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A low-tech depot for Roman archaeological finds

The task

From the moment they are established, museum collections, depots and archives only develop in one direction: they expand. As soon as a cultural asset, whether it be an archaeological find, a museum object or a written testimony to the past, has been classified as historical and valuable, it retains this status forever. No museum director or archivist would willingly deprive an object of its preservation-worthy status. At the same time, new preservation-worthy objects are being added to collections every year.[1] Many collections originated long ago, and consequently many depots and archives no longer meet modern conservation requirements.

Since the adoption of the Venice Charter in 1964, and especially in the last two decades, scientific research into the optimal conservation conditions of cultural assets has made considerable progress. Restorers have defined and documented the best possible conservation conditions (temperature, humidity, etc.) for various classes of objects. Since most museum collections consist of objects made of very different materials, the requirements for the room climate in a depot also have to be considered in a more differentiated manner.

This presents a conflict that very quickly becomes apparent when embarking on plans for new depot buildings: growing collections require more space and optimising the conservation conditions requires ever higher levels of technology in the building. This increases the construction costs and later the operating costs – costs that the respective body responsible for the collection (e.g. states, municipalities, foundations, universities,...) cannot always cover.

01 The new office building at LVR Archaeological Park Xanten. On the right is the administrative wing, on the left the depot for the archaeological finds. (Photo: Axel Thünker DGPh)

02 The new office building during construction. The find depot (left) is clearly recognisable due to its lack of windows

Since the LVR Archaeological Park Xanten was founded in 1973, its offices, staff rooms, workshops, warehouses and storerooms have always been provisionally housed in various buildings in the vicinity of the site. The decision to construct a new administration building that would incorporate workshops, storage rooms and storerooms in 2012 (Fig. 1) brought exactly this conflict to light: as ongoing excavation work continues, new finds are constantly being added to the storeroom. And as excavation methodologies improve, more and more sensitive finds need to be stored (e.g. organic remains instead of just stones and shards) in turn necessitating a very sensitively controlled air conditioning of the storage rooms.

In the course of the planning discussions, the requirements profile for the new depot were critically assessed and considered in a more differentiated way.[2] Do all finds need to be air-conditioned? Are there particularly sensitive finds? Do all types of finds have the same narrow room climate requirements? As a rule, the vast majority of the archaeological remains found during excavations consist of mineral materials (clay fragments, stones, architectural ceramics and wall plaster). These can certainly withstand a wider range of humidity and temperature fluctuations without sustaining damage provided that these do not occur abruptly but instead very slowly and continuously. These finds require a storage area of approx. 1,420 m^2 and account for a large part of the space required.[3] Only a small proportion of the collection has very narrow climatic requirements. They include a depot for organic materials (approx. 32 m^2) for finds made of wood, leather or plant remains, which must be kept relatively damp so that they do not become brittle. There is also a depot for metals (approx. 90 m^2) for iron finds, non-ferrous and precious metals, which require a relatively dry climate so that the materials do not corrode. Last but not least, a freezing depot (approx. 28 m^2) was required so that it is possible to immediately freeze freshly recovered archaeological finds from damp soil excavations. These three depots are the only ones that actually require special technical installations, and together they account for only about 10% of the total floor area.

The depot manager is usually the only person who works in the building. He or she selects the requisite finds and hands them over to the scientists or scholars. With a stock of some 30,000 find boxes, it is undesirable to allow scientists to help themselves and possibly put the boxes back in the wrong place. The physical work involved does not require a room temperature of 21° throughout; a smaller, heated office for the manager to administer the digital database of the depot collection is sufficient. Occasionally tours are given of the depot as part of public relations or museum communications. In such cases, 15-20 people may be in the depot under supervision for a limited time (1-1½ hours).

The construction

Over the course of the subsequent planning process, the concept was refined together with the architects, specialist planners, restorers and users. Approximately 95% of the finds are made of ceramic and stone, materials that can withstand moderate fluctuations in temperature and humidity. For this reason, a two-storey depot building was designed that makes use of the principle of mass and inertia, as seen in traditional construction methods in hot countries. Thick, solid walls and solid ceilings or vaults with small window openings ensure that the heat of the day penetrates the masonry only slowly. At night, when the temperature drops significantly, the walls and ceilings radiate heat back into the interior. The mass of these building components significantly reduces the highest and lowest temperature, i.e. the degree of fluctuation, and at the same time results in a phase shift of about 12 hours so that heat arrives in the interior when the temperature outside is falling again.[4] In addition, the team had first-hand experience of the qualities of a massive rammed earth building as the material was used for the reconstruction of three Roman craftsmen's houses in the Archaeological Park from 2007 to 2014 (see the presentation given at the LEHM 2008).

The new depot building at LVR Archaeological Park Xanten rests on a floor slab of approx. 35 cm thick reinforced water impervious concrete on 20 cm thick compacted gravel bed (Fig. 2) topped by a PE foil moisture barrier. The floor surface is a 6 cm screed compound and the floor is not otherwise insulated. The external walls are 24 cm reinforced concrete with 10 cm of mineral wool insulation and a curtain-type, back-ventilated panel cladding. The ceiling slab is 22 cm reinforced concrete with a rigid EPS thermal insulation cut to fall (min. thickness 12.5 cm) topped by an extensive green roof. Both the ventilated wall cladding and the green roof are designed to prevent the thermal insulation being exposed to particularly high or particularly low temperatures.

Inside, the walls and ceilings were given a two-layer coating of clay plaster (Fig. 3). The plaster thickness on the ceiling and walls is 25 mm. On the inner face of the external wall, warm-water wall heating coils have been embedded in the plaster, which is slightly thicker 30 mm (Fig. 4). Given the floor space of approx. 1,420 m^2, a total of 2,870 m^2 of wall surfaces were coated with clay plaster. Such a large surface area should be able to quickly absorb moisture from the air in the room and slowly release it again, thus stabilising the room climate.

For regulating the indoor room climate, large rooms are beneficial, but for fire protection, rooms need to be smaller. A compromise was found by dividing the

03 Section of the depot with clay plaster walls, ventilation ducts, wall heating supply and return pipes in the corner and the rails of the sliding racks on the floor

04 Pipes of the wall heating registers prior to application of the clay plaster

05 Sliding shelf system with red boxes containing finds showing clay plaster walls and smoke extraction vents

06 The two-storey depot for large finds. On the ceiling the supply line to the wall surface heating.

depot into five sections for smaller finds and a pallet warehouse for larger stone finds. Except for the heated offices, none of the walls have window openings, although smoke extraction vents were required as part of the fire protection concept.

Given the small number of staff, the ventilation system need only ensure the minimum hygienic air exchange rate. Some areas of the depot are used only very sporadically, when finds from that area are required. The ventilation system was designed to balance the temperature and humidity of the indoor air and the outdoor air. If the conditions of the air outside air are more favourable than those of the air inside, air is pumped in from outside into the rooms.

The interior is fitted primarily with electrically driven sliding tracked shelves (Fig. 5) which are programmed so that they automatically return to the home position at the end of the day, where the shelves are evenly spaced. This ensures that all the boxes with finds are ventilated and no "dead pockets" result.

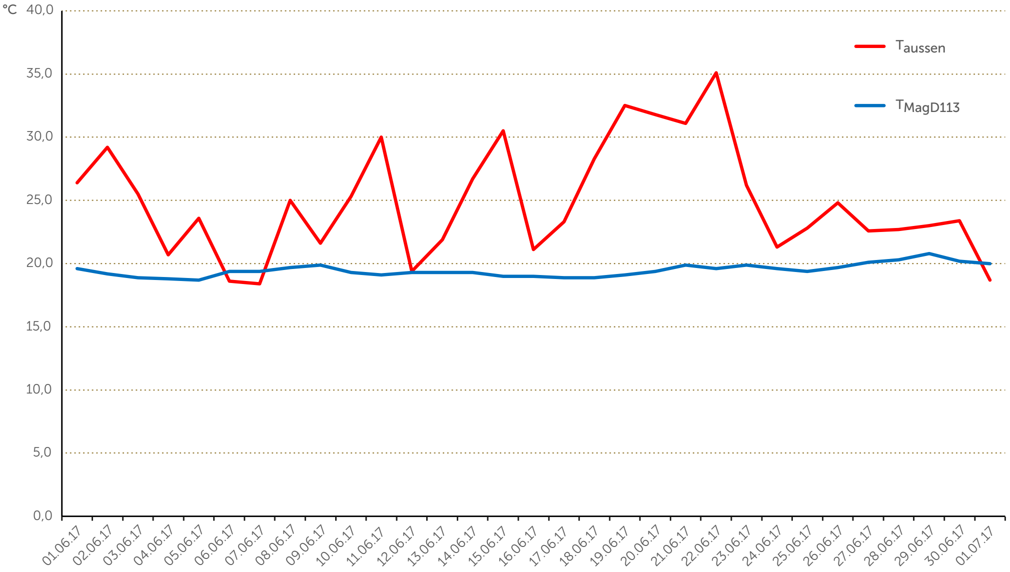
In the display and pick-up depots, regular shelving is provided, and in the stone depot, tall shelves capable of holding pallets were installed (Fig. 6).

The result

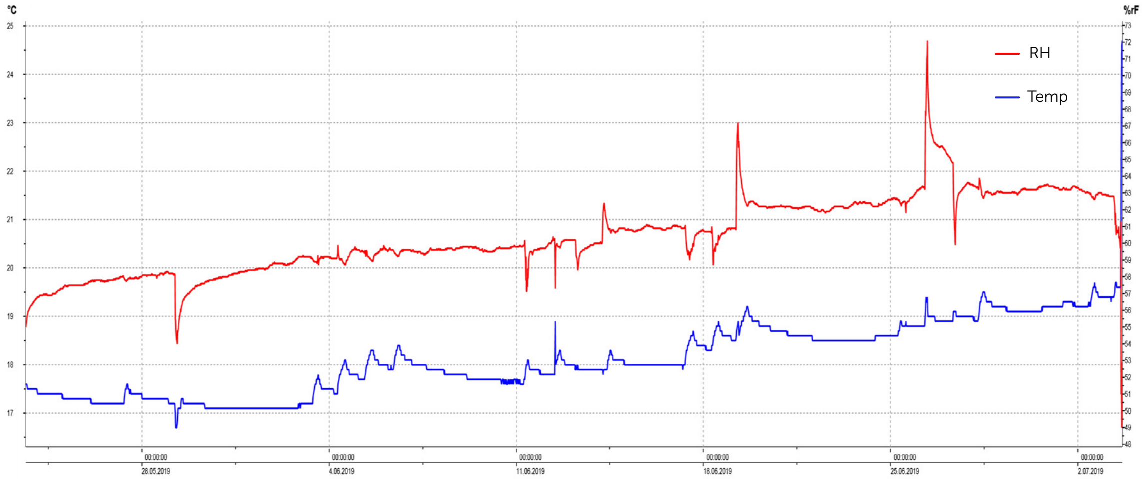
The construction design approach has largely fulfilled all the outlined requirements. Data loggers were installed at various points in the depot to determine actual temperature and humidity values in the individual rooms independently of the ventilation control system's measuring sensors. The temperature curve follows the outside climate but offset by a phase shift and significantly reduced. By way of example: 22 June was one of the hottest days of 2017 in the region with an outdoor temperature of 35.1°C.[5] The day after, a thunderstorm ended a spell in which temperatures had risen steadily over the preceding days. The temperature fell by 13.8° to 21.3°C by 24 June. Despite the intense heat outside, the temperature inside the depot only rose by about 2°C, and with a noticeable phase shift. A peak indoor temperature of 20.8°C was reached on 29 June, one week after the intense heat outside (Fig. 7), and then began to fall again.

A similar pattern can also be observed in winter, although there are some differences. On the one hand, the wall surface heating starts to operate below an outside temperature of approx. 18°C, providing additional warmth inside the depot to act against falling temperatures. The wall heating is supplied with a flow temperature of 25°C and can thus usually maintain

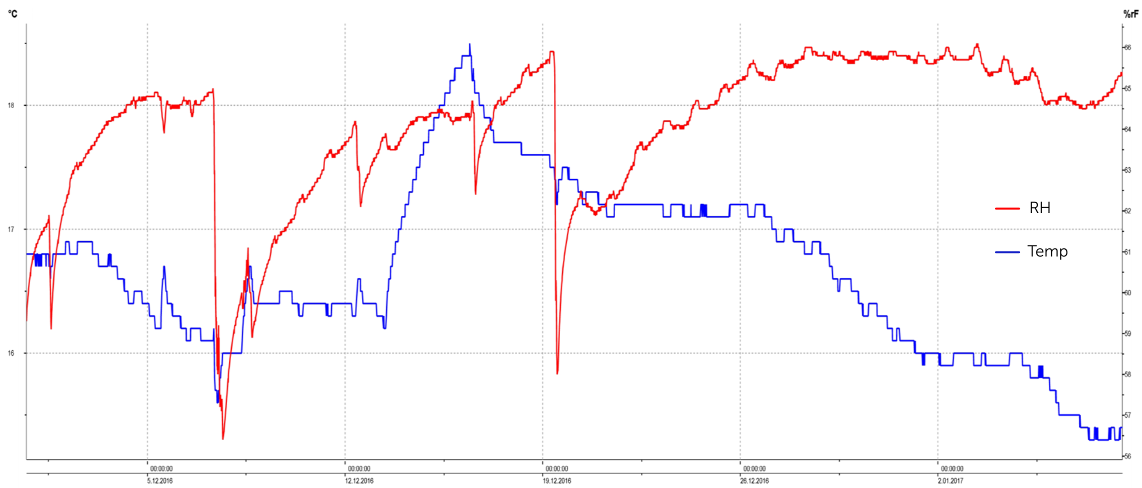
07 Daily maximum temperature of the weather station Tönnisvorst compared to the indoor temperature in the depot from 1 June to 1 July 2017. (Photo: Peter Kienzle)



08 Temperature and humidity curves from 23 May 2019 to 3 July 2019 in Depot D113 (Datalogging: Peter Becker).



09 Temperature and humidity curves from 30 Nov 2016 to 08 Jan 2017 in Depot D113 (Datalogging: Peter Becker).



a room temperature of approx. 18°C, though after a series of very cold days the temperature can drop to 14°C. The lower design limit was not to fall below a minimum temperature of 11°C, a value derived from statutory requirements (EnEV). The current minimum temperature of 14°C represents a good solution, and in fact only prevails on a few days.

The air humidity is now also within the required limits. The restorers' sensitive measuring devices record short-term peaks when the doors are opened for bringing in new finds for storage or the removing loaned objects for exhibitions, or when the ventilation is manually activated in the early morning. The diagram (Fig. 8) shows the period from 23 May to 3 July 2019 in which the outside temperatures have already become noticeably warmer in late spring and the warmer air can already absorb more moisture. The temperature in the depot is 17-18°C and warming gradually. If the absolute quantity of water in the outdoor air is lower than the quantity of water in the air in the room in the depot and the humidity in the depot is relatively high, the ventilation system automatically starts a targeted air exchange process. In the diagram, this is visible in the morning hours of 29 May where short-term ventilation causes the temperature to drop from 17.5° to 16.5° and the relative humidity from 58.5% to 54%. While the temperature immediately returns to the earlier level due to the mass of the building structure, a clear curve can be seen in the course of the humidity, which only reaches the former value again after two days. We attribute this to the buffering effect of the clay plaster.

Another special event can be seen in the same diagram on 26 June: on that day a door to the outside was opened to transport finds. Warm air enriched with water immediately enters the building and is cooled by the existing room air and mass of the building structure. The measurements show that the temperature rises by only half a degree, but the air humidity rises rapidly to 72%. Immediately afterwards, it drops back down to approx. 67% once the humidity has spread throughout the room. This, too, is a product of the buffering effect of the clay plaster, which absorbs the moisture. The moisture curve continues to fall at a slow pace. The next morning, the ventilation system registered an excessive level of humidity and supplied fresh air (the peak downwards) to balance the conditions of the indoor and outdoor air. Once again, the curve is then buffered by the moisture retention capacity of the clay plaster.

10 Depot D113 during the construction phase showing rainwater pooling on the ground

The mistakes

Mistakes are made to be learned from – ideally once only! Here we would like to discuss two points that future building projects should pay more attention to.

Initially, the moisture contained within the building itself during construction was not sufficiently taken into account. The floor slab and side walls up to a height of one metre are made of made of water impervious concrete, with normal reinforced concrete above. As the rooms of the depot have only small openings for smoke extraction vents, the air exchange rate during the curing and drying process was very low (Fig. 10). The application of clay plaster also introduces further moisture into the building. However, the ventilation system that was installed later in the construction process was dimensioned only for the minimum air exchange and could not help accelerate the drying process. Consequently, humidity levels in the depots was very high at first, so that in September 2016 only the admin staff and researchers could move into their new offices. The finds were left in the old depot so that the new depot could dry out over a winter period by selectively opening the smoke extraction flaps on cold, dry days to manually ventilate the interior. Although this produced a significant short-term drop in room air humidity, the building structure released new moisture after a short time. For this reason, additional dehumidification units were installed in the storage rooms to promote dehumidification when the vents could not be opened.

During this process, it became clear that the ceramic materials to be stored in the depot, which would be brought in from various unheated, uninsulated storage rooms, would also introduce additional moisture to the interior. The specialist planner estimated that a further 13,000 litres of water (absolute quantity) may be stored within the ceramic shards, bricks and stone objects.[6] The relocation of the historical objects into the depot began half a year later, in March 2017, but even then neither the finds nor the building structure had dried out fully, although the humidity levels were significantly better than in autumn 2016. Consequently, the large depot rooms continued to be dehumidified with additional equipment for another year after the finds had been moved into the building. As a rule, such construction projects are subject to considerable time constraints because the old buildings have to be demolished, temporary accommodation needs to be rented or new tenants want to move in. This time pressure is particularly problematic when it comes to sufficiently dehumidifying the building before the objects are moved. Since the old storage building in the Archaeological Park was to be demolished and no new projects were planned immediately at this point, it was thankfully possible to postpone the relocation of the objects until the winter months, which was extremely advantageous for the drying of the rooms.

Another weak point in this construction project was the technical regulation of the ventilation system. The ventilation system used for the depot was dimensioned to ensure the minimum air exchange rate and is thus small. In addition, it provides the possibility to supply fresh air to the depot rooms whenever the outside air conditions are more favourable than the conditions of the room air. In this specific case, the intention was to ventilate extensively in autumn and spring, and in the summer half of the year to supply cold and fresh outside air to the depot in the morning hours of hot days to cool the room air and reduce its moisture content. During the first two years of operation, however, it quickly became apparent that the number of installed sensors and the quality of the ventilation system control were not sufficient to ensure these processes. A single measuring point for temperature and humidity in the main exhaust air pipe did allow sufficient control of a U-shaped building complex with facades facing south and north, office areas and windowless storage rooms. For this reason, ventilation was carried out manually by the building services staff in the first few years. Every morning the temperature and humidity values of the indoor and outdoor air were compared, and the ventilation process was then carried out manually for 30 or 60 minutes. The diagram from 30 November 2016 to 8 January 2017 (Fig. 9) shows that the indoor air humidity is about 64%. On 7 December 2016 cold outside air was supplied manually. While the room air temperature only dropped by slightly more than 1°, the indoor air humidity fell to less than 57%. This process was repeated at irregular intervals in the following days. From 13 December 2016 onwards, the wall heating was activated to supply additional heat to the depots. This experience revealed that the low level of technical installations in the depot as a result of the mass and thermal retention capacity of the structure can reduce the amount of ductwork and dimension of the ventilation unit, but in no circumstances should the number of sensors in the building and the ventilation control system be reduced.

The conclusion

Overall, the experience gained from the construction of the depot for Xanten Archaeological Park has been positive. Leveraging the inertia of massive building components for the design of the depot is certainly a useful approach, provided that the type of museum objects it will contain are suitable. The combination of massive concrete walls to regulate the temperature and clay plaster to regulate the humidity continues to work impressively four years after the museum depot opened. Provided one takes into account the drying time and the necessary investment in extensive and suitably sensitive ventilation control, this construction method can be recommended without reservation.

Footnotes

1 These thoughts are taken from a lecture by Dr Joachim Huber, Co-Managing Director of Prevart GmbH, Winterthur, at the congress "Das grüne Museum", 18 October 2017 in Cologne.

2 Cf.: Joachim Huber and Karin von Lerber: Unbezahlbare Depots für Kulturgut? – Ein langfristig angelegtes Kostenbewusstsein in Museen ist gefragt. In: Museum Aktuell, July 2008, pp. 8-9.

3 All floor areas given are usable floors areas and do not include the space required for the construction, for ancillary areas and circulation.

4 Efat Hamza and Shlomit Paz: The Traditional Arab House in the Eastern Mediterranean and its Adaptation to the Mediterranean Climate. In: Geographical Research, Vol. 54, Issue 1, pp. 72-85.

5 Based on outdoor temperature data from the weather station at Tönnisvorst, about 35 km from Xanten. Weather data for Xanten is not continuously archived.

6 Due to the irregular geometry of the fragments and the completely different water absorption capacity of the non-standardised building materials, an exact calculation is not feasible without disproportionate effort.

Photo credits

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