New meets old – the requirements and limits of new collection facilities at the Museum für Naturkunde Berlin

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Abstract

In commemoration of its bicentennial anniversary in 2010, the Museum für Naturkunde (Museum of Natural History) in Berlin, the largest of its kind in Germany, reopened a wing that was bombed and ruined at the end of World War II. This was the first in a planned series of works to adapt the museum's infrastructure to modern standards of collections care and energy efficiency. In the first phase, the ruined east wing of the museum was rebuilt as a high-security storage space. It was designed to meet safety requirements for storing the flammable fluid-preserved collection of zoological specimens in the context of a listed building and with the aim of optimal use of available space. This new facility now safely houses one million specimens preserved in 276,000 glass jars containing 80 tons of ethanol.

The second phase of the construction programme is now in the advanced planning stage. In the first phase temperature control was implemented predominantly for safety reasons, however, in the next stage the environmental conditions are designed to i.) meet the requirements of the 'dry' collections which are to be re-housed in a dedicated collection hall, ii.) minimise energy consumption by using the building's inertia and geothermal heating and cooling and iii.) optimise air exchange for both public and collection areas.

This article aims to describe the new wet collection building. It presents how the various demands of building, safety and collections care were balanced and optimised, guided by the principle of 'new meets old'. The paper also outlines the different approaches considered to adapt a historic museum building with a façade listed under monument protection to modern standards of collections care and energy efficiency.

Introduction

The Museum für Naturkunde in Berlin (MfN) holds a huge collection of about 30 million natural history objects, including minerals, fossils and zoological objects. The collection is preserved and stored in different ways according to the nature of the material. The majority are dry and wet (fluid) collections, though they exhibit a wide range of physical properties, logistical and conservation demands.

The collections of the MfN are much older than the current building, which was completed in 1889. The early core parts of the collections date back to several natural history cabinets of the late eighteenth century. They were combined as a research museum of the newly founded Berlin University in 1810. The available space in

the University's main building was outgrown within a few decades and a new location was chosen on the site of the former royal iron foundry at Invalidenstrasse. There, the older part of the present building, designed by August Tiede (1834–1911), was opened in 1889 after several drafts had been dismissed. The opening followed a long-running controversy over the building concept between the then director W.C.H. Peters (1815–1883) and the architect. Interestingly, Tiede had proposed the more modern concept of a store-like construction in 1875 [1, 2]. However, the director's concept for the new structure prevailed, a traditional museum entirely open to the public (Figure 1). Due to a quirk of history, the Museum für Naturkunde in Berlin was never completely open to the public as Peters' successor, Karl August Möbius (1825–1908), changed the concept again. The generous staircases were never used (Figure 2) and the upper floors remained closed to the public and have been used as scientific collection areas ever since.
Until a few years ago, only the ground floor was accessible to the public, which housed a didactic exhibition designed for a general audience. This concept of separating exhibition from collection space, just emerging at that time, is still considered appropriate for the accommodation of the ever growing research collections of a large natural history museum [3 to 7].

As could have been predicted, the building soon became too small. The halls of the upper floors with their ornamented elevated ceilings were locked behind the scenes and the unused space above the collection cabinets contributed to the shortage of space (Figure 3). The design of the halls had originally been intended to provide well aerated and naturally illuminated exhibition space

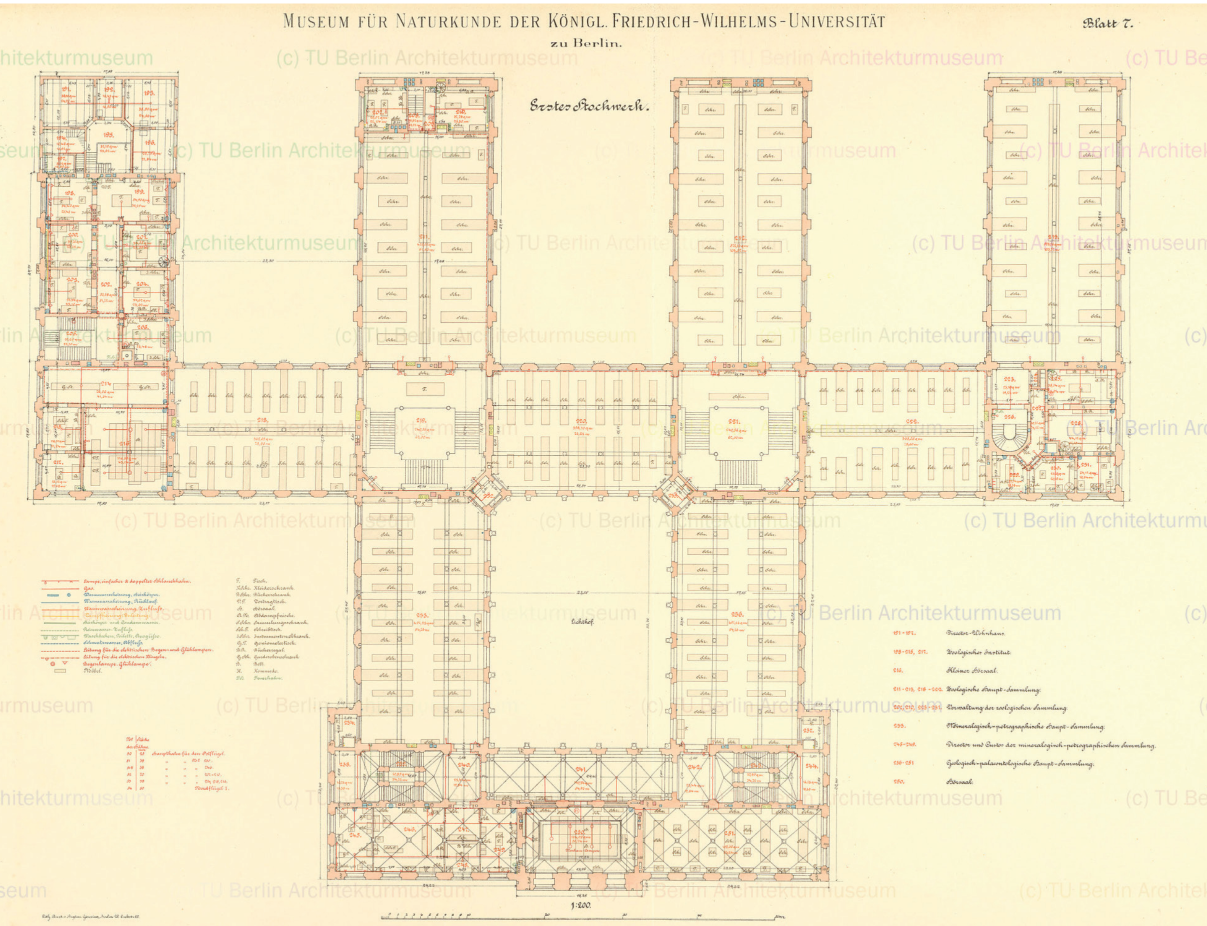


Figure 1. Original plan of the Museum für Naturkunde 1:200, first floor and layout
chart of furniture

Figure 2. Staircase 'Treppe 6' before renovation

for scores of citizens eager to increase their knowledge. Large windows were the solution for providing ample lighting in the absence of suitable artificial illumination; in Berlin electrical lighting only became available from 1884 onwards, with the foundation of the Städtische Electricitätswerke. One of our collection halls had no electric lights until 2012.

To address the shortage of space, the northern wing was added in 1917. This part of the building maintained the separation of collection and exhibition space by including two additional floors within the same height profile as the original building, meeting the demands of that time for a collection store. This northern addition provided office space and now also houses laboratories (compare figures 1 and 6). The only drawback with this addition was that the floors did not correspond to those of the original part of the museum building, not even on the exhibition level. This logistical problem presented a serious obstruction for disabled access and was not resolved until 2010 with the opening of the new eastern wing. The new wing now has a large freight and passenger elevator at the intersection of the two parts of the building, allowing all levels to be accessed.

As well as the collection space, Wilhelm Peters' 'all on show concept' has left us with the impressive imperial architecture of five- to six-metre high collections halls, an impressive façade (around half of which consists of windows), and two grand internal staircases. Despite being closed off, the public have always been inclined to rush upstairs to see our fascinating research infrastructure and the endless rows of objects representing the natural diversity of the planet, past and present.

Technically, a major part of the building no longer fulfils the requirements of a modern facility for natural history collections. At the same time, however, the building provides insight for the public into the research collections in a very natural and elegant way. This concept of authentically presenting the scientific basis and methods of our work has become a guideline for rebuilding the museum. The rebuilding programme has been divided into several phases so the museum can remain functional during the long-term reconstruction, and due to limited funding. Future plans will need to include a new collection storage area for the building, which can meet strict conservation guidelines.

Reconstruction of the eastern wing

In the years after completion of the northern addition, the collection halls became filled with new material. Luckily, war-time losses to the collection were comparatively minor, but the eastern wing of the original museum building was destroyed by a direct hit in an air raid in 1945 (Figure 5). Numerous plans to rebuild it failed due to shortage of money. Only the combined forces of the State of Berlin and the Federal Republic of Germany made possible the reconstruction of the ruin in time for the 200th anniversary of the museum. This reconstruction added urgently needed space: an effective usable area of around 5400 m2 was achieved. In the planning phase it soon turned into a simple clear-cut approach dictated by the conservation and fire security requirements of the alcohol-preserved material, enforced by laws and regulations [8].

A directive from the nineteenth century specified that wet specimens should be separated from dry collections, with which they had previously been mixed [1]. However, this directive has rarely been fully implemented in any natural history museum due to lack of space, unfavourable logistics and a concern to store specimens according to biological classifications. The Museum für Naturkunde was no exception and it incorporated fully integrated wet and dry collections. The separation of these two types of collections was only implemented when the new eastern wing was constructed.

As the core of the eastern wing had been almost completely destroyed (Figure 5), a modern building could be constructed behind the extant original façade without any detriment to the historic architecture [9]. With up-to-date technical systems for environmental control, a moderately low constant temperature of 18 °C can now be maintained in the more frequently accessed upper research collections behind the scenes (Figure 4b). In the lower area (Figure 4a) of the lower gallery, which is open to the public, a transparent barrier and a temperature of 15 °C meet

Figure 3. Collection hall on the second floor, the former Fish Hall, now empty and ready for restoration in the second phase of reconstruction

Figure 4. Wet collections in the reconstructed eastern wing: left ground-floor storage area with public gallery, right collection room on the upper level of the first floor. The 5 to 6 m high shelf system is horizontally divided by a lightweight grid-level, reminiscent of Thiede's first (1875) draft, with a rather industrial character

safety requirements (the inflammation point of 70 % ethanol is 18 °C) as well as avoiding temperature shocks when handling the material. Further details of conservation and safety specifications include an air exchange rate of 2.0 per hour and a nitrogen-based gas fire extinguishing system. In the original building the temperature extremes fluctuated between 13 °C in winter and 30 °C during hot summer periods, which led to a high evaporation rate of alcohol. Refilling glass jars was an important part of the every-day routine of collection management personnel. The adjacent northern part of the building with its more densely packed small rooms now provides air-conditioned collection space for dry collections of very high value with demanding conservation requirements. It also houses staff offices and laboratories for handling the collections. A conservation project supported by the Kulturstiftungen des Bundes und der Länder was also involved in creating this specialised storage space for the alcohol-preserved specimens by looking at improved collection management systems for wet collections [10]. This project mainly focused on replacing leaky glass jars, restoring and tightening of historical glass containers and the conservation of labels to ensure original information was retained securely.

The current project

With the reconstruction of the eastern wing, only a quarter of the functional area of the main building of the MfN has been renovated. Despite state of the art technology and insulation in the eastern wing, and despite renewal of numerous windows, energy consumption for running the estate is still high compared to former times, when the whole building was ventilated passively by convection through vertical chimneys (as in a termite mound) and heat loss through the leaky windows was mainly compensated by reducing the room temperature in winter.

The adverse interior environmental conditions in the halls housing various dry zoological collections, such as stuffed specimens, insects, bone, horn and skins, often require labour-

Figure 5. The ruined eastern wing in 2006. First preparations for the reconstruction

intensive temporary interventive conservation measures. Even paleontological material is not generally inert. Pyritic (fool's gold, FeS_2) and other components at high risk of weathering deteriorate under adverse environmental conditions. Environmental conditions and energy consumption are therefore the focus of the next stage of the reconstruction programme which is currently in an advanced planning phase (for a 6619 m^2 functional area). It is designed to:

1. Meet the environmental conservation requirements of the dry collections that will eventually be housed in the collection hall
2. Minimise energy consumption by using the building's inertia and geothermal heating and cooling
3. Optimise the storage volume, merge collections distributed over several areas of the building, make best use of the existing structure of the building for collections and provide nearby laboratory and office space for handling and research
4. Provide more space, improved infrastructure and more contact for the public with the research environment, to respond to increased public interest and growing visitor numbers
5. Optimise air exchange for both public and collection spaces.

Besides these criteria, there are a number of secondary requirements for the construction project. These include making some provision for the c. 600 guest scientists who visit the collections every year, the high intensity of scientific use of the specimens, the necessity for large-scale conservation programmes to safeguard particularly vulnerable areas of the collection, such as the large number of furs, stuffed specimens and skeletons, as well as the limited numbers of personnel in collection management.
In 2008, several collection halls were equipped with mobile climate sensors and data loggers to obtain planning data. The monitoring focused particularly on collection halls that were to be re-developed in the second phase of rebuilding the museum: the Fish Hall, formerly housing the wet collection of fish on the second floor; the Mammal Skin Hall, underneath the Fish Hall on the first floor; and the Bird Hall, located on the first floor further west in the building (Figure 2). These halls are oriented north/

south and provide 570 m2 area and 2840 m3 gross room volume, 566 m2 area and 3400 m3 gross room volume, and 470 m2 area and 2820 m3 gross room volume, respectively. The Bird Hall was recently equipped with double box-type windows incorporating new insulation glass (heat transfer coefficient of Ug = 1.1 W/(m^{2}K)) that also excludes 90 % of ultraviolet radiation. Of course, the resulting energy transmission (Uw-value) will also depend upon the quality of the frame restoration and the insulation of the window soffit. This upgrade enabled an experimental assessment of the impact of the new windows on the room climate before any other measures were introduced (Figure 7).

Previous incidental environmental monitoring work has indicated that the generally dry climate of the collection halls is not detrimental for dried organic matter like mammal skins or mounts and stuffed birds. Optimum conservation conditions are achieved in a cool and dry environment with relative humidity (RH) between 30 and 55 % [11 to 13]. The literature indicates that the optimum for tooth-bearing vertebrate skulls and mounted specimens (dermoplastic preparations) is at the upper end of this range, and our experience suggests that skins, chitin, horn material and uncleaned skeletons is at the lower extreme.

In terms of the MfN environment, particular causes for concern were the high summer temperature extremes measured (Figure 7) and the rapid changes of room temperature and relative humidity which followed external weather conditions. Both are disastrous for long-term conservation. The daily rhythm of temperature and relative humidity as seen in figure 7 leads to continuous stress on the material due to expansion and contraction driven by changes in moisture. These processes are particularly detrimental to specimens that consist of horn, bone or dentine, or collagen fibril networks [14]. In particular, mammal skins are endangered by increased air moisture content as residual acid from incomplete tanning processes may be mobilised [15]. As illustrated by figure

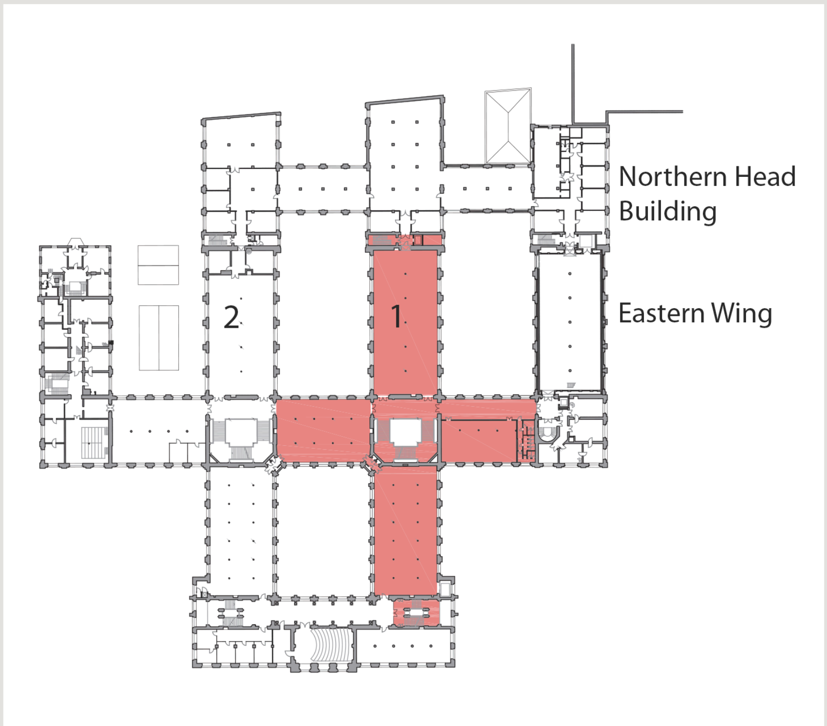
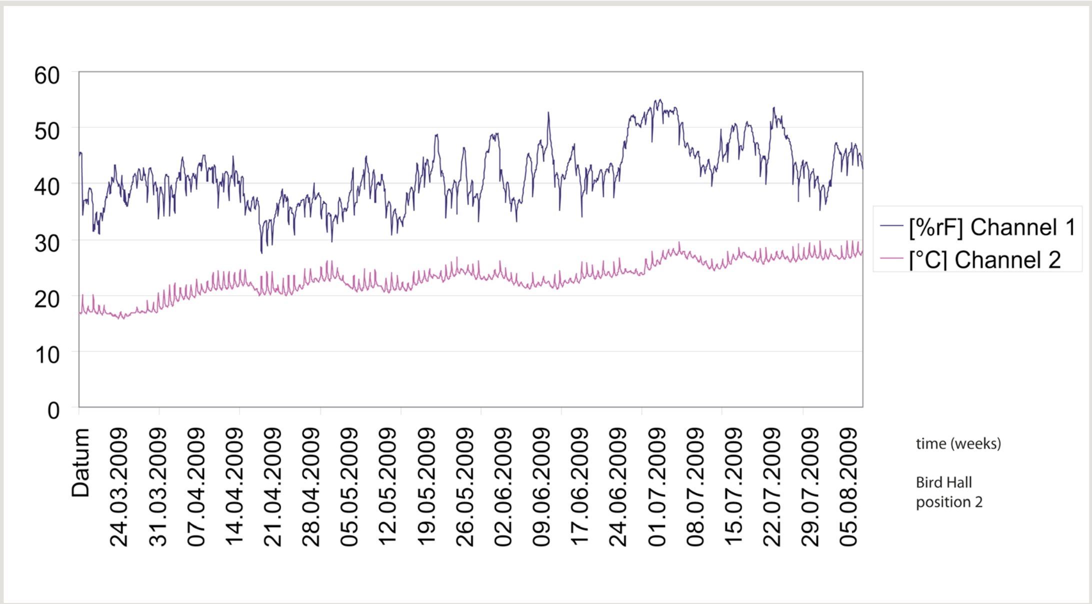


Figure 6. Survey plan of the MfN today 1:400, first floor: 1 Mammal Skin Hall, 2 Bird Hall; Fish Hall is on top of position 1 in the second floor, the area of the second phase of reconstruction in red



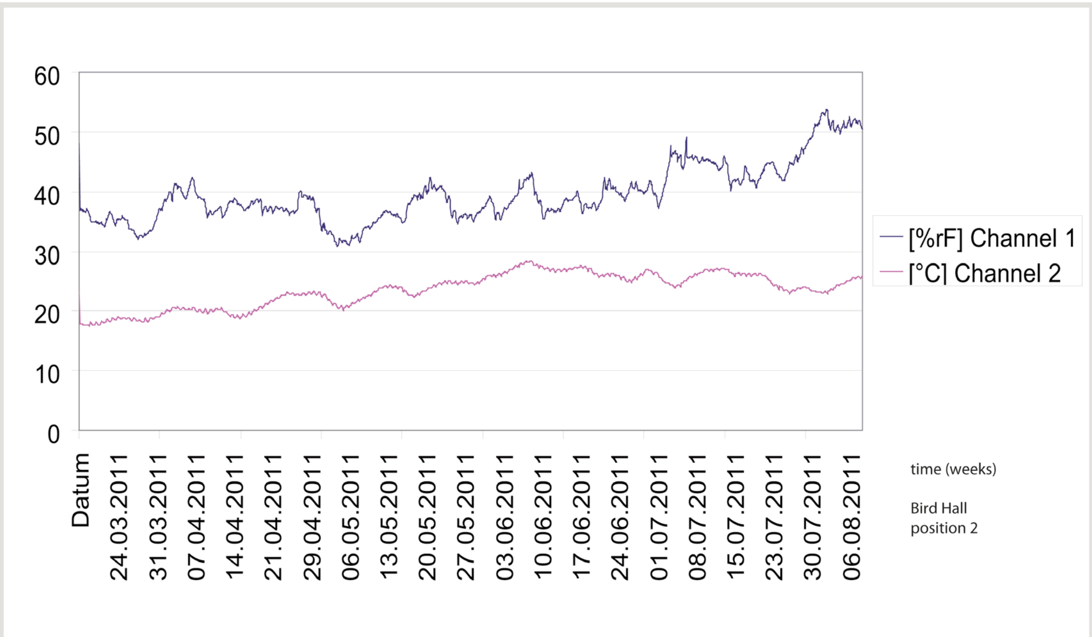


Figure 7. Top: Part of the record of temperature and relative humidity in Mammal Skin Hall (cf. Fig. 6, position 1); middle: Part of the record of temperature and relative humidity in Bird Hall (cf. Fig. 6, position 2) before window restoration; bottom: – after window restoration

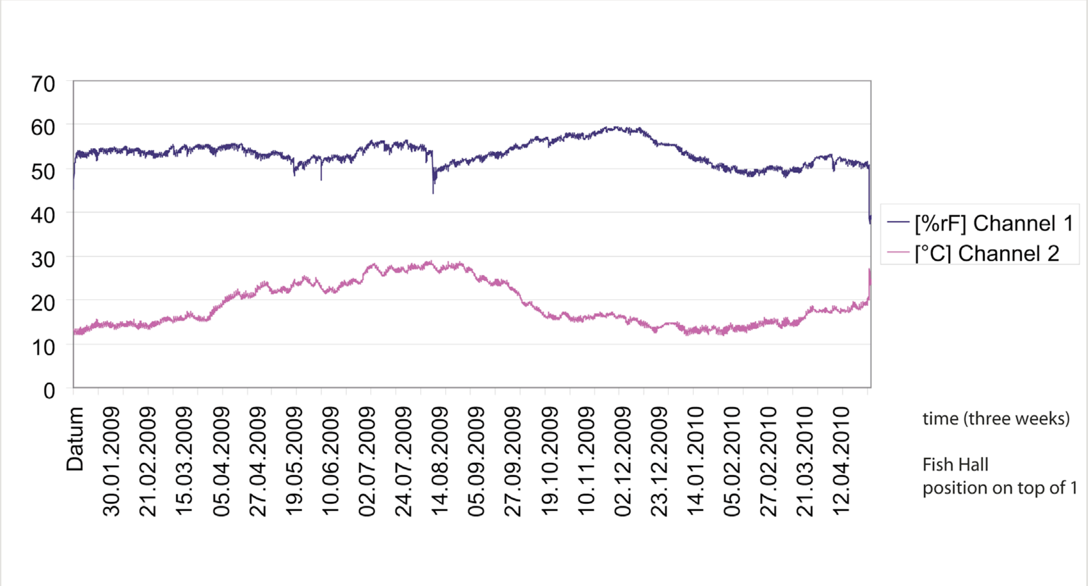


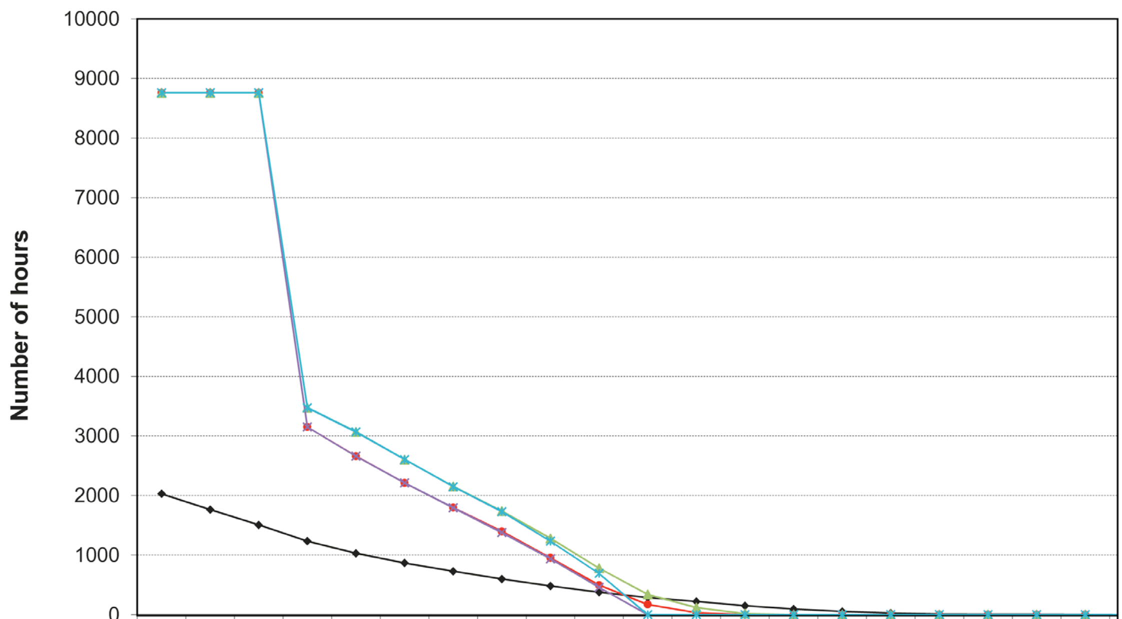
Figure 8. Measurement of temperature and relative humidity in the Fish Hall (on top of position 1)

8, the conditions in the upper halls on the second floor are worse than those on the first floor. Being more exposed to sunlight, they usually have higher annual extremes of temperature and as the condition of the windows is even worse in these halls, they also tend to be wetter. Our predecessors as curators were well advised to identify these areas for storage of the larger 'wet' collections. Leaky windows also increase the danger of pest infestation. Pests are best prevented by tight windows and cabinets and by low temperature storage. As expected, the window renovation in the Bird Hall did not lead to any reduction in the summer temperature extremes, but the overall pattern of temperature and relative humidity fluctuation became much more even (Figure 7c).

By comparing these environmental monitoring data with the recorded external weather conditions (monitored regularly by the Technical University of Berlin's Institute of Meteorology, courtesy of Dr. Klaus Müller) it was possible to simulate the climate in the collection halls under several different technological regimes and use scenarios. The aim of the simulation analysis was to find the optimum balance between the requirements of the collection on one hand and the energy consumption measured by the annual energy costs on the other. Therefore, a simulation model of the whole museum was compiled. Typical hourly weather data at the location were used as boundary conditions (TRY test reference year prepared by the Germany's National Meteorological Service). The software calculates solar altitude and resulting solar radiation on the façades of the building. With this model it was possible to simulate room conditions (temperature and humidity) under different weather conditions to investigate the effects of various scenarios, for example, different glazing and sun protection devices at the windows, natural infiltration, internal insulation, the presence of visitors or different building elements. The heating and cooling loads and the annual energy consumption were also calculated. To find the best solution, the simulation results were statistically analysed (Figures 9 and 10) and discussed between the MfN team and the architect. The analysis demonstrated that the great thickness of the external walls is an advantage for the museum as the large storage mass reduces short- and medium-term temperature fluctuations. Internal insulation of the walls would reduce this positive balancing effect. Consequently, it was decided that no internal insulation would be installed although this will result in slightly higher annual energy consumption. An in-wall heating and cooling system was selected to reduce energy costs. It requires only a low supply temperature delivered by a heat pump which taps into geothermal energy taken from underground loops.

Once thermal conditions were under control the attention was turned to the humidity trend. As the recent measurements illustrated, it is important to reduce the leakiness of the old windows. Low natural infiltration is necessary to maintain a distinction between the indoor climate and the external weather conditions, particularly in order to reduce short-term fluctuations in air humidity. The effects of different rendering materials and visitor numbers on the humidity trend were analysed with a special simulation model (Figures 11 and 12). The simulation shows that the type of rendering has a high influence on the humidity trend. Loam and clay renderings reduce the amplitudes of the relative humidity much more effectively than normal plaster [16]. On the evidence of these data and the measurements from the Bird Hall and Fish Hall it was decided to install a loam or clay rendering and to abandon technical humidification and dehumidification systems. The loam rendering can also be combined with the wall heating and cooling system. The second consideration was that the simulation demonstrated visitor groups of ten or more people increase the relative humidity considerably (Figures 11 and 12). It is therefore advantageous to encourage visits to the collection halls during dry winter periods, and to close the spaces to the public during wet summer periods.

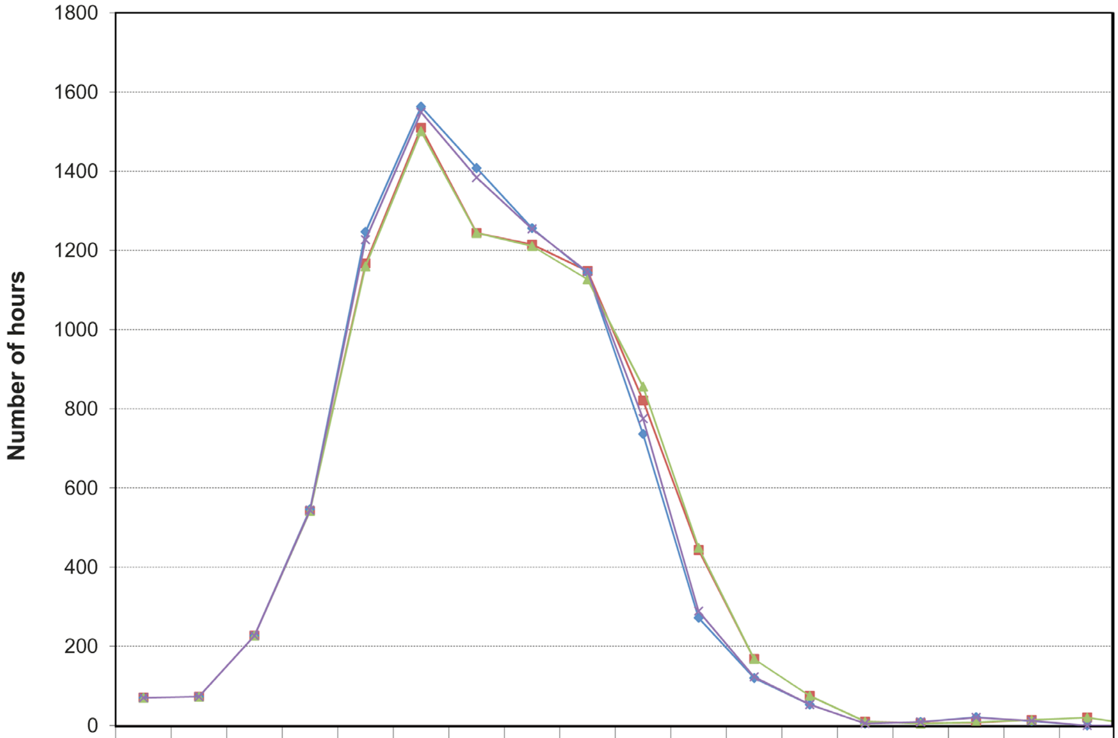
In summary, the analysis of room conditions by computer simulations to test the influence of various approaches was found



	T > 16°C	T > 17°C	T > 18°C	T > 19°C	T > 20°C	T > 21°C	T > 22°C	T > 23°C	T > 24°C	T > 25°C	T > 26°C	T > 27°C	T > 28°C	T > 29°C	T > 30°C	T > 31°C	T > 32°C	T > 33°C	T > 34°C	T > 35°C
Outdoor temperature	2028	1762	1505	1234	1029	867	728	597	481	376	287	221	149	94	53	26	8	6	5	3
Heating	8760	8760	8760	3149	2660	2210	1796	1396	952	495	171	34	0	0	0	0	0	0	0	0
Heating + internal isolation	8760	8760	8760	3474	3068	2603	2152	1737	1280	779	338	118	17	0	0	0	0	0	0	0
Heating + Cooling	8760	8760	8760	3149	2659	2210	1794	1378	937	459	0	0	0	0	0	0	0	0	0	0
Heating + Cooling + internal isolation	8760	8760	8760	3473	3066	2602	2146	1729	1234	692	0	0	0	0	0	0	0	0	0	0

Air temperature [°C]

Figure 9. Cumulative frequency of the temperature in the Mammal Skin Hall, employing large area wall heating and cooling (violet X) using the inertia of the building and adding internal insulation (blue *)



	< 10%	10 - 15 %	15 - 20 %	20 - 25 %	25 - 30 %	30 - 35 %	35 - 40 %	40 - 45 %	45 - 50 %	50 - 55 %	55 - 60 %	60 - 65 %	65 - 70 %	70 - 75 %	75 - 80 %	80 - 85 %	85 - 90 %	90 - 95 %
Heating	70	73	227	542	1167	1510	1244	1215	1148	821	443	168	75	10	6	7	14	20
Heating + internal isolation	70	73	227	546	1247	1563	1408	1256	1143	736	272	120	53	5	9	21	11	0
Heating + Cooling	70	73	227	542	1160	1501	1244	1211	1127	856	449	168	75	10	5	8	14	20
Heating + Cooling +internal isolation	70	73	227	544	1227	1549	1384	1254	1146	775	289	123	53	5	9	20	12	0

Relative humidity

Figure 10. Frequency distribution of the prospective relative humidity in the Mammal Skin Hall employing large area wall heating and cooling (green Δ) using the inertia of the building and adding internal insulation (violet X)

to be an appropriate tool to guide decision making during the planning process and it stimulated target-oriented discussions between all parties involved.

Conclusion

Our conclusions for the planning process were that it is feasible to introduce an energy-saving heating and cooling system driven by geothermic energy which takes advantage of the inertia of the building, if summer maxima inside the collection halls are permitted to reach 25 °C. It is expected that the temperatures can be kept below 20 °C during most times of the year (29429 hrs, figure 11). We would allow a gradual temperature change and permit the temperature to drop to 15 °C during winter. The only restrictions are the health and safety regulations ('Arbeitsstättenrichtlinie') and the structural-physical limitations of condensation and heat transfer between neighbouring rooms. This approach would contribute to saving energy and avoiding steep drops in relative humidity.

The monitoring data for annual relative humidity in the Mammal Hall over recent years (Figure 7a) are actually better than the pattern indicated by the simulation (Figure 9); RH exceeded 55 % only in late summer. This may be a result of the huge volume of fur materials actually present in the collection hall, which absorb moisture. Extremes and fluctuations of relative humidity would be mitigated further by a humidity-buffering layer of loam rendering and tightly-fitting cabinet doors. The alternative solution of adding internal insulation to the outer walls would be

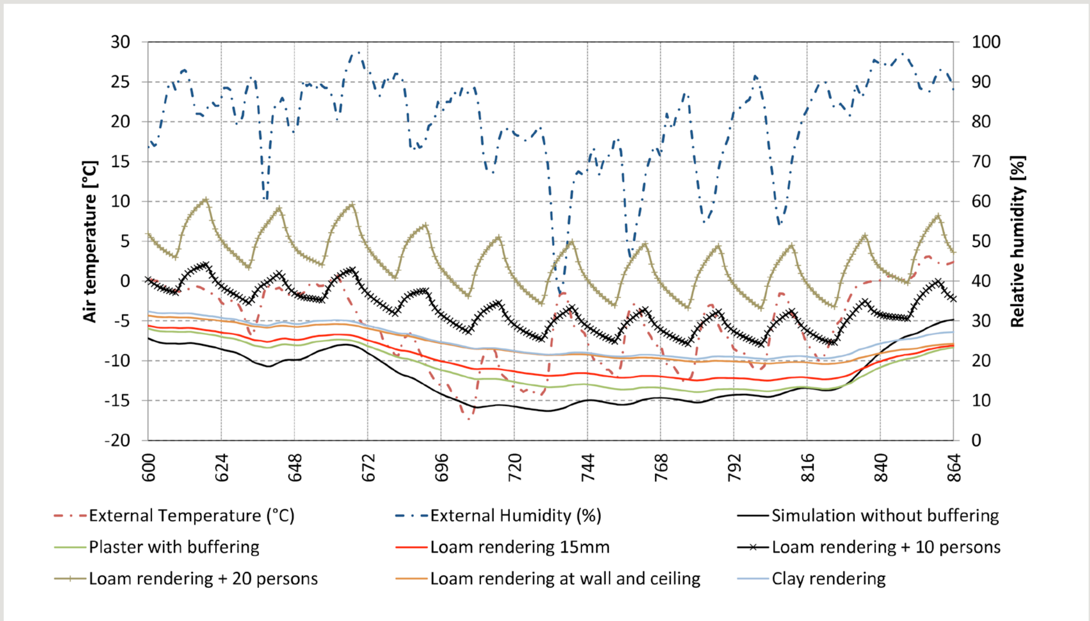


Figure 11. Simulation of the course of the relative humidity in the Mammal Skin Hall during a dry winter period under scenarios of use of heat buffering, different types of loam rendering and introducing guided tours in the collection hall

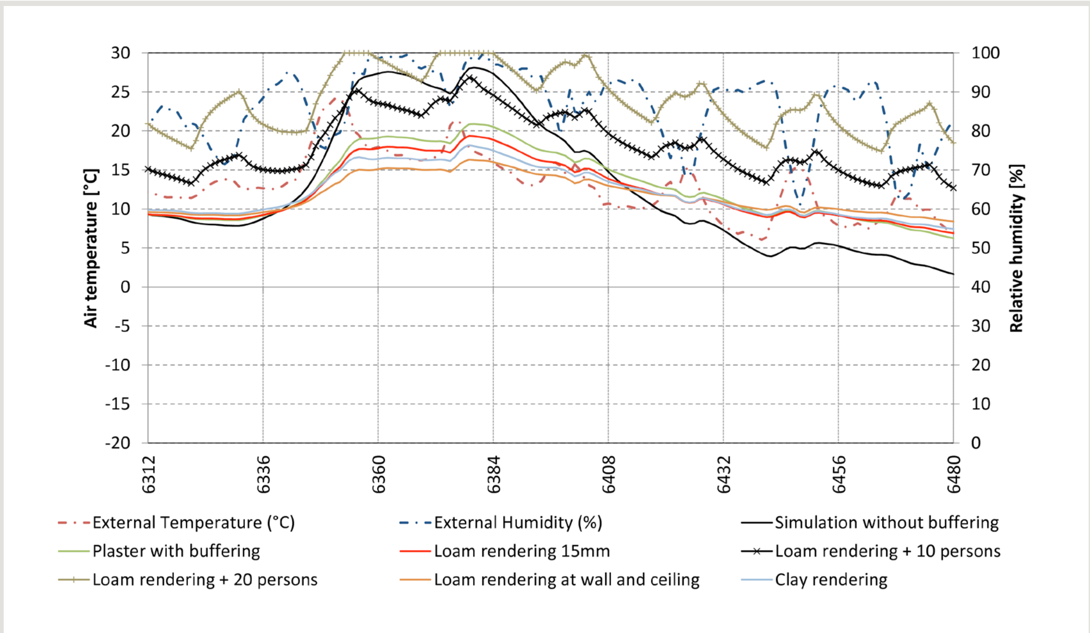


Figure 12. Simulation of the course of the relative humidity in the Mammal Skin Hall during a hot and wet summer period under scenarios of use of heat buffering, different types of loam rendering and introducing guided tours in the collection hall

complicated and costly in an architecturally significant monument and demonstrates only marginal advantages in the simulations (Figures 11 and 12). Furthermore, this intervention would minimise the favourable influence of the inertia of thick walls of the original museum building. As demonstrated by the positive impact of the window restoration in the Bird Collection Hall, we will aim to achieve an appropriate conservation environment by combining all these measures with effective light and UV protection in the box-type windows. Previously, the extremely low temperatures in the current building were effective at preventing pest infestations, retarding decay processes and hindering the development of bacteria, fungi, and dermestid (i.e., museum beetle) larvae. However, tightly-fitting cabinets and well-sealed windows combined with an integrated pest management system that includes constant pest monitoring by collections management personnel will remain essential barriers against the influx of pest organisms.

Our optimistic conclusion is that the collection halls can be used for storage of the dry collections at reasonable energy cost. As a bonus, the collection halls can also be opened to guided tours of visitors in winter without compromising the environmental conditions.

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