and it was not logistically possible to relocate the objects elsewhere on site. The hangar least-used for collections storage, due to its poor condition, was therefore chosen This was a C-type hangar - a 38,211 m^3 building with asbestos cladding, leaking wooden roof, cracked and broken windows, asbestos board annexes and corroding full-height metal overhang doors with resident populations of pigeons and jackdaws. Only a very few, very large objects, were stored in this building but so was a lot of other material.

While a working group from the Science Museum, NRM and NMeM was formed to devise and cost an plan to vacate the Bradford and York stores, the objects were moved, the junk thrown out and renovation work was planned. This was based on specifications provided by the working group to produce a building which would securely house approximately 6000 objects from each of the northern museums. Due to funding limitations, it was determined that the building would only be wind and waterproof, with limited vapour barrier and insulation. There would be no heating or cooling system and therefore no relative humidity (RH) or temperature control but it was hoped that fluctuations and excesses of RH and temperature would be moderated to a limited degree by the upgraded building envelope. Neither the chill factor from the concrete floor slab nor potential for condensation would be eliminated. Pest entry would definitely be reduced as the hangar doors would be replaced at one end by a wall, at the other by a roller shutter door.

By the definitions of storage grade defined in the SMG collections management storage procedure where storage areas are ranked by environmental standards required for the types of materials that they house, the renovation would result in a Grade 2 facility, suitable for the storage of robust industrial and transport collections. With no heating system, the RH levels over the winter months could still be higher than 70% but this would be an improvement on at least one of the northern stores, which had a large hole in its roof.

Objects destined for storage in the hangar would have to be of robust materials and in good condition or would have to be protected by surface treatments, packing materials and crating. More environmentally susceptible objects for which this was not a suitable environment, even with mitigation, would be stored elsewhere if possible.

Renovation works undertaken were:

- All asbestos (cladding, boards and insulation) removed and annexes demolished;
- Hangar doors removed; galvanized steel framework and brick footings installed to support conventional composite wall panels with insulated core and limited vapour barrier properties (Kingspan KS1000RW[2]);
- Hangar walls clad externally with Kingspan panels, windows completely covered by panels;
- Foam and butyl rubber sealant gap fillers along edges;
- Gutters relined and drainage upgraded;
- Some roof panels upgraded along gutter edges;
- Interior metal framework and brickwork sandblasted and painted and concrete floor deep cleaned;
- Sodium arc light fittings replaced by high intensity halides**;**
- Fire alarm, intruder alarm and CCTV systems installed.

[2]http://www.kingspanpanels.co.uk/Kingspan/media/PDFs/Data%20sheets/UK_R_KS1000RW-Wall_PDS.pdf

- Vertical rise shutter door installed on north side;
- Fire exits installed in south wall; double access door installed on west side.
- Two-room portable office cabin installed for staff working with collections with heating, toilet, small kitchen and data access points.

The roof was not replaced as it was considered to be in good condition; no insulation was added to the roof. The thermal insulation U-value[3] of the 70 mm thick wall panels was .30.

In order to utilise the space most effectively, fourteen 75 metre long rows of eight metre high conventional long span racking were installed; half to accommodate large (1830 x 1370 mm) wooden pallets and half small (1220 x 1020 mm) pallets. Each row was lettered and each bay numbered to pinpoint object locations in the collections database. A corridor was left around the perimeter of the hangar to provide access for maintenance. A lighting plot prepared prior to racking install ensured that ceiling lights would be accessible as well. A large space was left in front of the racking for object deliveries, unpacking and the office cabin. Access to and movement of the objects is by 2.5 tonne electric reach truck with 9 metre mast and pallet trucks; the reach truck charging station is at the front side of the hangar

More objects than originally estimated by the project team turned out to be too large or heavy for the racking and these objects have had to be stored on the floor, on pallets where possible. A few, such as a turntable, had to be found alternative locations on site.

The renovations were completed to the June 2011 deadline (the object move took over a year longer than originally planned). Leaking from the roof under certain wind directions is an on-going problem and one lesson learnt from this project is that, no matter how good it *seems*, the roof should be replaced; it will be cheaper in the long run.

Initially the temperature and relative humidity were monitored in five different places, from floor level to ceiling using Tinytag data loggers, but the data showed that the environment was the same throughout the hangar. Consequently, only one Hanwell monitor has been connected to the museum's environmental monitoring system. Data indicate that there is some minimal moderation of the RH in comparison to external conditions, but the temperature can be colder inside than out- especially in the winter.

The renovation fulfilled the brief of providing Grade 2 storage; for many of the objects it has provided improved overall storage conditions but not all the objects transferred to C1 should be stored in a space where the relative humidity can be over 75% for more than 50% of the year. More objects than originally planned are stored at floor level which may cause issues with object and racking access. Many of the objects are crated or are covered with poyethylene or Tyvek sheeting to prevent condensation on their surfaces.

SECOND STORAGE PROJECT – HEMCRETE MUSEUM STORE (HMS) IN HANGAR D2

The second storage project was initiated about the same time as financial aid was offered from the Department of Transport to the NRM for storing the Rail Industry National Archive (RINA). Due to an exhibit development project, three distinct collections of the Science Museum also required conditioned storage, these being the large ship models, the fine art collection and the horse-drawn carriages. The project scope was enlarged and a project team formed with Science Museum Estates and Conservation and National Railway Museum Archives staff.

It was decided to build the store inside a D-type hangar next to the reserve store for the Science Museum Library and Archive. This had been built inside half of the hangar some years previously using conventional building techniques and a heating and air-conditioning system. There were two reasons for this decision; building a building within a building would

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[3] U -Thermal transmittance W/m²K where W = watt, m^2 = metre squared, k = degree
U-value or U-factor measures the rate of heat transfer: R-value measures thermal resistance (thickness of the material divided by thermal conductivity). R-value is reciprocal of U-factor.

assist in providing an improved level of environmental control and no planning permission was required.

Motivated by the Science Museum's Group's commitment to sustainability and with ideas gleaned from participating in a workshop on low-energy control in museums and archives[4], a seminar on hemp-lime construction [5], and an inspiring beer warehouse[6], some of the project team championed pre-cast hemp-lime panels as a building material in order to create a passively controlled store. As described by the manufacturer[7] the panels provide a combination of thermal inertia and insulation which prevents fluctuations in temperature to create a stable environment which can greatly reduce energy usage.

Ranges of 15-18C and 45-55%RH had been specified by the archivist based on the guidelines of the British Standards Institute (BSI) BS5454:2000 as advocated by the UK Code of Practice on Archives[8]. Lime Technology Ltd. along with Emission Zero Engineering Architecture [9], using IES (Integrated Environmental Solutions) software, were contracted to model a storage facility using the environmental data from the hangar interior and Hemcrete® panels[10]. The modelled results initially were encouraging but indicated that an extensive mechanical and engineering system would be required to maintain the tight environmental specifications. Additional modelling was carried out after it was found that the software did not accurately simulate the behaviour of the panels and this resulted in a three-fold reduction in the design of the heating and ventilation system.

As a modular building design was preferred for better thermal performance and better climate control, Lime Technology and Stora Enso Building Solutions[11] designed a three storey, six room building which would be built right to the rafters of the hangar. Criteria for environment, floor-loading, storage furniture, object type, accessibility and space-usage provided by the museum's collections care and archive staff informed the design for 980 m^2 of space. Ceiling height was dictated by the needs of the collection and the rafters of the hangar. As the ground level height had to accommodate the tallest of the carriages, the other two levels ended up with slightly lower than average ceilings.

Pre-cast panels of Hemcrete® were used to clad a steel frame with cross laminated timber floor cassettes. Hemcrete® panels, prefabricated and force-dried, are available in a variety of sizes dependent on use. Timber- framed, they can be pre-fitted with services; and slotted into timber or steel structural frames. The hemp in a lime matrix provides extremely efficient hygric buffering with a thermal transmittance range of U-values from 0.11 to 0.19 W/m^2K. Hemp - lime has a high pH which give it insecticidal and fungicidal properties. The panels meet current British Standard fire resistance tests.

The cross-laminated timbers of fully sustainable and certified spruce were prefabricated and were used for both the floors and the roof. Due to the confined space caused by the hangar rafters, the roof panels had to be slid into place. CLT are formed by kiln-dried softwood panels bonded together perpendicularly, with high structural strength, excellent dimensional stability, and are vapour permeable

The building was covered externally with wood fibreboard and wire mesh (as rodent protection), and finished internally using a permeable unpainted magnesium-silicate board.

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[4] Copenhagen 2009, led by Poul Klenz Larsen and Morten Ryhl-Svendsen, National Museum of Denmark; Tim Padfield, consultant in museum climate control

[5] Gov Today presentation at the Barbican Hemp-Lime Construction Dr Mike Lawrence of the Building Research Establishment Centre for Innovative Construction Materials at the Department of Architecture and Civil Engineering in the University of Bath

[6] Adnam's Distribution Centre, built 2009, Lime Technology Ltd.

[7] Lime Technology Limited, Abingdon, Oxfordshire OX14 4S; http://www.limetechnology.co.uk/

[8] Although BSI 5454 was withdrawn during 2011, the revised wider ranges and emphasis on seasonal drift in PD 5454:2012 did not alter the specifications set out for the building.

[9] Emission Zero Engineering Architecture, Birmingham,http://www.emission-zero.com/

[10] Tradical® Hemcrete® (a low embodied energy material comprised of Lime and Hemp shiv ModCell®, The Proving House, 21 Sevier Street, Bristol, BS2 9LB, UK http://www.modcell.com/.

[11] http://www.storaenso.com/timber

Roller shutter doors as well as access doors were installed for each object storage room; each archive storage room has its own access door; each room has a fire exit at the rear as well. Stair access to all levels and the roof was installed at the front and back at the archive end and an object-only lift installed at the front right corner. Balconies run across the face of the building with reach truck access through gates in the safety railings.

Construction of the building was within the 16 week timeframe allotted by the project despite the discovery that the hangar concrete slab was surprisingly shallow and insufficiently load-bearing. The slab was strengthened with a mass of concrete pads which also allowed the floor to be insulated.

Based on the updated modelling, a small air-handling system circulating cool dry night-time or warm daytime air, depending on the humidity requirements within the structure, was installed. It was specified to use the moisture content of external air to either reduce or increase the internal relative humidity through air circulation. This in addition to the passive regulation of the building fabric was to provide very energy-efficient management of the ambient environment.

Initial issues with the install included difficulty in obtaining internet connection for remote control, technical problems with sensor boards and missing or defective sensors. When monitors for the museum's Hanwell environmental monitoring system were installed they revealed serious issues with both the software running the air handling unit (AHU) and the mechanics of the unit itself. Instead of pulling in cool dry air at night to reduce the RH levels, it was bringing in warm moist daytime air- a complete reversal of the design specification. In addition, there was unanticipated moisture from both the drying concrete mass and Hemcrete® panels. The Hanwell monitors were showing RH levels in excess of 80%. Large portable dehumidifiers were put in and the AHU switched off. Although the RH levels were brought down to acceptable levels by this method, for several more months there were problems with the AHU until the software programme was rewritten and all the dampers replaced. In May of 2013, the AHU was turned off to see if the building could passively control the internal environment and, despite the unseasonal (for Britain) warm summer, there has been no need to turn the units back on yet.

While there have been glitches with the mechanical and engineering functions of the store, the building itself, now dried out, is functioning as anticipated. It operates at less than a third of the running costs and emissions of a conventional environmentally-controlled museum store. It has taken much longer than specified for the building to have stabilised but the overall success has mitigated the time over-run and no objects were harmed in the process. The Hemcrete® Museum Store has won three major awards for innovation and sustainability both in the museum and the building industry sectors[12].

While HMS is not a store for really Big Stuff, we hope the building becomes an exemplar for future new builds on site. By taking advantage of the ability of natural materials such as hemp and lime to buffer and insulate, we will provide suitable and sustainable environmentally controlled storage for most of our objects, large and small, A research park to study low carbon, low impact construction materials is being built at Wroughton by the University of Bath's BRE Centre for Innovative Construction Materials[13] and the author has recently embarked on a part-time PhD to study how these materials can assist museums to maintain current standards for storage and display environments. As it looks very likely that the remaining stores for the Science Museum Group will be relocating to Wroughton in the (quite) near future, we may be building sooner than we think.

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[12] 2013 Greenbuild Awards, Best Workplace New Build; Museums and Heritage Awards 2013, Sustainability; Chartered Institute of Building (CIOB) South West Built Environment Awards 2013, Innovation.

[13] Building Research Establishment (BRE) Centre for Innovative Construction Materials (BRE CICM), Department of Architecture and Civil Engineering, University of Bath http://www.bath.ac.uk/ace/research/cicm

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