Cultural Heritage Agency
Ministry of Education, Culture and Science

Built to keep

Heritage storage facilities in the Netherlands

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Colophon
Editing: Bart Ankersmit and Marc Stappers
Copy editing: Taalcentrum-VU, Amsterdam
Cover image: Jarno Pors (RCE)
Design: Xerox/Osage

Cultural Heritage Agency of the Netherlands
Postbus 1600
3800 BP Amersfoort
www.cultureelerfgoed.nl

Inhoud

Preface

Bart Ankersmit – Researcher, Cultural Heritage Agency of the Netherlands
Marc Stappers – Building Physicist, Cultural Heritage Agency of the Netherlands

We are very pleased to present to you the English translation of the book 'Gebouwd om te bewaren, waar staan we met erfgoeddepots in Nederland?' that was published in 2021. Although these storage examples are all Dutch, we expect that these stories are not only familiar to colleagues abroad but might also be helpful.

In 2020 the Cultural Heritage Agency of the Netherlands initiated a publication on storages for heritage. We reached out to Dutch colleagues with variousexperiences, responsibilities and knowledge aiming to make a wide overview of how we keep what is precious. We were very fortunate that everybody we invited responded enthousiastically about our idea. After several months we were able to publish 'Gebouwd om te bewaren' with 23 contributions from the Dutch heritage field. Contributions ranged from the political context in which these building came to be, via the logic behind a schedule of requirements to an evaluation of the buildings in which we store our movable heritage. This all merged in a wide overview of different buildings with different collections and of different points of views.

Since the publication was made available online we became aware that this information might also be of international interst. It was decided to translate the articles and make them available to a wider international audience. The Dutch stories were translated into English. Since the original articles do not contain many international references, the international context is missing. But it should be known that many of the projects presented here were made possible by the work done by intenational colleagues. Teams of Dutch museum staff visited sites in Denmark, Austria, Germany and the UK to name a few. We learned from our Danish colleagues about building low energy storage faclities, from our Canadian collegues about the risk management approach and from our other European collegues about collection management in sustainable buildings. We trust that you will recognise these valuable implicit international references from our Dutch stories about storages that were built to preserve our national collections.

We hope that with this publication we provide new insights and inspire those who face the challenge of renovating an exsisting storage building or are developing a new one.

Preface

Hans Waalewijn - Collection Management Officer, Cultural Heritage Agency of the Netherlands

The introduction of the Delta Plan for the Preservation of Cultural Heritage in the Netherlands (Deltaplan Cultuurbehoud) in the 1990s heralded a new phase of collection management in Dutch museums.
The significant maintenance backlogs in management and conservation were rapidly remedied over the course of eight years thanks to a central government subsidy. What this plan meant in practice was that the collections that had gathered dust were carefully processed and storage facilities were subsequently improved. Numerous preventive measures were also developed at that time like acid-free storage, proper registration, padded hangers, climate control and light levels. Professional courses were established to train people in the skills of conservation and the profession of registrar was introduced. It was also at this time that climate-control systems began to be used in museums. Their aim was to achieve a constant climate all year round: not only in the attic areas of antiquity rooms, but also in modified commercial buildings that served as storage facilities. The latter were often located in business parks rather than directly alongside museums.

As was the case with the Delta Plan for water management, by the end of the government subsidy scheme for its cultural preservation namesake, the work was still incomplete. Developments in information technology, digital photography, the use of barcoding and the latest innovations in preventive conservation left museum staff with a continuous sense of a need to catch up on ever new backlogs. In addition, the climate-control systems did not always turn out to be fit for purpose. They were also vulnerable to malfunctioning, risking significant deviations, placed huge pressure on historic buildings and, perhaps equally importantly, consumed large amounts of energy.

Based on the realization that collections do not always need a consistent climate, especially in terms of temperature, that it is possible to exhibit objects with a carefully-considered lighting policy and that acid-free boxes are not always necessary, the Cultural Heritage Agency of the Netherlands introduced value based decision-making and risk management in the Netherlands and abroad. In other countries, people had similar ideas and new storage facilities were designed, in which a state-of-the-art storage environment was created passively. Energy-neutral storage facilities began to appear in Denmark. Collections were brought together in buildings that acted like a tea cosy on a thick, uninsulated floor slab. The ground emits heat in winter and provides cooling in summer. As a result, the temperature matches the seasons while remaining moderated and only limited dehumidification is required in order to maintain the relative humidity at the right level. In the museum world, this remarkably sustainable concept is known as the Denmark Model (or Danish model in this publication).
Meanwhile, in the Netherlands, museums also increasingly began to work together. In 2017 the Kolleksjesintrum Fryslân was built in Friesland: a central storage facility for five Frisian museums where everything is stored together in an energy-neutral way. Following in its footsteps, CollectieCentrum Nederland was opened in Amersfoort in 2021.

In recent years, the realization that only five percent of the collection held by Dutch museums is accessible to the public has led to an increasing desire for more loans and for open storage facilities. The Cultural Heritage Agency has developed a more active loans policy together with guidelines specifically aimed at non-museum loans.
The new Depot Boijmans Van Beuningen actually combines storage and permanent public access.

In this publication, specialists share their experience and expertise from the field. The role of politics, collaboration and experiences of recently-completed storage facility projects provide an enlightening picture and valuable insights on which others can subsequently build. With this publication, the Cultural Heritage Agency hopes to inspire readers to take on future challenges in the field of collection management, ensuring that the collections that provide a past for our future can continue to remain accessible for a long time to come.

2 October 2021

Social and political background of culture policy in the Netherlands

Agnes Brokerhof – Researcher, Cultural Heritage Agency of the Netherlands

Introduction

Developments in the design and construction of museum collection storage facilities in the Netherlands are a reflection of the wider political and social trends in the country, especially when it comes to publicly funded institutions. Politicians set budgets, identify priorities and provide funding from the culture budget in order to enable the conservation and management of public heritage and ensure its accessibility. Since the mid-19th century, politics has varied widely between the views of the liberal politician Thorbecke, who felt that government should not interfere with art, and government adviser De Stuers, who instead advocated an active role for government in heritage conservation, convinced that art could serve a useful role in educating the populace. By the same token, the role played by culture and heritage in and for society has changed over time. This can be seen from the way in which *art* and *culture* have been allocated to different ministries over the years. This chapter charts the social and political developments and the wider policy context in the Netherlands over the last century in major steps and somewhat sweeping generalizations.[1]

[1] The following have been useful sources: Boekmanstudies (2007). *Cultuurbeleid in Nederland*. Den Haag en Amsterdam: Ministerie van OCW en Boekmanstudies.

1917-1940 First Ministry for Education, Arts and Sciences

In the period between the First and Second World Wars, the world was developing at a rapid pace. The wake of the Industrial Revolution saw the introduction of an eight-hour working day, freeing up time for the working classes to enjoy entertainment and leisure. The oil economy came of age. The washing was done in the tub, the floors were swept, but the radio, vacuum cleaner and washing machine had only just been invented. Women gained the right to vote. In the Netherlands, groups who shared the same philosophy of life gathered together in so-called columns or pillars: the religious (Catholics, Protestants), liberals, and socialists (followed later by humanists) took to organizing their own education, healthcare, broadcasting and press. These private associations received financial support from the government, based on their membership numbers.

In 1917, a Ministry of Education, Arts and Sciences (OKW) was established for the first time. These three areas were closely interrelated. Art had a role in elevating the populace, now that they had been given time to engage with it.
The Arts portfolio also encompassed the management and maintenance of listed buildings, monuments and archives and management and operation of existing museums.
As a response to the major changes brought about by industrialization and urbanization, private individuals took the initiative in the 19th century to begin to protect

Figure 1 *Opening of the Netherlands Open Air Museum in 1918. Photo: Nederlands Openlucht Museum*

the nation's heritage. They applied their passion and knowledge in drawing up lists of monuments that had to be isolated from their changing surroundings and protected for the future. For example, the Netherlands Open Air Museum (*Vereniging voor Volkskunde Het Nederlands Openluchtmuseum*) brought together important buildings, traditions and crafts on a museum site in order to keep the past alive, see Figure 1. From 1918, in the Netherlands' first-ever open storage facility, visitors were able to see for themselves how people had lived and worked in the past.[2] The period between 1920 and 1940 saw the establishment of more than a hundred new museums. From 1926, the museums' directors joined forces to set up the Netherlands Museum Association (*Nederlandse Museumvereniging*). Donations and bequests rapidly boosted the collections, which could still be stored on the premises.

1940-1945 Occupation and exile

In the Second World War, Gerrit Bolkestein, Minister of OKW, was in exile in London. The German occupier set up a Department of Upbringing, Science and Culture Protection (*Opvoeding, Wetenschap en Kultuurbescherming*, OWK) and a Department of Public Information and Arts. Art and culture were used as propaganda. Interestingly, subsidies were no longer based on the number of users, but a system of quality criteria was used instead. It will come as no surprise that not everyone shared the same views with regard to that quality.

Figure 2 *Vault for national art treasures in Sint-Pietersberg mountain. Photo collection: Nationaal Archief / Anefo*

Monuments across Europe were subjected to bombing and gunfire. In the Netherlands, the government collections were stored in bunkers in the dunes and, later on, in a special underground vault in Sint-Pietersberg mountain (Figure 2) and a specially-designed storage place in Paasloo. The Netherlands Open Air Museum was temporarily renamed Rijksmuseum voor Volkskunde (National Museum for Folklore). It also served a social function, providing shelter to refugees during the Battle of Arnhem in 1944 (Figure 3).

Figure 3 *Evacuees in the Open Air Museum in 1944 (then under a different name). Photo collection: Gelders Archief / Photo: P.J. de Booys*

1945-1965 The post-war Ministry for Education, Arts and Sciences

After the Second World War, the Netherlands had to be rebuilt. With help from the Marshall Plan (1948-1953), the economy began to shift up a gear again. Farmers, entrepreneurs and fortune-seekers from the middle classes emigrated as the influx of migrants from the former Dutch East Indies and guest workers from Turkey and Morocco began. The decompartmentelization and secularization of society took effect and the introduction of the old-age pension, The General Assistance Act and healthcare laid the foundations of the welfare state. The Flevo polders were drained to make way for housing and the first manned space flight showed that technology had a solution for everything. Vacuum cleaners and washing machines found their way into increasing numbers of households (see Figure 4), freeing up women's time for their personal development, education and employment. The 40-hour working week created a weekend of free time.

[2] See https://nl.wikipedia.org/wiki/Nederlands_Openluchtmuseum.

Figure 4 *Opening of exhibition showcasing household appliances, 30 August 1960. Photo collection: Nationaal Archief / Photo: Hugo van Gelderen/Anefo*

The Ministry of Education, Arts and Sciences (by now abbreviated to OK&W) had its policy areas broadened to include cultural education, youth work, physical education, nature protection, broadcasting (radio and now also television), press, leisure and sport. As part of this ministry, the National Service for State-Owned Works of Art (*Dienst voor 's Rijks Verspreide Kunstvoorwerpen*) was responsible for managing the artworks owned by government that were outside the national museums. In 1984, it was subsumed by the Netherlands Office for Fine Arts (*Rijksdienst Beeldende Kunst*, RBK). The year 1950 saw the publication of the very first official policy document on art (*Kunstnota*), which included such objectives as 'conserving, preserving and where possible increasing the art owned by the Dutch state' and 'the social and geographic propagation of culture'.[3] Culture was seen as a means of helping to repair the moral and psychological damage inflicted by the war, partly through government subsidies for art education and libraries. The number of museums doubled to reach almost 300, together attracting visitor numbers in excess of six million. One of these was the Anne Frankhuis, opened in 1960 to recount the story of Anne Frank and inspire young people to build a better world.[4]

Figure 5 *Truus Wijsmuller, board member of the Anne Frank Foundation, removes the plastic covering from the pictures in Anne's room before the museum's official opening. Amsterdam, 3 May 1960. Photo collection: AHF/ International Instituut voor Sociale Geschiedenis, Amsterdam / Photo: Ben van Meerendonk*

[3] Pots, R. (2000). *Cultuur, koningen en democraten: Overheid & cultuur in Nederland*. Nijmegen: Uitgeverij SUN. See https://pure.uva.nl/ws/files/3074253/11630_UBA002000048_12.pdf.

[4] See https://www.annefrank.org/nl.

1965-1982 The Ministry of Culture, Recreation and Social Work

The post-war reconstruction was followed by a period of policy focusing on income and welfare. Vacuum cleaners and washing machines became the norm, Tupperware parties plasticized domestic life and the throwaway society began to take shape. Whereas the optimism and sense of unity of the reconstruction had meant that government interference was still accepted, increasing numbers of young people now felt it to be patronizing and oppressive. Women's liberation continued apace and feminist groups like the Mad Mina (*Dolle Mina*) made their voices heard. The family reunification of guest workers and Suriname's independence led to an increase in immigrants, some of whom were able to climb the social ladder, while a large proportion were left behind. Society was becoming increasingly decompartmentalized. In the 1970s, two oil crises demonstrated the world's dependence on the black gold.

However, the increase in general welfare had failed to lead to an improvement in well-being. People were becoming richer, but not necessarily happier. In 1965, the government decided that culture, media, sport and youth work should become part of the new Ministry of Culture, Leisure and Social Work (CRM). In Marga Klompé, the ministry had the country's first female minister. The word *art* had made way for *culture*, which was seen as a means of promoting well-being. From the 1970s onwards, it also had the job of helping to put right the deprivation experienced by minorities in society. The policy document Art and Art Policy (*Kunst en kunstbeleid*) from 1976 aimed to bring about the 'the effect of art on society' and 'encourage the population to participate in art'.[5] Whereas subsidy grants to cultural institutions in the 1960s still took account of innovation and experimentation, as assessed by advisory experts, by the 1970s, the focus was on eradicating social deprivation, at times resulting in positive discrimination. Subsidized museums were expected to 'work for everyone' and prove to be of use to society' in terms of social engineering.

The world of museums became increasingly professionalized. From 1963, the Ministry began to provide support with its Central Laboratory for Research on Objects of Cultural Heritage. In the museums themselves, curators were now joined by new experts in collection management, restoration, marketing and above all education. The aim was to reach out to a wider public, in a way they could understand. This marked the birth of 'New Museology'[6]. The Netherlands Open Air Museum relocated much of its collection to the Diogenes bunker, which was already being used by the Regional Archive as an external storage facility. In 1978, professional training for restorers was introduced. In 1979, the Rotterdam municipal museums moved into a newly-constructed storage facility on the De Metaalhof business park, considerably less expensive than accommodation in the city centre. As the 1970s drew to a close, there was increasing resistance from artists and museums to government interference. By that time, there were almost 500 museums with a total of almost 15 million visitors, of whom only 1 percent had the Annual Museum card they had introduced.

1982-1994 The Ministry of Well-being, Public Health and Culture

In the years that followed, the concept of *globalization* made its début. It was the era of the hole in the ozone layer and acid rain. The economic crisis of the 1980s led to the realization that growth could not continue forever. Although this primarily affected the growth of the economy and population, it also applied to the growth of collections. The neoliberalism of British Prime Minister Margaret Thatcher and US President Ronald Reagan ran rampant throughout the Western world, as *market forces*, *privatization* and *efficiency* became the buzzwords of the age. In its first report in 1990, the International Panel for Climate Change (IPCC) warned about global warming.[7]
It was time for the world to start living and thinking more sustainably. Men now found themselves able to use the vacuum cleaner and do the washing and women became increasingly integrated within the labour force.
The digital revolution was set to start. At the same time, it was becoming clear that certain groups in society who were socially deprived and did not have a Dutch ethnic or cultural background were increasingly facing exclusion. Guest workers became *allochtonen* or *immigrants*.[8]

5 See https://www.parlementairemonitor.nl/9353000/1/j4nvgs5kjg27kof_j9vvij5epmj1ey0/vk11bdx08cx8/f=/kst13981n2k2.

6 Smit, R. (2015). *Erfgoed en publiek*. Erfgoed Cahier #01. Amsterdam: Reinwardt Academie.

7 IPCC (190). *First Assessment Report*. See https://www.ipcc.ch/report/climate-change-the-ipcc-1990-and-1992-assessments.

8 Bos, E., & Smithuijsen, C. (2009). Culturele diversiteit en kunstbeleid in Nederland. *Momenten* (4). See https://demos.be/sites/default/files/culturele_diversiteit_en_kunstbeleid_in_nederland_-_momenten_4_-_demos_vzw.pdf.

Figure 6 *National Museum of Enthnology storage facility in MIBO warehouse in 's-Gravenzande. Photo: Irene de Groot, Nationaal Museum van Wereldculturen*

In 1982, the government replaced the term social work with well-being and at the same time culture returned to the Ministry of Well-being, Public Health and Culture (VWC). Despite this, cultural policy was no longer part of the overall policy on well-being. Societal value and the well-being of the population became less important, although the very first policy document on minorities in 1983 focused on participation by lagging minorities in all parts of society, including culture and religion.
The emphasis shifted back to quality as government withdrew. The Netherlands Open Air Museum barely survived this new policy. The year 1988 saw the introduction of the art planning system together with the Culture Council (*Raad van Cultuur*), a selection of experts tasked with assessing the quality of cultural institutions on a four-yearly basis. Thanks to four-year subsidies, cultural institutions had slightly more security. The economic crisis meant that government had to cut costs. Efforts were made to explore whether cultural institutions could reduce their dependency on government, which was welcomed by those resisting a government eager to interfere. The tide turned, cultural institutions were privatized, as the government looked to distance itself, interfering less with the population and 'not directing, but creating conditions for a thriving, artistic and cultural life'.[9]

By 1990, there were 700 museums, attracting a total of 22 million visitors. The National Audit Office noted that these museums were barely aware of everything in their possessions, pointing out that the condition of the collections was less than ideal. Minister of WVC Hedy d'Ancona published a policy document Opting for Quality (*Kiezen voor kwaliteit*) devoted to the accessibility and preservation of museum-based heritage. In it, she introduced the Delta Plan for the Preservation of Cultural Heritage, a government subsidy scheme intended to address the backlogs in conservation and maintenance of the 'Netherlands Collection' (museums, libraries and archives).[10] The privatization of state-funded museums went hand in hand with additional investments in the conservation and management of the collections. Between 1990 and 1998, more than 200 million guilders was invested in registration, evaluation, conservation and improvement of storage conditions. As far as 'passive conservation' was concerned, much of the subsidy was spent on climate control for museums and storage facilities and filters in air-conditioning systems in order to keep the acid air outside. With technology and funds available, strict specifications were set and traditional roof structures made way for modern machinery. The interior of the National Museum of Enthnology (*Rijksmuseum voor Volkenkunde*) was completely refurbished and the cramped collections in storage were relocated to four large civil defence MIBO warehouses with climate control in 's-Gravenzande. At the same time, all of the objects were photographed and recorded in a digital database. As a result, the museum was among the first to put its entire collection online.[11]

[9] Pots, R. (2000). *Cultuur, koningen en democraten: Overheid & cultuur in Nederland*. Nijmegen: Uitgeverij SUN.

[10] Ministerie van WVC (1990). *Kiezen voor kwaliteit: Beleidsnota over de toegankelijkheid en het behoud van het museale erfgoed*. 's-Gravenhage: Tweede Kamer, vergaderjaar 1990-1991, 21 973, nr. 1-2.

[11] See https://www.volkenkunde.nl/nl/themas/geschiedenis-museum-volkenkunde.

Reflecting both the wave of privatization and opposition to government interference, 1993 saw the enactment of the National Museum Services Privatization Act (*Wet verzelfstandiging rijksmuseale diensten*) and a government subsidy via the Basic Infrastructure (BIS). Special funds were established for other government subsidies, including the Mondriaan Foundation in 1994, the incentive fund for fine arts, design and cultural heritage. Ultimately, the Delta Plan culminated in the bringing together in 1997 of the Netherlands Office for Fine Arts (*Rijksdienst Beeldende Kunst*), the Central Laboratory and the training programme for Restorers (*Opleiding Restauratoren*) to form the Institute Collection Netherlands (*Instituut Collectie Nederland*), which combined research, consultancy and the training of restorers with the management of the national collection. The Cultural Heritage Inspectorate (*Inspectie Cultuurbezit*) was tasked with guarding the quality of management and conservation of the collections held by the privatized government museums.

1994-the present Ministry of Education, Culture and Science.

By the end of the 20th century, the digital revolution was reaching its peak as the bursting of the internet bubble in 2001 heralded a moment of self-reflection, quickly followed by unprecedented growth in social media and networks. The industrial, oil, technological and plastic revolutions had left a trail of pollution. As both sexes were gainfully employed, the vacuuming and washing were left to cleaners and maids. In the meantime, the Earth continued to heat up as the third IPCC report was now able to declare with confidence.[12] This global overheating was also reflected in wider society. The attacks in New York and Washington on 11 September 2001 were followed in the Netherlands in 2002 by the murder of Pim Fortuyn and that of Theo van Gogh in 2004. The integration of ethnic minorities was causing political unrest as the Party for Freedom (PVV) became a confidence-and-supply partner in Premier Mark Rutte's first government term. The international credit crunch and economic crisis that followed created a widening gap between rich and poor. The Dutch government had little choice but to introduce major budget cuts. Eventually, when everything appeared to settle down, the COVID-19 pandemic struck the world in 2020.

In 1994, culture returned home and was welcomed back into the Ministry of Education, Culture and Science (OCW). Culture was expected to make a contribution to the national identity, bolstering cohesion and solidarity in a multicultural society. There was also an increased focus on culture in education, aiming to portray the Netherlands

12 IPCC (2001). *Third Assessment Report*. See https://www.ipcc.ch/report/ar3/syr.

Figure 7 *Full storage facility at Frisian Museum in 2005. Photo: Bart Ankersmit*

Figure 8 *Roof canopy over the National Maritime Museum inner courtyard. Photo: Agnes Brokerhof*

as an 'open, tolerant and peace-loving nation, in which diverse cultures can live together harmoniously and where, despite this diversity, there is a culture characterized by the Dutch language and character'.[13] This also fuelled a debate among museums on museum policy and art subsidies. The exhibitions in the art museums were no longer understood by the general public. Visitor numbers fell for the first time in years. The Cultural Outreach Action Plan (*Actieplan Cultuurbereik*, 2001-2004) aimed to change that by involving more people in culture, primarily targeting young people and minorities. At the same time, a new policy document entitled Culture as Confrontation – Principles on cultural policy in 2001-2004 (*Cultuurnota 2001-2004)* focused on more effectively showcasing cultural capital and cultural entrepreneurship.[14] The Accessible Heritage Project (*Project ErfGoed Bereikbaar*) was launched. Collections grew and the storage facilities invested in during the Delta Plan filled up once again (Figure 7). This unleashed a debate about why all these storage facilities actually existed: was it not possible for the objects to be removed, deaccessioned or put on display? The government had already answered these questions back in 1999 in its Guideline for Deaccessioning of Museum Objects (*Leidraad Afstoting Museale Objecten*), which was revised in 2006 with input from museum specialists. That same year also saw the compiling of the Canon of the Netherlands (*Canon van Nederland*), a chronological history of the Netherlands across fifty themes, as the basis for the National History Museum that never came into being. The term *collection mobility* was coined, and if objects were not to be physically accessible, digital access definitely needed to be possible. E-culture had the potential to reach a wider public.

Deaccessioning proved more difficult than it seemed as collections continued to grow and visitor facilities increasingly demanded more space. By the end of the first decade of this century, the Stedelijk Museum Amsterdam and the Amsterdams Historisch Museum (now Amsterdam Museum) both decided to construct their own storage buildings in Amsterdam-West and Amsterdam-Noord as a means of creating more space on their main sites in the city. They were fitted with sizeable climate-control systems. This was just too early to learn lessons from the major research project conducted jointly by the Heritage Inspectorate and Eindhoven University of Technology (TU Eindhoven), which revealed that strict climate specifications were unachievable in practice and confidence in the technology had been misplaced.[15]

The main themes of the policy document published in 2007 (*Kunst van leven. Hoofdlijnen cultuurbeleid voor 2009-2012*) were cultural participation, excellence and innovation.[16] The new BIS provided € 530 million in

13 Pots, R. (2000). *Cultuur, koningen en democraten: Overheid & cultuur in Nederland*. Nijmegen: Uitgeverij SUN.

14 Ministerie van OCW (2000). *Cultuur als confrontatie: Uitgangspunten voor het cultuurbeleid in de periode 2001-2004*. Zoetermeer. See https://www.parlementairemonitor.nl/9353000/1/j9vvij5epmj1ey0/vi3ahior13k3.

15 Erfgoedinspectie (2007). *Luchtspiegelingen: De mens en het museale binnenklimaat*. See https://docplayer.nl/7820569-Luchtspiegelingen-de-mens-en-het-museale-binnenklimaat.html

16 Ministerie van OCW (2007). *Kunst van leven: Hoofdlijnen cultuurbeleid 2009-2012*. The Hague.

funding for the cultural institutions, as the government stepped back, leaving the allocation to professionals. Adjustments were made to the way in which subsidies were granted. Central government funded the BIS, culture funds and management of the national collection. The provinces paid for diversity, distribution and the provincial collections while the municipalities were responsible for the accommodation and the municipal collections. The museums were facing an existential crisis, as they continued to see visitor numbers decline and government cutbacks also hit the culture budget. These cutbacks were supported by the population, providing proof of the extent to which museums had become remote from the public. Arnoud Odding described what he termed the 'network museum', a new type of museum with communities instead of target groups, focusing on meaning and changing values in the present day.[17] The idea was that museums should generate more of their own income in order to continue to receive funding and attempt to improve public support. They defended their right to a future by emphasizing their economic value as precious city treasures and their international appeal as an engine of the tourist industry.[18] They focused their activities on paying visitors by staging exhibitions, renting out facilities via events and fundraising. Spaces were created or modified in order to make it possible to host events. One example of this is the National Maritime Museum, which installed a roof canopy over its inner courtyards in 2011in order to host parties and events, see Figure 8. This example was soon followed by the Rijksmuseum and the Haags Gemeentemuseum (the municipal museum in The Hague) in their efforts to stage new public activities. In the meantime, the ministry combined the forces of the Instituut Collectie Nederland with the other heritage disciplines in the Cultural Heritage Agency of the Netherlands.

The calls for increased accessibility, visibility and reaching out to new audiences continued to resonate. The Netherlands Open Air Museum refurbished its entrance pavilion and opened the exhibition about the Dutch Canon in 2017. Many museums shifted their focus to the front end of the organization and towards revenues, at the expense of collection care. Already by 2016, the Heritage Inspectorate had warned that staffing capacity for management and conservation was starting to come under pressure.[19] Fewer staff faced an increasing workload, more museum loans and larger collections.

In the policy document devoted to the subject of museum synergy (*Museumbrief. Samen werken, samen sterker*) published in 2013, the subsidy granted to national museums was linked to the results they achieved in terms of cooperation, education and reaching out to new audiences. In order to strengthen the link between collections and the public, policy was based on two pillars: wide-ranging cooperation between museums themselves and with other partners, and the preservation of quality and access to the collection. Some € 2 million was made available in additional subsidies for cooperative projects, which proved to be a catalyst for the development of shared storage facilities, such as the Kolleksjesintrum Fryslân and the CollectieCentrum Nederland (see the article by Luc Schaap), providing a place for the collections from the Netherlands Open Air Museum, together with those from the Rijksmuseum, the Cultural Heritage Agency and the Paleis Het Loo (see the articles by Donny Tijssen and Wim Hoeben.) Sustainability was a key priority at both of these centres. Museum accommodation also became a source of debate. A large proportion of the funding received was spent on high rents that the 17 national museums paid to the Central Government Real Estate Agency. Since accommodation was seen as essential for the conservation, management and accessibility of collections, museums were eager to explore how they could gain greater control over their accommodation. At the same time, work was underway on a new Heritage Act that would also include movable heritage alongside built and archaeological heritage.

In the policy document on culture in an open society (*Cultuur in een open samenleving*) published in 2018, the emphasis shifted to the value of heritage to society. Heritage was seen as 'an excellent example of how culture can be a connecting force in our society'.[20] As society became more divided and diverse, it was up to culture to bring parties together. Art and culture had to be accessible to all, in urban as well as rural areas. At the same time, new genres and narratives had to reach out to people for whom the traditional offering of theatre, concert halls and museums had less appeal. In 2019 Ingrid van Engelshoven, Minister of OCW, commissioned a review of the Dutch Canon calling for 'a balanced focus on the stories and perspectives of different groups in

17 Irwin, A. (2011) *Het disruptieve museum*. The Hague: O dubbel d. See https://odd.nl/wp-content/uploads/2018/10/Het-disruptieve-museum.pdf.

18 Marlet, G., Poort, J., & Woerkens, C. van (2011). *De schat van de stad Welvaartseffecten van de Nederlandse musea*. Utrecht: Atlas voor gemeenten. See https://www.museumvereniging.nl/media/publicationpage/publicationFile/de_schat_van_de_stad-2.pdf.

19 Erfgoedinspectie (2016). *Zicht op de rijkscollectie*. The Hague. See https://www.inspectie-oe.nl/publicaties/rapport/2016/04/29/zicht-op-de-rijkscollectie.

20 Ministerie van OCW (2018). *Cultuur in een open samenleving*. The Hague. See https://www.rijksoverheid.nl/documenten/rapporten/2018/03/12/cultuur-in-een-open-samenleving.

society and for sufficient attention to be paid to the darker sides of Dutch history'.[21] By then, there were more than 600 museums, attracting a total of 34 million visitors. No one at that time could have suspected that visitors would completely stop coming to museums during the pandemic and 'Museum 2.0' would have to be rapidly put in place in order to reach the public in their homes, with virtual exhibitions, lectures and guided tours.

The future

Over the course of time, culture's role in society has shifted between artistic quality and social relevance. At the same time, museums have alternated between a focus on the preservation of collections and public access. There has been a shift in emphasis from material preservation to value management, as the heritage world has increasingly asked itself: whose values, for whom and with whom are we managing them? Museums are investing in curators and education staff with diverse backgrounds, telling new and different stories. Many museums are investing heavily in the public-oriented front-end of the organization to the detriment of the back-end that focuses on the collection. This calls for vigilance in order to prevent the need to once more deal with backlogs in the future.

In its newly-developed definition of the museum, the International Council of Museums calls for museums to take on a new role as social organizations with a political agenda.[22] Museums as 'social hubs' with more room for meeting and dialogue – out with the collection and in with the people. That collection will be displayed outside museums, at other sites, in temporary galleries and churches and combined with other forms of culture, such as dance and music. The Paris Climate Agreement and the energy crisis force museums to reduce their energy consumption even further. This calls for sustainable climate control, LED lighting and the controlled use of daylight. Works on loan will need to travel courier-free, virtual couriers become the new standard. The digitalization of the 'Collection Netherlands' continues apace, the digital generation gains inspiration from it, creating new designs and their own virtual exhibitions as the collection is able to remain in storage.

Government will need to make significant investments in healthcare, education, housing, infrastructure and the energy transition. Culture in turn can respond by seeking out collaboration in healthcare, education and housing and combining funding opportunities. This is already happening widely in the case of built heritage, for example at Fort WKU, where the conservation of nature and historic building is linked to employment for people who would otherwise be excluded.[23]

Taking their lead from the Faro Convention, museums are seeking ways to boost public participation and facilitate citizen initiatives that reveal different stories, value different heritage and value heritage differently. Museums need to reach out to a new public, and the public must gain greater access to collections. The solution chosen by Museum Boijmans Van Beuningen involves returning the collection from De Metaalhof and other external storage facilities back to the centre of Rotterdam and allowing the public access to the storage facility (see the article by Wout Braber). This is the storage facility as one big display case. Perhaps it is just an interim step on the road to the ultimate in participation and back to where everything started, with people's home collections: the private repository, where robots do all the vacuuming and the washing.

21 See https://www.rijksoverheid.nl/onderwerpen/voortgezet-onderwijs/nieuws/2019/05/31/james-kennedy-benoemd-tot-voorzitter-herijking-historische-canon-van-nederland.

22 See https://icom.museum/en/resources/standards-guidelines/museum-definition/

23 See https://www.fortwku.nl.

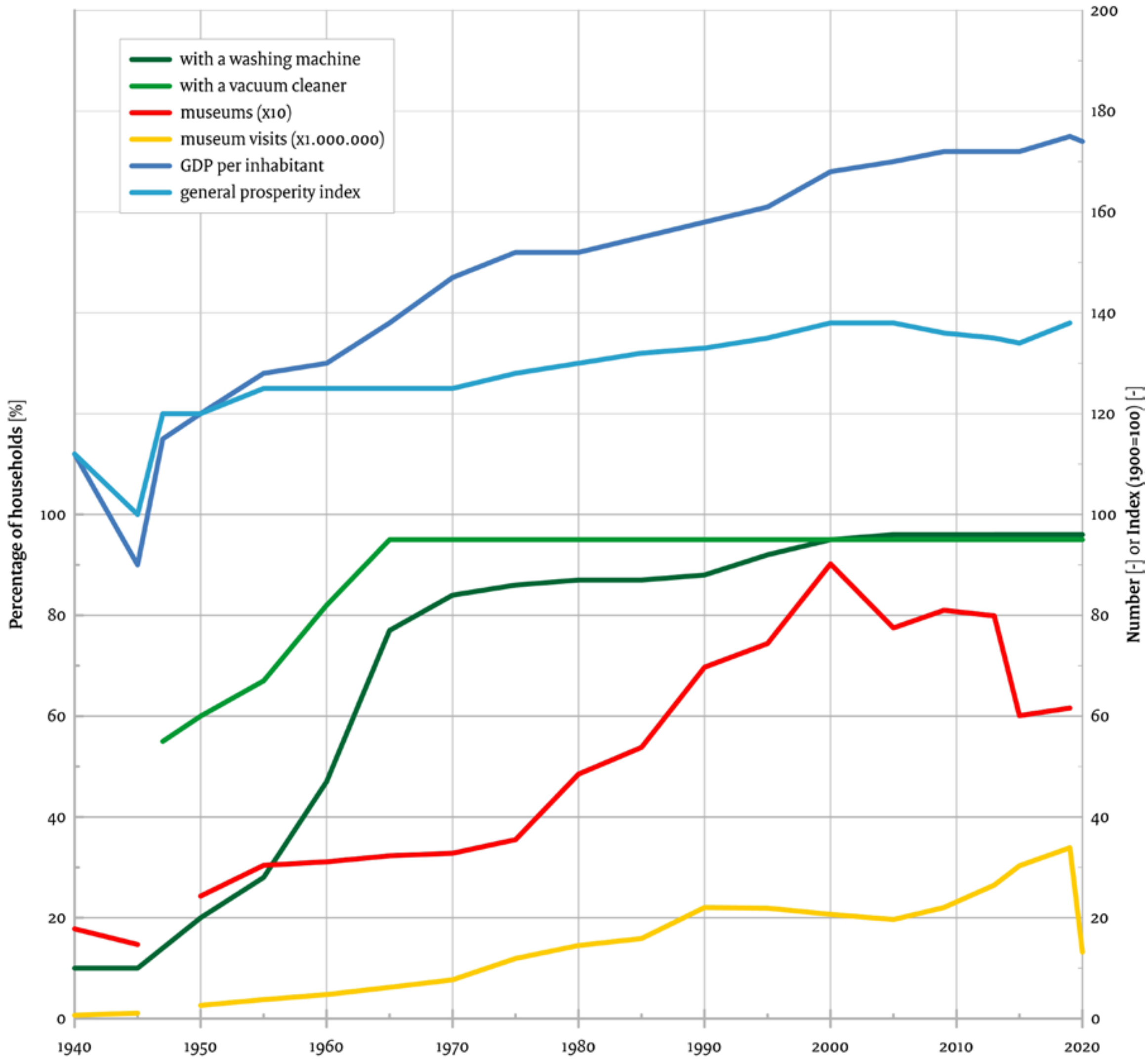

Figure 9 *Development of the Netherlands between 1940 and 2020*[24]

[24] Statistics Netherlands (CBS), see https://opendata.cbs.nl/statline/#/CBS/nl/dataset/37650/table?ts=1624283711270. Schot, J.W., Lintsen, H.W., Rip, A., & Albert de la Bruhèze, A.A. (Ed.) (2001). *Techniek in Nederland in de twintigste eeuw* (7 volumes). Volume 4: *Huishoudtechnologie, medische techniek*. Zutphen: Walburg Pers, Zutphen. p. 148. See https://www.dbnl.org/tekst/lint011tech04_01/lint011tech04_01.pdf. CBS (2010). *Terugblikken. Een eeuw in statistieken*. The Hague. See https://www.cbs.nl/nl-nl/publicatie/2010/51/terugblikken-een-eeuw-in-statistieken.

The storage facility of Museum Boijmans Van Beuningen in 2021. The first open museum storage facility in the world. Photo: Bart Ankersmit

From dream to reality – the role of the schedule of requirements

Jean Hilgersom – Project Manager, Museum Expansion, Kröller Müller Museum

Introduction

On average, a museum is refurbished around every twenty years. As a result, only very few museum staff have any experience of projects of this kind. When making adaptations to a building, they often appear to reinvent the wheel. As a means of preventing that, a systematic approach with a project team is a good way of working towards an optimum solution. Before any definitive list of wishes or requirements can be presented to an architect, that team will draw up a schedule of requirements (SoR). This design brief must stipulate all the functions important to the museum, how they will be used, what the overall appearance should be and how large these functions should be in order to enable the architect to create a suitable design. The most important purpose of a SoR is for the organization to make it clear to the architect what exactly the conditions should be in order to make it possible to work effectively and efficiently with the result, a museum building that works. This article explores the writing of a schedule of requirements. Since the process that needs to be followed for newbuild and renovation is very similar, any reference in this article to 'a building' may refer to a new museum building, refurbishment or extension.

Step-by-step process towards a schedule of requirements

The SoR is an overview of the purposes and functions of the building and the conditions it needs to meet in order to reflect the organization's vision and enable the required working processes in the museum or storage facility. These conditions, the set of requirements and wishes, can be considered as the (new) standard for the organization's working methodology in the new building. A careful description of the characteristics of the collection, building and organization can then be translated into a list of functional rooms or areas that combine to form the building. At the same time, the SoR forms the foundation for estimating the investment and operating costs.

The process is not linear

The development of an SoR is not a linear process: steps are repeated and information is evaluated and reformulated. Several activities that must always take place are:

- Describing the context
- Is there a vision in place? What is it all about? What type of collection is involved? What problem needs to be resolved?
- Setting up working groups
- Working groups are set up for a range of different themes, such as exhibiting, logistics, hospitality and catering, security and collection.
- Collecting information
- An SoR requires a lot of information, covering such areas as legislation and regulations, collection characteristics, desired functional relationships and the working procedure in the organization.
- Describing functions
- This is about describing the various functions of the building, security, mechanical engineering, etc.
- Collating information
- Information is processed, evaluated, integrated and where necessary improved.
- Writing and evaluating a draft
- Write a draft report that can be reviewed and completed by a specialist team on specific themes, such as security, sustainability and climate for collection and / or people.

The SoR expresses the organization's wishes, such as how the collection is treated and the operational processes that will happen in the building. In order to describe the working processes, information is required from all levels of the museum organization. It is a good idea to put together a project team that covers the entire spectrum of the organization and is capable of making the required information from the organization available. This covers topics such as collections, building and infrastructure systems and installations, but also operational processes and procedures. The project team formulates the requirements as accurately as possible, for example by detailing how many objects the collection contains, the volume of the collections (or parts of them), the extent to which they can be transported and the working processes in which they are used. Collections can often be spread across different places and even various locations. In order to draw up an SoR for a museum storage facility, a thorough survey of the collection is the only way of gaining a good sense of the total size of the building required. Only after such evaluation will it be possible to categorize the collection by type of object, size, type of material or storage method. Other essentials include questions concerning the access required to the collection, more general reachability, climate requirements, whether objects can be moved or are too fragile or whether they can be placed in mobile storage units or not.

Other crucial subjects in any SoR include an insight into risks (to the collection) and the associated risk-management measures at building level. This might include the risk of theft and security measures to prevent unauthorized access to the collection. The risk analysis should be based on the ten agents of deterioration that can result in a loss of value of (part of) the collection.[25]

It is useful if the project team collates all the information clearly in the form of charts to ensure that it is easily read and understood by stakeholders. The collected information needs to be translated into size of the rooms and storage furniture. For the individual storage cabinets, this might include length, height and depth and, of course, quantity. But it could also include the breakdown in terms of fixed and mobile cupboards, racks and shelving. For the purposes of the SoR, there will be research into the different ways of arranging the collection by type of material, type of object, climate class, accessibility and security. The result will be the most efficient method of arranging the collection. To a large extent, the storage method determines the size of the storage facility, taking account of the width of any corridors or aisles and accessibility of the storage racks and shelves. If a rack does not necessarily need to be reachable by trolley or if it can be mobile, this will affect the number of aisles, enabling a much denser collection storage than using fixed furniture.

Detailing the working processes

The analysis of the characteristics of the collection is directly linked to the working method applied and can therefore prove useful in detailing the desired future working procedures. This forces the parties involved to flesh out future working processes in more detail, which can be helped by means of such questions as these:

- What is needed in order to be able to work effectively?
- What functions are required? These may include transport equipment (and its storage), collection registration, photography, restoration and space for quarantine.
- How will people and the collection move from one functional area to another?

It is also recommended that consideration be given to the digital infrastructure in order to optimize collection access and accessibility. However, there can be a clash between the collection's accessibility and security.

[25] Brokerhof, A., Ankersmit, B., & Ligterink, F. (2016). *Risicomanagement voor collecties*. Amersfoort: Cultural Heritage Agency of the Netherlands. See: https://www.cultureelerfgoed.nl/publicaties/publicaties/2016/01/01/risicomanagement-voor-collecties.

Obviously, organizational protocols will need to be developed to tackle this, which can also have repercussions in terms of the building's use. In many cases, measures will be taken that are not only organizational in nature, but also require space. This may include facilities for security and technology, such as space for server equipment and airduct systems, and for staff and visitors, a lunch room, cloakroom, toilets, bicycle storage and parking space.

The position of the SoR in the project

In the development of any building, there are four consecutive phases, from the initial idea to completion of a building:

1. definition phase;
2. design phase;
3. construction phase;
4. inaugural use.

Each phase is divided into subsidiary phases.
For example, the design phase comprises the concept design, schematic design, developed design and technical design. To enable these designs to be completed, the SoR is written in the definition phase. The SoR often marks the conclusion of this phase.

Translating working processes into space

Often, an external consultant is deployed to work with the project team in writing the SoR, which of course is only possible with information he or she obtains from the museum organization via the project team, because an external consultant is incapable of articulating the finer details of operational processes and ambitions for the collection without the input of people directly involved. As a result, various sessions will be needed in order to discuss everything properly.

During the development of the SoR, there will be countless, often very practical questions that require answering, such as questions about working processes, collection access, general accessibility, usability, collaboration, room finishings, room dimensions, climate control, security and risk management. However, this is preceded by an important theoretical question: what is the heritage organization's vision for the building? This question often covers three different dimensions: working with the collection, receiving visitors and using the building.
This not only applies to buildings used for exhibiting, but also to storage facilities. In the process of achieving the ideal working conditions in the storage facility, a dream

can become reality. It is a process to go from the ideal, dream situation, the vision, to a new working environment as described in the SoR – in other words a realistic schedule of requirements, and not of dreams.
The process leading towards that is intensive and requires a lot of mental capacity from an organization. Taking a critical look at the existing way of working with the collection, considering alternative working methods and determining new methods for the long-term is not easy. The working processes formulated in this way will form the basis for what happens in the new storage facility building, such as the storage of objects, registration of the collection, quarantine, restoration, photography and logistics. These working processes can be divided across the functional rooms and the relationship between them. Examples of working processes that occur frequently in museum storage facilities are (in no particular order):

- Object delivery process: arrival, unpacking, assessing, registering, photographing, moving, storing.
- Object departure process: can delivery and departure happen simultaneously in the same room?
- Restoration: will the building have a restoration department? What aspects of museum object restoration have an effect on the building, the rooms and room specifications?
- Furniture and transport equipment: what will be stored where? What equipment or resources are needed or available and how will the choice be determined? How will objects be transported internally?
- Object needs salvaging after an emergency: what equipment or resources should be stored and where do we do that?
- Arrival of staff in the building, the development of protocols (what impact do protocols have on the building?), translation into rooms and room specifications.
- Are there workstations, office spaces, a canteen, a cloakroom, facilities?
- Arrival of other goods: is a separate entrance required for this?
- What else will be organized in the storage facility, such as workshops, education, exhibition preparations?
- Archiving of work documents.

Rooms required for these processes might include:

- a loading dock;
- a room for packaging materials;
- a quarantine room;
- photography area;
- space to store transport equipment;
- electric charging space;
- restoration area.

Each process can be described using a flowchart in order to ensure clarity with regard to the sequence of the process and how functional rooms will be positioned relative to each other. Figures 1 and 2 show a highly simplified flowchart for an imaginary storage facility, for an object arriving and departing.

The charts make it obvious that it is only possible to detail these relationships with input from museum staff. For this reason, the scenarios are discussed with them. The box shows a possible scenario for the arrival of objects in the storage facility.

Scenario: arrival of an object in a storage facility
An object arrives at a storage facility at the entrance, usually some form of loading dock. Here, it is removed from the vehicle as safely as possible. There is a clearly-defined protocol outlining handling of the collection. The transport box arrives in a packing and unpacking room, where there is a large table on which the object can be placed. In this room, there is access to equipment and materials for packing and unpacking; if necessary, alternative packing and unpacking materials can be found in an adjacent room. During unpacking, an assessment is immediately made of how clean the object is: can it go straight into storage or is cleaning required first? Will the object need to be placed temporarily in quarantine?
Separate hoisting equipment will be present for very heavy objects. The height and structure of the room is designed in such a way that it is also possible to manoeuvre large or heavy objects easily using this crane. Transport boxes are kept in a separate room close to the packing and unpacking room.
The object is registered and transported to its position in the storage facility in the appropriate way.

The museum organization must develop various scenarios for incoming objects in order to ensure there is a focus on proper handling and reducing any potential risks. After unpacking, the object is generally registered, and then examined, analysed and checked for damage. This can take place in the packing and unpacking room. Alternatively, it can be done in a separate room, the registration room. In this room, adequate access is required to specific tools that are frequently used.
The registration process may also involve photographing the object in a photo studio. It is then transported to the storage room. For that transport, trolleys will probably be used and a location to park these trolleys will need to be

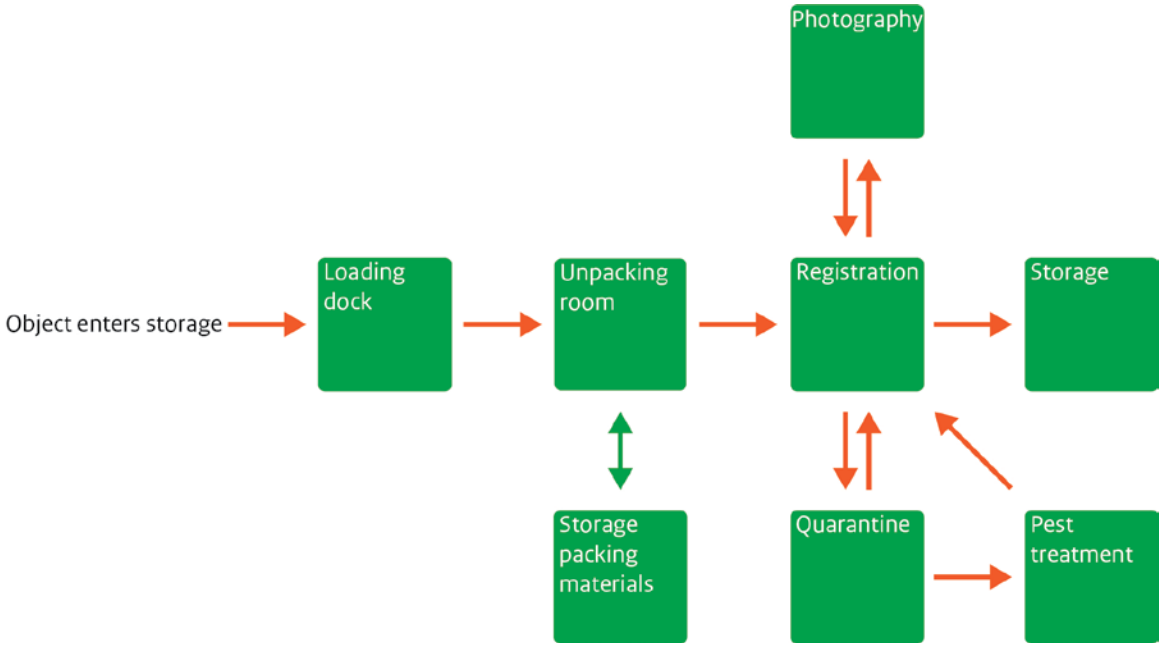

Figure 1 *Flowchart showing functional areas for an incoming object in an imaginary storage facility. Image: Bart Ankersmit*

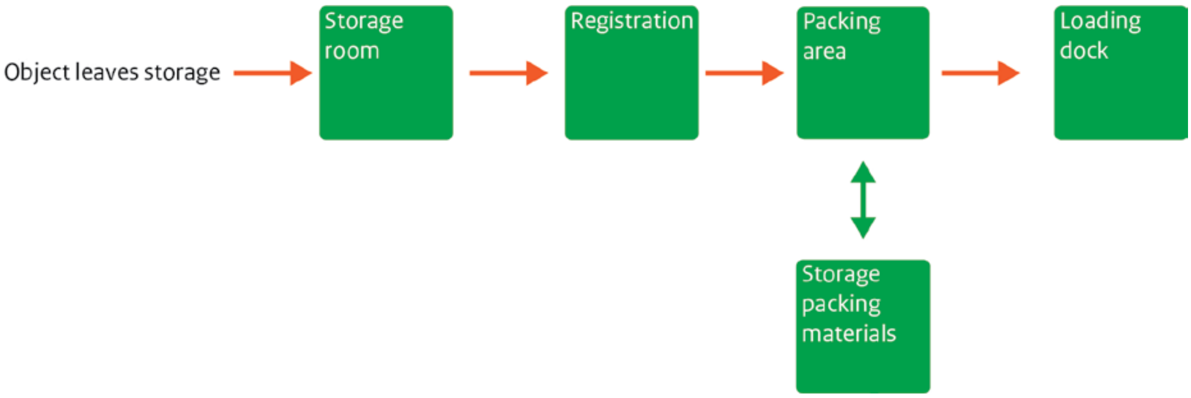

Figure 2 *Flowchart showing functional areas for an outgoing object in an imaginary storage facility. Image: Bart Ankersmit*

available. If there are electric trolleys, (fire-safe) charging facilities must be available, possibly in a separate room.

The object's route out is more or less the same as its arrival, but in reverse order. In this, it is important to consider the space required carefully: objects arriving and departing must not obstruct each other. Organizational agreements will need to be made about this. If special transport boxes need to be produced in the building, a wood- and metal-working area will be needed. Which ideally is close to the packing and unpacking room.

Collection managers know exactly how objects enter and then leave the building, security staff know how the building should be compartmentalized and which procedures are to be followed and facility staff know exactly how the climate systems create an appropriate climate. All this information needs to be collected and also presented in a new flowchart. This can visibly show the different zones for security and climate. An imaginary schematic example is shown in Figure 3. Ultimately, these charts are used to choose the optimum configuration of rooms and zones.

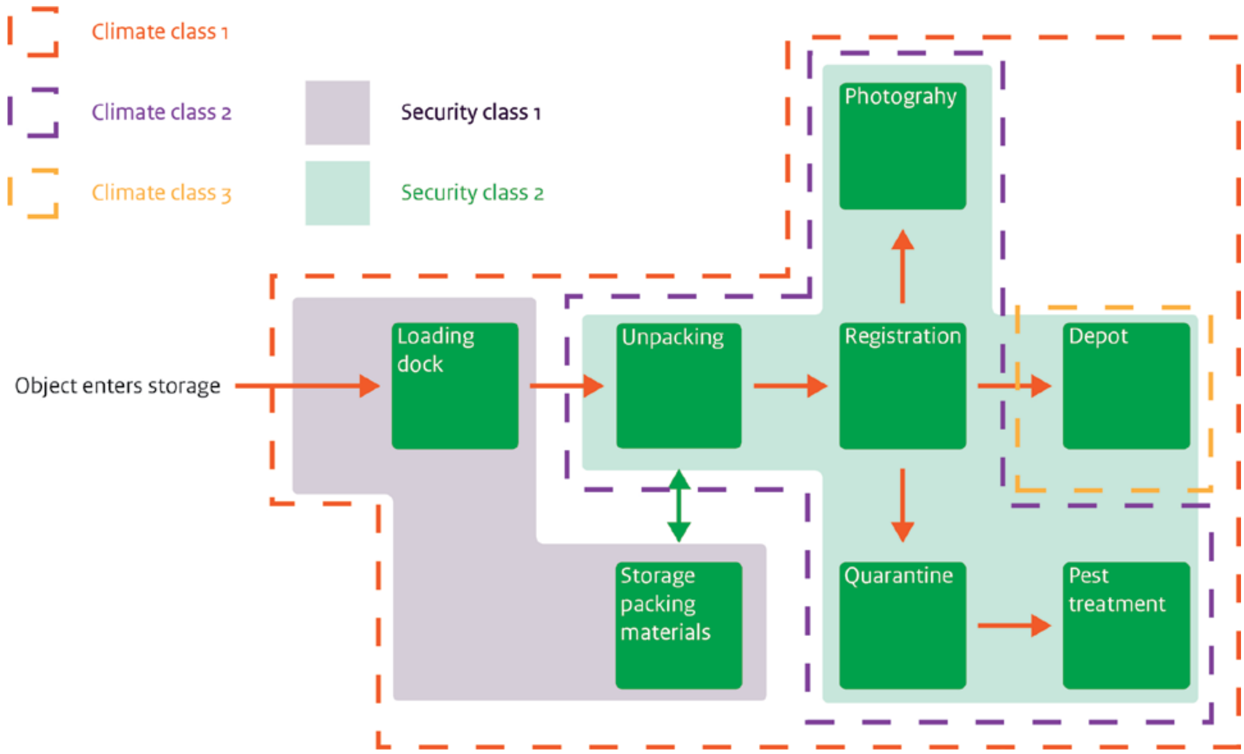

Figure 3 *Flowchart of functional areas for an incoming object with two climate and security classifications. Image: Bart Ankersmit*

Designers
The quantitative details of everything laid down in the SoR ultimately need to be converted by a team of experts into products, such as design and construction drawings. For example, the climate requirements, expressed in degrees Celsius and percentage relative humidity will need to be converted into systems made up of air ducts and pipes. Designers involved will include the:

- architect – for the design of the built environment;
- installations consultant – for the design of the systems and ducts;
- building physicist – for the design of energy and moisture-management concepts;
- structural engineer – for the design of the building's load-bearing structure.

Writing an SoR

The SoR is a physical document. In it, the findings, wishes and requirements are presented. The box shows an example of what the table of contents might contain. Please note: this is not a representation of the process; new-build projects for museum storage facilities can often start with the outfitting, (see the article by Cindy Zalm).

Example of the table of contents of an SoR
1. Brief and objective
2. General requirements
3. Functional aspects
4. Functional requirements
5. Security requirements
6. Sustainability requirements
7. Structural requirements
8. Building physical requirements
9. Installation requirements
10. Outfitting requirements

Writing an SoR comprises four steps, shown here as layers: Figure 4 depicts these layers in a chart.
The innermost layer is slightly more abstract and as we gradually move outwards, the requirements must be formulated increasingly precisely.

- Layer 1: vision and ambition
- The SoR starts with the description of the vision and ambition: where does the organization wish to be and why does it wish to care for the collection in the long

term? Questions that may prove helpful here are: what is the museum's focus? What factors are important in this? What is the strategy for achieving the vision?

- Layer 2: problem and solution
- A new or modified building is all about resolving a problem and finding the solution, so what is the problem? What are the basic principles for the solution being sought? Where will the storage facility be? The location may mean that adaptations are required. For example, measures may be needed to account for the groundwater level, local industrial activities and the accessibility. Legislation, regulations and standards will also need to be considered for safety, health, usability, sustainability, energy efficiency and the care of the environment. This is the second layer around the vision and ambition.
- Layer 3: organization policy
- The third layer is the organization's policy with regard to accessibility, security, climate and sustainability. This policy will definitely have an impact on the use of rooms and the working procedures. Clarity on such matters can prove hugely helpful in drawing up an SoR. Often, organizations can discover during the writing process that they have no clear policy on accessibility, for example. Of course, this is not really a major problem. In this respect, writing an SoR provides an organization with a useful tool for considering a range of subjects, making choices and developing a strategic direction.
- Layer 4: description and relations
- Once the first three layers have been configured, this is then followed by the further description of rooms in relation to their use and the working methods, specifications of size, volumes, structural finishing, technical installations, special requirements, outfitting, logistical requirements and landscaping the site. All of these subjects can now be described.

Some of these subjects are interdependent and influence each other. For example, the climate installation requirements have an influence on the structural requirements. If the climate control systems become bigger and therefore heavier, there may also need to be adaptations to the load-bearing floor. Building physical requirements determine climate installation requirements and vice-versa: a well-insulated passive building will need considerably less technology to maintain a stable temperature than an uninsulated building envelope. The process adopted for security and climate also involves thinking in layers. A climate-stable, well-secured core area for collections and a public space for visitors in the outer layer which is less climate-controlled and adequately-secured. The Collectie-Centrum Nederland has been designed based on a head, neck and torso, each with its own separate security and climate classification (see the articles by Donnie Tijssen and Wim Hoeben).

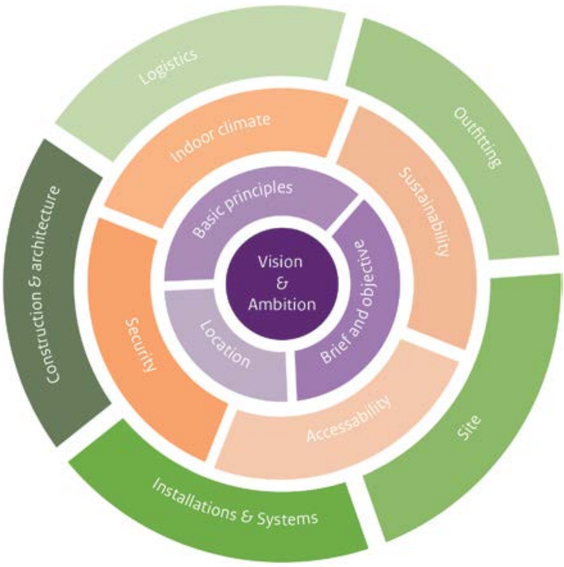

Figure 4 *Diagram depicting the different layers contained in an SoR. Image: Bart Ankersmit*

Quality document for the longer term

The SoR is not only important for an architect at the outset, but remains the frame of reference throughout the entire project. After that, during the in-use phase, the SoR is important for verifying whether the working processes and what has been designed actually match what was intended and whether the working procedures still reflect what is applicable. Organizations change as a result of societal changes, through the improvement of working processes and possibly new functions, as a result of which the original SoR will no longer reflect the new reality. Identifying these changes may reveal possible trends to which the museum organization is adapting. An SoR will never last forever: it is a document that adapts with the dynamic of time. There are countless examples of newly-built museums that needed to be adapted several years following completion, for example because the assumptions about growth in the number of visitors turned out to be different than expected. For example, the Guggenheim Museum that was opened in Bilbao in 1997 underwent various major adaptations within a decade in order to accommodate the larger flows of visitors than originally expected.[26] Even after extensive refurbishment (2000-2014), the Rijksmuseum was forced to adapt its cloakroom within two years because of the large increase in visitors. Museum storage facilities will also be subject to changes in society and improvements. It is essential to keep track of these changes in the SoR in order to record the quality requirements and to clarify exactly why operation turns out to be different than intended or in order to justify and account for future investments.

Finally

There is no doubting the importance of an SoR. It is a quality document and frame of reference. More than just a description of the building, it also provides insight into the organization's working processes and objectives. This not only applies during the design and construction phases, but throughout the building's lifespan. The more effectively the schedule of requirements describes what museum operations require, the more satisfied museum users will be. It will also make passing on collections to future generations – the main purpose of any museum – easier and more efficient. Because a museum organization is not set in stone, the SoR needs to grow and adapt with it. This also provides an insight into the extent to which adaptations are needed. This means it is worthwhile for organizations to invest in an SoR and keep it up to date and alive.

26 Loddo, M. (2019). Storage facilities for the collections of western art museum. *Ricerca sul Restauro e la Conservazione* (12), 154-156.

Benchmark for museum storage facilities

Merel van Heesewijk – Collection Service Officer, Dutch National Museum of World Cultures

Summary

In order to compare quantitative data concerning storage buildings, the *Benchmark voor Museumdepots* ('Benchmark for Museum Storage Facilities') has been developed: a method that offers collection managers an insight into the opportunities and impact of certain choices early on in the construction process. This article will explain the usefulness and application of this benchmark based on questions that are of relevance to collection managers.

Background

Since 2019, the Nationaal Museum van Wereldculturen has been working with the Rijksmuseum Boerhaave, Museum De Lakenhal and the municipality of Leiden to explore the possibility of developing a storage building that the three institutions can all use to store their collections: Collectiecentrum Leiden ('Leiden Collection Centre').

During the preparation phase for new storage buildings, attention often turns to recently-developed storage buildings. Visits to storage facilities provide a valuable source of inspiration and allow collection managers to share experiences with peers who were closely involved in the project. However, these visits often fail to explore the qualitative data that formed the basis for the building. Because these data are not shared with external parties, storage buildings merely provide a source of inspiration. However, if these data are made available, this increases our joint knowledge and enables us to understand the impact that choices have.

Storage buildings vary considerably, in terms of location, furnishing and use. The Kolleksjesintrum Fryslân (Collection Centre Friesland), for example, was developed based on a brief to keep the cost of operations, such as energy, as low as possible going into the future. This is why sustainability was a key factor for the design. On the other hand, the development of Depot Boijmans Van Beuningen in Rotterdam focused on creating an interesting visitor experience for large numbers of people. The development of a benchmark, which enables information about various aspects of realization and operation to be collected and compared, enables developers of storage facilities to use the available data to fine-tune their own wishes and ideas.

This article presents the development of a Benchmark for Museum Storage Facilities and the results achieved. It focuses specifically on the answers to four questions that anyone faces in the development of a new storage facility:

1. How many square metres will be required for the storage building in order to accommodate the desired functionalities?
2. How many square metres of storage space will be needed?
3. What is the budget required for the storage building?
4. What is the budget required for furnishing the facility?

The section 'The benchmarking method in context' looks at the type of benchmarks developed previously, after which 'Development of the Benchmark for Museum Storage Facilities' explores how the benchmark came about and how it is structured. In the section entitled 'Data analysis', it will be explained how benchmarking data provide input for answering the four key questions in a new construction project. In the section 'Collectiecentrum Leiden', the values from the benchmark for the Leiden project will be compared with the values determined according to a bottom-up method for drawing up a business case. At the end a reflection on the benchmark itself will be presented.

The benchmarking method in context

The benchmarking method is applied widely in business. Van Assen describes how benchmarking is used to systematically compare the performance of different organizations.[27] One can use this kind of comparison to determine how one's organization is performing vis-à-vis other organizations or as a means of measuring the impact of improvements. According to *The Benchmarking Handbook*, this method is suitable for institutions with overarching functions and is used for quantitative comparisons, to compare trends and to identify potential improvements.[28] The method involves collecting data based on a survey, after which averages and deviations from the average can be calculated. It is possible to compare the results by analysing the figures in terms of production per employee or, in this case, analysing investments and calculating the investment per square metre.

[27] Leen, J., & Mertens, J. (2015). *Praktijkgericht onderzoek in bedrijf*. Bussum: Coutinho.

[28] Andersen, B., & Pettersen, P. (1995). *The Benchmarking Handbook*. London: Chapman & Hall.

Applying benchmarking to museum institutions is not a new development. *Benchmarks in Collection Care* explores the steps taken to meet conservation requirements and guarantee sustainable storage.[29] The results of benchmarking have also been published in the Netherlands. Since 2007, the *Museum Analyse Systeem* (Museana) has sent out an annual survey collecting information about visitor numbers, exhibitions and data about Dutch society, etc. The accompanying results are published in *Museumcijfers*.
In *Performance of Danish low-energy museum storage buildings30*, benchmarking was used for the first time to compare storage buildings with each other. This study focused primarily on energy consumption at Danish sustainable storage facilities developed according to the so-called Danish Model. As a result, the values revealed in the benchmark are only of use in identifying differences in energy consumption for buildings developed according to the same principle or in showing how buildings built according to a different principle differ from these Danish buildings.

The information included in the Benchmark for Museum Storage Facilities can be used to gain a better understanding of key construction cost indicators and the effect of certain choices in the development of storage buildings in the Netherlands. As a result, early on in a construction project collection managers can gain an insight into the cost per square metre or per object, the ratio between gross floor area (gfa) and net floor area (nfa: the square metres of gfa excluding space for structures), and the influence that building functionality has on construction costs.

Development of the Benchmark for Museum Storage Facilities

In order to gain an understanding of the issues of relevance for museum staff when developing a new storage facility, discussions were held with staff who have been closely involved in this kind of storage construction project in recent years. The result was a questionnaire focusing on four aspects: construction costs, energy consumption, accessibility and furnishing of the facility. The results of the questionnaire are the so-called performance indicators, i.e. the variables that can be used to describe the storage facility in quantitative terms. When all of the different answers to the questions are collated, this reveals new information. This collated information is referred to as the *key performance indicators* (KPIs). The results from various museums are then compared with each other, making it possible to identify averages, bandwidths and outliers. It is up to the institutions themselves to make the assessments, based on the results for the objectives they set themselves rather than any clear definition of what constitutes good or bad. This enables them to assess the financial consequence of their ambitions based on other storage buildings that have been developed.

When drawing up the benchmark only data was collected from storage buildings that have been developed recently. This is because it proved impossible to collect all the necessary data for older buildings. If any institution did not have access to certain data, this element was omitted from the results. Research has shown that there has been an increasing focus on the sustainable construction of storage buildings since 2010.[31] One could ascertain the degree of sustainability by looking at the energy consumption per square metre, but annual energy consumption also depends significantly on the weather and other factors. So far it was impossible to obtain data about energy consumption across several comparable years for all of the buildings included in the benchmark. For that reason, this aspect is not considered here. Table 1 shows the storage buildings for which data have been processed. Important information about each building is also provided.

[29] Collections Trust (2013). *Benchmarks in Collection Care. For Museums, Archives and Libraries*. Collections Trust.

[30] Ræder Knudsen, L., & Rosenvinge Lundbye, S. (2017). *Performance of Danish low-energy museum storage buildings*. ICOM-CC 18th Triennial Conference Preprints. Consulted on 15 July 2018 via http://www.konsv.dk/wp-content/uploads/1515_200_KNUDSEN_ICOMCC_2017.pdf.

[31] Ankersmit B., Loddo, M., Stappers, M.P.M., & Zalm, C. (2021). Museum Storage Facilities in the Netherlands: The Good, the Best and the Beautiful. *Museum International* (73), 132-143.

Table 1 *Overview of storage buildings showing basic data*

Depotgebouw	**Year of realization**	**Gfa in m^2**	**Nfa in m^2**	**Storage facility in m^2**
NEMO Science Museum Depot	1993	2,635	2,600	892
Naturalis storage tower	1998	15,000	-	8,000
National Maritime Museum Het Behouden Huis	2001	4,185	3,937	2,200
Collectiecentrum Amsterdam	2011	7,000	5,600	3,659
Kolleksjesintrum Fryslân	2015	3,007	2,757	1,915
Depot Ghelamco Arena	2018	3,156	2,500	2,522
Louvre Conservation Center	2019	20,000	18,500	9,600
CollectieCentrum Nederland	2020	31,626	27,710	23,600
Depot Boijmans Van Beuningen	2020	15,540	-	3,800

Data analysis

The data in the questionnaire provide input for responding to the four key questions when developing a new storage building. This is discussed in this section.

What is the size of the storage building and the storage space?

Early on in the process of development, collection managers want information about the required dimensions of a storage building and rooms. For this purpose, several answers from the questionnaire can be used, such as: gross floor area (gfa), net floor area (nfa), square metres of storage space and the number of objects.

One can examine practical examples based on the various KPIs. Figure 1 shows that the bandwidth for the gfa/nfa ratio is between 83% and 93%. The gfa is made up of the square metres of floor area including such elements as walls. The nfa is made up of the square metres of floor area, excluding the space used for structural elements, such as walls, columns and pipe ducting. In other words, the space that can actually be used. At the Kolleksjesintrum Fryslân (KSF), the gfa/nfa ratio is relatively high (92%) because it is a single-story building, but it is lower (88%) at the CollectieCentrum Nederland (CC NL), because the building has several floors. The need to support upper floors places requirements on the walls and the number of columns needed.

Figure 1 shows the number of square metres of storage space for each storage building. This averages out at 50%. This KPI is useful in order to gain an insight into the influence that the function of the building has. The results reveal that if a storage facility is more accessible to external visitors, the percentage of floor area of storage space relative to the gfa falls. A good example of this is the storage facility, Depot Ghelamco Arena (DGA). This achieves the highest score for this aspect (80%). This is because it is the only storage building used solely to store objects. Other storage buildings also include working areas. The Depot Boijmans Van Beuningen (DBVB) has the lowest percentage of storage space relative to gfa (24%). This is because the museum aims to admit the public to the storage facility on a large scale, there are staff working on site and part of the building is let to third parties. This not only means that more working space was included in the design, but that more public areas, sanitary facilities, facility areas, climate-control systems and wider aisles or corridors are needed. The difference between KSF and CC NL is because ten times as much space has been created in the case of CC NL, but the number of square metres of working space has not increased proportionally.

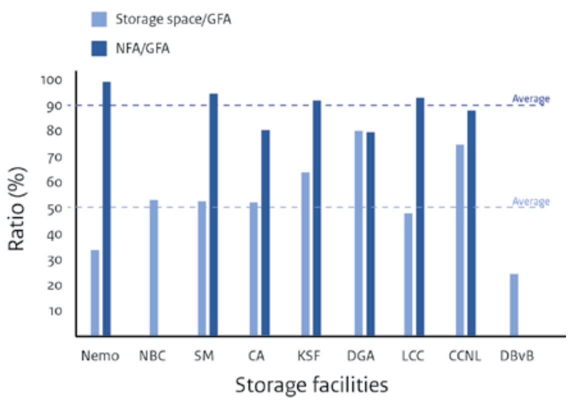

Figure 1 *KPIs for percentage of storage space and nfa relative to gfa. Image: Merel van Heesewijk*

What is the budget required for the storage building?

Alongside the amount of space required, the development costs are also a key element. The total construction costs are the sum of all of the contracts awarded to building contractors. When comparing the costs of construction for different storage buildings, it is important to ignore the cost of land. Quite aside from the fact that the cost of land varies year by year[32] and by location[33], land is not always purchased and there are also situations where the option of leasehold is preferred. It may be of interest to include the cost of land in the benchmark if research is conducted into the differences between building in a central location or one that is much less central. This is why these costs have been assessed separately and an average calculated based on the available data. According to the data available, the cost of land ranges from € 1.2 million to € 16 million for the plot. This shows that the cost of land accounts for around 16% of the total cost of construction.

In order to compare the construction costs of different storage buildings, KPIs were calculated. Figure 2 shows the number of stored objects per square metre of storage for each storage building together with the construction costs for each stored object (excluding the cost of land). Ideally, the construction cost for each project should have been indexed using the same price level. This has not been done in this case, but will prove necessary in the further development of this benchmark. In calculating the average cost of construction for each stored object, the decision was made not to include the two outermost values (for DGA and DBVB) in the calculation. This is because DGA is the only storage facility developed within existing walls, which means it is essentially an integrated storage facility. Compared to other storage buildings, DBVB has high development costs (€ 411 per stored object compared to an average of € 88). This storage building was designed as a landmark building at the heart of Rotterdam, providing full public access to the complete collection. Generally, the average construction costs per square metre for working areas and visitor facilities are higher than for storage rooms. This is because of the different level of finishing, the need to offset disruption to the climate and the security measures required in areas where it is less possible to restrict access than in storage areas. Compared to other buildings, DBVB has a very low percentage of designated storage space relative to gfa (24% compared to an average of 50%), which perfectly explains why the development costs turn out to be relatively high. Moreover, the building's circular shape means that space is lost if rectangular blocks of storage units need to be used, as a result of which fewer objects can be stored per square metre. The Louvre Conservation Center (LCC) in the French city of Lens also has higher development costs per object compared to other buildings. There may be various reasons for this. As Figure 3 shows, a large amount of the space in the LCC building is used for other purposes than storage space. As a result, fewer objects can be stored in the storage building. It also has a higher proportion of functional rooms than other storage buildings, which may have increased the cost of construction.

In calculating the average figure for the number of stored objects per square metre, the Naturalis Biodiversity Centre storage tower was not included. This is because much of the Naturalis collection comprises insects and plants, which are generally small and can be stored very compactly. As a result, Naturalis stores an average of 3,750 objects per square metre of storage. This is exceptional and unachievable for most other collections. Looking at the other buildings, KSF stands out because it stores a relatively high number of objects per square metre of storage: 209. This is because most of the storage areas in the KSF have been fitted with double-decker storage units. The CC NL uses double-decker storage units in some storage rooms, but, at 21, the number of stored objects per square metre of storage is significantly lower. This may be because CC NL has more large objects in its collection, making efficient storage more difficult. In the storage zones for the large objects, no double-decker storage systems have been used and the aisles are significantly wider than elsewhere in the building. The fact that the CC NL was built only recently is another reason. Part of the building still has space for the collection to grow. This area is currently still empty, whereas all of the space in older storage buildings has already been taken up by additions to the collections.

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32 Leve, E. de, & Kramer, I. (2020, August). *Wat is grond waard? Onderzoek naar gemeentelijk grondprijsbeleid*. Stec Groep commissioned by the Association of Municipalities in the Netherlands (VNG). Consulted op 10 February 2019 via https://vng.nl/sites/default/files/2020-08/19.430-stec-groep-wat-is-grond-waard.pdf.

33 Leve, E. de, Geuting, E., & Kramer, I. (2019, December). *Benchmark Gemeentelijke Grondprijzen 2019-2020*. Stec Groep commissioned by the VNG. Consulted on 17 March 2019 via https://stec.nl/wp-content/uploads/2020/01/Stec-Groep-Benchmark-gemeentelijke-grondprijzen-2019-2020.pdf.

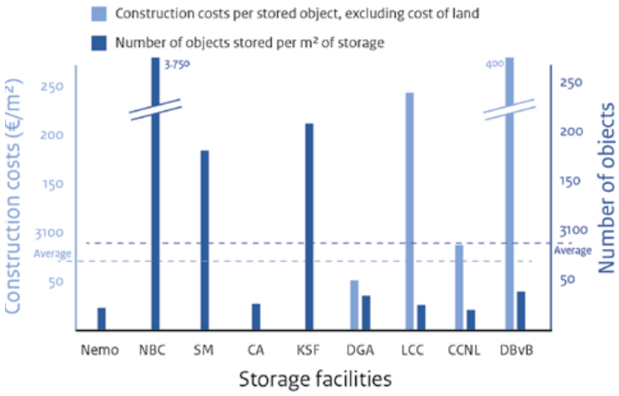


Figure 2 *KPIs for construction costs per stored object and number of stored objects per m2 of storage. Image: Merel van Heesewijk*

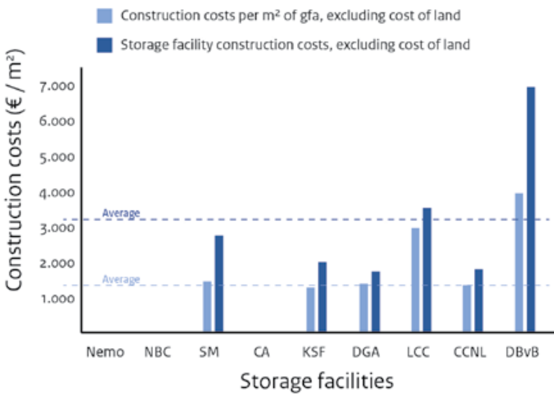


Figure 3 *KPIs for construction costs per m2 of GFA and storage rooms. Image: Merel van Heesewijk*

What is the budget required for furnishing the facility?

The investment required for double-decker storage units is greater than for conventional shelving units. This is clearly demonstrated by the costs KSF paid for its furnishing, see Figure 4. This means that the type of storage chosen has an effect on the ultimate price. Painting racks are relatively more expensive when one considers the investment per square metre of floor area. In the case of DBVB, the proportion of mobile painting racks explains the high cost per square metre (€ 436). While KSF has the most expensive storage furnishing per square metre of storage (€ 574), DGA has the lowest investment (€ 79). Not only does DGA not make use of any double-decker storage units, the ceilings are also lower, resulting in lower storage units being used. Although the use of double-decker storage units results in a higher investment in storage equipment, savings are also made in the installation of structural floors. Using the values in the benchmark, it is possible to calculate the impact of a future building.

The data collected in the benchmark enable us to calculate averages and to work backwards, i.e. taking the average values and using them to make an initial estimate of the size and costs of a new collection centre. It is generally possible to determine how many objects the collection contains and how many objects need to be stored in a new storage building. The benchmark makes it possible to multiply this by the average cost per object, both for construction and furnishing. Since choices made in the design process may influence the size of the building and the cost of construction, one can also opt for using data from a storage building that corresponds with one's own preferences. In other words, there are various ways in which the benchmark can be applied. This specific aspect was tested in the case of the Collectiecentrum Leiden (CCL).

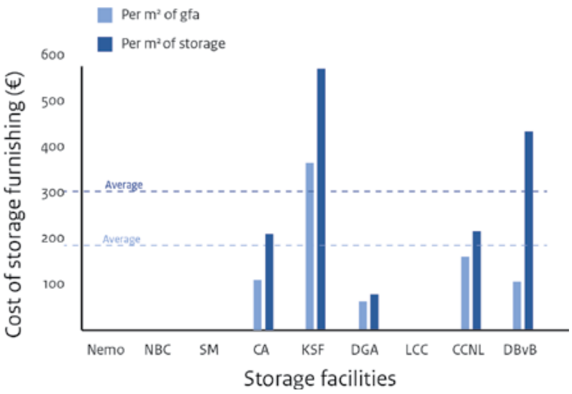


Figure 4 *KPIs for the costs of storage furnishing. Image: Merel van Heesewijk*

Collectiecentrum Leiden

In terms of the building's accessibility, the CCL is comparable to the CC NL and LCC. Both of these storage buildings are not only accessible to staff, but also to the public to a limited extent. CCL will allow researchers, students and communities appointment-based access. In addition to storage space, offices and workshops will also be built. Double-decker storage units will be used in storage areas.

As the construction process is in its initial stages, very little data is currently available. When only the number of objects is known, an estimate of the storage furnishing and construction costs can be made based on the average from the benchmark.

This can be done using this formula:

$$\text{Storage floor area required} = \frac{\text{total no.of objects}}{\text{average no.of objects per m}^2} = \frac{591{,}000}{70} = 8{,}443\ \text{m}^2$$

In other words, it can be assume that CCL will need 8,443 m² of floor area for storage.
The average furnishing price per square metre of storage space is € 303 (see Table 2). € 303 multiplied by the number of square metres of storage space required, in this case 8,443 m², amounts to a required budget of € 2,558,186 for storage equipment. That is the equivalent of € 4 per object.

To calculate the total size of the storage building, the average percentage of storage space relative to the gfa is used (50%). This means that the CCL will require 16,886 m² of gfa. 16,886 multiplied by the average construction cost per square metre of gfa (€ 1,392) amounts to a total of € 23,505,312. The investment required for the CCL is the sum of the construction costs per gfa and the required costs of storage equipment, in other words, € 23,505,312 euro + € 2,558,186 = € 26,063,498. The cost of land has not been included in this because it varies significantly according to the location.

In the meantime, the three collection managers involved have drawn up a business case with a budget and schedule of requirements, and taken stock of the storage equipment that will be needed in the future. During this phase of a construction process, data from the business case can be compared to the average costs from the benchmark or data from similar storage buildings. In the case of CCL, that means CC NL, LCC and KSF. Table 2 presents a comparison of these figures.

Table 2 shows the average values for each aspect for all buildings in the benchmark, the average for the chosen reference projects and the value calculated in the business case. From this, we can extrapolate that the expected construction costs in the business case are between the overall average and the average for the reference projects. The same applies to the ratio between storage space and gfa. The two averages show that it can be assumed that an average of 70 to 85 objects can be stored for each square metre of storage space.
This makes the expectation of 94 objects outlined in the business case seem quite optimistic. The actual figure will depend on the size of the objects and the type of storage chosen, with drawers and double-decker storage units generally being more efficient. However, this also has an impact on the furnishing costs for the storage rooms.
Both the average and the three similar storage buildings (CC NL, LCC and KSF) turn out to be € 7 for each stored object. The € 2 budgeted for CCL are nowhere near that figure. In the business case, the estimated costs for storage furnishing per square metre of storage are also much lower than the other averages. This could provide an indication to the developer of the business case that the costs of storage equipment have been underestimated.

Table 2 *KPIs based on different selections*

Explanation	**Average**	**Average for similar storage buildings**	**Business case**
Construction cost per m² of gfa (excluding cost of land)	€ 1,392	€ 1,899	€ 1,422
Construction costs per m² of storage (excluding cost of land)	€ 3,245	€ 3,388	€ 2,710
Construction costs per stored object	€ 88	€ 113	€ 29
Ratio of storage space-gfa	50%	62%	52%
Number of objects per m² of storage	70	85	94
Cost of storage furnishing per m² of storage	€ 303	€ 395	€ 213
Cost of storage furnishing per stored object	€ 7	€ 7	€ 2

Conclusion

The benchmark was developed during the preliminary research for CCL, in order to be able to compare data from storage buildings already developed and benefit from that knowledge. As well as using the benchmark as a means of estimating the influence of certain choices, it is also possible to assess data from a business case in terms of its feasibility. By looking at the gfa/nfa ratio, the storage space per gfa, the number of objects stored per square metre of storage and the construction cost per object, we can see the effects of choices.

The trend observed in the last two decades for storage buildings to be increasingly used as a working location for staff alongside storage[34] is also visible in the benchmark results: the percentage of storage floor area relative to gfa is getting lower and lower. At the same time, construction costs per square metre are increasing as a result of the difference in finishing costs for different types of room.

The Benchmark for Museum Storage Facilities should be seen as an initial step in the comparison of storage buildings. Of course, improvements can be made, useful data on energy being one exapmle. It would also be valuable to apply a price index to the construction costs and the cost of land. During the development of the benchmark, the conclusion was reached that institutions may vary in how they record objects. For example, one institution may classify each component in a set as a separate object whereas another will count the whole set as just one. As increasing numbers of storage buildings are included in the benchmark, it will prove an increasingly valuable resource.

For management teams and collection managers, the Benchmark for Museum Storage Facilities makes it possible to gain insight into the use of floor area and the costs before embarking on a construction project. This provides a clearer picture of wishes and needs and a better understanding of the financial impact of certain choices. If museum organizations are well informed when they initiate construction processes, this can have a positive effect on expectations, schedule and budget.

[34] See Note 5.

Impact of recent trends on the development of new museum storage buildings

Cindy Zalm – Sector Manager of Delivery and Realization, Nationaal Museum van Wereldculturen (National Museum of World Cultures)

Summary

This paper describes how trends in sustainable construction and the use of compact storage units have had a significant influence on the way in which museum storage buildings have developed. This trend has made it more necessary to determine the amount of storage equipment (shelving and racking) – with precision and above all a high level of detail – increasingly earlier in the process. Also the changing role of supplier of storage facility furnishings from that of supplier to consultant in response to the increasing use of innovative outfitting solutions is described.

Introduction

An analysis of storage and depot facilities in the Netherlands reveals two key trends in the last two decades (see the articles by Bart Ankersmit & Marc Stappers and Merel van Heesewijk): the development of increasingly sustainable buildings and a growing desire to enable access to collections kept in storage. Above all, the need to build sustainably has had an impact on how storage facility buildings are developed and constructed. Like any other non-residential building, the construction of a storage facility building happens in phases: from the initiative phase via the compiling of a schedule of requirements and the design through to construction and inaugural use of the building. The very fact that an effort is being made to achieve sustainability already implies that the operational phase will be a more important factor in the realization process. After all, investments in sustainability affect operations and the expected lifespan of the building. Choices have to be made in each of the phases: by the commissioning authority, the architect and the technical consultants involved in the design and realization. Choices made in one area of expertise can often have an impact on others. For example: the use of robust concrete structures with only limited wall openings makes buildings less vulnerable to burglary, possibly reducing the need for security equipment.
The two trends in museum storage buildings – more sustainable construction and improving access to collections in storage – come together in the outfitting of museum storage rooms. In this articlethe changes in the field of specialized museum storage units and relate this to the desire for increased sustainability and improved access are explored. The effect that this has on the process of developing museum storage facilities is explained. In recent years, it has become common practice to refer to museum storage facilities or depots as *collection centres* (see Wim Hoeben's article about the CC NL). This alludes to the fact that the building's purpose is not solely to conserve and preserve collections, but also allow to actively working with that collection. In this chapterthe term *museum storage facility (or depot)* is used. This is because this chapter primarily focuses on the outfitting of those areas of the building where the collection is stored.

The Delta Plan and the drive to build storage facilities in the Netherlands

In 1988, the National Audit Office published a report on its investigation into the question of whether state museums were operating in such a way as to enable them to effectively fulfil the key tasks laid down for them in policy.[35] In it, the National Audit Office concluded that eight of the 17 state museums either faced a shortage of suitable storage space or had poorly maintained storage facilities.[36] The Court of Audit's general conclusion was that museums were unable to sufficiently fulfil their management role. This was partly attributed to the issue of collection registration and partly caused by backlogs in maintenance and climate control facilities in the buildings in which the museums were based. The report culminated, in 1990, in the Delta Plan for the Preservation of Cultural Heritage (*Deltaplan voor het Cultuurbehoud*),[37] a large-scale subsidy scheme aimed at dealing with the backlogs identified.[38] The Delta Plan also highlighted concerns about changes in environmental conditions and the acidification of the air in particular. It led to research focusing on the optimization of filtering in museum climate systems. Since management and conservation were (and still are) seen as basic tasks of museums, the additional resources were made available in accordance with the matching principle: the museums had to fund 40% of the total project costs themselves and the government contributed the remaining 60%. Since the maintenance backlogs in the museums were seen as a key cause of the poor storage conditions for collections, additional funding was also made available

35 Tweede Kamer der Staten Generaal (1988), Rapport Rijksmusea, session 1987-1988, 20697 nos. 1 and 2.
36 Tweede Kamer der Staten Generaal (1988), Rapport Rijksmusea, session 1987-1988, 20697 nos. 1 and 2, p. 13.
37 Tweede Kamer der Staten Generaal (1991), Bedreigd cultuurbezit, session 1991-1992, 21965 no. 7.
38 Ministerie van Welzijn, Volksgezondheid en Cultuur (1990). Deltaplan voor het Cultuurbehoud. Onderdeel: Plan van aanpak wegwerken achterstanden musea, archieven, monumentenzorg, archeologie. Rijswijk.

for the Central Government Real Estate Agency (*Rijksvastgoedbedrijf*, RVB), which was responsible for managing state museum buildings at that time. This resulted in an additional 42.5 million guilders in the available budget for the years 1992-1995.[39]

The Delta Plan brought about increasing professionalization in museum collection management and conservation, a development also underway in other countries at that time. The additional financial resources enabled improvements to the storage conditions in existing depots, the shifting of storage to purpose-built buildings and the realization of several new museum storage facility buildings. The early 1990s saw the emergence of the so-called MIBO warehouses (*MIBO-loodsen*). These special warehouses had been used to store materials to treat the large numbers of injured expected in the event of a nuclear war. Managed by the RGD, the buildings were adapted to be used for museum storage. The Zuiderzeemuseum, the Scheepvaart-museum, the Rijksmuseum, the Openluchtmuseum, Museum Volkenkunde and Rijksmuseum Boerhaave all transferred parts of their collections to this kind of warehouse.[40] Figure 1 shows the MIBO warehouse used by the Museum voor Wereldculturen.

In the 1980s, it was already clear that many museum and archive storage facilities were suffering from a lack of space. As a result, specialized suppliers of storage equipment began to make use of compact storage units. Compact storage units are not placed back-to-back with aisles between two rows, but the rows are placed alongside each other on a rail system, making it possible for the rows to move by means of a chain-driven system. As a result, only one aisle was needed for ten rows, for example, making it possible to use up to a maximum of 80% of the available floor area compared to around 45% in the old arrangement. These kinds of mobile storage units had also been widely used in outfitting or re-furnishing storage facilities in the light of the Delta Plan. Precisely because one of the key problems was the lack of proper registration and recording of collections, any attempt to make an accurate assessment of what storage facilities were needed was impossible. Because of this, the principle applied in (re-)furnishing storage

39 Idem note 3, p. 3.

40 Ruiter, T. (1994, 15 April). Tienduizend speren, en allemaal uniek. De Volkskrant. Consulted on 20 April 2021 via delpher.nl. Walton, S., & Bertram, B. (1992). Estimating space for the storage of ethnographic collections. La conservation preventive, 137-144.

Figure 1 *Museum Volkenkunde's storage facility in MIBO warehouse in 's-Gravenzande. Photo: Irene de Groot*

depots focused on maximising available capacity. In addition to the use of former MIBO warehouses (see Figure 6 in the article by Agnes Brokerhof), the introduction of the Delta Plan also triggered a wave of initiatives to develop new storage facility buildings. In 1994, the Zuiderzeemuseum in Enkhuizen gained access to a completely new building designed exclusively to store collections.[41] In 1998, Naturalis Biodiversity Centre began to use its new storage tower. Although the Delta Plan was initially targeted primarily at the collections of state museums, funds were quickly also invested in municipal and provincial collections. As the number of projects increased, knowledge about developing buildings of this kind grew, resulting in an increase in innovation. Het Behouden Huys (the storage building of the National Maritime Museum – het Scheepvaartmuseum – in Amsterdam, completed in 2001) features a design in which a 'box-in-box' structure helps stabilize the indoor climate, obviating the need for bulky climate control systems (see the article by Frans van den Hoven). In the decade that followed, society became ever more aware of the environmental consequences of emissions and energy consumption. The construction of sustainable buildings became increasingly important.

Estimating or counting?

Determining how much storage space is needed somewhere new is difficult for poorly catalogued collections, see Figure 2. The same applies to (reasonably) well stored collections in fixed storage units if they need to be transferred to movable storage in order to gain space. In the first case, there is simply insufficient understanding of the size of the collections and dimensions of the objects and in the latter case it is primarily a question of whether it is possible to apply a simple factor for the removal of objects to mobile storage units. The extent to which the floor area can be used is heavily dependent on the shape of the room and the position of any doors, equipment and columns. In the 1990s and early 2000s, various publications appeared exploring the question of how to determine what size a storage facility should be or how much storage equipment would be needed. In the US, National Park Services (NPS) published two guides on this subject: one to identify storage equipment needs and the required quantity and another aimed at fitting the determined amount of storage equipment efficiently into the available space.[42] In the approach recommended by the NPS, the collection is first divided into categories or types of objects before an assessment is made of which type of storage system is required. After that, the objects are categorized according to size. For each of the size categories, rules of thumbs are then suggested with regard to the number of objects that would fit on a shelf or in a storage unit. This can then be used as a starting point for determining how much storage furniture is needed.[43]

After explaining this, the NPS also suggests an alternative method: taking a selection of objects and attempting to determine the average number of objects that will fit in a storage unit and then using that average to calculate the total requirements for storage equipment. In other words, making an educated guess or 'guesstimating', which is also the term used by Chapman as the title for his publication dating from 1998: *Guesstimating storage space*.[44] He recommends starting by identifying the volume of stored objects in the current situation by determining the volume for each filled storage unit, possibly adjusting it by a certain factor if there are actually too many objects in it. It is possible to calculate the amount of floor area required for the total volume determined, based on the guidelines provided by Chapman for the number of cubic metres that can be placed on a square metre of floor for each type of storage. If desired, an additional factor can be added to the number of square metres calculated in order to account for future growth. The method Chapman describes is very similar to the RE-ORG method introduced in 2011 by the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) in collaboration with UNESCO. However, the RE-ORG method is slightly more detailed, comprising four steps.[45] It starts by identifying how much storage equipment is in use, before checking each storage unit shelf by shelf to determine the level of utilization and use of the available height.

The effectiveness of the use of the available floor area is then determined and extra space added for objects stored on the floor or standing in aisles or corridors.

41 Het Parool (1992, 23 May). Zuiderzeemuseum kan uitbreiden. Consulted on 20 April 2021 via delpher.nl.

42 NPS (1997a) Determining museum storage equipment needs. Conserve O Gram (4/10). Consulted on 21 April 2021 via https://www.nps.gov/museum/publications/conserveogram/04-10.pdf. NPS (1997b) Determining museum storage space requirements. Conserve O Gram (4/11). Consulted on 21 April 2021 via https://www.nps.gov/museum/publications/conserveogram/04-11.pdf.

43 Idem note 8, NPS (1997a).

44 Chapman, V. (1998). Guesstimating storage space. Natural Science Conservation Group Newsletter (9), 34-42. Consulted on 21 April 2021 via http://bit.ly/1paH1ST.

45 RE-ORG (2011). Tools for museum storage reorganization and documentation systems. ICCROM-UNESCO. Consulted on 21 April 2021 via https://www.iccrom.org/section/preventive-conservation/re-org.

Figure 2 *Counting objects can be challenging. Storage facility at Museum Volkenkunde (National Museum of Ethnology), part of the Nationaal Museum van Wereldculturen. Photo: Irene Groot*

The result is then corrected to account for future growth. In addition to the methods described here, methods are also recommended that apply a more detailed approach, starting by determining the dimensions of each object.[46]

The wide range of methods described in the literature led in 1994 to a study into their effectiveness by Lambert and Motte.[47] In it, the authors conclude that most of the methods investigated require a certain degree of interpretation, especially in determining the number of objects that can be safely stored together on a shelf. For their study, they compared the results of the calculations for the number of square metres required when several members of staff apply the same method to the same collection. They also record how many seconds are needed on average per object to perform each method. The time required varies from nine seconds to apply a basic method to 36 seconds per object for the method involving the most detailed assessment of the dimensions of each individual object.[48] Remarkably, it is actually this detailed method that shows the greatest standard deviation: 35% compared to 3% in the case of the least detailed method. According to the authors, the size of this standard deviation is caused by the significant room for interpretation with regard to the concepts that are not sufficiently defined in the method. The authors rightly argue that any choice of method is a question of determining the level of precision required to determine the size of the collection in the specific project. After all, the larger the collection, the greater the difference between the methods described in terms of the time invested. In many cases, a method in which an estimate is made of the future requirement for storage units will constitute adequate preparation for the design process. It was this kind of method that was used in determining the number of square metres of storage

46 Maximea, H. (2012) Planning for collection storage. In Lord, B., Lord, G.D., & Martin, L. (Eds.). Manual of museum planning: Sustainable Space, Facilities, and Operations (pp. 250-284). Lanham: AltaMira Press.

47 Lambert, S., & Mottus, T. (2014). Museum storage space estimations: In theory and practice. In Bridgland, J. (Ed.). ICOM Committee for Conservation 17th Triennial Meeting Melbourne Australia 19-23 September 2014 Paris: The International Council of Museums.

48 Idem note 13, p. 6.

floor required for a shared collection centre in Leiden. This started with agreement on the types of storage equipment to be chosen. If a global estimate is required, it is now also possible to use the data collected in the benchmark (see article by Merel Heesewijk). The data from this benchmark show that an average of 70 to 85 objects can be stored for each square metre of floor area in a movable storage system storing a mixed collection. The number of square metres required for a future storage facility can be calculated using this by dividing the total number of objects to be stored by this average.

Optimising storage facility configuration

In the Netherlands, experience has shown that realising a new storage facility generally requires a long period of preparation. During this preliminary process, the focus is on identifying the requirements that will be placed on the building and pursuing a political process to obtain funding and have land allocated. In a number of recent cases, it has easily taken a decade or more to progress from the initial idea to realising a new storage facility and its completion. During that period, various different versions of a document of requirements often appeared. Because the chance of success was often unclear in this period, there was not always an investment in an extensive inventory of the existing storage units and future needs. Often, an assessment was made of the number of square metres of storage floor currently being used and this was then corrected to account for future growth of the collection or plans for deaccessioning. When construction work ultimately started, there was still sufficient time to think about the storage units needed and how they would be positioned in the space. As compact movable systems were introduced, it became necessary to start thinking of the positioning of storage equipment at an earlier stage. After all, the rail system needs to be integrated in the top layer of the concrete floor. This meant that any floor plan would need to be in place at the time the construction work was tendered. The interior of the storage unit (number of shelves and other features) could ultimately be adjusted later on. Since thinking about the building's design and storage plan now had to happen more or less simultaneously, the design process for the Amsterdam Museum Collection Centre was the first ever situation where the architect already had a quite clear idea of volume of storage equipment to be placed in the various rooms of the building being designed (see article by Marysa Otte). This had the advantage of enabling the columns structure, lighting, security equipment and aisles or corridors to be taken into account in the positioning of storage units. When designing the Kolleksjesintrum Fryslân (Collection Centre Friesland, see also article by Luc Schaap), the design team were able to go a step further than this. This building was designed by a team made up of an architect, a mechanical installations consultant and a building physicist. I myself also took part in this integrated design team as a representative of collection managers, focusing primarily on the building's logistics, storage methods for the various collections and the conditions for preventive conservation in the building being designed. The design team researched the optimum relationships between the length and width of storage rooms in proportion to the required span and construction costs needed. The team did not want any columns in the storage rooms, opting for a structure in which the partition walls support the roof (see Figure 3). Because of the low cost of land in Friesland, it was possible to build one single floor. During the research, it was learnt that the tipping point was rooms that were around 16 to 18 metres wide. Within that, the design team was able to install a spacious main aisle in the centre with a block of storage equipment on either side that was no deeper than 7 to 8 m, which also proved to be an effective working dimension for the zone with painting racks. During the research, details of the future storage equipment were already itemized, which enabled us to tender for the outfitting of the building at an early stage. This meant that the furniture supplier was contracted as part of the process at an early stage and was able to become involved in the detailing of the floors and plan of action for installing the rails.

At that time, the storage building in Friesland was the first collection building in the Netherlands to apply the so-called *Danish model*: a sustainable method of building museum storage, one of the key features of which is the use of an uninsulated floor slab. The advantages in terms of energy that this provides apply in principle to the ground floor only. That was not a limiting factor for the Kolleksjesintrum Fryslân, since the building has only one floor. However, in areas where land is more expensive, such as the Randstad, or in the case of buildings that are expected to house a much larger collection volume, it means that it is necessary to make optimum use of that ground floor. One option for that involves making the ground floor as tall as possible. Research conducted during the design process in Friesland showed that the temperature and relative humidity in a room up to 9 m tall were sufficiently similar at different heights within the space (see also the article by Luc Schaap). However, from the perspective of object accessibility, that is too

Figure 3 *Double-height mobile storage system in the Kolleksjesintrum Fryslân. Photo: Marcel van der Burg*

high. This is why double-decker mobile storage units were used in the storage rooms in Friesland. The second level of these storage units can be accessed by stairs. Objects can be placed directly onto the slatted floor using a forklift. The slatted flooring enables the air to circulate freely between the storage units and higher up in the room. If it is necessary to design a building across several levels, it is possible to organize access to the double-decker storage units in the central aisle area. The lift in the building can then be used to transport objects in and out of the upper layer of the double-decker storage units. This can be achieved by equipping a storage room completely with double-decker storage equipment and connecting the slatted floor to a structural floor in the aisle area (see Figure 4). Although this construction method offers numerous logistical advantages because objects do not need to be placed on pallets or carried up the stairs and because no major ancillary equipment is needed in the room, such as a forklift or pallet stacker, choosing this method has implications for the design process and tendering of the outfitting. Because the storage equipment needs to align precisely with the structural floor in the aisle area and the various storage equipment suppliers use different standard heights, the outfitter needs to be contracted when the initial design is being developed. If the outfitter has to adapt to predetermined ceiling heights, this will necessitate a bespoke approach that will almost inevitably increase the costs. If, instead, the furniture supplier serves as a consultant in the design team, its contribution changes from that of equipment supplier to outfitting consultant. That, in turn, has repercussions when putting the outfitting out to tender.

This type of storage equipment mainly offers advantages of scale if large numbers of objects are being stored. In most cases, the amount of storage equipment required is then at such a level that it exceeds the limit for European tenders. A public procurement process of that kind can easily end up taking three to nine months.[49] This means that the tendering process needs to happen when the provisional design is not yet complete. In order to achieve good pricing for the outfitting without running too much risk of facing additional costs during the project, the request for tender needs to be described in as concrete terms as possible. However, the shape and dimensions of the storage rooms have not yet been determined at this stage. It is also not yet possible to determine the height of the storage equipment. This makes it necessary to identify in as concrete terms as

49 Expertisecentrum Aanbesteden PIANOo (2016). Termijnen Aanbestedingswet 2012. Consulted on 21 April 2021 via https://www.pianoo.nl/sites/default/files/documents/documents/termijnenaanbestedingswet2012aug2016.pdf.

possible how the collection will be spread across the various storage rooms and the amount of storage equipment required for each type of storage must be determined and allocated to the various zones or rooms. To do this, one of the more precise methods outlined in the previous section will be necessary. This means that the tender specifications not only need to include the price for supplying storage units, but also the consultancy process required for the design team to come up with the optimum outfitting and building design. One of the options is to determine pricing based on an example solution for blocks of furnishing, with a predetermined number of shelves or units. Prices can then be determined for ordering additional batches of the different components.[50] In this, it is important to realize that the dimensions of the blocks of double-decker storage units affect the price of production. The longer the rows and the taller the cupboards, the greater the total weight load in each block of storage units and therefore the greater the number of floor rails and drive chains that will be needed. This means that, in attempting to set pricing, the commissioning authority will always need to accept a certain level of uncertainty with regard to the ultimate total costs of outfitting in the first phase of realization. In the tender documents, the commissioning authority will need to attempt to identify these uncertainties as much as possible and reach price agreements for these factors in order to prevent any additional work being priced unnecessarily high. Drawing up and implementing this kind of tender is a complicated process and not every buyer has sufficient knowledge of regulations and this very specific market for storage outfitting. It is therefore quite feasible that this specific knowledge will need to be added from outside when putting together the team to compile tender documents.

Conclusion

Trends in sustainable construction and museum storage furnishing have led to a situation in which outfitting suppliers are increasingly playing a role as consultants in the process of realising museum storage facilities or collection centres. As a result, they need to be contracted earlier in the process, which makes it increasingly important to have a very precise level of understanding of the future needs for storage equipment, both in terms of type and quantity, at a very early stage.

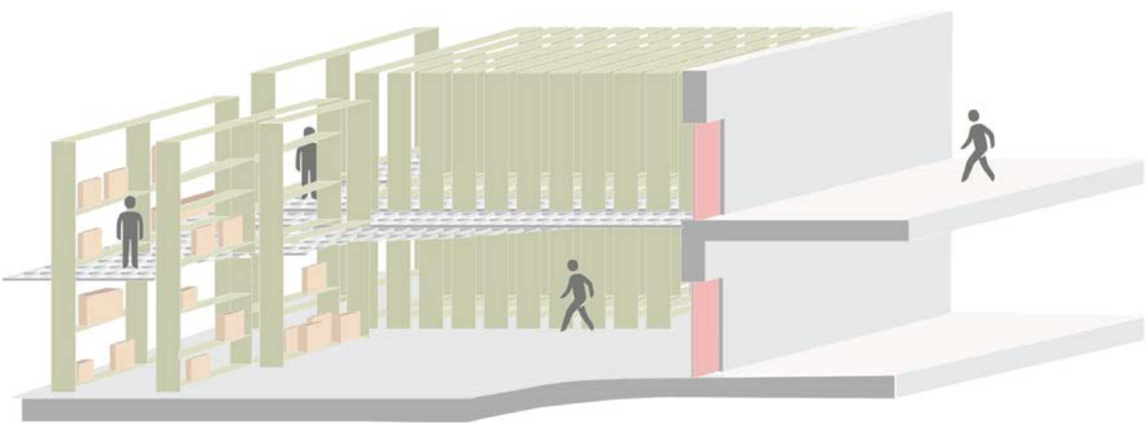


Figure 4 *Diagram of a double-height storage block connected to a structural upper floor. Image: Bart Ankersmit*

50 Interview by Cindy Zalm with Susanne Brackmann about tendering strategies and tendering for museum storage outfitting (2019).

Alignment of interests – a new heritage storage facility in Utrecht

Bas van Stratum – Project Manager, Municipality of Utrecht

The city of Utrecht faces a major challenge. Municipal construction projects are under considerable pressure as the city is tasked with intensifying its spatial planning, finances and organizational capacity. For a project manager, it is important to ensure sufficient momentum is maintained in order for projects to proceed. But how can you balance this with other spatial development challenges in the city? This article explores several decisive factors and moments in the development of all scenarios considered. Applying an analytical and project-based approach to exploring the different scenarios ultimately resulted in a proposal to build a new storage facility. In that process, public support, necessity (political and otherwise), financial coverage and cooperation both within and outside the municipality proved to be key issues.

Why a new heritage storage facility?

The current storage facility for the Centraal Museum and Heritage Department collections no longer meets the national and international standards for managing museum collections (see the photospread by Marije Verduijn). The existing storage facility is bursting at its seams and the Centraal Museum and the Heritage Department are renting storage space elsewhere. In 2015, the Centraal Museum formally reported this to the municipality, which owns the storage building.
The technical aspects of the building require significant maintenance. The roof needs replacing because of the risk of leaks and problems with insulation and condensation. The outer façade also needs modifying. The cost of this refurbishment work was estimated at €6.2 million (2017 price levels). This unavoidable investment was partly what prompted the investigation into a new storage facility. Besides this, a suitable location will be needed in order to implement the long-term policy of the Centraal Museum and the storage policy of the Heritage Department. As part of its collection action plan, the Centraal Museum has made progress in recent years in bringing the collection up to standard by means of multiple restorations. If the collections are to be properly preserved, the next essential step will be to raise the standard of the storage conditions. The focus here is on sufficient storage capacity and suitable climate conditions.

In 2019, the municipal executive decided to develop three scenarios for a suitable storage facility for the Centraal Museum and the Heritage Department:

1. new construction at the current location;
2. new construction at a new location in the Province of Utrecht
3. new construction in collaboration with the Utrecht University Museum.

These scenarios were formulated based on answers to questions asked in the starting document on the subject of a suitable storage facility that was approved by the executive at the end of 2018. This starting document also includes the conditions according to which the municipality is willing to cooperate in the search for a suitable new storage facility. These are: available storage space with capacity for growth, stable and secure storage conditions and a sustainable building. Collaboration with other parties and effective logistics (accessibility and the combining of different functions) were also expected to bring about further benefits in terms of efficiency.

The Centraal Museum and Heritage Department collection

The Centraal Museum collection comprises approximately 60,000 objects, 95% of which are owned by the municipality of Utrecht. When the museum was privatized in 2013, a collection management agreement was signed for the municipal collection. Since 1996, the Centraal Museum stored collection has been kept in the storage facility in Vlampijpstraat in Utrecht, see photospread of Marije Verduijn. The storage facility there was expanded in 2019 and the municipal and provincial heritage collections are also kept here.

In preparation for the privatization of the Centraal Museum, a baseline assessment was conducted in 2012 to ascertain the state of the collection and storage conditions. This baseline assessment was conducted by CollectieConsult using the methodology of the Dutch Heritage Inspectorate. Its key conclusions were:

- the collection is not properly registered and documented;
- the maintenance of the objects has fallen behind schedule and there is a clear need for large-scale maintenance and restoration of parts of the collection;
- the storage facility is full and measures need to be taken to improve the conditions of storage;
- there is a need for set guidelines and risk management.

Immediately following the privatization of the Centraal Museum on 1 January 2013, work began on tackling the key issues raised by the benchmark assessment. Improvements were made to collection registration and work began on barcoding objects. An action plan was also drawn up outlining the measures required in

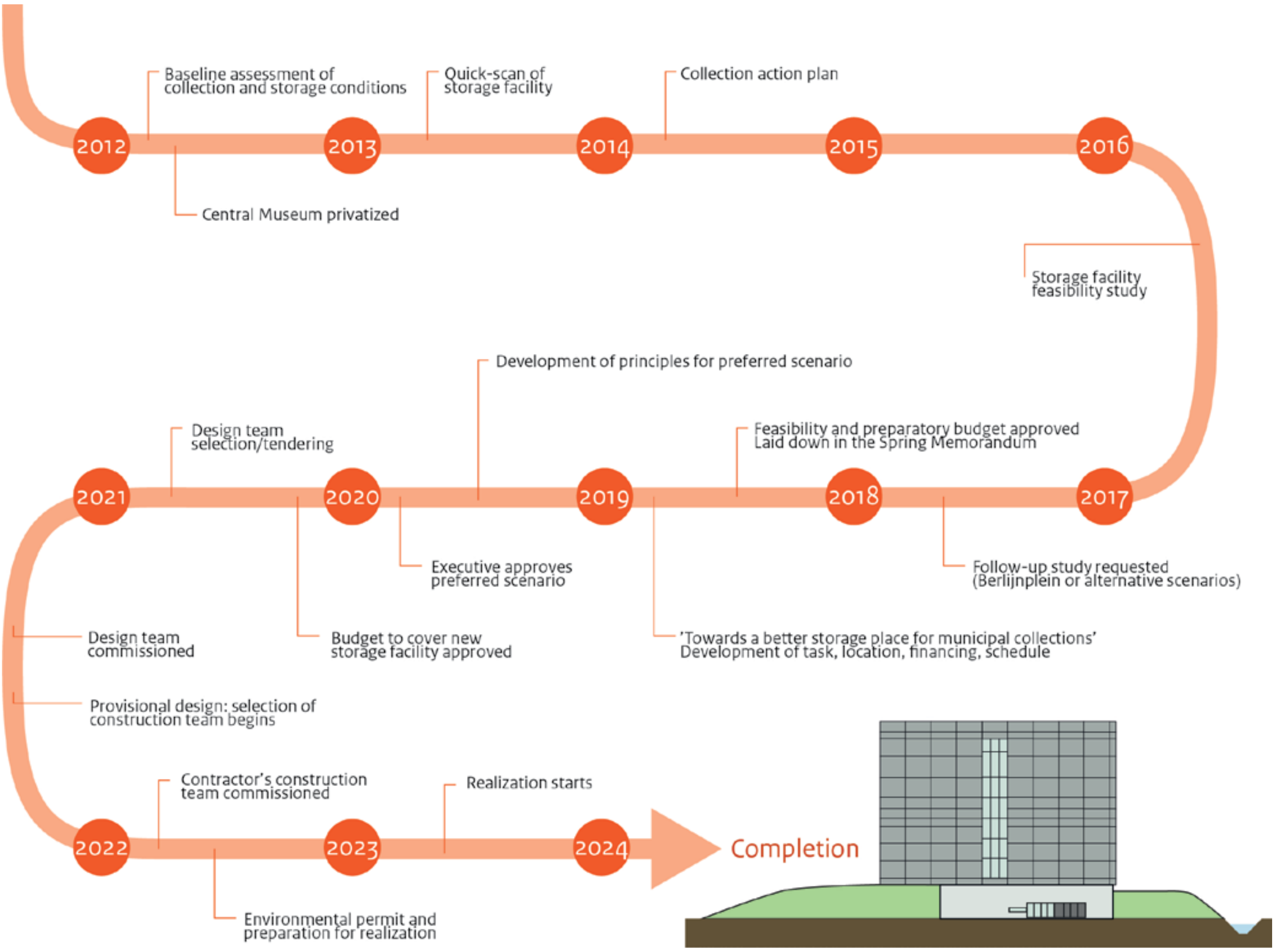


Figure 1 *Project planning for a city storage facility in Utrecht. Image: Bart Ankersmit*

response to the baseline assessment and the budget and time likely needed to bring the collection up to scratch. In order to gain a better understanding of the storage conditions and areas for improvement in the storage facility, a quick scan was conducted by Helicon Conservation Support[51]. This revealed that the building was in a worse condition than anticipated. The roof leaked in unpredictable places. As a result of previous repairs, there are various layers of roof covering, preventing a proper analysis of the leaks. In order to improve the roof on a permanent basis, it requires replacement. This calls for a significant investment and temporary relocation of the collection. In addition, the building is not sustainable. The walls are poorly insulated and not airtight, as a result of which the indoor climate is heavily reliant on climate-control systems. As the owner of the building, the municipality decided not to tackle these issues, but to wait until the future plans have crystallised. Only a small number of improvements are being made.

In a nutshell, the existing building was no longer suitable as a museum storage facility for the medium to longer term. At the end of 2015, the Centraal Museum informed the municipality of Utrecht that the existing storage facility would ultimately no longer meet current museum standards. In response, the municipal Cultural Affairs Department approved the granting of a subsidy for a feasibility study exploring a new storage facility or

[51] Commercial firm providing conservation support to heritage institutes in the Netherlands

improving the existing one. This feasibility study was completed in early 2017.[52] Figure 1 shows the planning for the project for a new city storage facility.

Municipal complexity

How are the roles of the municipal departments of Real Estate, Cultural Affairs and Spatial Planning, with their different interests and diverging briefs within the same city, effectively brought together within the administrative organization? It is important to strike a balance between making more intensive use of the city and finding political support. This means there are three challenges:

- *Aligning different policy lines and creating a need or urgency as a means of ensuring that the resources required are made available.*
  It is important to ensure that the interests of the different policy departments and various policy lines associated with the task are properly identified. This involves searching for a solution in which problems are tackled in agreement with and via the different portfolios. The Centraal Museum felt responsible for the fact that the existing storage facility does not meet current museum standards. It was only when it became clear that, as the owner of the collection, this was actually the responsibility of the municipality that the project was accelerated. From then on, the urgency and risk became tangible for the municipality and the politicians, more people got behind the task at hand and decisions were made that reflected the responsibilities.

- *Everyone believes it is important, but nobody will make funds available for it – it doesn't have the political 'wow factor'!*
  The task at hand involves more risks than opportunities. That means it is necessary to identify the legal frameworks and administrative responsibilities that will enforce decision-making. For the storage building, that urgency came about as a result of municipal ownership of the collection and the potential for fulfilling the management role that lies with the Centraal Museum itself.

- *Responsible management of municipal collections*
  The Centraal Museum needs a suitable storage facility in order to put its multi-annual policy plan into action. This was formulated in the multi-annual policy plan *Centraal Museum 2017-2020: Utrecht Verrijken* ('enriching Utrecht') and will be reiterated in the 2021-2024 policy plan. This plan contains a justification of the relevance of the museum in the city, the locations that belong to it (Agnietenstraat building, Nijntjemuseum, Rietveld Schröderhuis, storage facility) and the relevance of the storage facility in it. Continuing to manage the municipal collection professionally and responsibly, as agreed in the Collection Management Agreement, will require a storage facility that offers sufficient space for the collection now and in the future while also meeting international standards with regard to security and climate.

The municipality also has a statutory duty to archive archaeological finds. The implementation of the Malta Convention (1992) and its application in the municipal bye-law (*Verordening op de Archeologische Monumentenzorg*, 2009) has led to an explosive increase in archaeological research. At the same time, Utrecht continues to grow at the same fast rate. Despite artefacts being preselected, the storage capacity of the archaeological and historic building storage facility is reaching a critical level. Every year, 200 boxes of archaeological material are added to the collection. In addition, if the municipality of Utrecht is forced to reject finds from completed projects, it will no longer be able to meet its statutory duty of storage.
In 2020, the Heritage Department introduced a new archaeology policy that outlines and justifies the choices and decisions to develop a new storage facility.

The location of the storage facility

Various scenarios were explored in the search for the best possible storage facility. These are presented in Figure 2. The most obvious scenario would be to revitalize the existing location. Renovating the existing building did not appear to provide a solution to the problems, although some technical issues could be partially resolved through extra investment. This could, for example, involve placing a shell around the building. However, energy loss via the floor would continue in that case. At the same time, the existing building does not have the potential to achieve the schedule of requirements demanded. Renovation would not appear to provide sufficient space for the current collection, making any future growth impossible. In addition, the entire collection would need to be temporary stored in the event of renovation, making it necessary to move twice. The Centraal Museum and Heritage Department's storage collection would therefore need to be kept in

[52] Driepas/SBM. *Haalbaarheidsonderzoek depot CM*, report dated 21 March 2017

external storage, which involves additional operating costs because of transport, staff and rent.

As a result, new construction took preference over renovation. Although it may be more expensive, it also offers opportunities in terms of climate control. Recent developments in museum storage management have shown that it is possible to manage the climate passively with a robust insulated building envelope and an uninsulated floor on the ground floor. Well-known Dutch examples of this are the Kolleksjesintrum Fryslân (see article by Luc Schaap) and the CollectieCentrum Nederland (CC NL, see articles by Donny Tijssen and Wim Hoeben). The so-called Danish Model is an important development in terms of sustainability and structural operating costs. This model leans heavily on principles of building physics, which are most effectively implemented in a new building.

In view of the lack of space in a centrally-located city like Utrecht with relatively high land prices, thoughts turned to whether a storage facility actually needed to be based here or whether it was financially desirable to have two separate locations. A location outside the Province of Utrecht was rejected because its only advantage was the lower cost of land. Dividing the storage facility into a small one for frequently-used objects in or close to the city of Utrecht and a larger facility at a location further away is only an option if it has financial benefits. However, the higher cost of managing two buildings is not offset by the lower cost of land. There are also other reasons why dividing the collection has disadvantages.

An essential element in the choice and operation of a location is public access. In general, storage facilities are not accessible to the public. The new storage facility built for Museum Boijmans van Beuningen (see the article by Wout Braber) is a well-known example of a storage facility that is open to the public, but it is also the exception to the rule. Accessibility was the most important design principle here. Because of the more stringent management requirements, the negative impact on the collection and the high operating costs, the Utrecht storage facility will not be accessible to the general public.[53]

Collaborative partners

'As the museums of Utrecht, we stand for careful and cost-effective conservation and management for the unique "Utrecht collection". With the Centraal Museum as coordinator and with financial support from the municipality, we are investigating the possibility of shared storage solutions in the period ahead.' This joint ambition was formulated by the various Utrecht museums in 2016. In the feasibility study commissioned by the Centraal Museum, there were discussions with all Utrecht museums. After stock had been taken of the needs of all parties involved, it turned out that Museum Speelklok, the University Museum and the Spoorweg-museum (Railway Museum) were all eager to see a new, communal Utrecht storage depot with shared facilities.

Shared accommodation for several parties offers advantages of scale in terms of management and also facilitates collaboration in other ways. In the search for

53 The storage facility service that the Centraal Museum had between 1999-2003 was discontinued because it was hardly ever used.

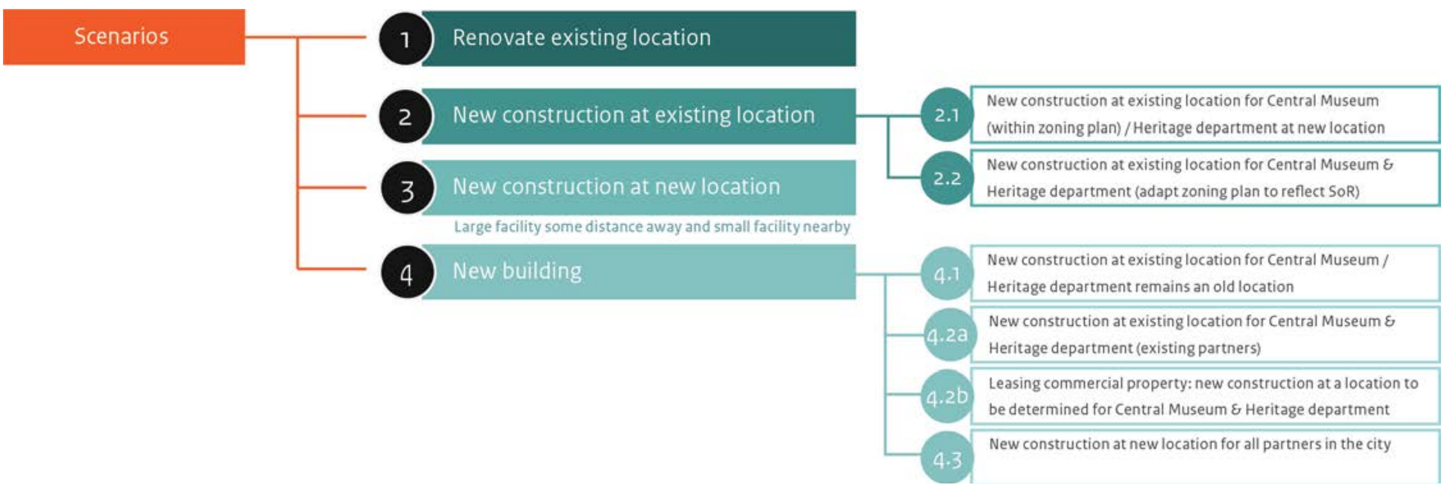


Figure 2 *Various scenarios for the development of a city storage facility in Utrecht. Image: Bart Ankersmit*

potential partners, the decision was made to collaborate with the University Museum and Museum Speelklok. In addition, the Heritage Department of the Province of Utrecht, which is already a collaborative partner, is also part of the storage facility. In the case of the other Utrecht museums, the requirements envisaged for a suitable storage facility are too different from the schedule of requirements drawn up by the Centraal Museum and Heritage Department. These museums are also funded in different ways, which makes collaboration difficult. Alternatively, they may not have the financial resources available to participate in a shared storage facility or they may not need to expand or replace storage facilities.

Different parties collaborate as a result of shared ideas and an attempt to connect. This may not immediately lead to partnership or solutions. It is important to be transparent and open about different interests and obstacles in order to make it possible – at a later stage – to be able to identify shared interests and collaborate in an integrated way.

The University Museum storage facility can no longer remain at its existing location. In recent years, it has become clear how the university is organizing the relocation of the University Museum storage facility and what financial resources are available for this. In the process of searching for a location, the existing relationship between the Centraal Museum and the University Museum has helped create a connection between the real estate departments of the municipality and the university. Initially, the municipality's timeline for storage facility housing issues was irreconcilable with that of the university. In spite of this, they had things in common. Based on municipal real estate policy, providing accommodation for other parties is not an obvious move. However, the Cultural Affairs Department and the Centraal Museum deemed a substantive partnership with the University Museum to be valuable and saw a shared storage facility as a very desirable development in this context. In the summer of 2020, it turned out that the university's accommodation plan envisaged a different scenario for accommodation for the University Museum's storage facility. This made the idea of rental for the storage facility and long-term collaboration between the municipality and the university a possibility and something worth discussing, which ultimately formed the basis for more far-reaching collaboration. For both university and municipality, this offers advantages, including:

- Intensifying collaboration between the Centraal Museum, the University Museum and the other partners;
- Intensifying the use of space at the location, a key tenet of the Utrecht spatial planning strategy (RSU 2040);
- The inclusion in the programme of long-term space for growth. The extra space rented out will allow the municipal collection to grow over time.

A spatial programme aimed at gaining space

The spatial programme was determined based on various studies and inventories of the collections. This offers significant opportunities for additional space, by moving towards an officially integrated storage facility and making more use of moveable furnishings, a form of storage that was unconventional for museums until recently. The spatial programme is based on capacity for the collections of the Centraal Museum, the Heritage Department of the municipality and Province of Utrecht and the University Museum. In addition, capacity was also added for other municipal and provincial collections, such as the Museum Speelklok and the *Kunst Openbare Ruimte* public art project. Altogether, the spatial programme (including 20% potential for growth) will comprise approximately 13,500 m^2 of gross floor area. Whether growth of 20% compared to the current situation is necessary or desirable was not clear at the feasibility stage. After all, a link between the percentage growth in terms of numbers and growth in the collection's volume is difficult to predict. In support of the spatial requirements and to prevent the storage facility reaching its maximum capacity at the time of opening, Nicole Delissen, from the Bureau voor Museaal Management, compiled the report entitled *Second opinion depot Centraal Museum* in 2019. This report assesses the Centraal Museum's vision and ambition that forms the basis for the scenarios explored, with a specific focus on the need and desire for the square metres demanded. In order to provide spatial and technical climate-related scenarios for the new storage facility, the Cultural Heritage Agency of the Netherlands was also asked to assess these based on recent developments in collection management.

Bringing expertise together

In developing the spatial programme, the municipality is working with users to select parties based on their ability to fulfil the task effectively, i.e. parties that have the knowledge and experience. However, it is even more important that they are able to collaborate and take on board the knowledge and experience of other experts, such as those in collection management and conservation, in order to reach an optimum solution.

Following the market consultation in 2019, there were conversations with contractors, consultants and architects. Based on these, it was decided to supplement the team, where necessary, with knowledge appropriate to the relevant phase of development. In working on the design for the Utrecht collection storage building, the actual collection is what matters most. The museum and heritage collections and associated storage concepts and logistical movements organically shape the design of the building. The collection and its associated requirements determine how the building can be designed to be as efficient and sustainable as possible. In developing the design, furnishing concepts, building physics and collection security are the key disciplines that determine the basic principles for the architecture and, therefore, how the collection will be presented.

Integrated design

In a collaborative partnership with market parties, how can we ensure that the knowledge of users, consultants and the contractor is put to optimum use, enabling a team to grow?
For the design phase, the municipality worked with users to identify an integrated design team. This again envisaged a team with experts, focusing on collaboration. Since the furnishing of the storage facility is a decisive factor in the style of storage and management, a party in that field has been selected as a design team partner and supplier. This party is developing the design as a fully-fledged member of the team.
Based on the provisional design, the municipality is working with users and in coordination with the integrated design team to designate an executive party as a construction team partner. The design team is developing the chosen concept into something that can actually be built, also taking account of maintenance in order to reach an integrated solution in terms of balancing investment and operating costs. Throughout this entire process, users remain a key source of knowledge and a sounding board, ensuring that the plans meet the conditions for storage and management.

The indoor climate

'Changing standards for the conservation of collections: from high-tech storage facilities to facilities that are more sustainable, less expensive to operate and also better for collections.' In the spatial programme, the Danish model was chosen as the guiding principle. This is a good example, which, just like the pyramids of Egypt, uses significant thermal mass and an airtight building as a passive, energy-neutral storage facility. The protection against the outdoor temperature and heat from the sun consists of concrete outer walls that are insulated on the outside. In order to stabilize the indoor climate naturally, an uninsulated concrete floor with a large ground surface is being used. Just like in Denmark, temperature fluctuations in Utrecht can also be absorbed naturally by the building through making use of the ground temperature. The surface area available at the construction site in Utrecht is limited, but the accumulating capacity of the building's mass ensures that heat or cold can be very easily maintained. The challenge will be to use the stability of the ground temperature and accumulating capacity of the building as the basis for developing a smart, passive building and installation principle that sets a new storage facility standard that will be known as the 'Utrecht Model', see Figure 3.[54]

In conclusion

In developing a new storage facility, the basic principles involve the joint creation of a solution with minimum depreciation over its life cycle, a building that has sufficient space or volume, stable and secure storage conditions and low environmental impact. Efforts are being made to minimize the increase in annual operating costs. Effective logistics in collaboration with other parties are the basis for achieving efficiency.

The provisional design for the new storage facility is currently under development. In this, a balance has been

54 DP6 (2021). *Inschrijving selectie ontwerpteam.*

achieved between the task and the location, as the building also creates green, ecological quality on the site. The building itself will be optimized by striking a balance in terms of height and the use of the ground in order to achieve optimum conditions with regard to the available space, climate conditions, internal building logistics and a structure that is aligned with the collection's storage method. As a result, an iterative process involving different levels of scale – from urban design and architect to end-user – will ultimately lead to a sustainable, energy-efficient building in an ecological context.

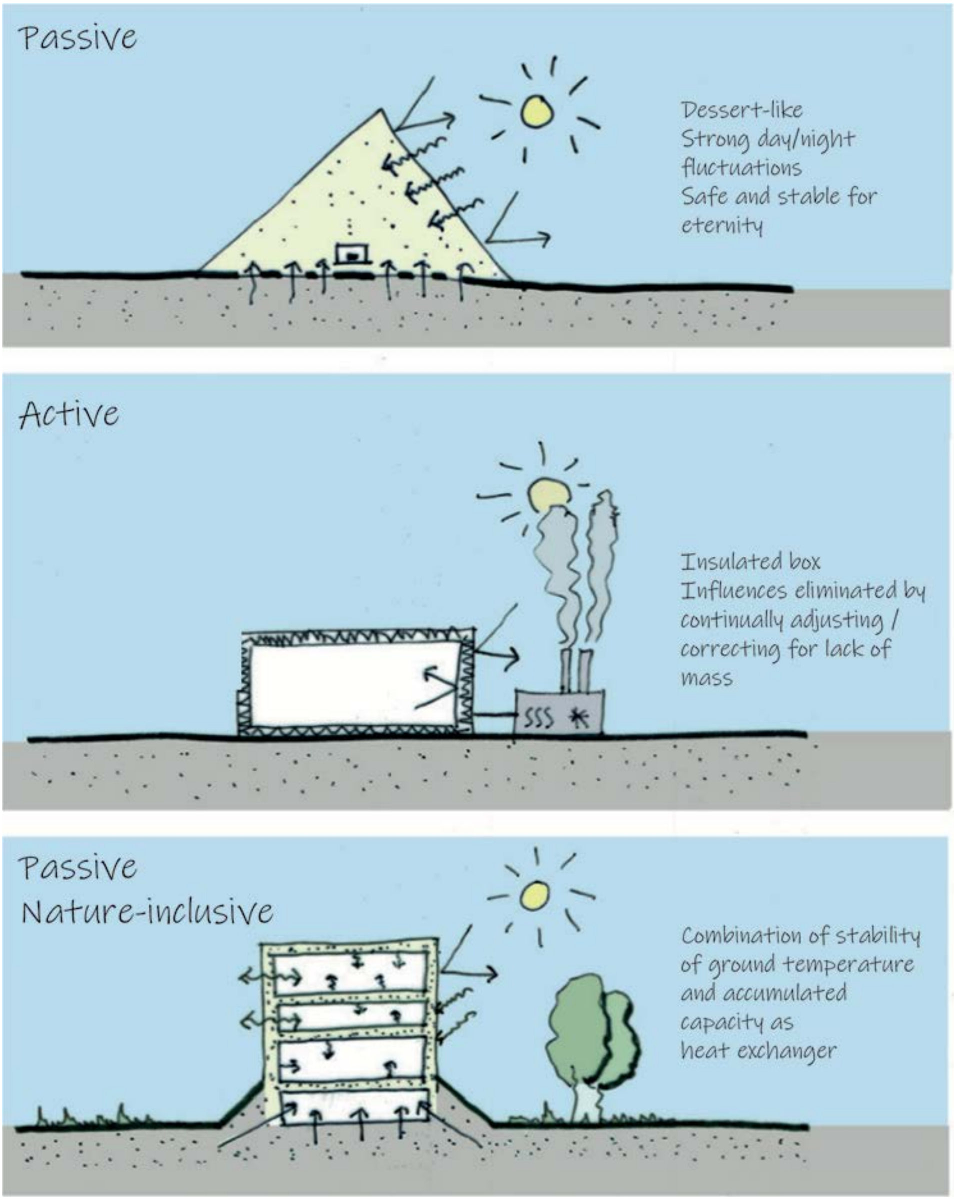


Figure 3 *From passive to passive nature-inclusive, 2021 . Image: DP6*

Museum Tetris – collection storage in the CC NL

Donny Tijssen – Storage Depot Coordinator, CollectieCentrum Nederland

Summary

The development of the CC NL was a complicated puzzle. The initial choices set down in a schedule of requirements were severely tested by the reality of the construction processes, the preparations and the relocation of the collections.

Het CollectieCentrum Nederland

Het CollectieCentrum Nederland (CC NL) is a collaboration between four museum partners: the Nederlands Openluchtmuseum (Netherlands Open Air Museum), the Paleis Het Loo Museum, the Rijksmuseum and the Cultural Heritage Agency of the Netherlands (see the article by Wim Hoeben). The CC NL is more than just a museum storage facility, because the collaboration focuses not only on storing collections, but also active conservation, restoration and collection logistics.
Preparations for the CC NL started in 2014. A schedule of requirements (SoR) was drawn up by the parties involved. This brought together all of the requirements and wishes for the building, enabling Delft-based architects' firm cepezed to come up with a design for the building. The result was a building made up of three sections: a head, neck and torso, each with its own specific function. In the head are the offices, conference facilities, kitchenettes and staff restaurant and the porters are also based there. The neck houses all of the museum processes and activities. It features two well-equipped very spacious restoration studios, a photography studio, transit area, a wrapping room, a machine workshop and a quarantine area that includes four treatment chambers. A cold store, an ITOX area and two low-oxygen chambers guarantee pest-free collections. Finally, in the building's torso, the collections are stored.

The four partners' collection-related activities were key factors in determining the form and dimensions of the building. It needed to be possible for all objects to reach all facilities. As a result, the largest objects determined the size of the access doors to the workshops and studios, loading platforms and the storage area.
This meant that large and heavy steam engines from the Nederlands Openluchtmuseum determined the lifting capacity of the lifting table alongside the loading platforms, as well as the maximum floor load on the ground floor. The largest paintings, some civic guard portraits from Amsterdam's Rijksmuseum, dictated the dimensions of the collection lift and the size of the access doors to the painting compartments. The width of the aisles and corridors, doors of the compartments and positioning of the storage equipment were all designed with the collections in mind.

A schedule of requirements as a wish-list

For the schedule of requirements, the partners needed to consider what size they wanted the storage facility to be. Architects' firm cepezed had to achieve all of these wishes and requirements for the building on a plot in Amersfoort Vathorst covering around 27,000 m². One of the key wishes was a flat building, but this was impossible with this surface area, since an evaluation of all of the four partners' existing storage facilities showed that storage of the collections alone – over 500,000 objects – would require around 19,000 m² of net floor area. Combined with the required size of the head, neck and the access routes, parking spaces and green landscaping, the plot was simply too small for that. If all of the collections and facilities were to fit, the torso of the building needed to be four storeys high. This also meant that there had to be elevators for both the collections and the people. As a result, with all these facilities, the torso has a floor area of more than 25,000 m².
Armed with all of these wishes and requirements for every part of the building, the architect had the figures required to embark on the building's design. The number of square metres of net storage area was based on the partners' existing storage capacity, together with a rough estimate of the storage equipment required.

Torso Outfitting Project Group

The estimated storage capacity did not provide sufficient basis for a request for tenders from storage furniture suppliers. For this, it needed to be known in detail how much storage furniture would have to be made available for the storage of more than 500,000 objects. In addition, the collection consists of a very wide range of object groups, from coaches and carriages, sleighs and carts through to large collections of prints and ceramics, frames and paintings, textiles, jewellery and furniture. Virtually anything you might think of can be found in the collection.

Together with the project group charged with outfitting the torso, the four partners decided to carry out an

assessment of the storage capacity required. The project group was made up of representatives of the partners, taking on this role alongside their existing work. They were not only tasked with cataloguing their collections and preferred storage equipment, but also had an opportunity to optimize the storage. In the existing storage situations, some collection units were stored in such compact conditions that effective storage management, including collection monitoring and logistics, presented a major and often unenviable challenge. This attempt to make improvements carried a real burden of responsibility with it, because the project group had to think carefully about which collection storage equipment and techniques were necessary and what impact this would have on the amount of storage equipment required. A good understanding of museums was a key condition for anyone charged with compiling these inventories. For each collection unit and each object, they had to decide which method of storage and which storage technique was most appropriate. This was not only aimed at object preservation, but evenly so on the accessibility of the objects. Moreover, the situations in the existing storage sites were not always identical to that in the CC NL. For example, some objects needed to be stored in a box in the CC NL despite having previously been kept loose on a shelf, or vice-versa. This meant that the project group had to estimate the effect that this would have on future storage capacity and what means of storage was most suitable.
Not only did the project group have to make very clear agreements, even within their own organizations, any potential changes in storage technique had to be agreed with curators and restorers in order to ultimately achieve an ingenious, efficient and exact list of storage furniture.

Basic principles for storage

Each of the four partners manage state collections that have some similarities, but are also characterized by significant differences. In order to restrict the variety in the type of storage equipment for all of these collections, a choice was made for a series of standard storage methods in which all of the collections would have to be stored. The basic storage equipment chosen consisted of:

- parking spaces;
- mobile furniture boards;
- cantilever racking (Figure 1);
- long-span racking (Figure 2);
- shelf racking:
- roll storage units;
- door racking;
- mesh racking and,
- chests of drawers.

Where possible a distinction was made between static or mobile variants. The project group also determined the heights required in order to ensure that the storage facilities would have a uniform appearance. In the cantilever and long-span racking, they opted for a compartment height of at least a metre, with steps between half a metre and 2 m. In shelf racking, a minimum compartment height of 25 cm, with steps from 25 cm up to 125 cm, was chosen, see Figure 3. The steps made it possible also to include a combination of standard types of cupboard. Each type has a specific configuration.
For example, a shelf rack has cupboard type I with 8 25 cm compartments. Cupboard type 2 has two compartments of 50 cm and four of 25 cm and cupboard type 3 has four 50-cm compartments. This meant that there were several cupboard types for each type of storage equipment.

Figure 1 *Cantilever racking in various configurations. Photo: Donny Tijssen*

Figure 2 *Long-span racking in various configurations Photo: Donny Tijssen*

For each partner, the preferred storage furniture and compartment heights required were laid out in an Excel spreadsheet, in which they were able to note down the required amount of storage furniture for each object group (collection unit). This made it clear for each type of storage what quantity and configurations would be needed for each partner and object group. For the inventory, each partner used the same spreadsheet, ensuring the same point of departure for everyone.

Interim discussions to reach agreement

This process of drawing up inventories proved an intensive job for the partners. Their existing storage furniture was quite varied. Over the course of time, a variety of types of storage equipment had come into being, the contents of which would now need to fit in the agreed storage furniture.

At various meetings, the project group discussed the interim results. Any differences of views and chosen solutions had to be discussed for each object group and agreed with each other. In addition, it was necessary to discuss those groups of objects that are specific to a particular partner, such as the Cultural Heritage Agency's large, heavy sculptures and the carriages from the Nederlands Openluchtmuseum. The optimum storage also had to be agreed for each and every object group. But how do you define the optimum? In any case, it means that all objects must enable easy access and must be able to be removed from their position without needing to move other objects. At the same time, the project group also had to ensure that all of the objects would fit within the number of square metres agreed. This meant striking the right balance between perfect and efficient storage. In this, the choices were determined by the nature of the collections that needed to be stored.

Figure 3 *Double-decker storage units. Photo: Donny Tijssen*

Storage facility staff, restorers and curators would prefer to store the most fragile object groups, such as ceramics and glass, on static shelf racking. Moving collections involves risks. Interim results from the inventory process made it clear that so much shelf racking would be needed for storage that double-decker storage units would have to be used: tall rows of cupboards with a mezzanine floor to enable access to all locations on the unit (see Figure 3). In addition, it also turned out to be necessary to store most of the ceramics on movable shelf racking after all, see Figure 4. Otherwise, the amount of storage furniture required would not fit within the square metres available. This meant that the project group had to carefully assess which object groups definitely needed to be stored statically. Mobile storage units can enormously increase the capacity within a compartment (see the article by Cindy Zalm).

From theory to practice with the supplier

The inventory made it clear which storage equipment would be needed in which quantity in order to store all of the collections. After the tendering process, the project group and Bruynzeel Storage Systems reached the next phase of their project. Initially, this was still on paper. The project group had roughly determined where which collection should be and what key conditions applied for them. For example, each long-span and cantilever racking unit had to be accessible by forklift truck, requiring a certain amount of space between the units. Also, the ground floor has the highest floor load in the torso, and it is therefore here where the heaviest and largest objects were to be placed. The six painting compartments and the compartments for semi-precious and precious metals actually had to be on the third floor because of the specific climate requirements. In addition, a minimum walking distance needed to be determined between the shelving.

Figure 4 *Ceramics on mobile shelving. Photo: Donny Tijssen*

Bruynzeel and the project group ultimately agreed all of the preferred storage equipment. A storage facility with a surface area of 19,000 m² may seem quite sizeable, but if it also has to accommodate another 24,250 m² of mesh partitioning, 8,650 m of long-span racking, 18,060 m of shelving and 3,655 drawers, it will inevitably require some measuring and adjusting. In this, the project group placed great focus on ensuring that each type of storage equipment was effectively positioned, which meant that there was insufficient attention paid to positioning different types of storage in order to cluster collection units in specific compartments. As a result, some collection units were spread across different compartments over the four floors. A collection unit, such as sculptures, requires a wide variety of storage equipment. Ranging from shelves with different compartment heights for statuettes and busts through to cantilever racking or even a parking space for garden sculptures. But mesh racking is also needed for reliefs and plaques. Combining the same collection units from the different heritage institutions in the same storage room turned out to be such a challenge that it appeared impossible within the available time and space. Not only would it take a lot of time, it would make Bruynzeel's brief to be able to use all of the preferred storage equipment in the available compartments complex and time-consuming. There were also very strict deadlines to meet.

In terms of the processes, the construction and outfitting of the torso ran simultaneously, which meant that certain choices made for construction limited the flexibility for positioning storage furniture. The inventories should have determined more than just the configuration of the torso. If the project group had been able to find the time, it would have been possible to bring collections together and the floor plan could have been achieved more efficiently for each floor. It is obvious why this happened – in an ideal world, the inventories would have been the deciding factor in configuring the torso during the design phase. Together with Bruynzeel, the detailed configuration of the total of 39 compartments was agreed and approved.

A network of planning schedules

Now that the project group knew which storage equipment would be available, it was possible to determine the positioning of the object groups. The planning schedules for construction, Bruynzeel and the CC NL partners began to run in parallel and become intertwined.

In June 2020, the collection relocation had been scheduled to start, but the building had only been completed at the end of May. That meant that it was already quite clear that the partners would not be able to start moving collections to a fully-completed building where we would be free to move around all floors in the torso of the building. Bruynzeel had calculated that it would need a year to build all of the storage furniture, so a decision was made to work on a floor-by-floor basis. That meant that the schedule for the relocation was also affected by this. The plan was therefore to complete the ground floor first, followed by the second floor, then the first and finally the third floor. This sequence was determined in order to make it possible for Bruynzeel's activities and the relocation of the collection to run more or less in parallel, without obstructing each other. Only when all of the storage equipment had been completed on each floor would it be possible to start putting the collections into position.

This meant that the delivery sequence for storage equipment determined the sequence of collection relocations. Because the relocation had been planned for a year, there was considerable pressure to deliver the storage equipment on time. If this were to overrun, it would have major consequences for the relocation schedule. For the partners, the urgency to relocate was caused primarily by the need to dispose of the old storage facilities, most of which had to be vacated as quickly as possible in order to minimize the time in which double rent – for the existing storage facility and for CCNL – would need to be paid. Bruynzeel had therefore already started installing storage equipment when the builders were still at work, ensuring the building was ready for completion. This meant that the contractor had to hand over the ground floor of the torso to Bruynzeel at an early stage.

By the time the 'CC NL storage facility team' took residence in the building on 2 June 2020, the ground floor had been completed and, according to the schedule, it was possible to begin relocating the collections. By the end of January 2021, Bruynzeel had delivered all of the storage equipment and the whole building was entirely at the disposal of the CC NL. The sequence of the consignments to be relocated – collection units divided into groups with specific packaging requirements – had already been determined in advance by allocating specific storage equipment in each compartment to the different partners.

The CC NL storage facility team

The CC NL storage facility team was made up of staff from the different partners, with the numbers being determined according to the size of the collections. The team consists of 15 permanent staff. Basically, the team members are being seconded to the CC NL as a stand-alone organization. This means that this team is responsible for handling all the collections; as soon as the objects arrive at the CC NL, they are considered part of its collection. Of course, the specific collection knowledge and skills of staff, who have often worked for decades in the old storage facilities, is being put to good use. The details of this extensive partnership have been recorded in a cooperation agreement between the four partners. Bringing together collections here also entails combining four corporate cultures into a new CC NL corporate culture.

Although the CC NL storage team places the collections in the CC NL, the scheduling and coordination of the relocation is the responsibility of the 'CC NL relocation office'. It kept an overview of the schedules of the shipping addresses and the CC NL as well as Bruynzeel's delivery of the storage equipment.

The CC NL relocation team

After the tendering procedure, 13 of the 15 consignments became the responsibility of Kortmann Art Packers & Shippers and two further consignments were allocated to Hizkia van Kralingen, both companies specializing in art transport. In order to optimize the processing of incoming transports, both companies were tasked with transporting the collections from shelf to shelf.
That required teams to be on hand at the existing storage facilities and in the CC NL at all times in order to meet the schedule. The storage facility team was supplemented by staff from Kortmann and Hizkia van Kralingen. As a result, the whole team, including the additional staff from the partners, was made up of around 30 colleagues. This 'CC NL relocation team' took care of internal logistics and the ultimate placing of the collections in their new positions.

Relocating to the CC NL

On completion of the building by the contractor and of the ground floor of the torso by Bruynzeel, it was still not possible to begin the relocation immediately. The storage facility team still had several weeks to prepare the torso to receive the first objects. Following intensive cleaning of the neck and torso, the first of the more than 35,000 positioning sites required had to be put in place.
The parking spaces for the largest objects, totalling more than 1,900 m² had to be placed on a floor that was still unfinished. This was where the first coaches and carriages from the Nederlands Openluchtmuseum would very soon be stationed. The climate in the building also had to be in order. When Bruynzeel began working on the assembly of all of the storage equipment, the climate control systems were also put into operation. At the start of the relocation, the climate conditions in the ground floor were as desired by CC NL. The other floors were also quickly adjusted to the right climate, facilitated by the decision to minimize the pouring of concrete and make maximum use of prefab components.

The Nederlands Openluchtmuseum had the honour of sending the first consignment: a collection of clocks.
The CC NL relocation team was on tenterhooks, eager to receive and position this collection. After a calm start to the relocation process, around seven trucks, complete with trailers, were soon arriving on a daily basis.
This calm beginning gave the team the chance to carefully discuss the processes and structure all of the work and preparations. It also gave the team an opportunity to become acquainted with each other and the new building.

Results and conclusions

The CollectieCentrum Nederland project is almost complete. From the very start, the project brought to mind the successful computer game Tetris; each partial project or collection unit added new blocks of different shapes and sizes to the big puzzle that had to be solved, see Figure 5. All of these blocks had to be positioned in a predefined field, with the shapes having to be adjusted and shifted to and fro. By adapting and changing the positioning of these blocks, it proved possible to place all of them in the playing field. At times, gaps were left that

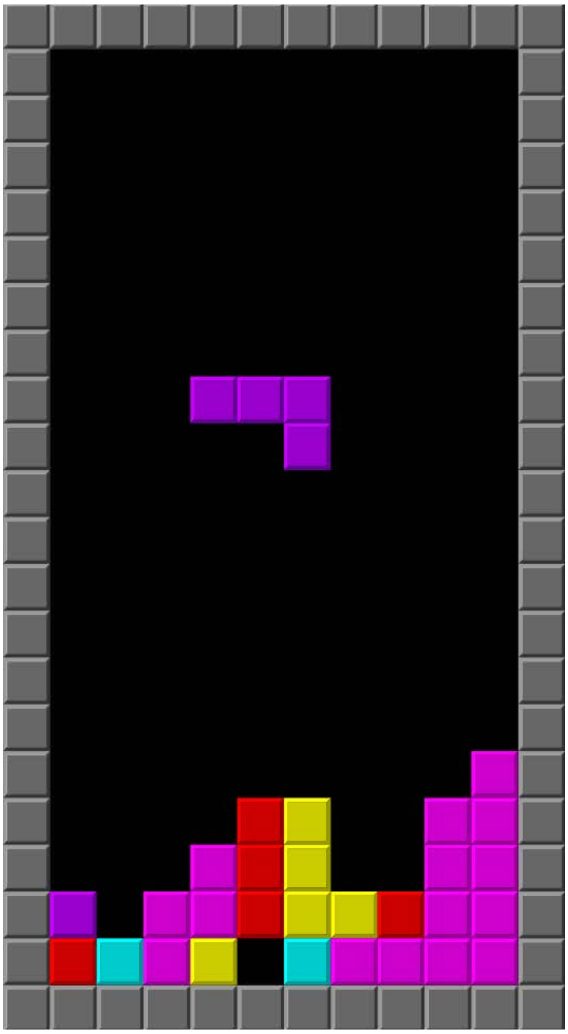


Figure 5 *The computer game Tetris. Photo: Wikipedia*

we will be able to fill in the future, in order to make even more efficient use of the field of play, or in this case the torso of the building.

After over 840 individual transports, the relocation process was now approaching its end, in June 2021. Increasing numbers of compartments were becoming available, giving increasing freedom in positioning the collections. The efficient positioning of the storage equipment also enabled to gradually bring together some collection units that had been stored separately, initially on a piecemeal basis for each partner and ultimately allowing to reunite all of the CCNL collection units.

The inventories compiled by the torso outfitting project group were done in such a way as to enable all of the collections to fit and there will even be room to accommodate growth in the collections. The decision to opt for standard storage equipment and types of storage unit makes it possible to add shelf space in the future, because the storage area is still remarkably roomy.

In terms of the process, the outfitting of the torso proved successful, but it would have been more efficient if the exact configuration of the torso had been decided on before construction started. This would have enabled the project group to divide up the compartments even more effectively, allowing the notional merging of collection units at that early stage. This would have prevented collections being divided up. However, the results are already impressive. The CC NL has been realized in a seven year timeframe, from design through to outfitting. Ultimately, all of the choices made have resulted in a collection centre of which we can be proud. Our prize national exhibits are now stored here in the best possible conditions. In addition, the facilities for these state collections are so extensive, that they have raised their management and conservation to a completely new level.

The ‘CC NL project’ now moves on to ‘CC NL in operation’. Although the collaboration between the partners has already borne fruit, this will be even more visible in the operation phase. The partners will be combining their knowledge and expertise, ensuring all museum processes are raised to a higher level and the collections safeguarded for future generations.

Storage of nitrate films in an underground bunker in 2019. Photo: Bart Ankersmit

The Zuid-Holland provincial archaeological storage facility

Mark Phlippeau – Storage Facility Manager, Province of Zuid-Holland

Summary

The archaeological record faces threats on a daily basis and in order to preserve all of the information, archaeological research is necessary as a last resort. Every Dutch province has a statutory duty to maintain a storage facility. This article explores the history of the Zuid-Holland provincial archaeological storage facility, the layout of the building, the indoor climate and aspects of building physics, how the storage facility operates and the search for a new storage building.

Introduction

In many cases, archaeological research is necessary in order to properly document the archaeological record. When archaeologists have completed this field research and objects have been excavated, further examination of findings and interpretation of the pieces of the puzzle begins. Within two years of field work being completed, the project must come to an end and the final step in the cycle takes place, i.e. the archiving of the finds and excavation records in the Zuid-Holland provincial archaeological storage facility.[55]

During the storage process, certified excavation companies must adhere to the Dutch Archaeology Quality Standard (*Kwaliteitsnorm Nederlandse Archeologie*). The provincial storage facility must also follow this protocol, which includes a duty to enable access to the data and provide optimum management and conservation of the collection. The Dutch Monuments Act of 1988 (*Monumentenwet 1988*) stipulates that provincial executives must maintain a storage facility in which 'Movable monuments, discovered in archaeological digs within the province, are to be stored in a responsible manner from the perspective of conservation and accessibility. The related excavation documentation must be stored in the same facility.'

Development of the collection

Starting in 1971, the National Museum of Antiquities (*Rijksmuseum van Oudheden*, RMO) in Leiden provided a workspace and the possibility for the storage of Zuid-Holland find material in a museum storage facility on Raamsteeg. At the time, it was home to the Provincial Archaeological Record and the first finds were brought there in 1972 by the Lek- en Merwestreek Steering Committee of the AWN Association of Volunteers in Archaeology.[56] In 1997, the storage facility collection was separated from the RMO collection. From 1990, both collections had been stored in a former MIBO warehouse and their management was the responsibility of the RMO. It was already on 20 December 1962 that the municipality of Alphen aan den Rijn issued planning permission for the construction of such a MIBO warehouse.[57]

These so-called MIBO warehouses had been set up during the Cold War to store large stocks of medicines, gas masks and other materials, such as emergency beds. In the event of a nuclear attack, the warehouses were intended to play a role in supplying makeshift hospitals. On one side, trucks could ride into the warehouse to stock up before exiting via roller doors on the other side.

With the fall of the Berlin Wall in 1989, the MIBO warehouse became surplus to requirements and was redesignated as a storage facility for the RMO and the Province of Zuid-Holland in 1990. Previously, medicines had been stored in a climate chamber of the MIBO warehouse in Alphen aan den Rijn at a temperature of 10°C. Half a century later, this same climate chamber, with some adaptations now part of the Zuid-Holland provincial archaeological storage facility, is being used to store metal finds, which are now being kept at a temperature of 17.5°C and a relative humidity of below 30%.

From 1993, the national museums were privatized and it was agreed that the section belonging to Zuid-Holland, which was the province's responsibility, would be transferred to the Province of Zuid-Holland. In 2004, the RMO collection was returned to a storage facility in the museum in Leiden while the sizeable collection belonging to the Province of Zuid-Holland stayed behind in Alphen aan den Rijn. In that same year, a schedule of requirements was

[55] In the Province of Zuid-Holland, there are nine municipal archaeological storage facilities in total: The Hague, Rijswijk, Gouda, Rotterdam, Leiden, Gorinchem, Dordrecht, Delft and Vlaardingen. The municipalities themselves manage the finds and related documentation within their localities.

[56] Rijksdienst voor het Oudheidkundig Bodemonderzoek Amersfoort (1972). *Jaarverslag 1972*, p. 116.

[57] Kok, R, (2020, 20 January). Ziekenhuisinrichting voordat de bom valt. *Leidsch Dagblad*.

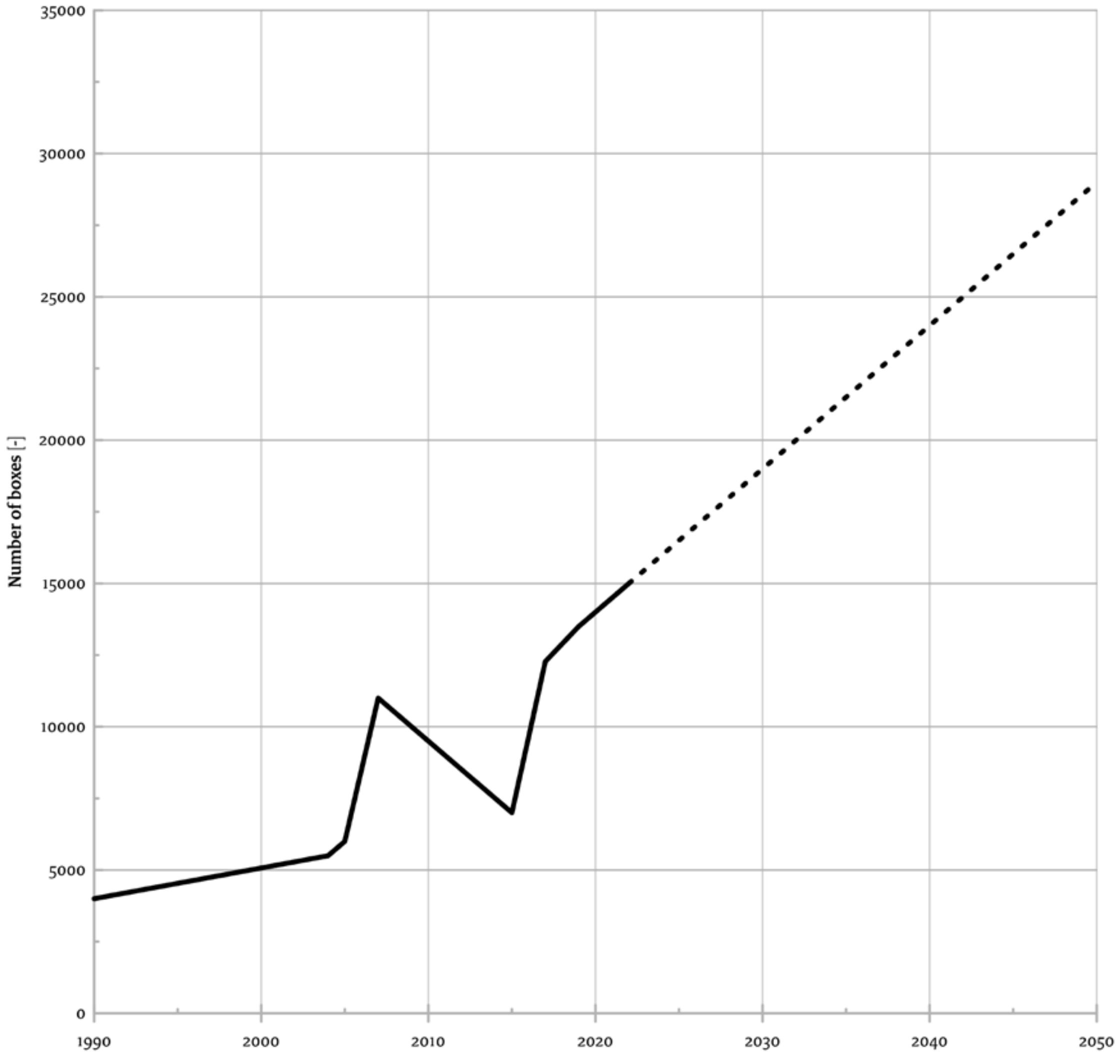


Figure 1 *Growth in the number of boxes in the collection. From 2022, an increase of around 500 to 600 boxes per year has been forecast. Image: Mark Phlippeau*

drawn up to increase the capacity from a maximum of 5,500 boxes to a capacity of 10,500. The Province of Zuid-Holland was anticipating further growth as a result of the transfer of find materials being kept in the central storage facility of the State Service for Archaeological Investigations in the Netherlands (ROB) in Amersfoort[58] and the Archaeological Services Centre (an excavation company), various universities and groups of amateur archaeologists.[59] A metal storage facility was also opened in the same year in order to store fragile metal finds in the appropriate stable conditions.

On 1 September 2007, the Archaeological Heritage Management Act (*Wet op de archeologische monumentenzorg*) was enacted, as a result of which the Province of Zuid-Holland became the owner of all archaeological finds from the province, with the exception of nine municipalities that had their own storage facility. In Amersfoort, the ROB (now the Cultural Heritage Agency of the Netherlands, RCE) managed the national storage facility, and as a result of the new legislation, a further 5,000 or so boxes were transferred to the Province of Zuid-Holland in 2010. This resulted in significant backlogs in registration. By 2013, this backlog had been dealt with at a basic level. That amounted to a global description of the box contents, global dating of the find material and recording of its location. After that, finds and documentation from the municipal storage facilities in Dordrecht, Leiden, Rijswijk, The Hague and Vlaardingen were also transferred.[60] These finds and documentation were transferred between 2013 and 2018, which meant that more space was created temporarily.

Every year, the provincial storage facility receives an average of 500 boxes of find material, the equivalent of 25-30 m^3.[61] Figure 1 provides an overview of the growth in the collection over the last two decades. Materials are generally archived by excavation companies and to a lesser extent by universities, museums, and historical and archaeological associations. There are now almost 14,000 boxes (700 m^3) in storage in the facility. The existing building in Alphen aan den Rijn has reached the limits of its storage capacity and external storage space is now being hired in order to accommodate the growing collection.

58 The ROB was founded in 1946 and merged in 2006 with the Department for the Preservation of Historic Buildings and Sites to form the organization that would ultimately become the Central Heritage Agency of the Netherlands (RCE) in 2009. From 2011, the former Netherlands Collection Institute (ICN) also merged with the RCE. The ROB storage facility in Amersfoort reflected more than a half-century of excavation research in the Netherlands. This included over 5,000 boxes originating from Zuid-Holland.

59 Provinciaal Archeologisch Depot (2004, February). *Programma van eisen*.

60 A total of 3,922 boxes were transferred to these municipal storage facilities: Dordrecht 1,300, Leiden 2,250, Rijswijk 58, The Hague 131 and Vlaardingen 183.

61 The size of a standard box is 50x50x20 cm; which amounts to a volume of 0.05 m3.

The archaeological record is under threat as a result of an increasing intensity in construction work, infrastructure and housing construction. The Province's archaeological record is unique in the sense that the find materials which are discovered tend to be well-conserved, because the soil conditions in Zuid-Holland are generally relatively moist. As a result, sensitive organic material can be excavated in good condition. Most of the collection kept in boxes comprises objects from Roman times (52%). The rest of the collection is made up of objects from prehistory (12%), the Middle Ages (11%), and the modern period (25%). In this period grouping, most of the finds are made up of earthenware (46%) and there is also a large category of organic material (17%). The other categories in the boxes are natural stone (6%), metal (4%) and glass (1%). Some 25% of the boxes contain a mixture of otherwise uncategorized find materials.[62]

The layout of the storage facility

The Zuid-Holland provincial archaeological storage facility is made up of a large hall with a mezzanine for the storage of boxes primarily containing ceramics, glass, animal bone and stone; see Figure 2.

The main hall contains pallet storage units for the temporary storage of newly-arrived find materials. The storage facility does not have a separate transit area, which means that there is a chance moulds and pests are free to spread through the room. The excavation records are kept together with the field drawings on the ground floor of the main hall and the excavation files, slides and field photos are kept in archive boxes on the mezzanine floor. In 2016, an internal fire-safe room was built with a stable climate, referred to as 'the Box', in which the most valuable parts of the collection are stored; see Figure 3. This includes restored ceramic and glass, horn, textiles, leather, rope, worked bone and wood and all the finds from the prime prehistoric sites Hardinxveld-Giessendam (5500-4450 B.C.) and Schipluiden (c. 3500 B.C.). The metal storage unit is in what used to be the MIBO climate chamber. This is a separate room with air-conditioning and a dehumidifier, where a stable climate is guaranteed. On the lot, construction materials made of natural stone and building ceramic are stored underneath an awning. As a result, these sturdy objects are exposed to the outdoor climate.

[62] Aanvulling collectieplan provinciaal depot voor bodemvondsten Zuid-Holland, April 2017, p. 9.

Figure 2 *The Zuid-Holland provincial archaeological storage facility with mezzanine floor and several workspaces for volunteers and researchers. Photo: Smits van Burgst Beveiliging*

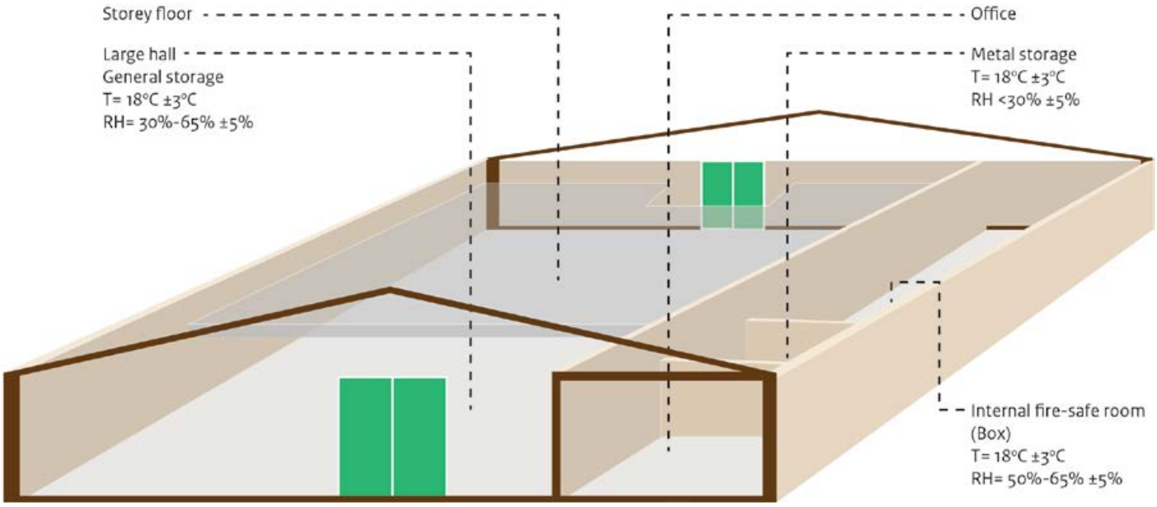


Figure 3 *Schematic representation of the storage building. Image: Bart Ankersmit*

Indoor climate and aspects of building physics

The provincial storage facility is based in an inconspicuous warehouse that is 35 m long and 21 m wide and has a roof apex height of 6.5 m. The façade is made of brick in a staggered arrangement and finished with flush pointing bonded with cement. Ventilation grilles measuring 50 x 50 cm have been fitted on both the front and back walls for natural airflow. External air flows through these grilles and back out again. The roof is a steel structure with strawboard sheeting: Durisol 'mevriet' boards. Daylight is provided via six skylights measuring 0.8 x 0.8 m^2. The interior walls have been plastered. The fire-safe compartment (the Box) consists of limestone blocks with a thickness of 15 cm.

The Soil Quality Infrastructure Foundation (SIKB) prescribes the climate specifications for archaeological storage facilities. Different indoor climates are prescribed for different groups of materials (see Table 1).[63]

One of the areas for improvement highlighted by the Heritage Inspectorate after a tour in 2015 was the lack of a logbook for climate monitoring.[64] In 2018, investments were made in data loggers to record the relative humidity and temperature in various storage rooms every 15 minutes. These take accurate readings of the temperature and relative humidity. Limit values have been set. If these are exceeded, the system reports this

[63] SIKB (2018, 19 February). *Protocol 4010 Depotbeheer* (versie 4.1). See https://www.sikb.nl/doc/BRL4000/Protocol%204010%20Depotbeheer%204_1.pdf.
[64] Erfgoedinspectie (2015, September). *Inspectie provinciaal depot bodemvondsten van de provincie Zuid-Holland in Alphen aan de Rijn*.

Table 1 *Climate conditions set by the Soil Quality Infrastructure Foundation*

	Temperature (°C)		**Relative humidity (%)**	
	Bandwidth	**Fluctuation**	**Bandwidth**	**Fluctuation**
Buffer storage for new deliveries with minimal conditions	15-18			±5
General storage room with minimal conditions for ceramic, glass, stone and bone, etc.	18	±3	30-65	±5
Storage room with relatively dry conditions for metals and slag, etc.	18	±3	<30	±5
Storage room with relatively moist conditions for leather, wood, textile, rope, worked bone, amber and jet	18	±3	50-65	±5
Space for effective storage of associated original documents on paper, drawing film, etc.	15	±3	55-65	±5
Space for effective storage of photographic materials	15	±3	<35	±5

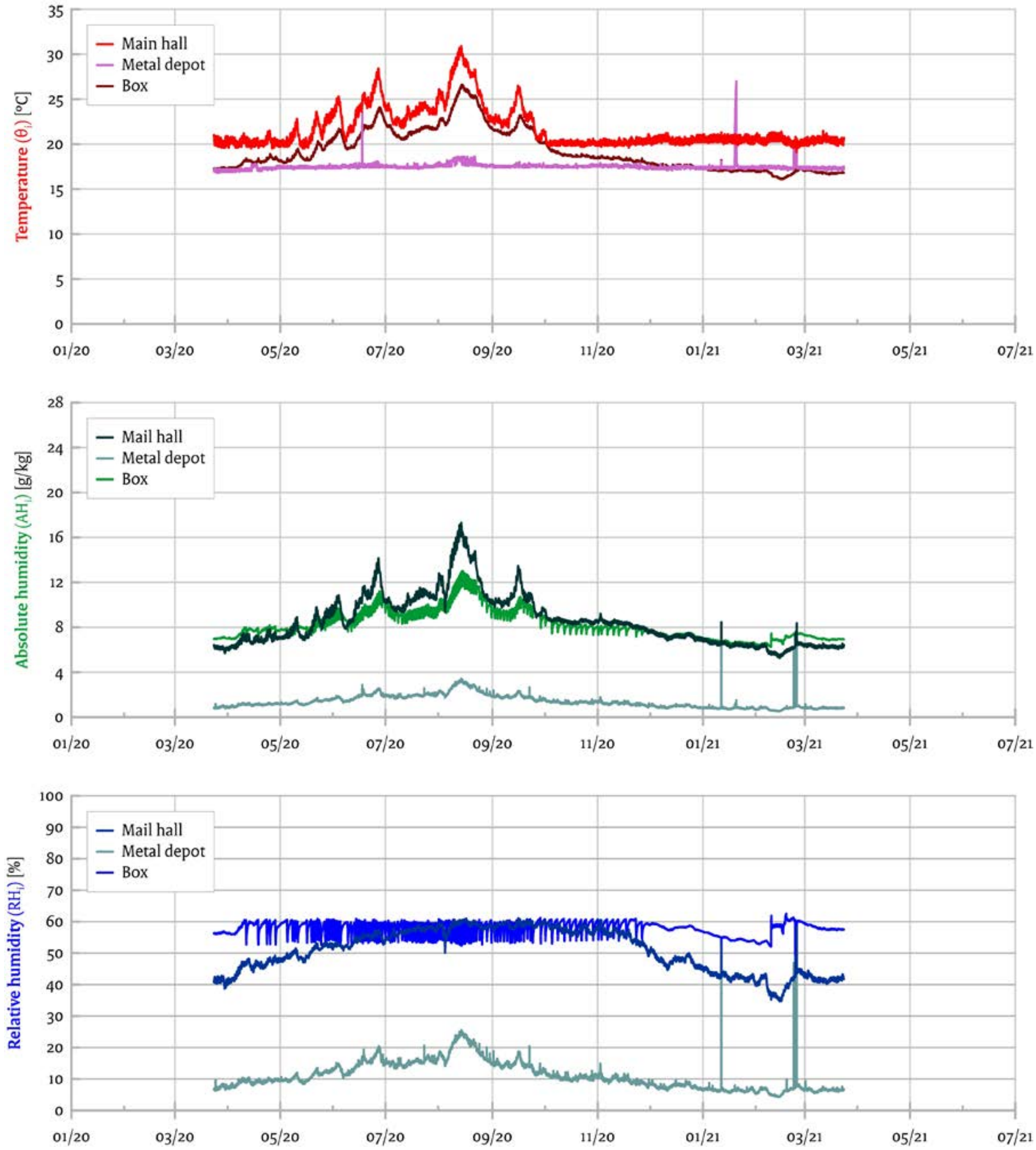


Figure 4 *The climate in the main hall, the metal storage facility and in a box in the main hall. The blue lines show the relative humidity (%) the brown-red lines show the temperature (°C) and the green lines show the absolute humidity (g/m3). Image: Mark Phlippeau*

by email and the storage facility manager can take immediate action in response. The measurement data show that the climate in the Box and the metal storage facility are in line with the relevant requirements. Depending on the season, a mobile humidifier or dehumidifier is placed in the Box. The 15 cm thick fire-resistant limestone walls also contribute to stabilizing the temperature and relative humidity; see Figure 4.

In the main hall, the temperature fluctuates between 19.8°C in winter and 30.5°C in summer. The relative humidity varies from 37% in winter to 61% in summer. In autumn and winter, the main hall is heated by blowing in hot air, but the air-handling unit is incapable of cooling, dehumidifying or humidifying. These data show that the indoor climate in the main hall fluctuates with the outdoor climate and is damper and warmer in summer and cooler and drier in winter.

The indoor climate in the metal storage facility is managed using an air-conditioning unit and a dehumidifier. As a result, the temperature and relative humidity remain within the desired bandwidth.
The relative humidity is between 5% and 25% and the temperature between 17°C and 18.5°C. On 19 January 2021, the temperature suddenly peaked. This appeared to be caused by a local disruption to the power supply, as a result of which the air-conditioning unit was reset and the temperature suddenly rose. After an alert, the air-conditioning unit was reset again to the right settings.

Most of the metal objects in the storage facility are in plastic bags. The climate in these bags is not the same as the climate in the room. Figure 5 shows that the short-term fluctuations are even smaller than they already were.

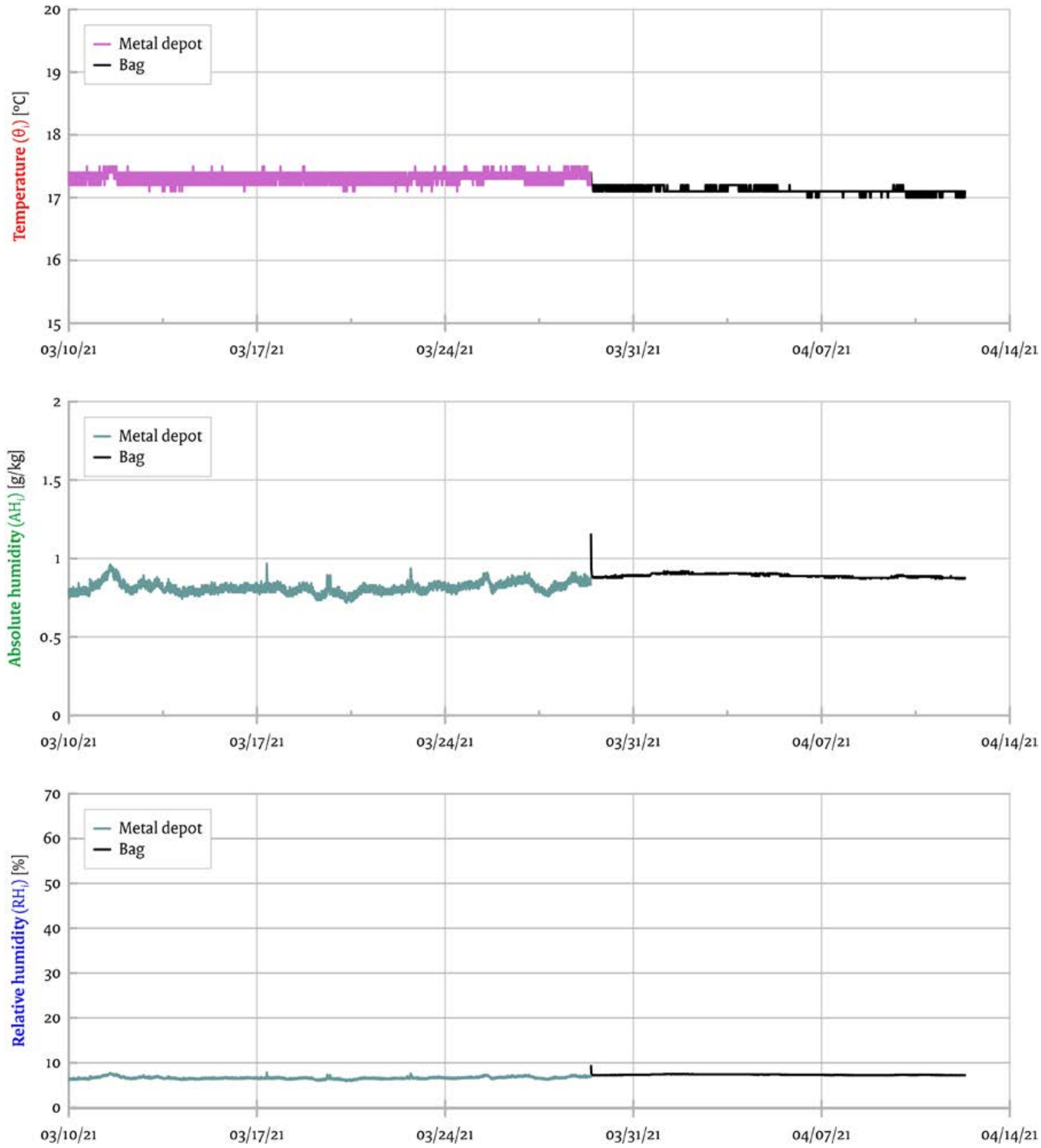


Figure 5 *The climate in the metal storage facility. The sensor was placed in a plastic bag halfway through the measurement period. Image: Mark Phlippeau*

The operation of the storage facility

Archaeological finds should preferably be conserved in situ. Thick parcels of soil have ensured that objects remain stable for hundreds of thousands of years and are subjected to only minimum influences, such as temperature fluctuations. As soon as the conservation of these objects in situ is threatened, the decision may be made to excavate them. Archaeologists have just a single opportunity to subject the soil to precise examination and document it. After that, the archaeological record at the location is partially or completely destroyed.
The quality assurance of archaeological research is laid down formally in the Dutch Archaeology Quality Standard (KNA) for which the SIKB is responsible.[65]

All parties involved in the SIKB network strive to guarantee both the quality of the archaeological process and quality in more substantive terms. The Central Committee of Experts (CCvD) manages the documents and meets regularly to update this documentation.
The CCvD is made up of representatives from certified excavation companies, municipalities, provinces and universities and it is within this that the archaeological sector reaches joint agreements about the quality of its day-to-day work. The KNA includes guidelines that are seen as best practices for specific aspects of archaeological research. For example, the provincial archaeological storage facility must adhere to Protocol 4010 on Storage Facility Management. The aim of this protocol is to safeguard long-term access to finds, samples and project documentation concerning archaeological sites for future research and the experience of cultural heritage.[66] This means that the

[65] SIKB (2016, 9 May). *Protocol 4004 Opgraven (landbodems)* (versie 4.1). See: https://www.sikb.nl/doc/archeo/Protocol%204004%20Opgraven-lb%204_0_definitief.pdf

[66] Ibid. note 9, p. 5.

archaeological research is of high quality and capable of reaching qualitative and possibly innovative impressions of the country's past.

When the archaeological fieldwork has been completed, the evaluation phase begins. In it, material specialists generally assess the finds and samples and contact the storage facility holder concerning the selection report. A selection report outlines information about which finds and samples have been selected for processing, which finds require conservation and a suggestion for finds and samples to be removed (deselected). Only after the storage facility holder and/or owner has given approval is it permitted for material eligible for deselection not to be archived. Within two years of completion of the fieldwork, the digital project documentation must be delivered to the storage facility. Until several years ago, the excavation companies transferred the data set digitally, using WeTransfer and DVD for example. The collection of DVDs covers approximately four linear metres and all of the data were migrated to an internal digital server two years ago. As the DVDs are chemically unstable and may become inaccessible within a few decades, there is a risk that some of the information will be lost. In order to find a solution and arrange the archiving of datasets via a single digital helpdesk, the so-called Archeodepot was introduced. In it, data are sustainably archived using DANS-EASY.[67] The majority of the provinces are now using Archeodepot and there are also plans for municipal storage facilities to do so. Once the project documentation has been approved, the finds can be transferred to the storage facility.

The finds are recorded in the collection database known as The Museum System. Cross-references are used to link finds to the discovery sites. In addition to basic registration, any objects worthy of exhibition, referred to as 'specials', are given a detailed description and photographed. As many as 11,000 of the specials have now been made available digitally via the collection website for the public, museums and researchers.[68] The storage facility engages actively in loans: every year, there are dozens of loans to various cultural institutions, including Dutch and foreign museums. In 2019, there was a total of 83 loan agreements for exhibitions.

Various researchers from the Netherlands and beyond have now discovered our storage facility. The Neolithic site at Schipluiden (c. 3500 B.C.) and the Late Mesolithic Hardinxveld-Giessendam site (5500-4450 B.C.)

67 DANS-EASY is an online archiving system for archiving and reusing research data. This sustainable form of archiving is used by various academic disciplines.
68 See: https://archeologie.zuid-holland.nl/collectie.

Figure 6 *Het Archeologiehuis (House of Archaeology) in Alphen aan de Rijn. Photo: Mark Philippeau*

are collections that are very much in demand with Dutch and international researchers. New research methods mean that the study of old excavations can reveal surprising new insights. For example, researchers from Groningen University studying bone material from the Schipluiden excavation have determined that farming communities in the early Stone Age in the Netherlands began to develop earlier than previously thought.[69]

Collection management is the responsibility of two storage facility managers, one assistant manager and five volunteers. The storage facility also offers internships to students. There is a display room for the provincial archaeological storage facility: Het Archeologiehuis, based in a reconstructed Roman villa located just in front of the entrance to Museum park Archeon in Alphen aan den Rijn; see Figure 6. Het Archeologiehuis displays many of the most important finds to the public. It is a collaborative venture involving the province, Archeon, the Rijnstreek chapter of the national amateur archaeological society and the Erfgoedhuis Zuid-Holland (centre of expertise for heritage, situated in Delft).

The development of a new storage facility

The existing storage facility is almost full, which from a climate-control perspective is not ideal for the long-term conservation of the finds and related documentation.

In mid-2018, the first steps were taken towards a new storage facility. First of all, Leiden-based architects' firm VVKH was asked to compile a schedule of requirements (SoR). The Province of Zuid-Holland contacted this firm because it had previously designed the Huis van Hilde archaeology centre in Castricum. The SoR included details on the following subjects:

- current number of square metres per storage room;
- future number of square metres required;
- outfitting of the storage facility;
- climate for each storage room.

Importantly, this involves adding storage rooms that are not included in the current building, such as a separate room for conserving analogue excavation documentation. Another example is the lack of any shipping and quarantine rooms to take receipt of new finds.
The portfolio holder (the provincial executive responsible for Culture and Heritage) subsequently took note of the document and advised a response from the provincial archivist. His response was that the SoR forms a good basis for further research. The definitive version of the document was delivered at the end of spring 2019.

From the end of 2019 and for much of 2020, there were initiatives to create an alliance with various heritage parties in order to develop a new storage facility. At the time of writing, these plans have yet to be fleshed out in any further detail.

[69] See: https://www.rug.nl/news/2020/10/prehistorische-inwoners-van-nederland-al-vroeger-boer-dan-gedacht.

CollectieCentrum Nederland – an open kitchen

Wim Hoeben – Location Manager, CC NL, Rijksmuseum

Summary

Four major heritage institutions decide to join forces and build a new central storage facility. It is based on the key concepts of *sustainability, cooperation* and *open and accessible*. The result is a joy to behold. But anyone who imagines that they can interpret sustainability as 'the avoidance of technology unless absolutely necessary ...' will be disappointed.

Introduction

In 2021, the official opening of the CollectieCentrum Nederland (CC NL) marks the culmination of a project with a history lasting exactly ten years. In a building covering 31,000 m², 19,000 m² of which is storage space, four key components of the Dutch national collection are being preserved: those belonging to the Nederlands Openluchtmuseum (Netherlands Open Air Museum), the Cultural Heritage Agency of the Netherlands, the Rijksmuseum and Paleis Het Loo. For a project of its size, ten years is not really that long. But the prehistory of the CC NL actually goes back much farther than that. This article portrays this prehistory mainly from the perspective of the Rijksmuseum, but the pattern it reveals is not exclusive to this institution.

For years, there has been a noticeable trend for heritage institutions, such as archives, museums and libraries, to move their storage facilities to the outskirts of cities or even beyond. Their aim is to be able to offer more facilities at their main site to the ever-growing stream of visitors. In their efforts to adapt their often listed buildings to meet the demands of the modern age, museums in crowded city centres have exhausted their creative options.
The Rijksmuseum building, completed in 1885, was designed to receive around 60,000 visitors per year. There was no storage facility, because the entire collection filled the galleries.[70] The exceptions were the library and print collections that were preserved in the monumental library and in offices and – even then – only available on request. It was a century later (a hundred years of continuous adaptations, renovations and improvements [71]), that a total renovation of the Rijksmuseum building was alluded to. Visitor numbers were hovering around a million a year and there was no

70 Within just a few years, there was already criticism of the fact that the museum was so full. Even in the 19th century, there were references to the museum's ''warehouse of paintings' and 'the desperate system of warehouse-like excess that makes a walk around the Rijksmuseum feel like running the gauntlet'.

71 The most far-reaching modifications were probably the filling in of the west courtyard in 1962, which added a further 30 galleries to the Applied Arts department on a surface area of 3,500 m², plus an auditorium. The second half of the 1960s saw the filling in of the east courtyard, with study collections, a large room for the history department, four painting galleries and an exhibitions room. Both of these adaptations were reversed in the recent major renovation work.

Figure 1 *Rather than publicly exhibiting all objects in the collection, a new trend emerged starting in 1920 to display only a selection to enable the visitor to view individual pieces properly. Photo: Rijksmuseum*

good space available to organize temporary exhibitions, something that was not yet an issue back in 1885.

By now, the museum galleries were completely different from those at the end of the 19th century. Aesthetic display had been introduced, in which galleries were set up to appear attractive and easy on the eye, enabling people to carefully view individual works. At the Rijksmuseum, this started around 1920. Its new director, Schmidt-Degener, aimed to achieve easy-to-navigate galleries of paintings organized rhythmically by subject and size and preferably with standardized frames, see Figure 1.[72] Achieving that not only required very careful selection, but also exchanges with other institutions. As a result, this new way of organizing museums triggered the first ever serious surge in long-term museum loans, while also heralding the rise of the notion of *depot* or *storage facility*.[73] Screened-off areas in the attics, cellars, staircases and towers began to emerge where parts of the collection that were temporarily or permanently excluded from exhibition were stored. In 2000, when the decision was ultimately made for a large-scale renovation of the Rijksmuseum, there were already more than 60 storage facilities in the museum building, ranging from large professional storage facilities to the familiar 'cupboard under the stairs'. In floorplans dating from that time, they can therefore be difficult to spot for the uninitiated.

Partly as a result of the various adaptations and renovations, visitor numbers have risen significantly over the course of time: from around 250,000 at the start of the 20th century to more than 2,500,000 shortly before the outbreak of the COVID-19 pandemic, when numbers fell drastically, see Figure 2. Clearly, having been built in 1885, the building was always going to need an expansion because of the large number of visitors. In order to be able to welcome all those people and offer them a pleasant experience, the building needs to be adapted and new functionalities added. If you also take into account the growth in the collection, it is also clear that the volume of storage facilities will inevitably increase over time.

[72] Somewhat wistfully, in the museum's 1922 annual report, Schmidt-Degener describes the process as 'the distribution of the mass of paintings across the main floor'.

[73] Since less was on display, places were needed to store the rest of the collection. Besides this, it was now no longer possible to use certain paintings even if they had the right artist and style, because format and size were now key factors. In addition, large numbers of new frames were also used, creating the need for storage for the frames no longer in use (if they were retained at all...).

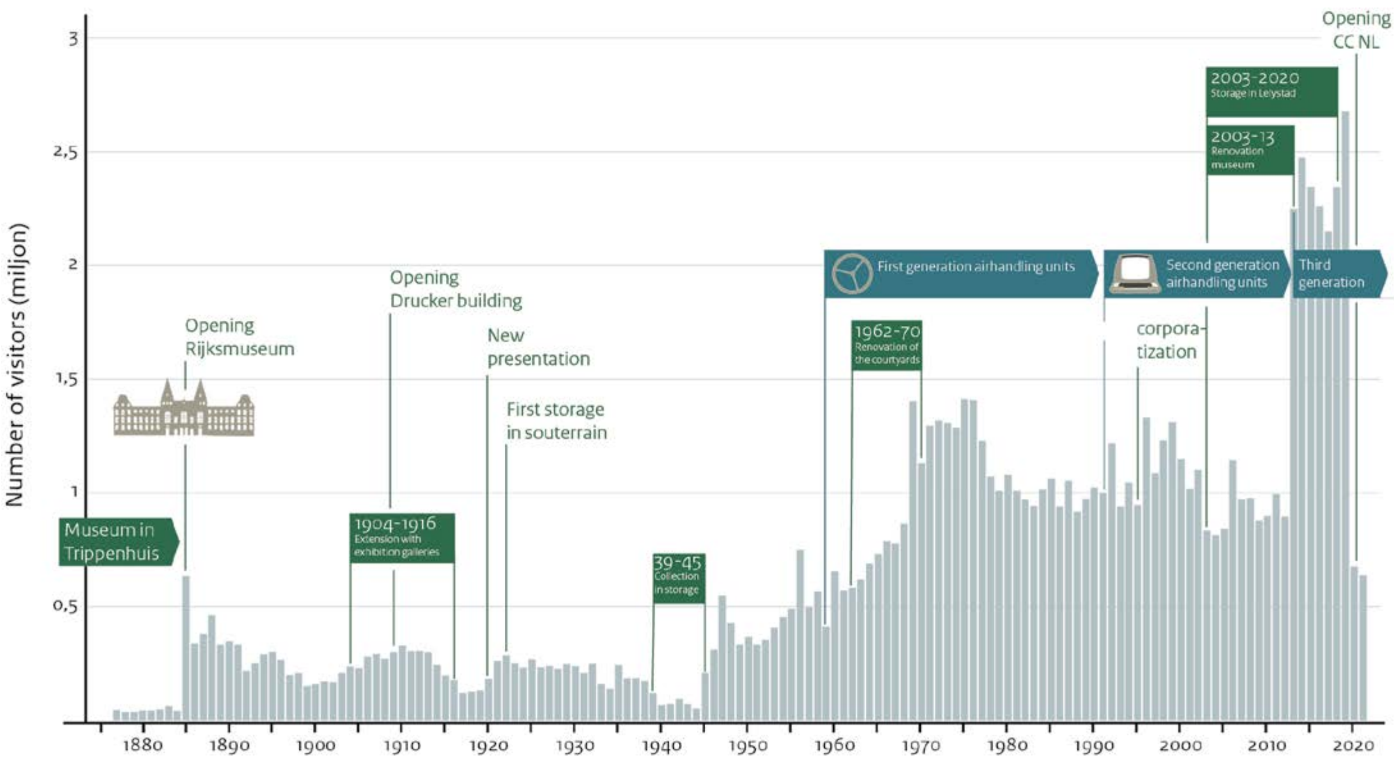


Figure 2 *Visitor numbers to the Rijksmuseum for the period 1887 until 2020, with some important trends. Image: Bart Ankersmit*

To Lelystad

During renovation work, it turned out that there was no suitable space to house the collection on site . A solution at an alternative location quickly needed to be found. This turned out to be: the Storage and Distribution Centre of De Nederlandsche Bank (Dutch National Bank) in Lelystad, a purpose-built warehouse for the storage of euro coins. Featuring advanced security and – important for the intensive traffic in art loans – located right next to the motorway. Starting in 2003, part of this gigantic building was let, and, after rapid refurbishment, it was possible to create around 6,400 m² of storage space in addition to a working area with office accommodation, a photography studio, wrapping and warehouse facilities. In the years from 2003 to 2013 while the Rijksmuseum was being renovated, it soon became clear that returning the complete collection to its home in Museumplein would not be an option. The aim to achieve at least double the existing visitor numbers of a million per year after refurbishment placed so much pressure on the available space that it soon became clear to the organization that a remote storage facility would ultimately become a permanent phenomenon for the Rijksmuseum. This was actually a positive development since storage facility staff had become used to the convenience of logistical processes in the facility being able to proceed without the restrictions of a characterful but impractical historic building.[74]
By that time, a good picture had also emerged of the key facilities required in an independently-operating museum storage facility and what was not needed. This resulted in an impetus to develop a schedule of requirements for a new storage facility or even better: for a collection centre, since a limited public function was also envisaged for it. As digital access to museum collections progresses, so the demand for contact with the 'real objects' also grows.

In addition to increased possibilities for visits, we were also keen to see a more sustainable building.
The warehouse in Lelystad was built for coinage and has no climate control system or efficient insulation. Although facilities were of course installed to enable it to operate as an art storage facility, the total energy bill for cooling and heating was impressive.[75] We were now envisaging a building with such a mass that it would heat up and cool down extremely slowly, ensuring it would have a relatively stable climate with only limited added energy all year round. 'The avoidance of technology, unless absolutely necessary...' became a motto for the future collection centre.

The CC NL

Once experience had shown that a good storage facility consists of a storage section together with several quality working areas, this led to the desire to share any future location with other users, as a means of at least sharing the working section and the associated costs. Only later in the project would be idea of sharing the storage area and the cost of deploying the people responsible for it also emerge.

With the key concepts of *sustainability, cooperation* and *open and accessible* in mind, tentative enquiries were made with various institutions responsible for managing collections, which virtually immediately revealed that the ideas being developed about an ideal storage facility bore a remarkable resemblance to each other. After a short time, a group of three players, already mentioned, began to emerge. Paleis Het Loo, the fourth partner in the CC NL, came on board later in the process. In addition to its collection of historic buildings, the Openluchtmuseum manages an impressive collection of folk art and everyday utensils. The Cultural Heritage Agency of the Netherlands is responsible for managing a great deal of fine and applied art from the national collection. Part of this includes an official collection used to fit out government buildings, for example. Paleis Het Loo is a former royal palace that has now opened as a museum and manages a collection that offers an excellent overview of courtly culture in the Netherlands.

In an effort to be sustainable, thoughts initially turned to reusing existing buildings for a new collection centre. Several locations were viewed, but the specific requirements for a storage facility building and its immediate surroundings, combined with the need to enable access for logistics, staff and visitors, quickly pointed in the direction of a new building.[76]

[74] Towers and staircases are characteristic features of the Cuypers building. The access doors are also only modest in size. In addition, the fact that the museum was designed as a gateway building, largely consisting of 'two halves' also made moving large and fragile artworks far from easy.

[75] Average for the last five years: 815,437 kWh of electricity and 95,612 m3 of gas.

[76] Numerous existing buildings were viewed, but it proved impossible to find the right combination of a building that is large enough or can be expanded, is located in an easily accessible place, can be effectively secured and adapted within budget.

It turned out to be difficult to find an easily accessible and sufficiently large plot that was also within reach of the (by now four) partners and preferably also above sea level (26% of the Netherlands lies below sea level). The CC NL was intended to be a building covering 31,000 m² and a suitable plot would need to be at least 19,000 m² (the equivalent of 73 tennis courts). In the end, a suitable location was found on the outskirts of Amersfoort (the church tower in the centre of which marks the geographic centre of the Netherlands). It was even within walking distance of a railway station.

Cohabiting and collaborating

The sheer clarity of the design by architects' firm cepezed provided a new impetus to think carefully about operational processes and ultimately also about collaboration. If basic facilities are being shared, will we then also be able to handle each other's collections, assuming that all of us are professionals? Will each member of staff have access to each of the almost 40 compartments in the storage facility? Will we be dividing up the practical facilities to be used by individual users, or is everything for everyone? The photography studio is a good example of this. All partners had long cherished the idea of having a spacious and well-equipped photo studio alongside the storage facility. Will we then take turns in sharing a suitable room for that purpose or will we also make use of each other's cameras and lighting? Or will a single photographer do all the photography for four institutions? In order to keep the building as simple and therefore as sustainable as possible and gain maximum leverage from the collaboration, the four organizations are increasingly striving to achieve far-reaching solutions. Reaching agreement on these can of course take time.

The four partners, three of which are foundations and one a government institution, do not have exactly the same tax situation when it comes to making investments. This makes it difficult to purchase land and buildings together. Ultimately, the approach chosen involves the Rijksmuseum paying for the investment of realizing the collection centre and its construction and organizing a number of basic facilities in it, such as security, utilities, cleaning and waste disposal. A breakdown by percentage, calculated based on how much space each of the different partners will take up in the storage facility, determines how much each participant has to contribute. This was agreed for a five-year period. A storage facility team, made up of staff from the four partners, is responsible for the day-to-day care of the storage facility and collection. Other, more organization-related activities are arranged by the partners themselves, but can be carried out partially or wholly in the CC NL.

The structure of the storage facility

What exactly is a storage facility and to what extent does a collection centre differ from that? These are obvious questions as soon as several parties start exploring the option of sharing this kind of facility. A *storage facility* or *depot* may merely be a storage place for the objects we wish to preserve for posterity; a warehouse for key requisites (a stock of replaceable objects) or a busy logistics centre for museum loans. A *collection centre* adds more possibilities to that: a study centre for researchers, a meeting place for private collectors or even an educational centre for teaching.
In the process of jointly drawing up a schedule of requirements, it soon turned out that there were quite a few differences of opinion with regard to what was required in addition to collection storage. An open-air museum deals with a lot of objects made from organic materials that also come from outdoors. For that reason, effective integrated pest management facilities are essential. The Rijksmuseum, with its intensive involvement in international museum loans and frequent traffic between the storage facility and the conservation and research centre in Amsterdam's Ateliergebouw, has demanding logistical requirements. In addition to its heritage work, the Cultural Heritage Agency also loans out art and applied art that can be used in government buildings and other public locations. The users also wanted a facility in the new collection centre where they can make test displays for ensembles.[77]

All operational processes were catalogued and where possible quantified. All wishes and requirements were weighed and discussed, resulting in a schedule of requirements. By comparing the functions of rooms and devising combinations, it was possible to prevent the demand for space and facilities becoming excessive. Early in the process, it was proposed dividing the building into three zones, in which:

- people work, but there is no collection;
- the collection is stored and where people's well-being is placed second to that of the objects;

[77] Paleis Het Loo, the fourth partner, is not mentioned, because they joined the project when the schedule of requirements was already in place.

Figure 3 *Aerial view of the CC NL. Photo: Chris Langemeijer, Rijksmuseum*

- the collection and people come together and where the most important operational processes happen.

Following the analogy of a type of farm often found in the northern Netherlands, the three parts of the Collection Centre began to be called the *head*, *neck* and *torso*, see Figure 3. Each part of the building has its own rules, its own level of security, structure, climate-control facilities and outfitting principles.

The head is largely made of glass, see Figure 4. It is a transparent, light and airy, welcoming building. The neck is slightly more enclosed, but, once inside still offers expansive lines of sight and a surprising view into the research and restoration studios, see Figure 5. Whereas this would have been unthinkable even in the recent past, the design now emphasizes that there is nothing secretive about what is going on here. If, for practical reasons, there is a door that cannot be seen through, there are signs in a large font indicating what is going on behind it: emballage, magazijn or fotostudio (*wrapping*, *warehouse* or *photography studio*). In the 6 m wide corridors, parking strips have been marked for the trolleys used to transport the collection. This building has no secrets to hide: collection management has become like an open kitchen. The storage facility section itself (the torso) is different: a huge monolithic concrete block with a metal shell. Ultimately, a collection centre is a storage facility after all, and we are taking good care of what it is we are storing.

Figure 4 *The head. Photo: Lucas van der Wee, cepezed*

Figure 5 *The neck. Photo: Lucas van der Wee, cepezed*

Climate

The large mass of concrete used for the building is also related to sustainability: it has been designed in such a way as to ensure that the indoor climate very gradually stabilizes at values deemed acceptable for the preservation of the collection. These can easily be confused with values designed for human comfort. That did not happen here. The storage facility has four floors, of which only the highest will have a comfortable temperature of between 18 and 20°C. The first and second floors will be heated only in the event that the temperature drops below 12°C in a long and harsh winter. The ground floor is virtually the only place where the amount of moisture will be controlled, even though the temperature there is not expected to drop below 12°C. The uninsulated floor on the ground floor will absorb cold or heat from the ground underneath. The heavy concrete casing and above all the numerous internal walls made of limestone (a total of 10,618 m²) have a hygroscopic effect while also buffering changes in temperature. On the ground floor, there is a cold store for photographic collections. As a result, four climate zones are created (see Table 1).

Table 1 *The climate specifications for the four floors in the CC NL*

Floor/zone	Temperature*	Relative humidity#
0	No minimum	50% ± 8%
0 (cold store)	4-6°C	45% ± 8%
1	>12°C	50% ± 8%
2	>12°C	50% ± 8%
3	17-23°C	50% ± 8%

*fluctuation no greater than 1°C per 24 hrs.
#fluctuation no greater than 1% per 24 hrs.

In the event of extremely cold conditions, three of the four floors will therefore be heated; this will normally be limited to the top floor. A deep well in the earth combined with photovoltaic cells on the roof can supply much of the energy required for the whole building.
The supply of fresh air in the storage facilities is minimal, but the air is continually being recirculated to some extent in order to prevent microclimates developing.

Security

The storage facility section of the building is an enclosed block with only two door openings. Unlike in the head and neck of the building, where a traditional sprinkler system has been installed, there is no extinguisher system apart from the familiar manual systems for use during the day. The volume of the building is too large for a gas extinguisher or low-oxygen system and the dimensions and large amount of racking and shelving positioned throughout the space would place extreme demands on any sprinkler system. The decision was made to configure fire safety by means of compartmentalization combined with organizational measures. All storage rooms and corridors have been designed with a 90-minute fire resistance. All of the technical areas are located in a concrete tube on top of each other. They are fitted with grated flooring, ensuring any leakage remains in the technical areas and does not flow over the structural floors of the building. Outside working hours, the torso is completely sealed off by means of two truly exceptional doors and all electricity in the storage rooms and corridors is switched off.
This requires quite some organization: any equipment or devices with their own source of power have to be removed from the torso at night. No forklift or battery-driven drill can be left overnight.

Water management

Obviously, a building of this size is likely to receive a lot of annual rainwater. Based on the statistics for Amersfoort, the CC NL can expect to receive around 10.5 million litres per year. Some of that will be collected separately and stored underground to use to flush the toilets. Most of it will be diverted to the large pond at the front of the building and if that becomes too full, to the water drainage channel that runs on the west and south sides of the building. This kind of water drainage system not only helps secure the site, but also provides an opportunity to create an attractive natural area, adding to the atmosphere and cooling the surroundings.
The total area of water and planting on the CC NL site is approximately 9,400 m².

Energy

Invisible from the ground, there are 2,180 solar panels on the roof of the torso, covering a total of 3,600 m², see Figure 6. They supply the energy (it is not yet possible to provide a representative figure of how much), some of which is used to pump the water that extracts energy from the thermal energy storage system in the ground. At a depth of 140 m underneath the front plaza, there are two wells for this purpose: one containing water at 7-9°C and another with water at 13-17°C. This is enough difference to gradually intervene in the indoor climate when necessary.
Since a great deal of energy is consumed in a building of this size and it is also a working environment, the CC NL is not completely energy neutral. However, if the roof of the head and neck are ultimately fitted with solar panels, energy neutrality will easily be achieved. The sustainability of the design and construction of the CC NL has been assessed using the BREEAM system for sustainable buildings, achieving the highest score of five stars: outstanding.

In conclusion

When we were considering a sustainable storage facility back in 2010, we envisaged some kind of cave with a few LED lights that could provide secure and stable conservation conditions otherwise free of technology. We have absolutely succeeded in creating these ideal conditions. However, even sustainable climate control and security methods turned out to require complex technical solutions. In the event of malfunctioning, the need for intervention is certainly less acute than in a traditional storage facility, but even the brand-new CC NL is packed full of systems and installations. Ultimately then, 'the avoidance of technology unless absolutely necessary' may be a great principle until such time as you discover that technology really is unavoidable. In the end, we are consuming the energy for the purpose of caring for the collections being preserved, and this is of course what it is all about: research, restorations, art and museum loans in an attractive and transparent setting. The new collection storage facility has been given an open-kitchen style design, where everyone can see how museum professionals are preserving our heritage as carefully as possible and making it available to the world.

Figure 6 *The solar panels on the roof of the CC NL. Photo: Rijksmuseum*

The new open storage depot at Museum Boijmans Van Beuningen

Wout Braber – Head of Facility, Museum Boijmans Van Beuningen / Depot Boijmans Van Beuningen

Introduction

The collection of Museum Boijmans Van Beuningen started with a bequest from a single private collector. Frans Jacob Otto Boijmans had originally intended to donate his collection to the municipality of Utrecht in 1820, but withdrew his offer in response to the lack of interest on the part of the city's mayor. Boijmans decided to contact the Mayor of Rotterdam instead. Following years of negotiations, an agreement was eventually reached between the Rotterdam municipal administration and Boijmans. At his insistence, the municipality also agreed to purchase the Schielandshuis in order to house the collection. The museum opened to the public in 1849.

In the night of 15-16 February 1864, a fire broke out in the museum's loft area – its cause unknown. Around 70% of the collection was destroyed within a few hours. Museum staff made heroic attempts to save the precious artworks. Their salvage efforts were seriously impeded by the fact that the key to the art storage area was nowhere to be found. In the wake of the devastating fire at Schielandshuis, the insurance company paid out 136,129.62 Dutch guilders. All of it was used to acquire new artworks and the building was restored probably using municipal funds. As the Museum Boijmans' collection continued to grow and visitor numbers increased, Schielandshuis ultimately became too small. Director Dirk Hannema (1921-1945) had ambitious plans for the construction of a new museum. In 1929, it became possible to start work on construction. In 1935, the new museum building, designed by Adriaan van der Steur, opened its doors.

Ideally, Van der Steur and the then museum director wanted the new museum building to be a place where visitors would come to enjoy art. Rather than walls packed with paintings or poorly or badly-lit galleries, as was the case in the 17th-century Schielandshuis, they envisaged a modern, transparent building fully equipped for its purpose. This is why, in a small temporary building erected on the construction site, there was extensive experimentation with an ingenious fan-light structure. Painstaking attention was paid to the format and details of the exhibition rooms. Van der Steur took inspiration from the living environment of private collectors, opting primarily for small and intimate rooms. After all, many of the artworks in the collection had come from such settings. In 1958, the museum acquired the collection of harbour baron D.G. van Beuningen. This was such a milestone, that the name of the museum was changed to Museum Boijmans Van Beuningen.

Over the course of time, the museum building underwent numerous changes. In 1972, a new exhibition building was added, designed by Alexander Bodon. Bodon designed this building at a time when modern art was demanding space, both literally and figuratively. This is why the walls are white and the exhibition rooms are bathed in diffuse light, with daylight even penetrating at the sides in some places. On the ground floor, the light enters from the side from the courtyard and Westersingel. The ground floor also features a presentation room for prints and drawings, into which no daylight can enter. Bodon's design was an excellent match for that of Van der Steur.

In 1991, the Henket Pavilion was completed. The basement included exhibition space for the Van Beuningen-de Vriese collection, while it was possible to organize changing exhibitions on the ground floor. In 1992, an annex was built onto the front of the Bodon building to accommodate a bookshop and a restaurant. A new entrance was also added here. In 2003 a wing was built, designed by Robbrecht & Daem architects. Despite all of these extensions, it was possible to exhibit only 8% of the collection in 2021. The lion's share of the collection was in storage, spread across various facilities and not accessible to the public, see Figure 1.

The storage rooms in the basement of the Bodon building were quickly outgrown by the burgeoning collection. The museum had no choice but to search for external storage facilities. The year 1979 saw the opening of De Metaalhof, see Figure 2. Built by the municipality, the building was intended to provide safe storage for collections from various Rotterdam heritage institutions. The shared storage facility not only housed objects from Museum Boijmans Van Beuningen, but also from the Museum Volkenkunde (part of the National Museum of World Cultures), the Archaeological Service and the Maritime Museum. De Metaalhof was soon outgrown by the collections and had an extra floor added.

In around 2000, flooding issues in the cellars of the museum buildings became increasingly frequent, creating growing risks for the collection, much of which was stored there. An intensive quest for a solution was initiated. For the collection of prints and drawings, which were stored below ground level, the new entrance was created in 2008 – not the location itself, but its outfitting – and the storage room for the collection was relocated in the ground floor of the Bodon building. The prints cabinet in the Robbrecht & Daem building on the east side also appeared at this time.

Figure 1 *Van der Steur storage facility 1935 (upper image) and the painting storage facility in the cellar of the Bodon building in 1972 (lower image). Photos: Museum Boijmans Van Beuningen*

Figure 2 *De Metaalhof storage facility, in which various collections are stored, including that of Boijmans Van Beuningen. Photo: Bart Ankersmit*

Background

The impressive Van der Steur building has now stood for 84 years. Over time, various adaptations have been made. These included the installation of fire doors in 1986, when links were also created between exhibition rooms. In the mid-1990s, it became possible to replace all of the window frames and install double-glazing in the building. Even the more recent Bodon building and the Robbrecht and Daem wing were in need of renovation by then. The backlog in maintenance was causing major problems. In 1999, water flooded into the museum cellar. It was painfully clear that the museum building was outdated and needed attention. When it flooded again in 2013, it all became too much. A short-circuit meant that the pumps stopped working and since the fire brigade had only limited time, they had to choose between keeping either the book collection or the art collection dry, but not both. From the end of the 1990s, there were a total of seven internal floods. It was clear that this could no longer continue. A leading collection deserved a better location.

To take pressure off the building and keep the collection safe, plans were drawn up for a new storage building. Various designs were considered. The first was a building in the shape of a table, designed by architects' firm MVRDV. This gigantic table was displayed to the public at the 2007 KunstRAI art fair. It was partly the presentation and the visualization of this controversial design that drew attention to the need for a new storage facility, making it possible to raise the conversation of a new storage with the local municipality. Two different variants were initially fleshed out: a closed, well-secured facility on the edge of the city and an open, public building closer to the centre. The difference in cost between the two buildings was substantial: the open facility was around €20 million more expensive than the closed building. The municipality suggested that the museum would fill the financial gapp by itself in order to realize the open storage facility. When a philanthropic organization, Stichting De Verre Bergen, unexpectedly agreed to make up the difference, the project to develop an open storage facility became financially possible. As a result, MVRDV was able to develop its design further in 2014-2015. In 2015, the municipal council approved the zoning plan and the go-ahead for construction was given in December 2016.

The purpose of the storage facility

The Museum Boijmans Van Beuningen collection was spread across five different external sites. The new storage facility aimed to significantly improve access to the objects while also improving efficiency and speeding up processing. Almost all objects are kept together in a single building within reach of the museum. The building also helps facilitate the organization of the more than 550 annual museum loans.

The idea behind the new storage building is to enable the collection to be shared with as many people as possible. Because only 8% of the collection can be exhibited in the museum itself, an open storage facility represents a huge increase in public access to the almost 152,000 objects in the collection. The aim of the museum is to raise public awareness of the importance of effective maintenance of a valuable collection and everything involved in achieving that. Ultimately, the collection belongs to all residents of Rotterdam. This building gives Rotterdam residents improved access to the collection, increasing engagement and making culture more accessible. Partnership with the business community also plays an important role in this. Businesses and private collectors are given the opportunity to hire storage space, which includes a multifunctional exhibition room.

The dynamic of the storage facility is different from that in the museum. In it, there are no exhibitions, but presentations are offered about collecting and on conservation issues. Visitors can browse the objects of art either on their own or accompanied by a guide. They can also observe museum staff working on conservation and restoration.
There are various ways of visiting the storage facility. In the evenings, visitors without tickets can access the roof and take in the views. Through the glass panels in the lift, they can see an impression of the atrium and the museum's rich collection. If they decide to buy a ticket, they can opt for a guided tour or wander around the museum independently. An app provides more in-depth information about the collection based on The Museum System/online collection, providing additional details about an initial 120 objects.
A glimpse behind the scenes and a visit to storage rooms are possible only with a guided tour. The maximum group size is 15 people: 13 visitors, a guide and a security officer. The storage room visit takes 11 minutes and four or five can be held every hour.

The Boijmans Van Beuningen storage facility has made Museumpark more attractive as an international platform for art. Some 40 m in height, this mirrored building has the potential to become a new Rotterdam icon and attract 200,000 visitors every year. The Boijmans Van Beuningen storage facility is the world's first to offer access to a complete museum collection.

Developing the storage building

The flowerpot design of the storage building is by Winny Maas. At the base, this circular building has a diameter of 40 m (1,200 m^2 of gross floor area (gfa) and 60 m at the top (2,590 m^2 gfa). The building is 39.5 m tall, spread across seven floors. Because of its shape, the structure that is designed to distribute and contain forces within the building is very important, especially since a storage facility in which objects must be stored as efficiently as possible will inevitably be a heavy building. Because the building is wider at the top than it is at the bottom and there are also openings at street level, it was a challenge to design a sufficiently sturdy structure, in which the smallest diameter with the most weaknesses (i.e. openings) can support the greatest load. This is why the first two floors were poured in concrete in situ, thereby creating a pedestal for the building, as it were. The other four floors were then put in place using prefab concrete elements.
On the outside of the building, the façade is covered with 6,609 m^2 of glass, divided into 1,664 mirrored panels.
For sustainability reasons, 116 solar panels (304 m^2) were installed on the roof, with a peak capacity of 37.5 KWp.
The rainwater is collected and used for the toilets.
The building has a thermal energy storage system linked to the climate control systems. As described below, the climate-control principle involves an innovative method for controlling the climate in the storage rooms.
Table 1 shows some key statistics for the storage facility.

Table 1 *The storage facility in statistics*

Reinforcement steel	1.500.000 kg
Steel structure	320.000 kg
Expected number of visitors	200.000
Collection items in storage	152.000
Floor area	15.541 m^2
Ground excavated	6.250 m^3
Storage furniture	4.949
Storage space for the collection	4.561 m^2
Force per foundation pile	4.000 m^2
Hiring of storage to private parties	1.900 m^2
Mirrored panels on the façade	1.664
Views	360°
Number of foundation piles	276
Depth of the wells	241 m
Hospitality and catering seating	120
Number of solar panels	116
Trees on the roof	75
Climate-controlled storage facilities	14
Number of different climate categories	5
Restoration studios	4
Exhibition rooms	3

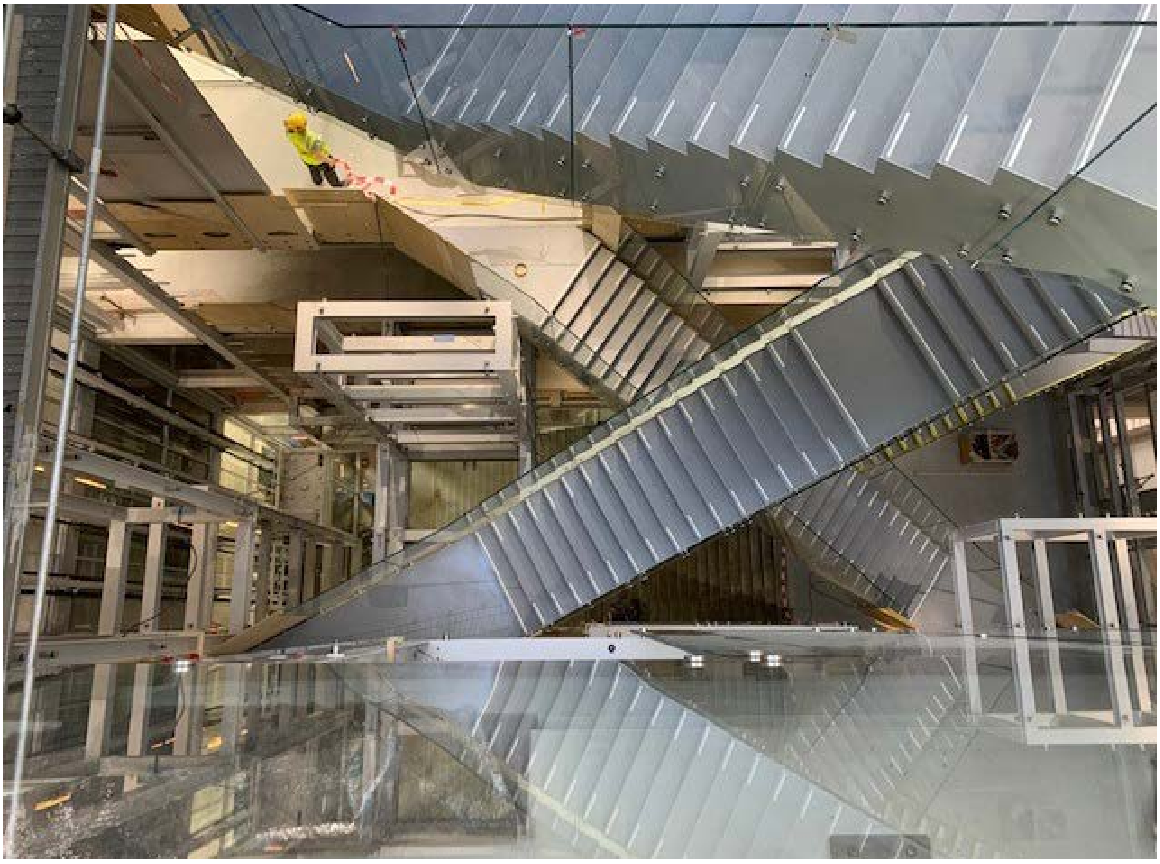


Figure 3 *The stairwell during construction (left) and after completion and installation of art (right). Photos: Museum Boijmans Van Beuningen*

In order to ensure that the building is as attractive on the inside as its mirrored exterior, an atrium was designed, 40 m tall, 28 m wide and 6 m deep. Inspired by drawings by graphic artist Piranesi, a three-dimensional maze of staircases and floating display cases has been designed, with a total presentation volume of around 400 m^3 (see Figure 3).

In outfitting the storage facility, the museum sought to collaborate with a range of artists and designers. Sculptor and architect John Körmeling designed the entrance area and the shop. A circular balcony has been fitted to the round side of the entrance foyer, as in a theatre. Visitors can see through a glass panel to the space where the art arrives into the building and can indirectly observe the processes of loading and unloading, packing and storing. As such, these activities take on the status of events, making the entrance foyer a permanent theatre.
Designer Marieke van Diemen was responsible for The Maze: instead of a defined exhibition route, the building invites visitors to pursue many different, undefined and non-hierarchical routes. This idea has been translated into a design with floating display cases and walls on which to display works. Thirteen different display cases, with a total volume of around 400 m^3, give the space a dynamic and playful effect. There are even several display-case footbridges enabling visitors actually to walk across the artworks. From the walkway, the stairs and the lift, visitors can view the collection and the building from multiple perspectives, repeatedly resulting in new vistas and insights. Video artist Pipilotti Rist creates an artwork of light projected on the outside of the building.
On top of the building are the restaurant terrace, an events venue and the rooftop garden. The restaurant, designed by the Concrete architects' firm, has a flexible layout. Ten large wooden tables can be folded away and connected to the wooden floor and roof sections, thereby creating five large frames that span a multi-functional area. The lighting for the sixth floor and the storage areas was designed by Beersnielsen.
The rooftop garden boasts 75 birch trees and every opportunity to enjoy the panoramic views.
Developing the building took eight years after completion of the Schedule of Requirements and included some important moments, indicated in Figure 4.

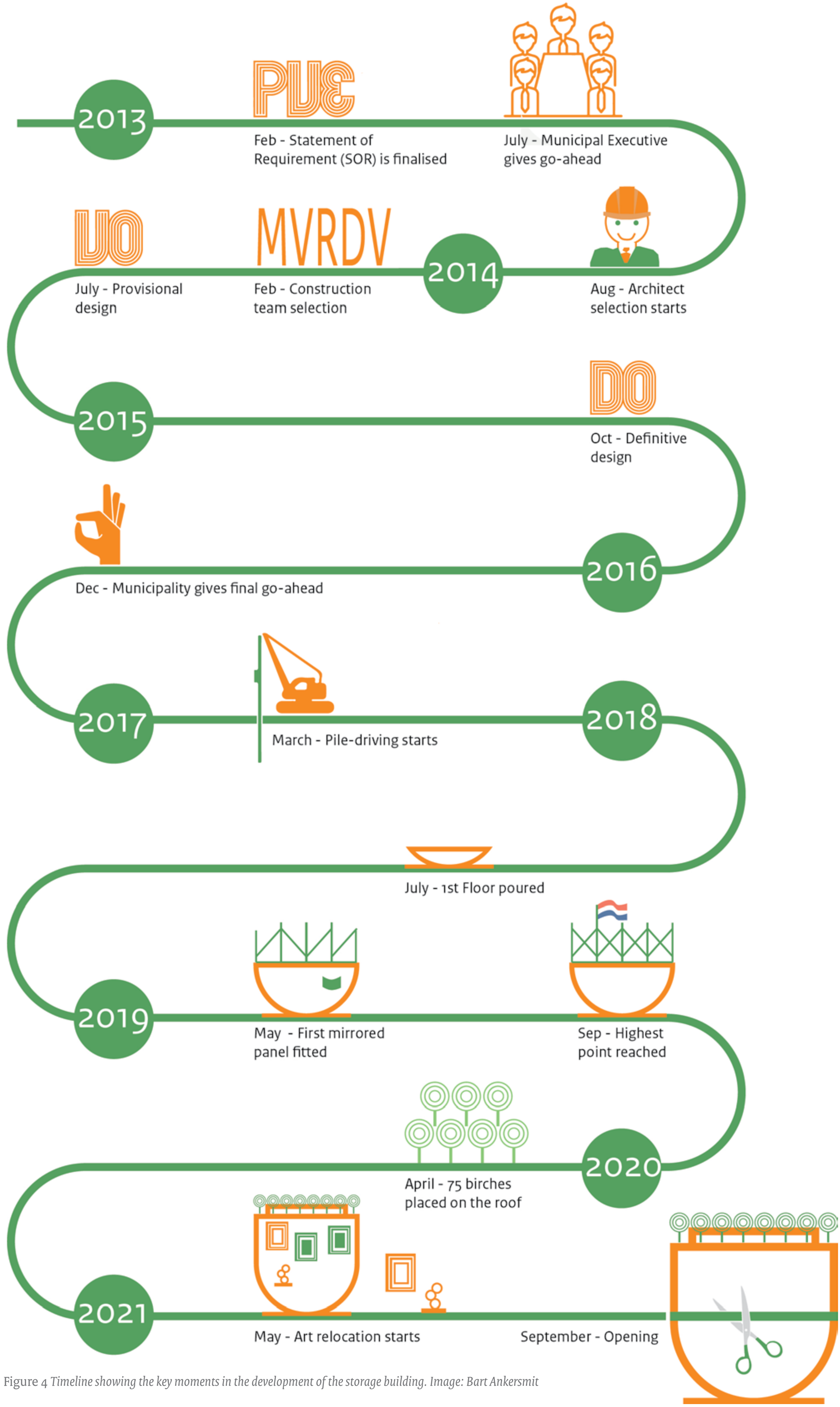


Figure 4 *Timeline showing the key moments in the development of the storage building. Image: Bart Ankersmit*

The indoor climate

Several measures have been taken in the building in order to ensure sustainability. Energy is supplied by the 116 solar panels on the roof of the sixth floor. Thanks to its compact volume, there is only minimal heat loss in the building. The shell of the building has been insulated with an Rc value of 3.5 m^2K/W for the floor on the ground floor, and 4 m^2K/W for the façade and roof. The solar-control glazing is high-performance laminated HR++ glass.

The indoor climate is maintained in an unconventional way. Designed by Royal HaskoningDHV, the climatisation principle differs from the type of climate-control system generally applied in heritage institutions in the Netherlands. Outdoor air is conditioned using traditional HVAC, with cooling, heating and humidification, to a temperature of 16°C and an absolute humidity between 7.8 and 8 g/kg. As a result, the relative humidity of this air is 68-70%. This air is then divided into three separate streams: cold, warm and dry.
The cold air stream is the same as that emitted from the initial HVAC, 16°C/68-70%. For the warm air, air is heated to 30°C. Because the absolute humidity remains the same, the relative humidity of this warm air stream drops to 29-30%. The dry air stream is created by reducing the absolute humidity of the cold air to 2 g/kg. With a temperature of 16°C and an absolute humidity of 2 g/kg, the relative humidity is 18%. By mixing these three air streams using a so-called VAV (Variable Air Volume) unit, it is possible to achieve the desired storage conditions for each storage facility separately. The total airflow is variable and adjusted to what is needed in the demand of the three streams. The amounts of air vary 49,500 and 55,500 m^3/h averaging around 52,500 m^3/h. Figure 5 presents a a schematic drawing showing the climate control strategy, including the different climate categories from Table 2.
The low temperature can be maintained in the cold storage rooms thanks to an additional cooling unit that recirculates the air in the room. Due to over pressure the air from the storage rooms is diverted into the atrium where the return duct is located.

Table 2 *The target values for the temperature and relative humidity in the different climate zones in the storage facility*

	Temperature in °C	**Relative humidity in %**
Category A General storage rooms, such as paintings, ceramics and plastics	16-22	47,5-52,5
Category B Metals	16-18	38-42
Category C Monochrome photography	16-18	43-47
Category D Colour photography	8-9	34-38
Category E Restoration studios	19-22	47-57

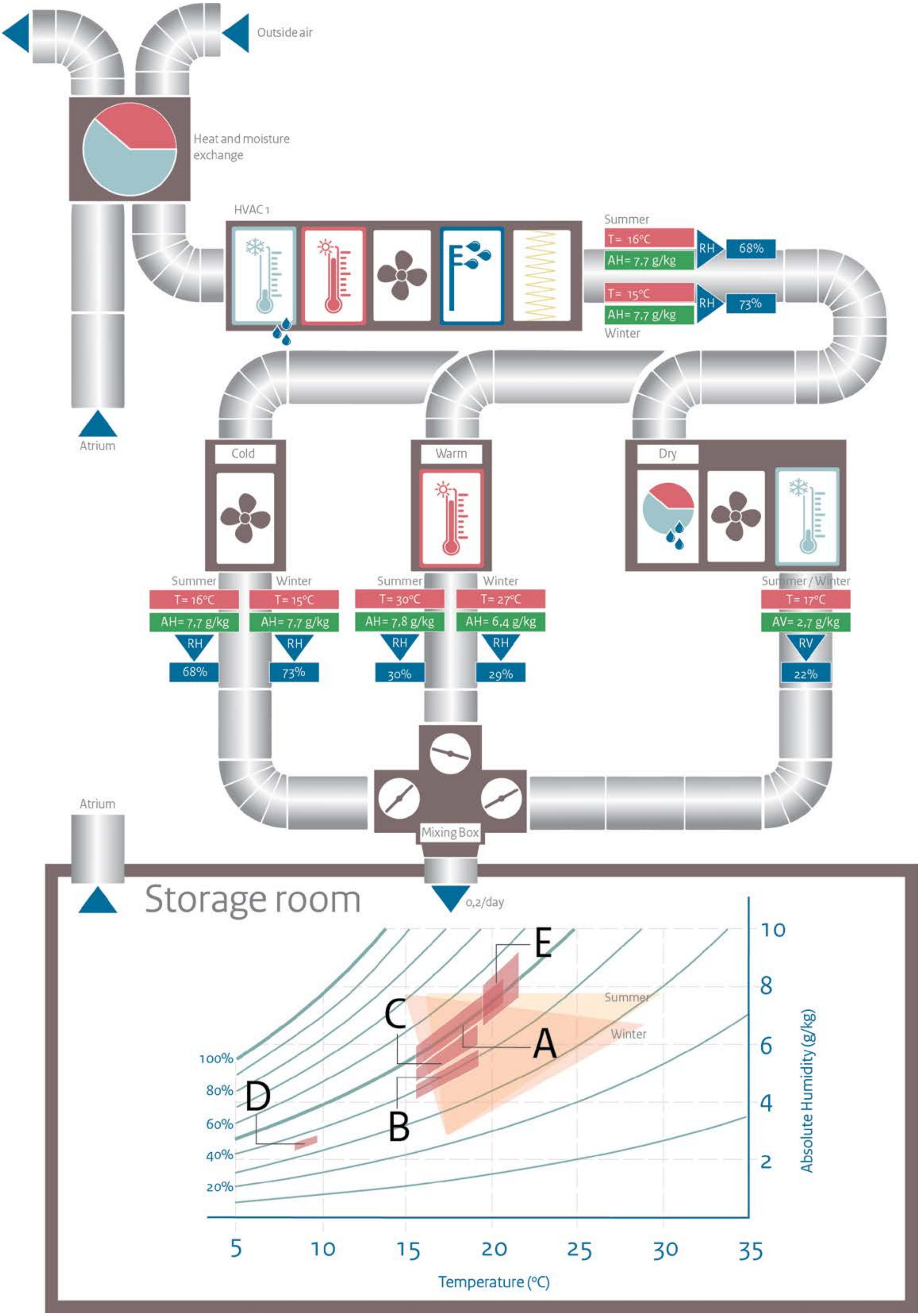


Figure 5 *Visualization showing how the indoor climate is achieved in the different zones. Image: Bart Ankersmit*

In conclusion

In a period of around 20 weeks, the collection was moved into the building in the summer of 2021. Every day, four trucks travelled from two external storage sites to the new facility: two journeys with small format objects and two containing larger works. All objects were given colour labels in advance, indicating their future position in the facility. This made it possible to configure consignments made up of objects that had the same destination in the facility, for example: all yellow labels are destined for the painting storage area on the second floor. Everything was immediately recorded on departure and arrival. Fridays were used for consignments containing very large-scale works or other complex components. Reusable packaging units were used based on the principle that objects with similar level of vulnerability are packed in a similar way.

High-tech and low-key – sustainable storage of the KB National Library's physical collection

Foekje Boersma – Head of Collection Care, KB National Library of the Netherlands

Summary

This chapter describes the plans developed by the KB National Library of the Netherlands to achieve a sustainable solution for the storage of the national library's physical collection in an external automated high-density storage facility. It explores the possibilities of passive climate control and how to generate support for a choice that will bring about significant changes to the organization.

Introduction

The KB National Library of the Netherlands (KB for short) is in the process of drawing up plans for the future, which will incorporate a functional separation between the main building, with offices and a public role, and an external storage facility for safe and effective collection management. The KB is aware of its role in society and the responsibility it bears for a sustainable future. In its plans, the KB therefore envisages a circular economy and is working to achieve a cleaner environment by means of an integrated strategy for reducing CO_2 emissions. Sustainability is playing an important role in the development of the new repository, the key aim of which is to be energy neutral by means of passive building solutions and the use of locally-sourced green energy.

Background

The history of the KB dates back to 1798, when the collection of books and manuscripts of the stadtholder William V, then in exile in England, was housed at the Binnenhof in The Hague. According to the first catalogue, the collection comprised around 5,500 books and journals. The library was given its Royal title during the reign of King Louis Napoleon Bonaparte. The collection grew rapidly and soon needed to be relocated: the KB found a new home in the Mauritshuis, but quickly outgrew that location as well. King William I decided to transfer the library to the City Palace at Lange Voorhout 34, where it was based from 1821 until 1982, see Figure 1.

Figure 1 *The reading room in Lange Voorhout. Photo: KB fotoarchief*

Figure 2 *The reading room at the current site. Photo: Beeldstudio KB, 2009*

Over the course of the 19th century, the library became too big for the building. A new building in Kazernestraat, just behind Lange Voorhout, provided breathing space for a while, but various departments ultimately had to be accommodated elsewhere. The most significant move of this kind happened in 1964 when the newspaper storage and reading room were moved to a building owned by removals company De Gruijter in Westeinde, where space was rented.

In 1982, everything was moved into a single building in the specially-designed building it now occupies next to the Central Station, see Figure 2. This building has a net floor area of 37,000 m² for the library and offices and 28,000 m² for the repositories. The collections are stored within the building in 29 conditioned compartments spread across nine floors, where the over four million titles take up approximately 120 linear kilometres.[78]

[78] Source: https://www.kb.nl/kbhtml/jaarverslag/2020/2-feiten-en-cijfers.html.

Challenge

Even 'modern' buildings require maintenance – in addition to large-scale maintenance, modernization is required over time and functional adaptations may be necessary. The world around us is changing fast and fundamentally as a result of digital technologies. In addition to the services we offer in our building, the KB has now become a digital library, with a public of millions, for which different requirements apply. However, despite the fact that services are increasingly focusing on digital, there is still a need for a building that has public functions. The library is a public space, where wide-ranging groups from society can meet, debate, acquire new insights and learn from each other.

Research conducted between 2013 and 2016 revealed that the necessary refurbishment work would cost more than a new building. The building was also not considered to be future-proof with regard to its role as an office and public space:

- It has functional shortcomings in terms of visibility, accessibility and in fulfilling its changing role in society.
- There are also disadvantages of a technical nature, including insufficient natural daylight for employees and visitors.
- As a result of several resident institutions moving out, the building is at risk of becoming too large.

The storage spaces used for the physical collection at the current location also have challenges. Much of the collection is stored below ground level, with an elevated risk of flooding. In addition, the current storage capacity will become insufficient in the foreseeable future. The climate-control systems, now 40 years old, are in serious need of replacement.

One may also wonder whether storage at a prime site in the heart of The Hague really is an economically feasible model. For all these reasons, the decision was made to separate the storage of the physical collection from the offices, reading rooms and other activities. At the time of writing, the plans for a new building and external storage facility are under development and their feasibility is being investigated.

Developments in large-scale library storage

The KB is certainly not the first library to be in search of a more efficient type of storage. For decades, so-called super high density storage has been used to store large, more or less static library collections of national and university libraries. The very first concept was developed and applied in 1986 by Harvard University in the Harvard Depository.[79] Extremely compact storage that makes full use of vertical space enables the collection to be stored securely and efficiently. Items in the collection are packed in manageable boxes or containers that are placed by hand on the warehouse racks. Staff use modified forklifts to access higher areas and cover longer distances.
This type of storage, referred to as the *Harvard model*, has been adopted by many libraries, primarily in North America, but also elsewhere.[80] In 2009-2010, the University of Oxford's 11 m tall Bodleian Book Storage Facility was developed in Swindon (UK) for a collection of 246 km including 13 million objects. Cambridge University Library followed suit in 2017-2018 with an external warehouse for 106 kilometres and 5.5 million items (Figure 3).

79 See https://hdep.library.harvard.edu/about-hd.
80 Weeks, D., & Chepesiuk, R. (2008). The Harvard Model and the Rise of Shared Storage Facilities. Resource Sharing & Information Networks, 16 (2), 159-168. Payne, L. (2007). Library Storage Facilities and the Future of Print Collections in North America. Ohio: Online Computer Library Center.

Figure 3 The Library Storage Facility of Cambridge University Library (Harvard model). *Photo: Mark van Egmond*

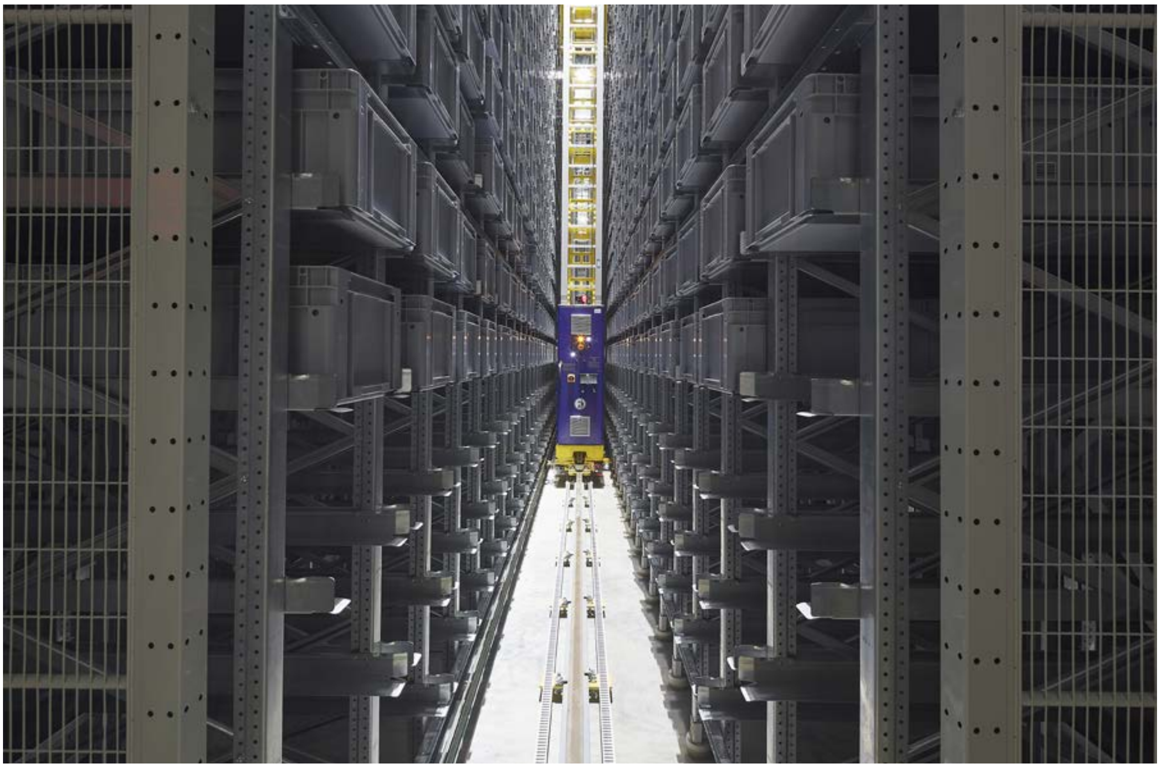


Figure 4 The ASRS warehouse of the Kooperative Speicherbibliothek Schweiz. *Photo: Ulrich Niederer*

The Automated Storage and Retrieval Systems (ASRS) model was introduced to the world of libraries from its origins in the commercial world of distribution centres. In this model, objects are put into larger containers that are then placed in racks by specially-automated cranes, also referred to as robots, that run in the corridors across a fixed rail system. In the classic version of this kind of ASRS, every corridor in the warehouse has its own crane. The containers find their way to a human-operated picking station via a logistical system of conveyor belts. Examples of these kinds of ASRS applications include the two British Library warehouses in Boston Spa dating from 2009 and 2015, where some 572 kilometres of library materials are stored[81] and the Kooperative Speicherbibliothek Schweiz for 1.6 million items that opened in Büron, Switzerland in 2016 (Figure 4).[82]

Further development of this robot technology has led to the use of so-called shuttles that can service several corridors, allowing the space to be configured even more efficiently and enabling ultracompact storage.
In Culemborg in the Netherlands, the distribution centre of CB (formerly known as Centraal Boekhuis), referred to as the new shuttle warehouse, was opened on 6 April 2021. In the new building that is 30 m tall, 30 m wide and 100 m long, 45 shuttles in three corridors service 150,000 containers of books and care products.[83]

The example that the KB is using on which to base its plans is the Kooperative Speicherbibliothek Schweiz. This facility was constructed in such a way as to ensure that active climate control is kept to a minimum, with a high insulation value and an airtight and damp-proof building envelope. When first completed and taken into use, this location has no integrated climate control equipment, but space has been set aside for it, should it prove necessary to adjust the climate at certain times in the future.

81 Nagy, A. (2015, 29 April). The Giant Robots That Serve the World's Largest Library Archives. Consulted on 14 May 2021 at https://gizmodo.com/the-giant-robots-that-serve-the-worlds-largest-library-1700712936.

82 Kooperative Speicherbibliothek Schweiz (z.j.). A Project of Superlatives. Consulted on 14 May 2021 via https://www.speicherbibliothek.ch/en.

83 CB (2021, 1 April). Nieuw high tech magazijn voor CB. Consulted on 14 May 2021 at https://www.cb.nl/nieuws/nieuw-high-tech-magazijn-voor-cb.

Sustainable solution

The new KB storage building (70 m wide, 45.5 m long and 19.5 m high) is largely made up of the technical ASRS warehouse system. In order to enable the collection to be brought into and removed from the building, the front of it features a logistics centre with offices and technical areas (70 m wide, 9 m long and 19.5 m high). The picking stations are located here (Figure 5).

The new storage space is intended for the entire library collection, including around half a million special collection items, and will be expected to be capable of accommodating growth in the collection (in 2020 at a speed of around 10 m per week[84]) until 2040. Depending on developments in the publishing sector and the speed of the digital transition, the storage facility can be expanded by adding a similar unit alongside it that will be able to make use of the same logistical systems and picking stations already in place. Based on the current growth in physical publications, a calculation was made of the containers required in the repository, which showed that the new storage facility should provide sufficient space until at least 2040.

The idea is that the new building will make optimum use of passive climate buffering by means of a high insulation value, but primarily by leveraging the intrinsic power of the collection itself. A high density of hygroscopic material in a space where external disruptions are kept to a minimum will ultimately result in a stable climate. This is low-key and does not require technical climate-control systems. Compared to the current situation, this concept would result in a lower average temperature that would move with the seasons. Most of the relative humidity buffering will be achieved by the collection itself and also as a result of a positive side-effect of maintaining a low oxygen environment. This low oxygen level is required to ensure that the collection is stored in fire-safe conditions. This approach is in line with a more sustainable climate strategy that abandons attempts to achieve strict bandwidths and is more focused on the avoidance of extremes.[85]

84 Source: https://www.kb.nl/kbhtml/jaarverslag/2020/2-feiten-en-cijfers.html.

85 ASHRAE (2019). Museums, Galleries, Archives, and Libraries. In ASHRAE Handbook—HVAC Applications. Atlanta: ASHRAE, pp. 24.2-24.3 and 24.24. Boersma, F., Dardes, K., & Druzik, J. (2014). Precaution, Proof, and Pragmatism: Evolving Perspectives on the Museum Environment. Conservation Perspectives. The GCI newsletter 29 (2), 4-9. See: http://www.getty.edu/conservation/publications_resources/newsletters/29_2/evolving_perspectives.html.

Figure 5 *A picking station in the Kooperative Speicherbibliothek Schweiz. Photo: Ulrich Niederer*

Risks and security

The implementation of this rehousing strategy will result in a significant change to the risk profile for the collections, primarily in a positive sense. Measures will be taken to mitigate any new risks. Storing the entire national library collection in a single space involves risks. These risks are partly associated with the location where the building can be developed. A location on the edge of The Hague is under option, which would ensure it is still relatively easy to access material from the collection.

A risk analysis focusing on flooding and climate change has been carried out by Wageningen Environmental Research[86] in order to assess the potential site.
This shows that, based on the anticipated increase in water levels up to 2050, the chance of a flood in which the water level rises by 0.5-1.5 m will be once in every 100 to 1,000 years. This study identifies no direct effects from the expected rises in sea level and impact of increased precipitation and run-off from rivers and lakes.
The models indicate that there will be no flooding on the site itself. Flooding in the building from water pipes is excluded, rainwater is kept outside and the storage facility is being built on a 2m artificial mound in order to protect against flooding.

The risk of fire will need to be excluded by means of measures that prevent the need for the installation of a sprinkler system. Because ASRS warehouses are operated by robots rather than humans, the storage area can be kept at low oxygen conditions (around 13%), preventing fire from developing. This fire prevention measure has been applied at the British Library warehouses in Boston Spa and at the Speicherbibliothek in Büron. Despite this low level of oxygen, the conditions are still safe for humans.

The security risks will also change. Using a single large space for storage with the help of a robot that is capable of randomly placing the containers in order to ensure efficient and equal distribution of the weight, has advantages. Assuming that no human errors have been made when adding objects to the system, also referred to as the ingest, it is possible to retrieve every single item. Anyone entering the storage room with malicious intent will be unaware of the location of any item of particular value or importance for the collection. Of course, strict security measures for the building, the operating system and stored data are of crucial importance.

There will also be new security risks, because, in the new setting, requested collection items need to be moved from an external facility to the main building in order to be accessed. In mitigating these risks, the knowledge and experience of librarians and heritage institutions who have already made the transition to external storages will be used. Besides, requests for physical works are expected to be more selective and reduced in number because increasing amounts of the collection are digitalized and can be made available online.

Climate simulation

At the time of writing (2021), the hypothesis for the passive indoor climate is being further investigated.
A climate study, subsidized by Metamorfoze Onderzoek, into the conditioning of a library collection for sustainable storage supports the development of such a building and the safe transition of the national collection.

A library collection is primarily made up of hygroscopic material, in which the moisture content in the material enters into a dynamic equilibrium with the moisture in the surroundings. In the new building, the indoor temperature will fluctuate with the outdoor temperature, moderated and delayed by the thermal mass of the building and the collection. In the relocation to the new, cooler facility with no climate control, the indoor climate will be directly affected by the current climate-controlled conditions of the collections (moisture content and temperature (mass)). The study will provide a better understanding of this process and also highlights potential challenges. In order to more effectively assess the current storage conditions and those in the new store, a dynamic hygrothermal simulation model will be developed that can be used to simulate the indoor climate before, during and after the collection's move. This model will make it possible to optimize the building envelope, including such aspects as the insulation value of the façade and colour of the roof, and to analyse the impact of the indoor climate in the office and working areas at the front. Ultimately, since these areas will have staffed picking stations in them, they will require an environment that is pleasant for humans. This simulation will make it possible to determine how much pre-acclimatization the collection would need in the current

[86] Bruin, K., de (2018). Klimaat risico scan voor twee potentiële locaties van het magazijngebouw van de Koninklijke Bibliotheek te Den Haag. Wageningen: Wageningen Environmental Research. Internal report.

building in order to ensure the best possible conditioning prior to this relocation.

The green dichotomy

In order to achieve more sustainable collection management, steps will first need to be taken that may appear at odds with this vision. A new building that provides strong insulation must be built – if this is made of concrete, this has an impact on the CO_2 footprint. In the ensuing years, operations will be energy neutral and it is envisaged that the generation of solar energy at the location will supply an excess of energy. It is to be hoped that smart and tested solutions will be found to tackle these challenges when the building is put out to tender.

The plans have been given the go-ahead and the development of the new storeage facility is expected to take at least five years. In the meantime, some urgent maintenance needs to be done in the current building, especially with regard to climate control. This presents an opportunity to incorporate more energy-efficient components in the existing climate-control system. An analysis conducted in 2018 revealed that the building-related energy consumption for spatial heating and cooling, ventilation, humidification, hot running water and lighting accounts for three-quarters of the total energy consumption.[87] Although the electricity involved originates from wind energy and therefore does not contribute to the CO_2 footprint, there is no reason for putting off efforts to improve sustainability. Progress has already been made by replacing some lighting with LED and making more efficient use of the climate-control systems where possible. For example, the climate system for the underground store rooms is switched off at weekends. Since there are no people present, there is no need for forced ventilation. The indoor climate remains stable because of limited external influences. Monitoring the climate shows that this results in a more stable climate at weekends than during the working week. A study of the climate in the exhibition area has demonstrated that the system can be adjusted more smartly by adding passive buffering in the display cases.

[87] Dupree, E. (2019). CO2-Footprint 2018: Rapportering en analyse van de CO2-footprint over het jaar 2018. Hoevelaken: Unica energy solutions.

Organizational challenges

Relocating the national library collection to an external site will have significant consequences for the organization. This is not only because of the changes to the working procedures and additional logistics. The strategy of storing the entire collection externally, excluding the special collection items, also faces some opposition. The idea of storing a mediaeval manuscript in a plastic container which is housed in a store manned by robots is a horrifying thought for some colleagues. This evokes a response that is partially rational, but is also a combination of fear of change and renewal, aggravated by an aversion to loss.

Some of these concerns can be alleviated by providing effective information about the relocation process and explaining that the chosen solution will ensure a longer lifespan for the collection while reducing energy consumption. It helps to raise awareness of the human impact on collections. This relates partly to the indoor climate and partly to the light exposure. Both arguments are explored in more detail below.

- Conserving heritage collections whilst simultaneously creating a pleasant working environment for people are objectives that are not easily combined and call for active control of the indoor climate in a building. People are more sensitive to temperature fluctuations than the collection and the collection is less able to withstand extremes in relative humidity. We often think in terms of climate control for collections, when we are in fact attempting to compensate for the negative consequences of climate control for human comfort, enabling collections to be stored safely at a temperature that is pleasant for humans. In winter, we need to heat our indoor environment in order to make it comfortable for humans. The heat lowers the relative humidity, which dries out hygroscopic materials, such as paper, leather and parchment, causing them to shrink and deform. If the human factor is removed from storage, heating is no longer required. The deterioration of materials in a library collection is also significantly slowed down at a lower average temperature. This is a huge bonus, especially for acidified paper collections of wood-containing paper, which are generally in poor condition.[88]
- Another key factor in damage to collections is light. In order to process requests in the current repository,

[88] Image Permanence Institute (z.j.). Welcome to the Dew Point Calculator. Consulted on 14 May 2021 via http://www.dpcalc.org.

staff need light, which means that large parts of the stored collection are exposed to light during office hours. This not only consumes energy, the cumulative exposure to light also results in irreversible damage. The new facility will always be in the dark, as robots do not need light to complete their tasks.

However, some concerns are indeed justified: soon it will no longer be possible to view the collection by walking along the storage cupboards and shelves. Since storage in the containers will be according to format, some of the previous ordering of the collection will no longer be possible. Positioning based on format rather than subject has long been standard practice, but in the past collections were placed by theme. This is indicative of the story of the KB's collecting history. For collection specialists and collection conservation staff, this visual information is important in carrying out their work. Efforts are being made to allay these concerns: our conservators are currently assessing the condition of the special collection using a survey which will inform future collection conservation care. Experiments are being done to record the current set-up using 360⁰ photography or VR technology.[89] In addition, in the autumn of 2021, a Residency was arranged for three artists who have been asked to apply their art to the issue of digitalization and advances in technology, as a social trend that is also clearly affecting libraries.

There is the additional risk of the organization being split into two, in the event that contact between the main building and the new facillity are not effectively maintained. In order to prevent the creation of two worlds, the facility is intended for storage only. All other aspects of our work on and with the collection will take place in the main building, where the consultation areas, reading rooms, conservation studio, image studio, exhibition area, etc. are located. The plan is therefore for all storage staff to continue to carry out some of their duties in the main building.

Conclusion

The KB faces an important challenge in sustainably conserving its physical collection. By dividing up the main activities – separating the storage of the collection from the office and other services – it becomes possible to improve sustainability both economically and environmentally. The new facility will have more favourable storage conditions because of a lower average temperature, the fact that it is always dark and there are no risks of unexpected disruptions caused by the failure of active climate-control systems, all of which will have a positive effect on the lifespan of the collections.

[89] Loddo, M., Boersma, F., Kleppe, M., & Vingerhoets, K. (expected in 2021). 360⁰ imaging and VR as access strategies to physical collections. In IFLA Journal XX(X). Consulted on 19 October 2021 via https://journals.sagepub.com/doi/pdf/10.1177/03400352211023080. Loddo, M. (2020, 10 October). 360⁰ image of the KB's Special Collection storage. See: https://www.youtube.com/watch?v=9lEEK44G_7Q (21 May 2021).

Painting storage in the Dordrecht Museum in 2004. Photo: Bart Ankersmit

The Amsterdam Museum Collection Centre – how does it work?

Marysa Otte – Senior Collection Affairs Advisor, Amsterdam Museum

Summary

In 2011, the Amsterdam Museum opened the Collection Centre to store and work on the museum's collection. This article shows how a building made of bricks and concrete moves along with museological and social developments by using a series of examples and a survey.

The construction of the Collection Centre

The initial aim of the Amsterdams Historisch Museum (now Amsterdam Museum) was to have a single building in a single location to safely store, preserve, and contextualise its collection.[90] The museum had been storing its collections in storage rooms at two museum sites in the city centre, some of which were quite a tight fit or difficult to access for large or fragile objects. Two other storage facilities were located outside the museum, one of which was 50 km away.

The storage facility project started in 2005. The schedule of requirements was agreed upon in 2006. In the same year, a site was found on a business park in Amsterdam-Noord, where there was enough affordable land for a storage building. Wim Quist from architectural firm Quist & Wintermans was selected as the architect. The definitive design was approved in 2007 and, following the European procurement procedure, construction was able to start in the spring of 2009. Structural completion took place in late 2010, see Figure 1. In 2011 and early 2012, the building was furnished and the collection relocated to the Collection Centre. Initially, the museum envisaged an airtight 'storage box'. However, it quickly became clear that working areas would be needed for transportation, handling, contextualising and visiting of collections. These were then incorporated into the design. The working areas were situated in the central section and the storage facilities in the aisles at the sides.[91] The storage facility is well equipped, with a low-oxygen pest treatment unit, an indoor climate control system adjusted to preserve fragile collections, and a semi-automated storage and racking system that can accommodate more than 80,000 objects (2011 figures).

The term *collection centre* is appropriate for this storage building, which was not only intended to store the collection, but also to enable research, access, treatment, and visits. The building is equipped to receive small groups of visitors by appointment and features such facilities as lockers, a spacious canteen, a study and conference room, and a multifunctional working area. This is an early example where the concept of a *storage facility or depot* has been replaced by the wider term *collection centre*, reflecting the fact that this is a collection building with multiple functions. In the heritage world,

90 The Amsterdam Museum is Amsterdam's main city museum and manages visitor sites in the former Burgerweeshuis in the city centre (Nieuwezijds Voorburgwal 359/Kalverstraat 92) and in Museum Willet Holthuysen at Herengracht 605. Since 2022 the location Burgerweeshuis is closed for renovation and the museum opened a temporary exhibition at Amstel 51. During the construction of the Collection Centre, the museum changed its name (Amsterdams Historisch Museum became Amsterdam Museum) and it was privatized, having previously been a municipal museum. For further information, see https://www.amsterdammuseum.nl and https://www.willetholthuysen.nl.

91 Behm, M., & Kloos, M. (Red.) (2011). *Amsterdamse Architectuur 2010-2011* (ARCAM-pocket 24). Amsterdam: ARCAM, p. 28.

Figure 1 *Front of the Collection Centre in 2011. Photo: Monique Vermeulen*

this term quickly took hold with the development of various collection centres in Friesland (Kolleksjesintrum), Amsterdam (Eye Film Museum), and Amersfoort ((CC NL).

For the relocation and registration of the collection, the Adlib collection management system was used. With a storage facility at some distance from the museum locations, museum staff welcomed Adlib as a useful initial source of information about and research into the collection. In 2011, the Amsterdam Museum placed its entire collection on the internet, enabling everyone to discover it digitally.[92] The collection had been placed somewhat remote, but was actually more visible and navigable than ever. At the same time, objects and their locations were bar-coded, making it possible to register their locations quickly and easily using scanners. Originally conceived as a stronghold for the protection of objects, the building became a collection centre for working on the collection and for receiving small groups of visitors.

How does it work? User experiences

How do staff currently working with the collection in the Amsterdam Museum Collection Centre feel about the layout, the various rooms, and furnishing of the building? Is the Collection Centre effectively aligned with the working processes? Nine colleagues took a critical look at the building, based on a questionnaire. In response to every question, they could choose between very good, good, average, mediocre, and poor. They could also make comments.[93] Figure 3 shows the results of the questionnaire.

The building as a whole

The building's location in Amsterdam-Noord, some 40 minutes by bicycle and ferry from the museum sites in the city centre, has both advantages and disadvantages. The staff rate the location as average to very good, partly depending on where they live and how much they commute. To prevent the need to shuttle backwards and forwards between the Collection Centre and the museum, the scheduling of everyday activities is important. Removing the collection not on show to a storage facility some distance away from the museum is seen as a realistic choice: 'In an ideal situation, you would want the storage facility not to be too far away from the museum, but this is difficult to achieve in a city like Amsterdam. Locating the storage facility on the edge of the city makes it possible to bring your collection to the museum relatively quickly and you're also easy to reach for visitors', one of the survey takers writes.

The building as a whole, its internal logistics, furnishing and the building as a workplace are all rated average to very good. The collection is distributed across the storage facilities according to format and material, a categorization that is seen as positive. On the ground floor, there are two storage rooms for large objects with plenty of room to manoeuvre and large access doors. A forklift truck can be used here. The storage areas for smaller objects are located on the two floors above. These are divided into collections largely made of organic materials, largely made of inorganic materials, and special areas for textile, paper, and audio-visual materials. The latter storage area has a slightly cooler and drier climate than the other storage rooms. The employees approve of this layout. There is no special storage facility for certain materials such as plastics. The staff decide which depot is best suited for these objects. When there is an increase of certain materials in the collection, an assessment will be made whether additional facilities are necessary within the existing storage rooms, such as additional air extraction for objects made of PVC.

Working in the building

To what extent do users find the Collection Centre supports the working processes? Based on the route of incoming objects, the staff share their views.

- Incoming
  The truck loading dock with space for two lorries and a transparent roller shutter as a gateway to the internal building is seen as positive. The loading bridge can be operated by anyone given access to this area. Although there have been no specific issues, its operation by third parties could result in unsafe use. For this reason, one area of concern is clarity over who is permitted to operate the loading bridge.

- Low-oxygen unit
  The presence of the low-oxygen unit to combat pests is seen as positive. This unit is in almost constant use for treating acquisitions and returning loans or exhibition materials that may be vulnerable to pests. The treatment process generally takes a month. The small storage area immediately adjacent to the low-oxygen unit for objects awaiting treatment can

92 See: https://www.amsterdammuseum.nl/collectie/collectie-online.
93 The survey was completed by six members of collection staff, two conservatorsrestorers, a registrar, and a photographer.

occasionally become too full. When emptying the unit, there is a risk of cross-contamination between incoming and treated objects.

- Unpacking
  The packing room is spacious in design, allowing for a consignment of around ten (painting) crates to be placed here temporarily and to be processed on one of several tables. The staff rate the space and the facilities as good. This room is also used for outgoing transport and for packing objects for safe storage in the facility, as well as to make any necessary improvements to the frames on incoming paintings and the existing collection. At peak times, it can become too full, despite its large size.
  The employees regret that there is no separate workspace available to work on crates and other packaging materials. Incidentally, many shipping crates are rented rather than bought, to prevent wasted space caused by empty crates and to make it possible to select appropriate packaging for each transport.

- Removing dust from the collection
  When the collection was moved in 2011, all objects had the dust removed in the old storage locations prior to transport.
  Currently, acquisitions sometimes arrive in a very dirty or even mouldy condition and cannot be cleaned at their place of origin. If this involves large quantities, safe cleaning while avoiding the contamination of rooms and the filter system is difficult. Staff would like to have a cleaning room for dust removal or further treatment of dirty objects, with its own water supply and air-extraction system to be used by collection staff and conservators.

- Numbering
  Until recently, a small room was used to briefly store and number acquisitions. In the design plan, this area was originally intended for a different purpose for the city archaeology collection, which did not require climate control or daylight. The users rate the suitability of this room as mediocre. The numbering and labelling of the objects, together with the administrative work, is now largely done in a multifunctional working area, see Figure 2. This has resulted in a row of tables on which objects progress from 'registering', to 'numbering' and 'ready for storage facility'. This enables the registrar and collection staff to keep a joint overview.

- Photography
  Before objects go to the storage facility, they are photographed for identification purposes. Alternatively, a professional photograph may be taken in the photo studio. After numbering and labelling, the object is taken to a separate floor. In principle, internal transports of this kind are simple because of the barrier-free design of the building and the spacious lift. The height of the doors in the photo studio and several other working areas can hamper the transfer of large objects. The storage facilities and lift are fitted with taller doors; staff would also like to see these kinds of doors in the collection working areas.

Figure 2 *Multifunctional room. In the centre: tables for viewing the collection. On the right: tables with collection still to be booked in and numbered. At the back: desks for staff. On the left: the artwork Van Ons by Ted Noten. Photo: Marysa Otte*

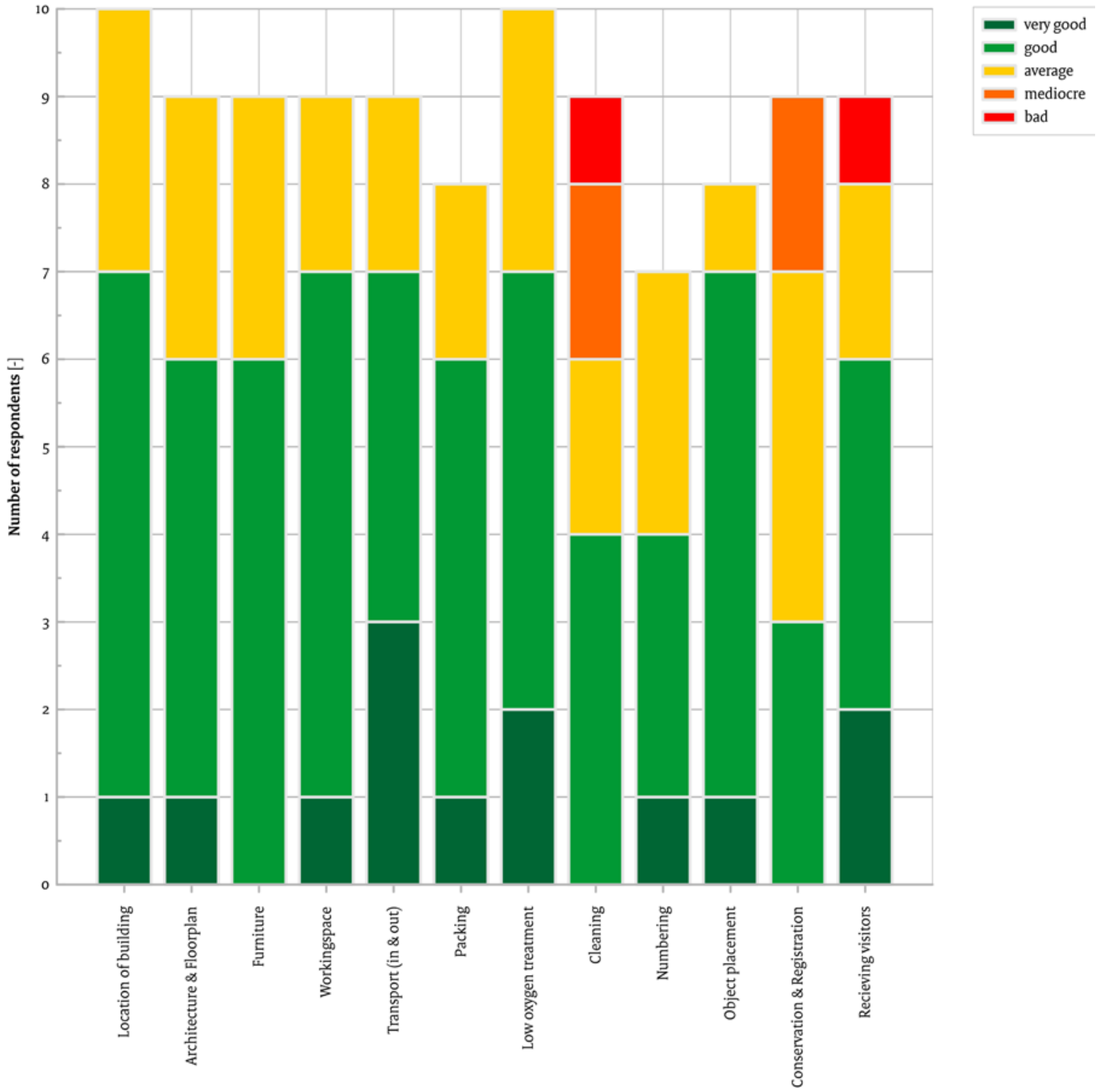


Figure 3 *Results of the satisfaction survey of the users of the storage facility . Image: Marysa Otte*

- Location registration
  The new location for an object in a storage room is quickly linked to the collection management system by means of a mobile telephone app that is used to scan the barcode on the object and the barcode at the exact location. Staff approve of this working method. However, they do point out that Wi-Fi coverage is not perfect everywhere due to the thick concrete walls of the Collection Centre.

- Conservation
  For internal and external conservators, a conservation studio is available for minor and clean work, featuring facilities such as air extraction and a fume hood. This was also initially used as a studio for the permanent textile conservator. This had the disadvantage that workflows occasionally coincided, but had the major advantage of making better use of the space.
  An additional room for dirty conservation work is required.

- Receiving visitors
  There are good facilities for receiving small groups of visitors, according to most staff members. This is important, because the Amsterdam Museum is eager for the collection in the storage facility to be accessible. In the multifunctional room, visitors can view objects taken from the storage areas.
  We offer guided tours in the storage areas, sometimes as a way of providing background to museum exhibitions or for students studying specific technical subjects or art. These are always guided, because the storage rooms have not been set up to be viewed independently. Group sizes are generally around ten people, partly depending on the size of the storage facility being visited. Additional supervisory staff and other facilities are needed if we want to receive larger groups of visitors, such as a larger reception area and more sanitary facilities. The configuration of the storage rooms themselves also needs to be adapted and the logistical processes reviewed to ensure working and visiting can be performed simultaneously and smoothly.
  The staff appreciate the fact that there are possibilities to receive visitors, but they also face limitations, which

Figure 4 *The paintings storage room at the far end small objects are stored. Photo: Marysa Otte*

explains the wide variety in answers to the question about the suitability of the building for visitors.[94]

An issue that was raised frequently in the survey is the layout of a storage room in which the painting racks with rail system have been positioned at the front, see Figure 4. Small objects made of organic material have to be transported across this to reach the racks at the back of the room. As a result, this part of the collection is exposed to the bumpy floor fitted with rails. Otherwise, the options for storage are generally rated positively.

The museum staff place great emphasis on functionality. The slanted wall across the whole of the front of the building may give it a more playful appeal, but on the inside it has created corners that cannot be put to good use and it has left the photo studio with one rather impractical wall.

Developments in and outside the museum

In their design, the architects envisaged a 12th-century Cistercian monastery style of architecture 'motionless, closed in on itself and independent of the cares of the world'.[95] But the world outside the Collection Centre does not stand still. How are social and cultural trends and new museum policy perspectives influencing the Collection Centre?

Improving sustainability

After the construction of the Amsterdam Museum Collection Centre, new collection centres have been designed that consume less energy. The constantly developing national and international policies on the energy transition and CO_2 emissions, new advances in climate control, insights into preservation of collections, and innovative storage facility construction methods, are resulting in facilities with more sustainable designs. There will always be new insights and advances in knowledge. Designing and constructing a building takes time and will inevitably be based on knowledge from several years earlier. The Collection Centre itself was fitted with a ground-source heat pump, a technology still under development at that time.
The museum sees sustainability as a core value and something to be worked on at all times. As a result, the operation of the ground-source heat pump has been adapted to use for storage facilities rather than offices. The temperature control is now based on continuous monitoring of the external conditions and no longer on two measurements per year. The cold storage facility has had its own cooling system installed and has been disconnected from the central pre-treatment system, which is expected to reduce average energy consumption. The same applies to the replacement of the drive-belt fans with direct-drive fans.

[94] In some cases, not all sections were completed or multiple answers given.
[95] This quotation by the architects was based on the description of the Cistercian monk Bernard van Clairvaux and can be found in: https://www.gebouwdin.amsterdam.nl/main.asp?action=display_html_pagina&name=detailpagina&item_id=778 and https://www.qwa.nl/projecten/cultuurenonderwijs/collectiecentrum.html (consulted on 26 April 2021).

The flat roof of the Collection Centre was fitted with solar panels in 2017. This supplies approximately half of the energy that the building needs. All of these adaptations have significantly reduced energy consumption.

Renting out and generating income

The original design plan also included storage facilities and working areas for the Archaeological Service of Amsterdam. However, this was accommodated elsewhere when it was realized that this collection requires less specialist environmental conditions. This made it possible to use the space left over for collections from other heritage organizations in search of storage space.
In the meantime, 2010 brought a change to the Dutch museum world, heralding much more difficult conditions. The country was in crisis and, under State Secretary Halbe Zijlstra, the cultural sector faced cutbacks.[96]
The now privatized museums were called on to become more entrepreneurial. Independently generating a significant portion of the revenue became more important in the cultural sector, something that has remained the case even after the crisis.
This and other factors led to storage rooms being rented out to heritage organizations, including empty racks in partially-filled facilities. This did not result in the kind of collaboration and shared storage of similar types of materials by various organizations that now is carried out in other collection centres. The empty racks in the storage rooms were soon needed for our own collection, which has grown by almost 9,000 objects since the Collection Centre was set up. The separate storage rooms were initially hired out for temporary use. This meant that more far-reaching collaboration was not a logical step, although the sharing of facilities and learning from each other's knowledge certainly was beneficial.

Display or hideaway

There is increasing demand from wider society and government authorities for collections to be displayed rather than kept in storage. The 2020 manifesto of the VVD (People's Party for Freedom and Democracy) reads as follows: 'Art must be exhibited and not hidden away in dusty storage facilities'.[97] The year 2016 saw the publication of a supplement to the *Volkskrant* newspaper describing museum objects and their lives in storage: 'A good 90% of the art spends the whole year in storage. Shouldn't we make that a thing of the past?'[98] Of the 93,316 objects belonging to the Amsterdam Museum, some 3,271 were exhibited in the year referred to (2015).

In the case of the Amsterdam Museum, the collection belongs 'to us', to the city and its residents. Our collection policy attaches more and more importance to putting the collection on display, in our own or other museums, in the Collection Centre, digitally and in non-museum locations. In the Collection Centre, we are promoting this sense of belonging 'to us'. This is why the artwork by Ted Noten, positioned in the multifunctional room when the Collection Centre was opened, has the title VAN ONS. It is made from signet rings of yellow plastic, that together form the words *VAN ONS* (Dutch for 'OURS', or 'to us'). Anyone who feels a connection with the museum and visits the storage facility is permitted to take a signet ring with them, see Figure 5.[99] It's very important to the Amsterdam Museum to connect residents to the collection, both in the Collection Centre, the museum and at other sites.

The museum seeks out opportunities to display the collection in public places and elsewhere, based on a risk and benefit analysis. An example of this is the placement of the paintings with views of the River IJ by Hobbe Smith dating from 1913. This series of paintings was commissioned for a temporary exhibition about shipping. After several exhibitions, they were rolled up in damaged condition. The old storage facility was too small to store these large paintings (approx. 2.5 m high and 4.5 m wide) in any other way. In the Collection Centre, it was finally possible for these works to be unrolled and stretched, conserved, and photographed. There is enough room to store them, but the walls of the Amsterdam Museum have insufficient space to exhibit all of these paintings. In addition, the paintings were in a relatively poor condition. To allow everyone to 'experience' these paintings once again, consolidation and other treatments, such as varnish removal were required.
A search for suitable places and organizations willing to contribute to the treatment and display of these works ultimately ensured that several paintings from this series can now be seen at suitable locations along the River IJ, such as in a meeting space in the Amsterdam Port Building. The painting's theme is a perfect match for the function of the building.

96 Coalition agreement between VVD and CDA (2010). *Vrijheid en verantwoordelijkheid*. The Hague, p. 33. Consulted on 24 March 2021 via https://www.rijksoverheid.nl/documenten/rapporten/2010/09/30/regeerakkoord-vvd-cda.

97 See: https://cms.vvd.nl/standpunten/cultuur.

98 Kooistra, S., & Kruijt, M. (2016, 19 February). Buiten de schijnwerpers. *De Volkskrant*, pp. 5-7.

99 Six rings of different sizes have been included in the collection and there are still enough rings available to give out. For further information about *Van Ons* by Ted Noten, see: https://hart.amsterdam/nl/collectie/object/amcollect/100932 and https://hart.amsterdam/nl/page/4827.

Figure 5 *In the multifunctional room, visitors choose a signet ring from the artwork 'Van Ons' by Ted Noten to take with them. Photo: Marysa Otte*

Figure 6 *Group visit to one of the large storage facilities in the Collection Centre, with a pull-out rack and one of the views of the River IJ by Hobbe Smith. Photo: Marleen van de Pol*

The time investment required for a project of this kind is considerable: making contact and liaising with the building managers, conducting a risk analysis of the site, commissioning treatment, and a tense process of hoisting to the 13th floor of the building. Although this act may have only resulted in reducing the 'hidden' collection of around 90,000 objects in the Collections Centre by one, the emotional impact of experiencing this work at an appropriate location is difficult to express.
Judging the number of objects purely by amount would suggest that very little progress is being made to reduce stocks held in storage, yet time-intensive projects like these do bring genuine benefits both for Amsterdam's citizens and in terms of the quality of the collection.

A changing collection

The collection includes increasing numbers of plastics, photographs, born-digital objects, and contemporary art. Will it all fit in our Collection Centre, bearing in mind both the size and the specific facilities required? In the near future, the e-storage facility is expected to grow considerably and this will have an impact on working processes.
Acquisitions will increasingly involve collaboration with residents from all districts of the city, as is the case in our 'Collecting the City' project. This project involves working with Amsterdam citizens in collecting new, inclusive, and diverse stories and objects celebrating the city's 750th anniversary in 2025. We are currently investigating the effect this project will have on collection management and the Collection Centre.

Future

In the period of more than a decade since the Amsterdam Museum Collection Centre's inception, there have been important developments both within and beyond the walls of this building, as the above has shown. What can we expect for the future?

Renovation of the Amsterdam Museum

The Amsterdam Museum has plans to renovate its site in the centre of Amsterdam. The collection is now on display on another location and more objects are temporarily included in the Collection Centre.
In anticipation of this, the storage facilities were organized efficiently, a process which is clearly showing that there are various methods of efficient storage. During day-to-day management, paintings tend to be hung in the most easily-reached places in the centre of the racks. In an effort to make more optimum use of the racking, from top to bottom, we were able to free up 17 racks out of a total of a hundred in one of the storage rooms. In connection with the renovation, work and storage space has been created in a vacated industrial building next to the Collection Centre. We are curious to discover whether the added activity and people will change the atmosphere in the Collection Centre. For staff working at the main site who are not directly involved in collection management, the Collection Centre can feel very remote. This could all change by relocating workspaces to Amsterdam-Noord during the renovation.

Growing with the collection and the city

What experiences from the recently-built collection centres, such as the Kolleksjesintrum Fryslân (see the article by Luc Schaap) and the CollectieCentrum Nederland in Amersfoort (see the article by Wim Hoeben and the article by Donny Tijssen), could be applied to improve the sustainability of our building? Perhaps we should turn our focus to Rotterdam, where Museum Boijmans Van Beuningen opened up its storage facility and exhibits the entire museum storage collection and the work on the collection to paying visitors (see the article by Wout Braber)? These are questions for the future. The Collection Centre in Amsterdam-Noord can continue as it is for decades to come and adapting the building in line with wider trends will require major investment.
There is more space for construction around the Collection Centre, that could be used to increase the building's volume and add new functions. However, during construction, no piles were driven into the ground in that area. This is a pity, since pile-driving so close to a building filled with collections creates obvious challenges. Whatever the case, the likelihood of construction work in the immediate vicinity is very high in the long term. The City of Amsterdam is looking for space for housing. Perhaps, by 2045, that housing will be in place and there will be a need for a cultural hotspot with a terrace overlooking the River IJ: a great future dream for the Collection Centre! The museum can follow suit and also take on an active role in helping develop social cohesion in the city. After all, the collection belongs 'to us', to the city of Amsterdam, the residents and anyone who feels connected to it.

Conclusion

How effectively does the Collection Centre work? In general, it works well and smoothly. After ten years, it will always be possible to find something in any design that we would now approach differently, because knowledge of technology advances or because working processes turn out to be different than envisaged. Everything changes: the organization, society, and collection policy, and it is impossible to simply incorporate that in a concrete building. Achieving a building that 'works effectively' means listening carefully to its users and it also places demands on the building's flexibility. This will continue to be a significant challenge for any new facility that is developed to preserve and work on collections.

With thanks to the staff from the Amsterdam Museum for participating in the survey and providing information.

Lessons learned from the Kolleksjesintrum Fryslân

Luc Schaap – LBP|SIGHT

Introduction

In the Dutch province of Friesland, several museums joined forces to develop a shared museum storage facility. This was prompted by the fact that the Fries Museum had been built without museum storage facilities. The collaboration presented an excellent opportunity for participating museums to bring together disparate collections and store them in optimum conditions. The Province of Friesland took on the role of commissioning authority. The aim was to develop a sustainable storage facility at reasonable cost. In early 2012, an expert team made up of Galjema BV Technisch Adviesbureau, Crown Fine Art, LEVS architecten and LBP|SIGHT was commissioned to conduct a feasibility study and draw up a schedule of requirements.

The Danish model

The expert team was convinced that the so-called *Danish model* showed great promise as a way of making significant advances both in terms of sustainability and the quality of the storage conditions.[100] Essentially, this model involves the use of a very well-insulated and airtight shell (walls and roof) combined with an uninsulated floor slab on the ground floor. As a result, it is the ground that largely determines the temperature in the storage facility. Although the climate fluctuates with the seasons, it is moderated and slightly delayed, in the same way as happens in bunkers (see article by Marc Stappers). This means that the climate in the storage facility is cooler in summer and warmer in winter than outside.
Previous studies had already shown that climate control systems offer no guarantee of risk-free effective storage conditions.[101] At the same time, it has become clear that lower temperatures are better for the long-term storage of heritage.[102]

[100] Ankersmit, B. & Stappers, M.H.L. (2017). Managing Indoor Climate Risks in Museums: Springer International Publishing AG Switzerland, p. 221.
[101] These risks include, for example, significant fluctuations in the event of air-handling failure, condensation problems in the building envelope, salt crystals on walls affected by salt damp, and rot in wooden parts of the building or systems that were not properly regulated, leading to significant and long-lasting periods of exposure to climate risks.
[102] High temperatures speed up chemical reactions, causing materials to age more rapidly.

The indoor climate

Before it was possible to build a storage building with only minimum installations, also referred to as a passive storage facility, a dynamic simulation was done of the anticipated indoor climate.[103] The model used for this purpose assumed insulated walls and roofs with an insulation value of Rc = 10 m^2K/W, and an uninsulated floor at ground level , the ground to a depth of 10 m underneath the building that delivered a constant ground temperature of 10oC and no active exchange of indoor and outdoor air (ventilation). Based on these assumptions, the model showed that the temperature in the storage facility would be between 6°C in winter and 16ºC in summer.
This result was discussed with the commissioning authority and the future users of the storage facility. The prospect of deviating from a traditional constant temperature of 20-21°C proved to be a point of contention, leading to discussions about a reduction in people's comfort compared to an improvement in the preservation of heritage.
The result of these discussions was that the minimum temperature to be maintained in the storage facility would have to be 10°C.

Additional modelling of the indoor climate

In order to realize the storage facility, several aspects required further research. The use of a building physical model provided answers to certain open questions:

- What is the influence of the height of the space? If the volume remains the same, a higher space has a smaller floor area, thereby reducing the impact of the uninsulated floor slab and increasing the effect of the insulated walls. It also means that less land is needed for the building.
- What effect does the insulation value of the building envelope have on the indoor climate?
- How does ventilation affect the indoor climate and is it possible not to ventilate?
- Is it really preferable to have an uninsulated floor or is a little insulation actually necessary?
- What influence does the building's mass have, especially that of the roof? In other words, is it possible to use a lightweight roof, made with steel sheeting, for example?
- Is it really possible to maintain an optimum indoor climate without heating, cooling, humidifying and/or dehumidifying?

[103] Capsol-Physibel software program.

- What effect would the answers to all these questions have on energy consumption?

Optimum height

From the perspective of building physics, the impact on the height of the storage facility of attempting to achieve a temperature that is as stable as possible is obvious: the lower the better. Of course, this is about striking a balance between the usability of the space, the land price, the surface required for the roof, floor and walls and the specifications for the indoor climate. Assuming a total volume of 15,000 m^3 was required, it seemed that it would be perfectly possible to control the indoor climate up to a height of around 9 m.

Insulation value

The insulation value influences the indoor temperature and the amount of seasonal fluctuation. The higher the Rc value, the less difference there is between the summer and winter temperature and the greater the influence of the ground temperature which is then more likely to be at 10ºC. The model revealed that the right balance had been struck with a high insulation value (Rc = 10 m^2K/W).

Ventilation

Ventilation has a significant influence, both on the indoor temperature and on relative humidity. Since collections do not require fresh air, ventilation only matters for the people present within the space.
Because there is no intention for people to spend a long time in the storage rooms and they will only be collecting or dropping off objects, the decision was made to refrain from installing mechanical ventilation in the space. This is based on the idea that as soon as someone enters the storage facility, the door is opened, resulting in substantial exchange of air with the corridor between the office and the storage facilities, providing natural ventilation in the storage facility at that time. This level of ventilation is sufficient for the few brief minutes that people generally spend in this space.

At least some insulation in the floor?

Since not insulating the floor is at odds with the traditional principles, this was a source of some uncertainty. Because the principle in building physics underlying the passive storage facility is based on the 'cooling capacity of the floor' combined with the thermal mass of the floor and walls, insulating the floor is counter-productive. This was also confirmed by the calculations, which is why the floor remained uninsulated.

Influence of the building mass: can the roof be made of steel?

In a storage facility, the mass of the building matters. The higher the mass, the more it will act as a thermal buffer. However, in this situation, the greatest mass is the floor in the ground floor and the ground underneath it. Replacing the concrete roof with one made of steel had only a slight negative impact on the stability of the indoor climate. A lightweight roof could therefor be considered from the perspective of building physics. Ultimately, a concrete roof was chosen after all, based on other considerations, including safety.

Is it really possible: no heating and no cooling?

The answer to the question of whether it is possible to forego heating and cooling is yes. The model showed that it was possible to keep the indoor climate within the specifications without installing any heating or cooling systems. With a completely passive building in which the floor slab determines the indoor temperature, a high-quality cool indoor climate can be achieved. But the requirement for the temperature to remain above 10ºC means that additional heating is required for winters that stay cold for long periods.

What about humidifying and dehumidifying?

As a basic principle, relative humidity must be maintained at between 45 and 60% throughout the year.
Any short-term fluctuations must be as small as possible and must not exceed plus or minus 5% within a 24-hour period. In order to factor in these parameters, the model showed that the air in the storage facility needs to be dehumidified for much of the year. This also means that for much of the year, the relative humidity is around the upper limit of 60% and the lowest relative humidity will be around 53%. This is the direct consequence of the relatively low room temperatures throughout the year.
The amount of moisture that needs to be extracted from the air in the storage facility is directly related to the amount of ventilation. If there is no ventilation, the moisture content in the outdoor air will have no influence on the indoor climate and dehumidification will not be necessary. The presence of people and the ventilation it causes leads to moisture that needs to be removed from the air again. The associated energy consumption is therefore directly related to the occupancy of the room and the length of time that doors are left open.

Figure 1 *Floorplan of the Kolleksjesintrum. Image: Bart Ankersmit*

Energy consumption

Since dehumidification primarily needs to happen in summer and also requires energy, this can easily be supplied by means of solar panels, which perform at their best at that time. For that purpose, 396 solar panels were installed on the roof, with an expected output of 89,600 KWh/year. That is roughly equivalent to the average power consumption of 33 households.

Determining the schedule of requirements

Once the results of this modelling had been discussed, it was possible to agree the schedule of requirements (SoR), establishing the basis for the Kolleksjesintrum Fryslân (Collection Centre Friesland). It took until mid-2013 for the Province to reach the decision actually to go ahead with construction of the building. Eventually, in the summer of 2014, the contract could be awarded for a design. Bouwgroep Dijkstra Draisma was commissioned to build the Kolleksjesintrum in the spring of 2015. It was finally opened in the summer of 2016.

The building

With a floor area of 2,000 m^2, the building consists of an office section separated by a corridor from three storage rooms, each 670 m^2 in size (see also the photospread by Bart Ankersmit). The storage rooms built had a clearance height of approximately 6 m and were separated from each other by means of metal stud partition walls.
The height of 6 m made it possible to install a double-decker storage system with slatted flooring in one of the storage facilities, thereby creating two separate floors. Figure 1 shows the floor plan for the storage building.

The systems installed

According to the modelling, a minimum temperature of 10°C requires heating and dehumidification is also necessary to achieve a maximum relative humidity.
There was also concern about the development of micro-climates because of insufficient mixing of air.
These requirements called for the installation of a system to recirculate the air in the storage facility. Because of the presence of the large thermal mass in the floors, walls

and ceilings, both the temperature and relative humidity were expected to be uniform. Despite this, a system capable of achieving a uniform thermal and hygroscopic climate was installed.
This comprises a recirculating air-handling system that includes two heat pumps: one to heat and when necessary also cool the air and another to dehumidify the air. The heat pumps are identical but the difference is that the heat pump for heating and cooling has a connection with outside (to supply and discharge heat). The dehumidifying heat pump cools the air in order to withdraw moisture but any heat removed from the air in the process is immediately re-added to the dehumidified air, minimizing as far as possible its effect on the temperature of this dehumidified air, and therefore also the room.
DX units (direct expansion by means of a coolant) were chosen, which means that they do not carry water.
This made it possible to install them in the storage rooms themselves, obviating the need for separate installation spaces on the roof. The only part of this system that carries water is the condenser that vents the dehumidifier. In order to reduce the risk of leakage, the systems were positioned against the ceiling just behind the access door. On the floor plan in Figure 1, they are shown as grey rectangles just behind the access doors. This location was chosen since heritage is never stored in this high-traffic area and any leaks will be immediately obvious when arriving in the storage facility.
The heated, cooled and/or dehumidified air is spread across the length of the rooms via two air socks (fabric duct systems) located directly under the ceiling along the two long walls (green dotted lines in figure 1). Since the systems are switched on continually in order to recirculate air, they contribute a certain amount of internal heat production. This means that heat (the energy that the ventilator uses) is actually being continually emitted into the space.

The separation between storage rooms and the facility building

As Figure 1 shows, the storage facilities are located along the corridor (yellow area) of the building. The indoor climate specifications in this corridor are based on human comfort needs, rather than the climate needs for the collection. The original plan was to install thermal insulation between the corridor and storage facility. Since the storage rooms were required to remain at a temperature of at least 10°C, it was decided not to insulate the wall. This decision was partly based on the modelling data. This is because the difference in temperature between storage rooms and facility areas is only minimal in summer and there is a certain need for heat to be supplied to the storage rooms in winter in order to maintain the lowest acceptable temperature of 10°C.

Assured of a good start

The construction of a passive building, in which the indoor climate develops naturally, requires a very carefully-considered process of construction. One key aspect in this is construction moisture. Construction takes place in the outdoor air and until a building is rain-proof, a great deal of moisture will be stored in the structure, mainly during rain showers. Numerous measures were taken in order to minimize the risk of a high moisture content when making the building airtight. These included using prefabricated concrete for the walls, just as for the ground floor and the roof, see figure 2. This enables rapid construction and also ensures that the concrete contains less construction moisture. The floor on the ground floor is always given a compression layer that is normally finished in cement. These layers were delayed until the building was watertight in order to prevent rainwater becoming trapped in these finishing layers. After the roof sheeting was fitted, a damp-proofing layer was applied and the roof was fitted with temporary rainwater drains. This ensured that the building was made watertight as quickly as possible, resulting in a very dry building.
If, despite everything, a lot of moisture is allowed to enter these types of buildings, it is a major challenge ensuring that they are sufficiently dried. The fact that the storage rooms are large, completely sealed boxes with just a single opening, where the door is, also means that the building cannot dry naturally as a result of the passage of air through the building during construction. This means that any moisture has to be artificially removed. The procedure that was followed in this project avoided all of that.

By November 2015, the building was more or less structurally complete and the storage units were assembled in the storage facilities. The installations in the storage rooms were not yet in operation, although those in the facility section were. When installing the storage units, the climate was measured in the storage facilities in November 2015, which showed that the relative humidity was 57% at a temperature of 17°C.

Figure 2 *On the left the building constructed from prefab concrete and on the right the insulated outer shell. Photos: Luc Schaap*

These conditions were within the set parameters without any adjustment by the systems installed.
It was then that long-term monitoring of the climate in the storage rooms began.
The temperature in the storage zones was higher than the model predicted for the time of year. The most likely reasons for this were:

- It was an exceptionally warm winter.
- During the move, the doors had stayed open for long periods enabling heat from the adjacent rooms to enter the storage rooms.
- During the process of outfitting and relocation, lots of people spent long periods in the storage rooms.

Moving in

Following the opening in May 2016, the relocation of the collections began. During this period, the doors were again often open. In one of the storage facilities, a low oxygen pest treatment tent was built in which the temperature was kept at a maximum of 23°C for several months. Of course, a heat source of this kind had a huge influence on the temperature in a passive, airtight building. This situation continued until the end of 2016.

Starting up the systems

Once the move was complete, it emerged that the systems installed had not been set up as originally intended. It turned out that the relative humidity was displaying many minor fluctuations. This was because of the setting that causes the systems to attempt to maintain the relative humidity between 52 and 58% (see figure 3, detail in lower left corner). It had also been set to maintain a minimum temperature of 16°C, which was not what had been planned. Adjustments were made to the climate control systems in May 2017. Whenever the relative humidity exceeds the upper limit of 60%, the dehumidifier is initiated and only when the temperature is below 10°C is there any heating. The air is also continually recirculated in order to prevent localized differences in climate.

Once the system controls had been adjusted, the relative humidity stabilized significantly, with daily fluctuations of 1%; see the dark blue line in Figure 3.

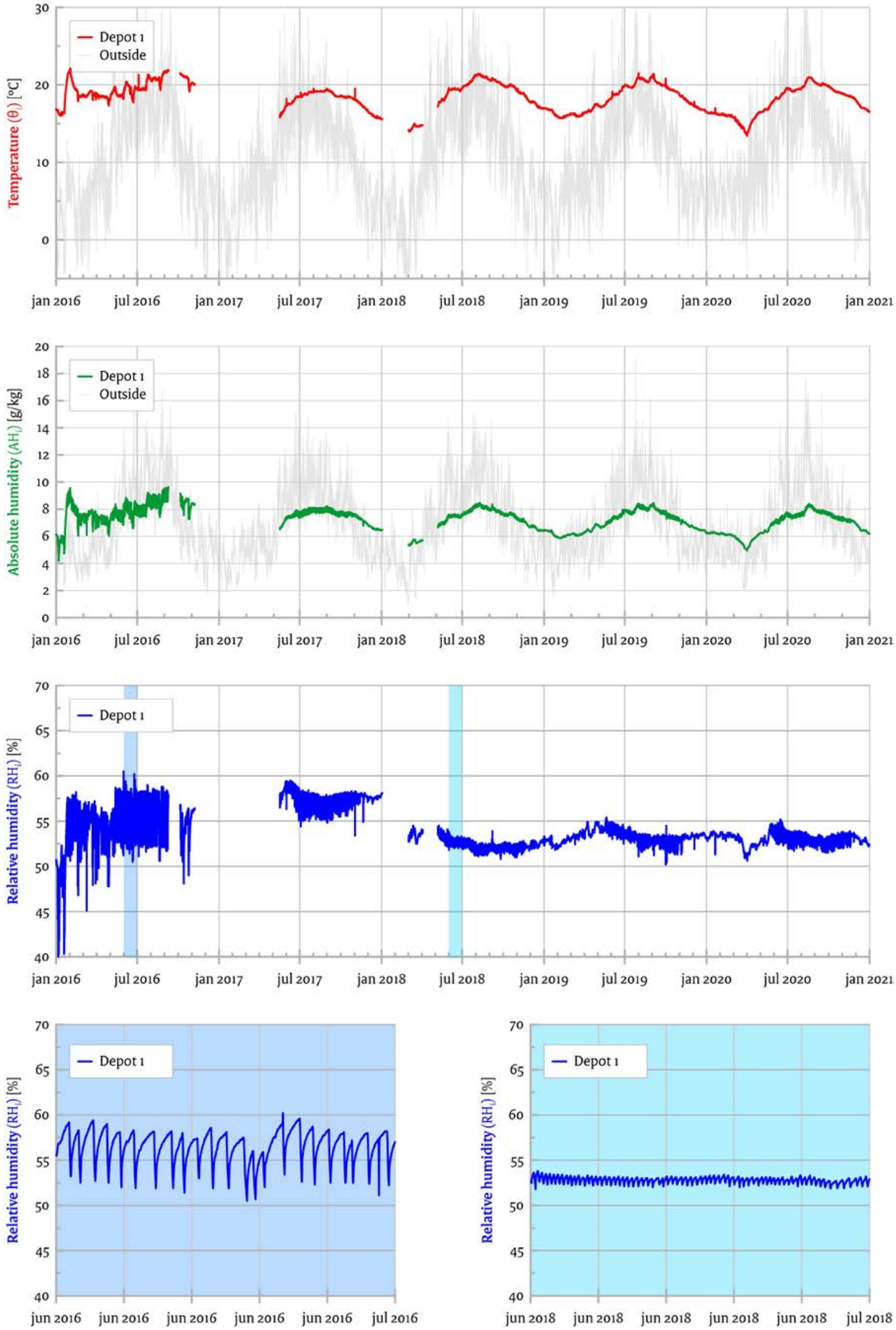


Figure 3 *The indoor and outdoor climate from january 2016 until January 2021. The temperature on top (red line), the absolute humidity in the middle (green line) and the relative humidity in below (blue line). Image: Luc Schaap en Marc Stappers*

Other variations in climate

Since the start of 2016, the building has been functioning as intended. The storage facilities have been filled and are entered on a sporadic basis only. The systems continually circulate air and dehumidify the indoor air at times when relative humidity is at risk of becoming too high (> 60%), which has virtually never happened in the meantime.

In the period 2017-2018, the temperature in the storage rooms fluctuated between 15 and 20°C, which was approximately 4°C higher than intended. In the summer of 2019, the temperature reached 21°C. The storage rooms appeared to be gradually becoming warmer. In all probability, this can partly be attributed to the extremely warm summers and winters. As a result of this, the decision was made to initiate cooling in early 2020. Fortunately, the demand for cooling in the summer coincides with high output from the solar panels. In 2020, the indoor climate was actively cooled throughout March, but this did not prove sufficient to completely cool the entire building. For this reason, there was permanent cooling from May until the end of the summer in 2021. As a result of this, the temperature in July 2021 was just 14°C, compared to 21°C in 2019. In order also to cool the thermal mass, it was decided to continue cooling for longer. These measures were taken as a means of regaining control of the building, which was no longer in balance for various reasons. Because of the significant thermal mass, this is a very slow process. However, it is interesting to observe that even when the temperature is adjusted, the relative humidity remains very calm and stable. The passive storage facility is proving to be extremely stable and robust when it comes to relative humidity.

Conclusions

The effort to create a storage facility based on the Danish model, largely applying passive climate control, has proved successful. However, the indoor climate behaves slightly differently from the predictions in the modelling. The initial conditions for temperature and moisture are important factors in this. The high level of inertia in the solid, passive building means that if the initial conditions deviate, it can take a long time until they are back under control. Thanks to a carefully-considered plan of action and a monitored process of construction, we were able to ensure that the initial conditions in terms of moisture in construction materials and relative humidity were effectively as envisaged.
The same did not apply to the temperature. At the time of the centre's initial use, a great deal of heat had already accumulated during the construction and relocation process. The hot summers of recent years were also key factors in our inability to achieve the intended temperature passively.
There were also the internal heat sources, which were known, (i.e.: an uninsulated wall and heat from the ventilator in the air-recirculation system), but which certainly did not help, in view of the initial conditions that were already too warm. These experiences taught us that, in the case of a passive building, it is very important to be aware of the problem of deviating initial conditions. This means that it must be possible to adjust the indoor climate and as many external influences as possible need to be ruled out (by insulating the internal wall after all, halting recirculation where possible). Fortunately, the systems required to make the adjustments had been installed.
What also emerged is that communication in construction processes can be very complex. The design team had a clear idea of what climate conditions were intended. When the centre was taken into use, it turned out that the installation company had a different understanding. Thanks to the continuous climate monitoring, this quickly became obvious. The controls were adjusted and the relative humidity was much more stable within a short space of time.
The excessive temperature remained a stubborn issue and even appeared to be gradually increasing. The exact reasons for this are unclear and will require further study, especially since other storage facilities in the Netherlands have been or are being developed using a similar principle. Attempting to correct the temperature by means of cooling is a time-consuming process. There is also the question of whether, when the system is back at the right level and cooling is stopped, the climate will continue to display the right behaviour passively. This remains to be seen from ongoing monitoring. The continual, independent recording of the indoor climate has proved to be essential. Currently, this is being done out of professional interest and at our own expense. However, measuring and monitoring should actually be a key component of the in-use phase. A great deal of time and money is invested in developing these kinds of buildings, but once what was called for has been realized, we seem to lose interest. Unfortunately, despite the measurement results, we are left with an incomplete picture.
For example, when and how the systems make adjustments is unknown. Questions remain as to when and how often there is dehumidification, cooling and

possibly heating and with regard to the energy consumption of the heat pumps and ventilators. A more extensive building management system with more data output would be highly desirable.
Another question is how the effects of the initial use and process of moving in can be minimized, for example by temporarily isolating the area or actively applying climate controls.

The sustainable storage building has now been in operation for five years and the climate may not have been completely as planned, but has proved to be very adequate. In addition, although we had to make use of the systems installed to some extent, more energy has been generated than consumed.

Bunker-based storage – how suitable is the indoor climate?

Marc Stappers – Specialist in building physics, Cultural Heritage Agency of the Netherlands

Summary

In the lead-up to World War II, bunkers were built in various places in the Netherlands to protect objects of art from the ravages of war, like in Castricum, Heemskerk, Zandvoort and Paasloo. The main aim of these heavy monolithic concrete structures was to reduce the impact of bombing raids. The sand on top of the bunkers helped a little, but served primarily as camouflage. In order to control the climate, air-handling systems were also installed. Because of the significant thermal mass, the temperature is relatively low and comparable to modern sustainable storage facilities. The infiltration of outdoor air combined with the low temperature leads to a high relative humidity. Dehumidification and limiting infiltration are two effective measures for reducing high relative humidity.

Introduction

In 1938, Jan Kalf, the Director of the Department for the Preservation of Historic Buildings (*Rijksbureau voor de Monumentenzorg*),[104] published a report outlining experiences from abroad and the options available for the Netherlands for protecting our heritage at times of war.[105] The prevention of physical forces and fire were the key factors in the choice of thick concrete walls and even thicker concrete roofs. In the First World War, there had been experiments in the UK involving the storage of art objects in rooms covered with soil. However, the high relative humidity caused the collection to degrade at a substantial pace because of fungal growth. In the Second World War, this knowledge was then applied in order to use the same type of rooms for the storage of art objects, but this time with some modifications involving waterproofing the structure and controlling relative humidity.[106] Increasing the temperature slightly to 16.7°C made it possible to keep the relative humidity at the desired level of 58%.

Although in his publication Kalf suggests establishing hiding places for specific types of movable heritage, he wrote nothing about how these should be equipped in order to achieve the desired temperature and relative humidity. However, he does include an interesting reference to Spain where, he says, for the purposes of preventive conservation, there is access to 'self-registering devices that make it possible to completely control the temperature and humidity of the air'.[107] Based on the construction drawings of the various (government) storage places, including those for Steenwijkerwold (see Figure 2), it can be concluded that also Dutch storage places had some degree of climate control.

Bunkers for art storage

In the run-up to and during the Second World War, various repositories were built in the Netherlands in order to store art objects. To protect from grenade attack from above, they were built in reinforced concrete with thick walls, floors and ceilings, and sometimes camouflaged with soil, as in the case of the storage place in Heemskerk (see Figure 1). In most cases, they were commissioned by the Central Government Real Estate Agency (*Rijksgebouwendienst*).[108],[109]

Figure 1 *The camouflaged storage place in Heemskerk built in 1940-1941. Photo: I. Beirigo*

[104] A forerunner of the Cultural Heritage Agency of the Netherlands.
[105] Kalf, J. (1938). *Bescherming van kunstwerken tegen oorlogsgevaren*. 's-Gravenhage: Algemeene Landsdrukkerij.
[106] Brown, J.P., & Rose, W.B. (1996). Humidity and Moisture in Historic Buildings: The Origins of Building and Object Conservation. *APT Bulletin* 27 (3), 12.
[107] Ibid. note 2, p. 29.
[108] Gol, E. (2018). Rijksbergplaatsen voor kunstschatten. The Hague: Rijksvastgoedbedrijf.
[109] A forerunner of the < >

Even during the Cold War, art storage remained an issue. In 1958, an English translation was published of *Les techniques de protection des biens culturels en cas de conflit armé*, possibly in the wake of The Hague Convention of 1954, describing in detail numerous protective measures, including methods of climate control.[110] In the war years, much was learnt about climate control and its influence on objects. One key lesson was that, with the exception of special cases, achieving the indoor climate primarily involved compromises. At times of conflict or disaster, a reliable system that is less strict in its control of the indoor climate always takes preference over a system that can precisely control the indoor climate but is less resilient.[111]

Indoor climate in bunkers

As is the case with many solid historic buildings, the indoor climate within bunkers depends on several aspects:

- the insulating properties of the building envelope;
- mass;
- water resistance;
- the degree of air exchange between inside and outside;
- the systems and installations in place;
- usage.

[110] Noblecourt, A. (1958). *Protection of Cultural Property in the Event of Armed Conflict*. Paris: Unesco. See: https://www.jstor.org/stable/1505011?origin=crossref.
[111] Ibid. note 7, p. 281.

Construction materials and resistance to water

Only a limited number of materials were used in the construction of bunkers. The most important of these are: soil, wood, brick, concrete, iron, steel, asphalt, tar and bitumen.[112] Concrete is relatively waterproof in any case, but the concrete surfaces that would be covered with earth were given a protective damp-resistant layer of asphalt before the soil was added.[113] As early as in 1928, the directive on field defensive positions (*Voorschrift Inrichten Stellingen*) was already prescribing 'adding asphalt to as much of the upper surface of the hiding place as possible (by spreading a 3 mm layer of asphalt on the walls) and a double coat of coal tar on the vertical outer surfaces that would come into contact with soil; this made the bunker more suitable for occupation'.[114]

The building envelope

Generally, the building envelope is made of concrete. Table 1 shows the thickness (t) and heat resistance (R) for the different building components for the casemates in Kornwerderzand and Den Oever.

[112] Visser, H.R., Wieringen, J.S. van, & Kruijf, T. de (2002). *Kazematten in het Interbellum: Vestingbouwkundige bijdragen*. Utrecht: Stichting Menno van Coehoorn, p. 36.
[113] Verbeek, J.R. (2020). *Kazematten op de Afsluitdijk*. Gorredijk: Uitgeverij Noordboek, p. 27.
[114] Koninklijke Militaire Academie (1928). *Voorschrift Inrichten Stellingen. Deel VII: Bouw van zware gewapend beton-schuilplaatsen* (Koninklijke Landmacht Voorschrift no. 77f). Breda: Koninklijke Militaire Academie, p. 94.

Table 1 *Thickness of building components in the casemates of Kornwerderzand and Den Oever*[1] *and the calculated R value*

Building component	**Kornwerderzand**		**Den Oever**	
	Thickness	**Heat resistance** [2]	**Thickness**	**Heat resistance**
	t [m]	**R [m²K/W]**	**t [m]**	**R [m²K/W]**
Floor slabs	2	0.87-1.05	2	0.87-1.05
Top layers	2	0.87-1.05	1.8	0.78-0.95
External walls not covered by soil	2.5-3	1.09-1.58	2.3	1.00-1.21
Other external walls	2	0.87-1.05	1.8	0.78-0.95
Internal walls reachable through embrasure	1.5	0.65-0.79	1.5	0.65-0.79
Other internal walls	1	0.43-0.52	1	0.43-0.52

[1] Ibid. note 9.
[2] The R value was determined using a thermal conductivity coefficient of 1.9 W/mK (dry) and 2.3 W/mK (wet). The soil coverage is not factored into this.

Each metre of sand coverage adds an additional R value of 1 m^2K/W.[115] This means that the thermal resistance for this kind of thick, usually concrete structure is low, up to a maximum of 1.58 m^2K/W (see Table 1). In the casemates in Kornwerderzand and Den Oever, the soil coverage was no more than 30 cm. Compared to the Dutch building regulations (*Bouwbesluit*)[116] and, more importantly, the Danish-style storage facilities in the Netherlands,[117] the Kolleksjesintrum Fryslân and the CollectieCentrum Nederland[118], the level of thermal resistance is remarkably low. The case of Castricum (see the case study below) is different, because the thickness of sand could easily reach 10 m (see Figure 6). Since concrete is capable of storing a large amount of energy, it also helps moderate the fluctuating outdoor temperature. This is a familiar phenomenon very much appreciated by tourists in summer when they seek refuge in a large cathedral to cool down. In building physics, this phenomenon is referred to as *thermal mass* (volumetric heat capacity): density multiplied by specific heat capacity. Concrete has a thermal mass of 2.00 MJ/m^3K, which makes it higher than brick: 1.47 MJ/m^3K, wood: 1.50 J/m^3K and insulation: 0.73 MJ/m^3K.

Heating and ventilation

In principle, the casemates in Kornwerderzand and Den Oever were equipped with heating and ventilation. Just like the lighting, the heating was electric.[119] Ventilation was a complex task. It needed to be possible for people to be able to stay there for long periods irrespective of the conditions. Manually-operated ventilators were used to supply fresh outdoor air. For the storage of art, measures were also taken to ensure dry conditions and there was also humidification at certain times (see Figure 2).[120] After the Second World War, this also became better regulated.[121] In the Netherlands, there were also relatively precise regulations describing the method of climate control.[122]

115 The thermal conductivity coefficient of wet sand is approx. 0.5 W/mK<l<2.0 W/mK. A value of lsand=1 W/mK is generally used.
116 The table accompanying Article 5.3 of the Buildings Decree (*Bouwbesluit*) 2021 set a thermal resistance (Rc value) of 6.3 m2K/W, 4.7 m2K/W and 3.7 m2K/W respectively for roof, façade and floor. See: https://rijksoverheid.bouwbesluit.com/Inhoud/docs/wet/bb2012.
117 Raeder Knudsen, L., & Rosenvinge Lundbye, S. (2017). Performance of Danish low-energy museum storage buildings. *ICOM Committee for Conservation 18th Triennial Meeting Copenhagen Denmark 4-8 September 2017*.
118 Ankersmit B., Loddo, M., Stappers, M.P.M., & Zalm, C. (2021). Museum Storage Facilities in the Netherlands: The Good, the Best and the Beautiful. *Museum International* 73 (1-2), 132-143.
119 Ibid. note 9, p. 67.
120 *Beschrijving en bedieningsvoorschrift van de luchtbehandelingsinstallatie, welke is opgesteld in de kunstschattenbewaarplaats te Steenwijkerwold* (1943).
121 Ibid. note 7
122 *Artos gecombineerde normale en gasbeveiligde luchtverversingsinstallatie met luchtbehandeling t.b.v. B.B.-Kommandoposten* (1964). Corsmit, E.J.A. (1962). Algemene eisen inzake luchtbehandelingsinstallaties voor onderkomens. 's-Gravenhage: Raadgevend Ingenieurs Bish & Partners.

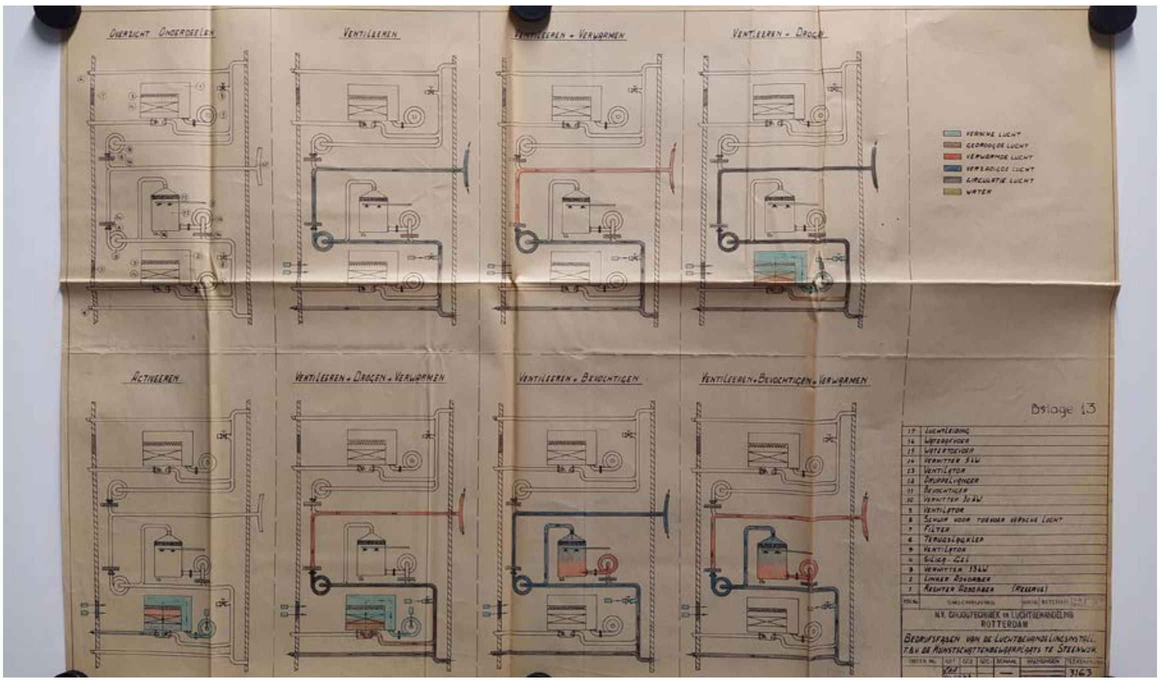


Figure 2 *Chart showing the different operational phases of the air-handling system at the storage place for art treasures in Steenwijk. Photo: Erik Gol, Central Government Real Estate Agency*

There is also an exchange of air via doors, embrasures and open ventilation channels and differences in wind pressure. The moving around of visitors will circulate and mix the air.

Case study: Kornwerderzand

The fortifications known as Stelling Kornwerderzand were built between 1931 and 1936. Like those in Den Oever, these fortifications were built to protect the Lorentzsluizen and Stevinsluizen. These played a vital role in managing water levels in the IJsselmeer for the inundations needed since the Afsluitdijk enclosing dam was built (1927 and 1932). Stelling Kornwerderzand consists of a total of 17 heavy casemates. In 2015, two students from Eindhoven University of Technology studied the indoor climate, analysing the climate in two casemates: Casemate VI, used as a museum, and Casemate XI, which is not in use.[123]

Casemate VI: used as a museum

Casemate VI was built for two cannons '5 cm by 50' (see Figure 3, left, room 1) and is currently being used as museum space. The bunker is made up of two floors. Readings were taken of air temperature, surface temperature and relative humidity in various places.

In their current condition, the bunkers are no longer airtight. The existing doors and openings no longer close properly, and any (ventilation) channels are either no longer in use or connected. Since it is in use, the doors are regularly left open. As a result, outdoor air can infiltrate, disrupting the absolute and therefore also relative humidity in the bunker. Three humidifiers have therefore been fitted to control the relative humidity; see Table 2.

123 Plas, J. (2015). The Indoor Climate of (Dutch) Military Fortifications. Eindhoven: Technische Universiteit Eindhoven. Paulussen, E. (2015). Indoor climate of fortifications: casemates of Kornwerderzand. Eindhoven: Technische Universiteit Eindhoven.

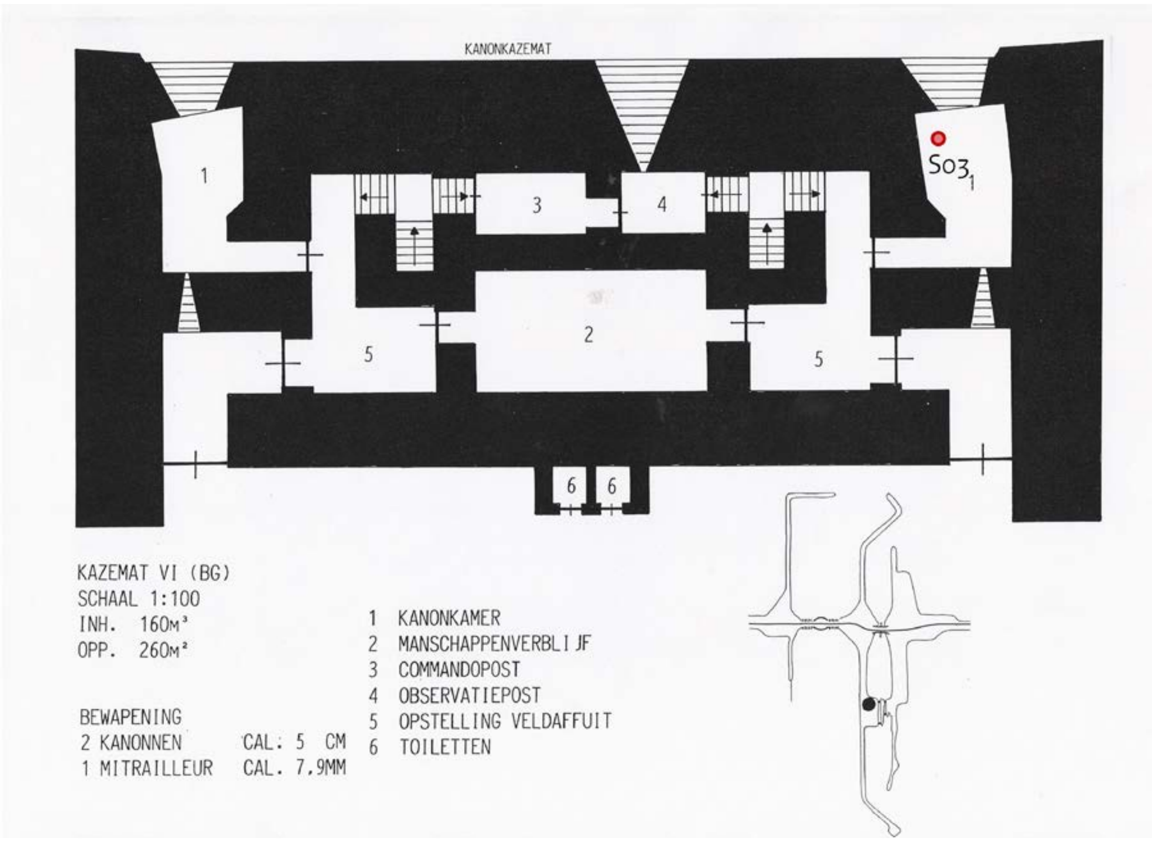


Figure 3 *Floor plan of cannon Casemate VI: ground floor (left) and cellar (right). This casemate is part of the Kazemattenmuseum and used by the museum. Source: unknown*

Table 2 *Overview of the dehumidifiers in Casemate VI*

Room	Type	Venting	Capacity	Relative humidity setting
			[litre/day]	[%]
Ground floor, room 5	Amcor D950E	Yes	60	60
Cellar, room 2	Boneco 7064	Yes	18	60
Cellar, room 5	Boneco 7064	Emptied manually	18	60

Casemate XI: not in use

Not all of the bunkers in the fortification are used by the museum: Casemate XI is empty. Any fluctuations in climate that occur are the result of the effect of the outdoor climate, particularly air exchange between outdoor and indoor.

The indoor climate: comparison between casemates in use and not in use

In the period between 24 April 2015 and 8 October 2015, temperature and relative humidity readings were taken every 15 minutes at various places in both casemates.[124] For the purposes of this comparison, two measurement sites in each casemate were studied in more detail: one on the ground floor with external openings and another below ground level in the basement with no openings (see Figures 3 and 4). This data was used to calculate the associated absolute humidity.

[124] In order to improve readability, the measurement locations in Paulussen (2015), Plas (2015) and Stappers *et al.* (2020) have been renumbered (see notes 22 and 28).

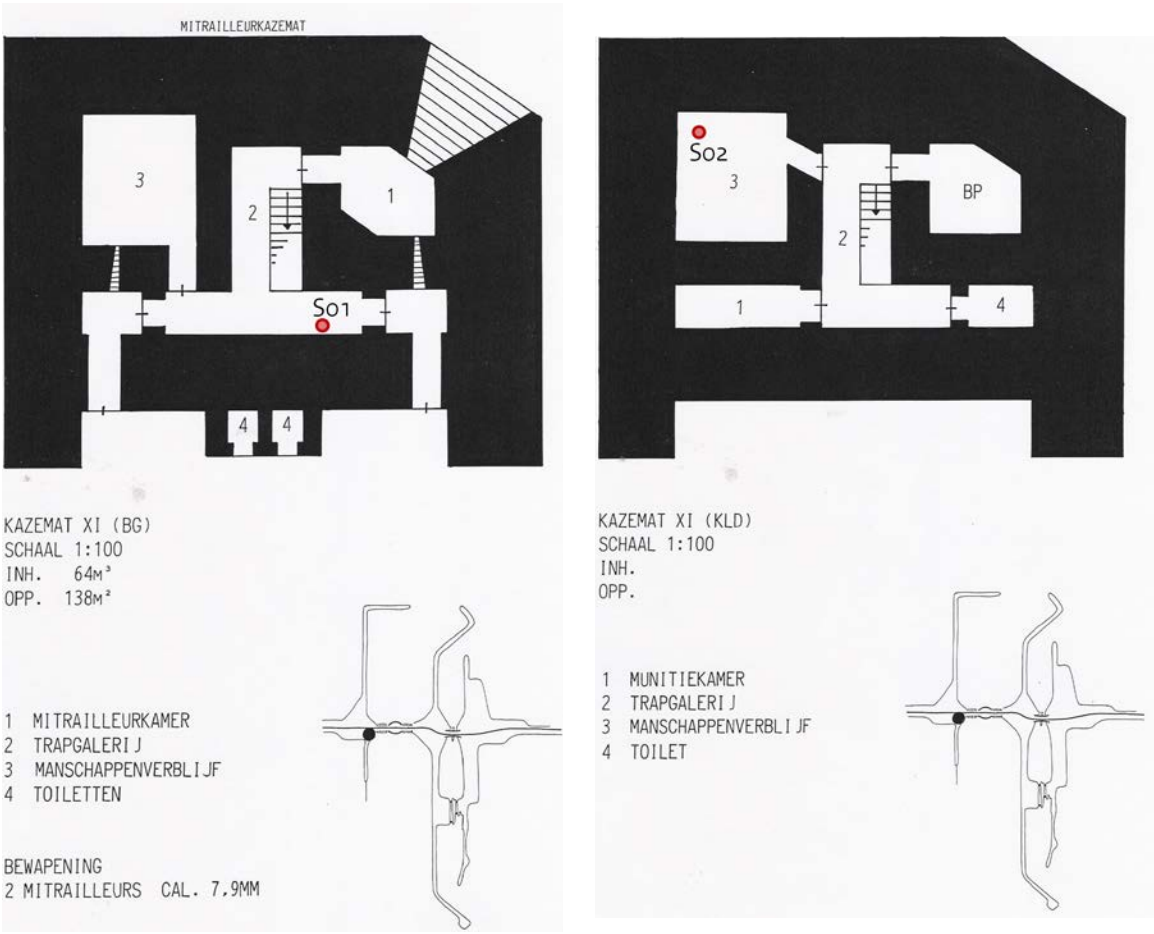


Figure 4 *Floor plan of cannon Casemate VI: ground floor (left) and cellar (right). This casemate is part of the Kazemattenmuseum and used by the museum. Source: unknown*

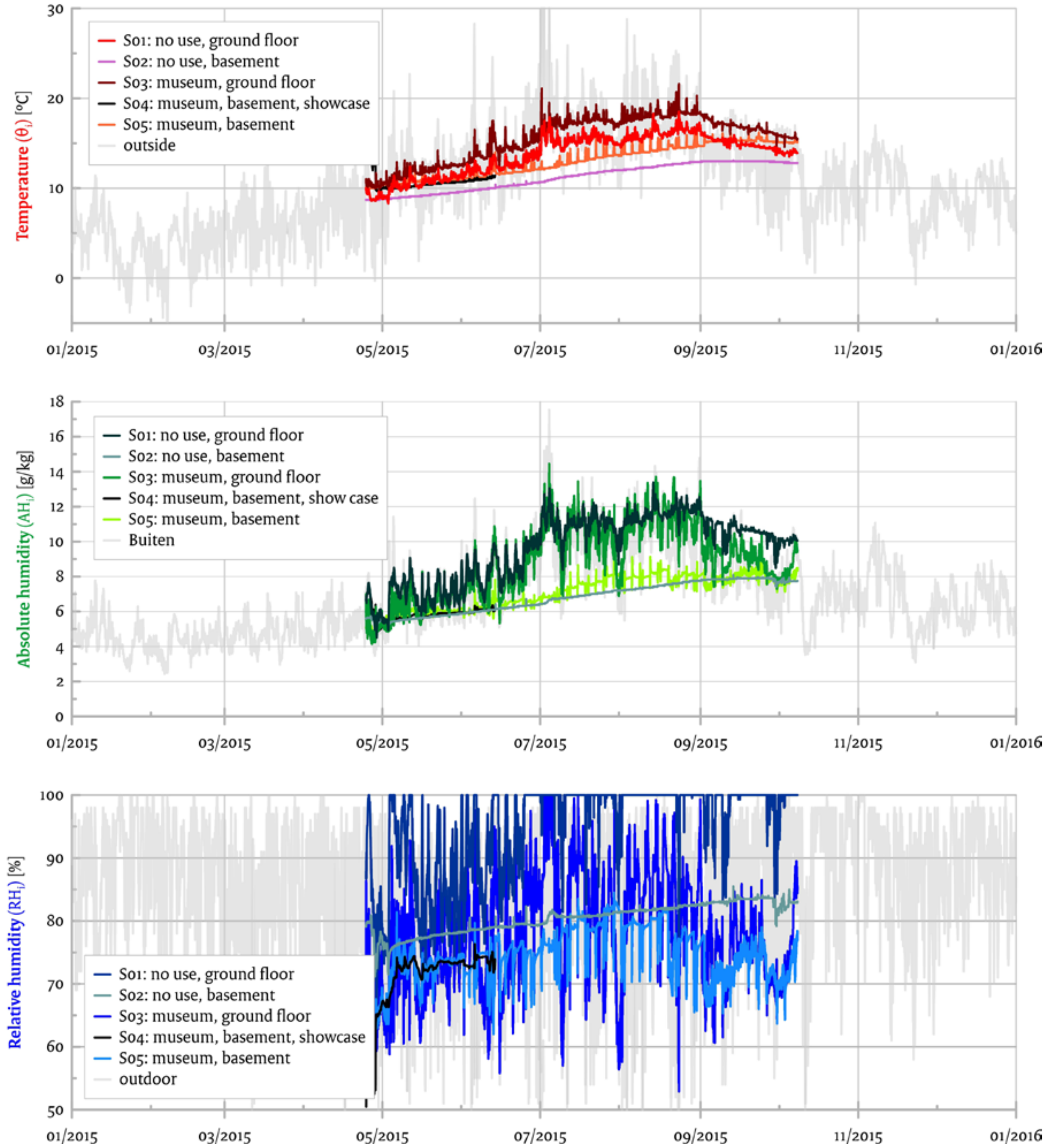


Figure 5 *Changes in temperature (above, red lines), absolute humidity (centre, green lines) and relative humidity (below, blue lines) in Casemate VI (museum, S03, S04 and S05) and Casemate XI (not in use, S01 and S02). Image: Marc Stappers*

The changes in temperature (see Figure 5, above) in the casemate mirror the outdoor climate, but are moderated and delayed. The more air brought in (increase in infiltration), the faster the temperature changes. What is interesting to note is a very gradual change in temperature in the cellar of both Casemate X1 (S02, not in use, purple line) and Casemate VI (S05, museum, orange line). Usage and therefore higher infiltration may play a role in this, and may also explain the day and night rhythm of sensor S05.

Absolute humidity is a contributing factor to the relative humidity. The level of absolute air humidity depends on evaporation of moisture on the ground through the concrete and the degree of infiltration. The releasing of water by the concrete is a relatively slow process. This is why the infiltration is particularly important. The rooms that are in direct (or more direct) contact with the outdoor air (Casemate XI, not in use, S01, and Casemate VI, museum, S03) have an absolute humidity that is identical to that outside (see Figure 5, centre, dark green and green line).

The relative humidity is high (see Figure 5, below). In Casemate VI, used as a museum and dehumidified, relative humidity levels are between 60% and 80% in the case of the ground floor (S03) and between 65% and 85% in the basement (S05). In Casemate XI, which is not in use, relative humidity levels are between 80% and 100% in the case of the ground floor (S03) and between 75% and 85% in the basement (S05). In other words, the casemate without climate control has a significantly higher relative humidity. This endorses the conclusion reached by Bootsveld and Van Ingen that rooms of this kind require dehumidification in order to make them suitable for use.[125]

The use of a display case helps. Which is to say: the absolute humidity in the display case (S04) is lower and more stable than the absolute humidity outside the display case (S05), which means that the relative humidity is also more stable. The extent to which this is affected by the rate of air exchange in the display case is unclear.

Case study: Rijksbergplaats Castricum

The construction of the nitrate film storage facility in the former art bunker in Castricum was commissioned by the City of Amsterdam in 1939-1940 to enable the safe storage of art objects during the Second World War.[126] Since 1960, this bunker has been used by Eye Filmmuseum for the safe storage of 6,000 to 7,000 cans (approx. 9,500 kg) containing highly flammable nitrate film.

This storage depot was made completely of concrete poured on site. The walls are 1.5 m thick and are covered by approximately 10 m of sand. This thick layer of sand on top of the layer of reinforced concrete provided additional protection and camouflage. The total volume of the bunker is approximately 212 m^3. The doors are made of steel and completely seal off the corridor, making it airtight.

Climate control

The bunker has a ventilation system that pumps in outdoor air to replace the indoor air, featuring an on-off drive system with a timer. The ventilation rate is 2,000 m^3 per hour at the highest setting. The bunker does not have an active heating or cooling system. However, there is a mobile dehumidifier in the bunker (brand: Dantherm, type: CDT50[127]) that works independently of the ventilation system and runs continually. The dehumidifier has a capacity of 50 l per day (at 30°C and 80%) and 25 l per day (at 20°C and 60%). Its ventilation rate is 800 m^3 per hour.

The indoor climate

In the period from 5 August 2016 until 29 March 2019, hourly readings were taken of the temperature and relative humidity. These data were also used to calculate the associated absolute humidity.

125 Bootsveld, N.R., & Ingen, M.M. van (2002). *Klimatisering van met grond gedekte gebouwen in de Nieuwe Hollandse Waterlinie*. Apeldoorn: TNO.

126 See: https://nl.wikipedia.org/wiki/Kunstbunker_bij_Castricum, consulted on 11 June 2020.

127 See: https://www.dantherm.com/mdeia/235374/cdt_22-35-35s-5-85_brukermanual_060707.pdf.

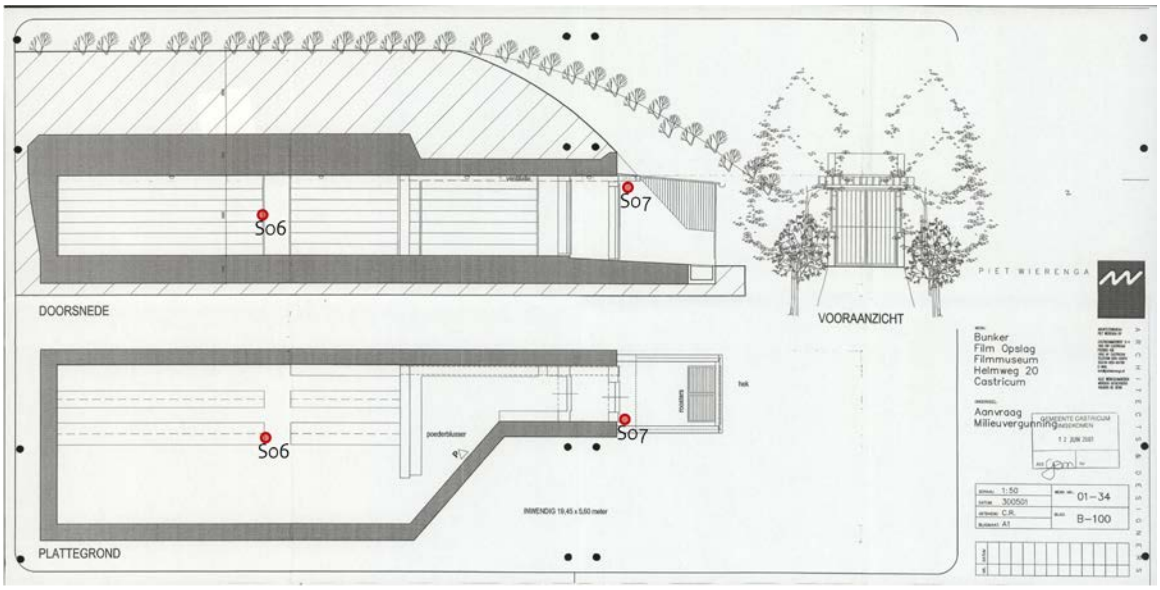


Figure 6 *Floor plan showing the two data loggers S06 and S07 for monitoring the temperature and relative humidity in the nitrate vault in Castricum, dating from 2001. Source: Architektenburo Piet Wierenga*

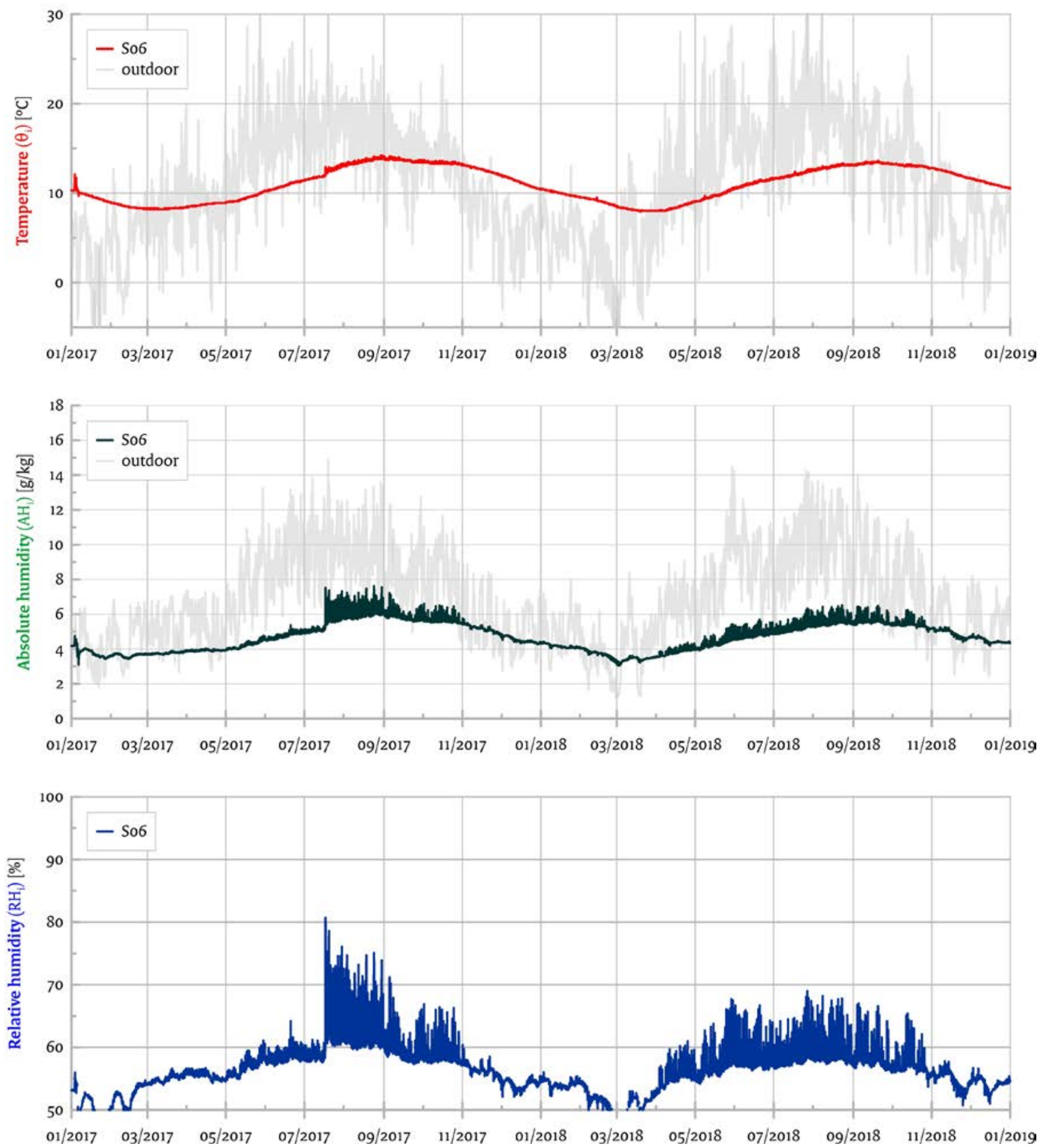


Figure 7 *Changes in temperature (above, red lines), absolute humidity (centre, green lines) and relative humidity (below, blue lines). Image: Marc Stappers*

Figure 7 (above) shows the temperature changes inside the bunker and the outdoor temperature for a two-year period, from January 2017 until January 2019. There are only very slight daily temperature fluctuations in the bunker. The indoor temperature matches the outdoor temperature with a delay of approximately 2.5 months and is substantially moderated. The average temperature in the bunker is 11°C with a seasonal fluctuation of 6°C, whereas the temperature outside has approximately the same average temperature, but with a seasonal fluctuation of 15°C is the same average all year round.

Figure 7 (centre) shows the changes in absolute humidity inside the bunker and outside during the same period. The absolute humidity inside matches the absolute humidity outdoors with a delay of approximately 1.5 months and substantial moderation, especially in the summer months. The average absolute humidity in the bunker is 4.7 g/kg with a seasonal fluctuation of approximately 1.1 g/kg in winter and 1.1 g/kg to a maximum of 3.0 g/kg in summer, whereas the average outdoors is approximately 7.0 g/kg.

Figure 7 (below) shows the changes in relative humidity inside the bunker and outside for the two-year period from January 2017 until January 2019. In the bunker, the relative humidity averages at 56%, with a 95% upper limit of 63.2%. It is also interesting to note that the first part of the graph (until mid-July 2017) shows few significant fluctuations. After that, there are suddenly a lot of significant fluctuations (until November 2017), possibly through changes to the settings. A slightly different picture can be seen in 2018. Starting in April, the fluctuations gradually increase, continuing into November. They then decline again.

Climate performance in perspective

It is important to place the climate performance of bunkers in terms of temperature and relative humidity in perspective: the bunkers in Kornwerderzand are empty and part of the museum and those in Castricum can be compared with several Danish storage facilities; see Figure 8.

This comparison shows that the bunkers have a comparable temperature regime. On the other hand, the relative humidity in the bunkers is significantly higher. Dehumidification would appear to be effective, because Casemate VI has a lower relative humidity than Casemate XI – although the fact that it is used cancels out some of that effect, as doors are left open and people cause the air to circulate. This explains why the relative humidity in Castricum is much lower: dehumidification is more effective and infiltration is low.

Conclusion

Both case studies show that temperature can effectively be controlled by the building physical properties of concrete structures. The temperature fluctuates gradually with the seasons and is heavily moderated. With regard to temperature, casemates and art hiding places can be compared to low-energy buildings from Denmark (see Figure 8). This is because of the significant thermal mass of the concrete and soil. As a result, the effect on

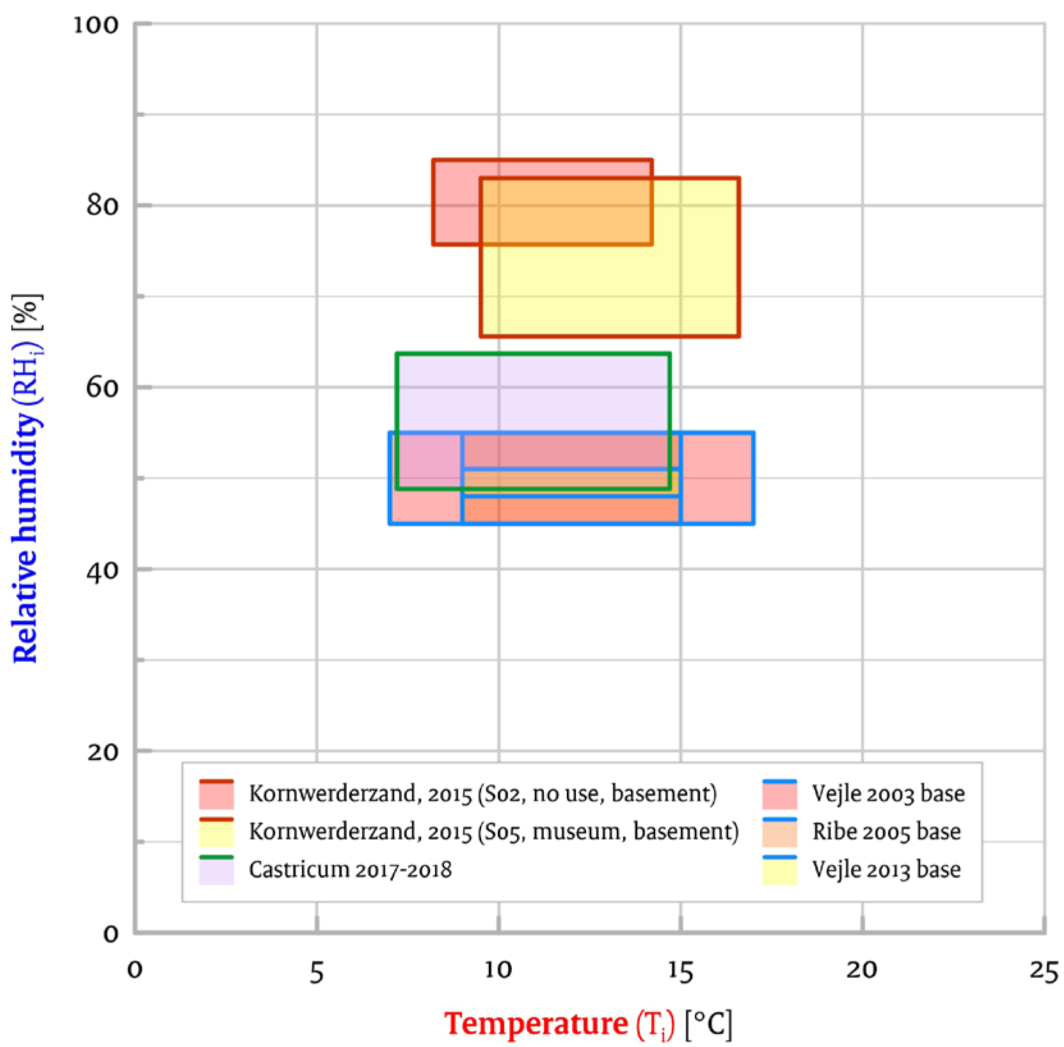


Figure 8 Comparison of the temperature and relative humidity in the casemates at Kornwerderzand and the bunker in Castricum with several Danish storage buildings. Image: Marc Stappers

the inside of the outdoor air temperature and solar radiation is significantly moderated and delayed.

In order to adapt a bunker (or fort) to be used for archives or for storing art, it is at least necessary to dehumidify the rooms.[128] Despite the low air exchange rate, determined for the art bunker in Castricum to be 0.2 per hour,[129] the infiltration/exfiltration of outdoor air is very noticeable. The dehumidifiers installed in Kornwerderzand and Castricum are able to reduce the absolute humidity sufficiently in order to prevent the most significant climate risks.

Because of the relatively low temperature, which fluctuates only to a limited extent, and the high absolute humidity, the relative humidity indoors is also high. This makes it unsuitable for storing art collections that are vulnerable to damp without additional measures. Controlling the relative humidity is rather less simple. But by ensuring adequate dehumidification and limiting infiltration, it is possible to manage the relative humidity

With thanks to Erik Gol (Central Government Real Estate Agency), Ton Heni (Kazemattenmuseum Kornwerderzand), Elianne Paulussen and Jesse Plas (both alumni of Eindhoven University of Technology) and Frits Duinkerke (Huis Doorn and Fort Ruigenhoek).

128 Ibid. note 24
129 Stappers, M., & Ankersmit, Bart (2020). Klimaat in een nitraatdepot van Filmmuseum Eye. Amersfoort: Cultural Heritage Agency of the Netherlands.

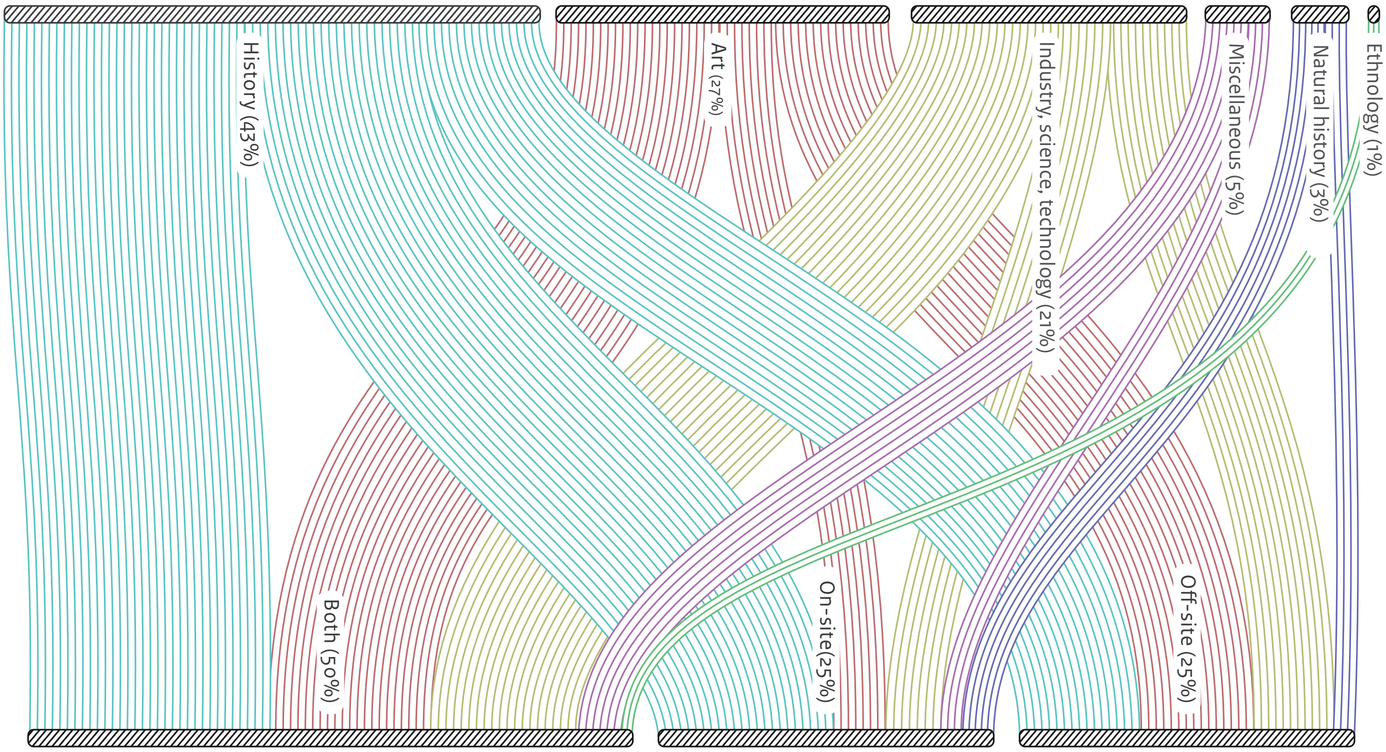
An overview of the situation of Dutch storage facilities

Marzia Loddo

438 museums approached

116 respondents

Type of museum and type of storage facility



50% of all museums have both off-site and on-site storage

75% of all museums have an off-site storage

50% of all museums have more than one storage

Collection

35% of all museums share their off-site storage facility

25% of the storage facilities are too full

Building and space

80% have a special area to prepare transport

60% of the museums anticipate a storage facility renovation in the next decade

30% of the buildings were designed as storage facilities

17% of the museums offer visual access to the storage facility

Climate control

75% continually monitor the climate conditions. Only two-thirds of this group actually look at the data

10% do not monitor the climate conditions

Use and access

60% have a special area for registering the collection

35% have space for quarantine, photography and restoration

25% have internal pest control

5% of the storage facilities are accessible to the public

These museums have a total of 84 million objects in their care, of which 640,000 are on loan

Effects of the COVID-19 pandemic

- Employee Layoff
- Lack of visitors
- Lack of funds
- Loans being postponed
- Loss of income

Some personal observations

"Our on-site storage facilities were updated between 1993 and 2005. Some of our facilities are not ideally located within the building, but that the consequence of our decision not to rent or purchase additional space in order to create a collection centre. I enjoy working in our internal storage facility, but am uncertain as to whether this romantic notion of having everything close at hand can last forever. We are very interested in finding out how the new storage facility at Museum Boijmans Van Beuningen will turn out.

In the future, we aim to open up both storage rooms for researchers.

We know what a new storage facility should be like, but our financial situation is uncertain, which means there is some doubt as to what can be achieved.

Our storage room is too small for most conservation work. Restorations are done abroad. Objects are photographed in our offices. In the future, we would like to improve the sustainability of our storage. Collection management is a challenge in itself and while we are aware that it needs to be one of the top priorities, it is simply unachievable without some form of funding from outside the museum.

Bear in mind that the majority of museums in the Netherlands are run exclusively by volunteers! Limited budgets are the main problem. The Executive Board often prefers to invest in things that attract more visitors.

We currently have eight locations for off-site storage. In the future, we hope to have only one on-site and one off-site location.

We have a storage room that functions relatively effectively. But we would like to improve its sustainability and climate monitoring. Space is too limited to prepare exhibitions or safely pack and unpack objects."

Background to the storage facility analysis

As part of the digital depot (DIPOT) project, starting in October 2019 a causative and quantitative study was conducted into museum storage facilities in the Netherlands. An online survey took stock of types of storage facilities and related background information. Questions also addressed future plans. For each type of storage under analysis, eight questions were asked about collection management and conservation. The topics covered the visibility of the stored collections, access to the objects in the storage facility, the space required and available to place objects in or remove them from the storage facility, rooms available to work on collections and space available to store incoming collections. Respondents were also asked about their museums' plans for modifications and improvements relating to climate control, additional rooms and areas with alternative functions.

The online survey was sent out between March and June 2020 to 438 museums (selected from the Museumcijfers 2019 list). The respondents were primarily collection managers, curators and museum directors.
Museums were categorized using the types distinguished in the Heritage Monitor (Erfgoedmonitor): trade and industry, science and technology, history, art, natural history collections, folklore and miscellaneous. The additional categorization by size was as follows:

- small museums: collections containing fewer than 5,000 objects;
- medium-sized museums: collections between 5,000 and 50,000 objects;
- large museums: collections of more than 50,000 objects.

The survey responses were collected online.
In addition to the online survey, there were also online interviews with a selection of collection managers.

Survey respondents were encouraged to leave comments at the end of the survey. Some examples have been included above. Some respondents comment on how the storage facility collections are managed in their museums, others express their uncertainty in response to the COVID-19 pandemic and how their collection care needs could be more effectively supported.

Evaluation of museum storage facilities in the Netherlands

Bart Ankersmit – Researcher, Cultural Heritage Agency of the Netherlands

Marc Stappers – Building Physicist, Cultural Heritage Agency of the Netherlands

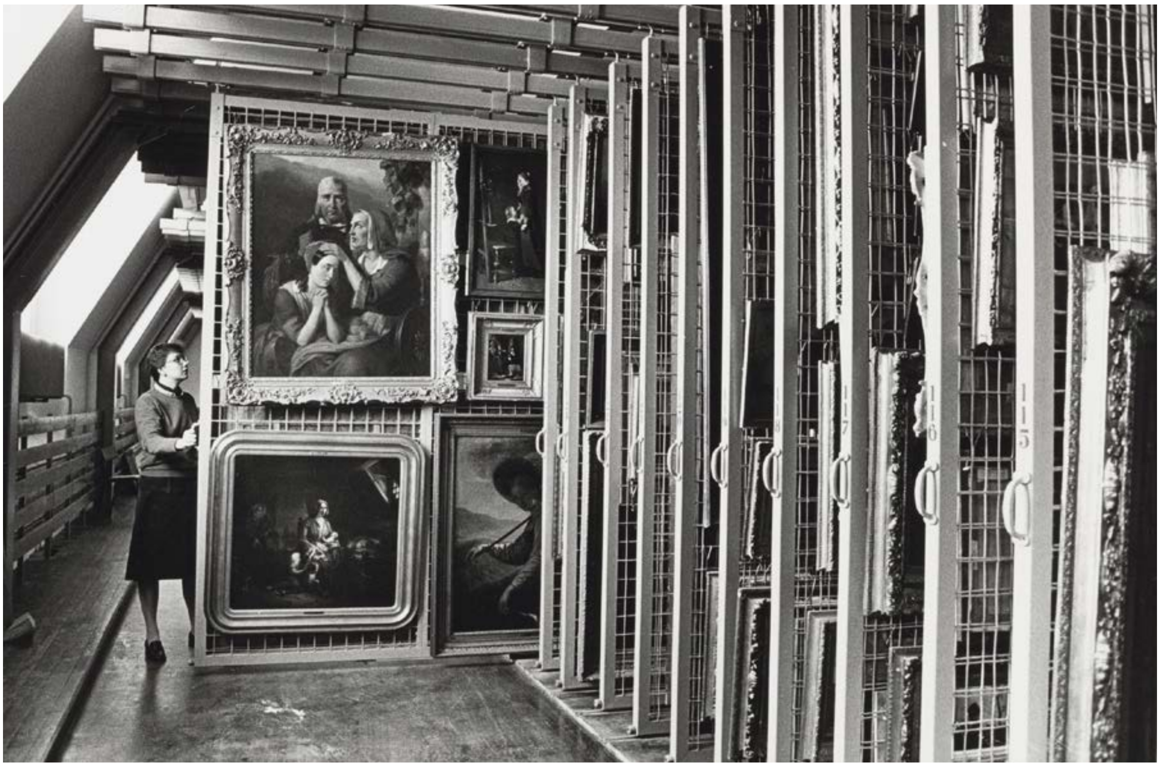
Summary

This article explores the development of storage facilities in the Netherlands. In preparation for it, various storage facilities were visited and a range of different aspects studied, including the building layout, collection management, climate control and building physics. The evaluation reveals that there are no general criteria that make a storage facility good, better or the best. Depending on the aims and objectives of its user or owner, any storage facility is either fit for purpose or inadequate. The socio-economic and political factors during the development of the storage facility ultimately determine what form it will take. Shared storage facilities were the result of political and economic forces, driven by the need to enable work on the collections. A shift has taken place from high-quality storage of cultural resources towards centres in which the collection is also stored sustainably and featuring everything needed for the collection to be studied, restored, loaned and brought into contact with a wide public.

Introduction

The storage of artworks is a relatively recent function for museums. At the start of the 20th century, all objects were displayed in the exhibition building. The walls were lined with paintings and every opportunity to display objects was used. In 1922, one of the forerunners of the Rijksmuseum, the Netherlands Museum for History and Art (*Het Nederlandsch Museum voor Geschiedenis en Kunst*), was given a storage facility in the basement. In the museum's annual report, its Director M. van Notten noted that 'by installing a wood partition and moving

Figure 1 *The storage of paintings in the Rijksmuseum: 1922 (page 119), 1950 (upper image, page 120) and 1975 (lower image page 120). Photos: Rijksmuseum*



some shelving, a separately closable department has been formed'. He continues: 'I can maybe? do with it for the meantime, but it was impossible to achieve an effective storage facility in this dusty and largely damp basement that daylight cannot even penetrate.'
The annual report from 1926 noted (also including a picture, see Figure 1, left) that in 'a section of the classrooms in the former School of Applied Arts, an art history section had been created from warehoused art, spread across 61 partitions that can be pulled out by hand'. It is possible to glean from more recent photos that this situation remained more or less the same until 1975.

It was not until 2003 that it was possible to abandon the many internal storage rooms and store the collection in the storage facility in Lelystad, in what was formerly the safe of the Dutch National Bank. By 2020, the

Rijksmuseum was able to move into a custom-designed building; in 2020-2021 the collection relocated to the CollectieCentrum Nederland (CC NL), see article by Wim Hoeben and article by Donny Tijssen.

Since the Dutch government's Delta Plan for the Preservation of Cultural Heritage in 1990 (see the article by Agnes Brokerhof) great progress has been made in optimizing the preservation and conservation of Dutch museum collections. Much of the focus was on the way in which the objects were stored. During the same period, numerous new storage facilities were built or existing ones refurbished. Around thirty years on, there is now a noticeable resurgence in the construction of storage facilities. Various projects have recently been completed and others launched. What is most remarkable about this is how different these storage facilities are in terms of their design, indoor climate concepts, sustainability measures and accessibility. As a result, an iconic, open storage building was opened in Rotterdam at the same time as a sustainable, cave-like storage building in Amersfoort. This raises the key question posed in this article: what has led to the development of these very different storage solutions?[130]

In order to gain an understanding of the aspects of building physics, collections and facility issues, various storage facilities and buildings were visited in 2019 and 2020 (see figure 2). Numerous factors were discussed and evaluated with the storage facility and/or collection managers, such as the layout of the building, collection management, climate control and building physics. A key area of interest was the extent to which the current building meets the key principles agreed on during the development of the building, its outfitting and climate control strategy. Figure 2 presents the storage facilities under discussion.

Results

Below, the findings of the storage evaluation are briefly presented in chronological order.

1970-1990: general logistics building

In the early years, the key principles for storage facility buildings were based on those four? general logistics buildings. In order to create a storage facility, existing buildings were structurally adapted and systems installed in order to meet the climate requirements for collection preservation and conservation. Generally, the building envelopes were uninsulated and the climate conditions primarily achieved by means of air-handling.
De Metaalhof, built in 1979, is a typical example of a relatively inexpensive building in what was at the time a low-cost location, with a focus on shared storage and only minimum space to work with or within the collections. The different floors were divided into compartments by means of wire fencing, providing each heritage institution with its own storage room.
The indoor climate is achieved using a single climate control system that maintains the required conditions for each floor.

[130] This text has been derived from: Ankersmit B., Loddo, M., Stappers, M.H.L., & Zalm, C. (2021). Museum Storage Facilities in the Netherlands: The Good, the Best and the Beautiful. Museum International (73), 132-143.

Figure 2 *The storage facilities considered in this review. Photos: Bart Ankersmit*

At that time, most museums and historic houses and castles did not have the option of external storage facilities, even shared, and had to resort to structural adaptations to the building. This meant that most storage facilities were in rooms not directly used for exhibiting, such as attics and cellars. In order to minimize the influence of the outdoor climate, box-in-box structures were built, as in the storage facility at Amerongen Castle (*Kasteel Amerongen*) shown in Figure 3. Mobile equipment was used to maintain the relative humidity at the required level. There are numerous examples of storages in museums and historic houses with this kind of structure.

When, in 1998, the natural history collection at Naturalis Biodiversity Centre needed a new storage facility, this was developed on the outskirts of the city centre. A 64 m tall storage tower with 22 floors was developed at a time when there was a strong national focus on preventive conservation which meant that a stable indoor climate was seen as essential. This stable climate was (and is) achieved by controlling the temperature in the internal wall cavity at exactly 18°C across the full height of the building.[131] Energy lost through the walls is reduced by a slightly insulated façade. The relative humidity in each storage compartment is controlled by means of individual HVAC (Heating, Ventilation and Air-Conditioning) systems.

2000-2010: box in box

When the National Maritime Museum in Amsterdam opened its storage building in 2003, it was an important example of advanced storage (see the photospread by Frans van den Hoven). The building stood out, not only because of the architectural features of its undulating façade and titanium outer shell, but also the box-in-box principle that was used for the design: large rectangular storage compartments surrounded by offices, workspaces and facility areas. Each compartment is climate controlled by a HVAC, positioned towards the top inside the building. The building envelope is fitted with 80 to 140 mm of insulation material.

During the period 2000-2010, the City of Amsterdam developed two storage facilities more or less simultaneously. One was for the Stedelijk Museum Amsterdam, completed in 2009, and one for the Amsterdam Museum, which followed in 2011. Both buildings were located on the outskirts of the city. The designs focused primarily on the buildings' functionality and the architecture resulted in less iconic structures. Until then, storage facilities had generally been developed by estimating the required

[131] Kruijsse, P.M.D. (1999). Museumschatten met zorg bewaard. TVVL (28), 58-62.

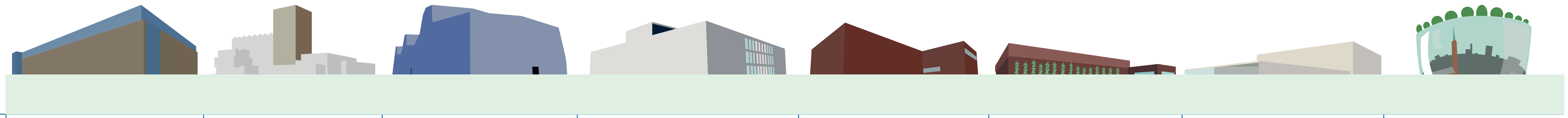
Figure 3 *The storage room in the attic at Kasteel Amerongen, developed in 2007. Photo: Kasteel Amerongen*

volume of the new building based on the number of square metres used in the old building and taking that as the starting point for the design process: Cindy Zalm explores this in more detail in her article. In 2009, for the first time a storage collection was divided into different separate units according to the material: all the paintings together, the furniture in a single compartment, and so on. The design was created in the form of a box around the volumes that the stored objects required.
The Amsterdam Museum storage building was designed with non-rectangular floor layouts; see also the article by Marysa Otte. This created alcoves in which objects could be placed. However, after the rectangular compact storage systems had been installed, these niches remained empty, reducing the efficiency of the storage facilities. On the other hand, the Stedelijk Museum storage facility (see photospread of Roel Prins) is made up of rectangular compartments, in which individual collection units are stored in an efficient compartmental layout.
Alongside the storage rooms, there are also offices, workspaces and project rooms to enable work to be done on the collection. Both of these Amsterdam examples can be seen as models for the transition from storage in repositories or depots to storage in collection storage facilities.

2010-2020: sustainable buildings

Just a few years later, the Province of Friesland developed the Collection Centre Friesland (*Kolleksjesintrum Fryslân*), marking a major shift toward sustainability.
This provincial storage facility houses the collections of various heritage institutions. The collection centre was developed as an airtight building with only three large compartments (see also article by Luc Schaap and the photospread by Bart Ankersmit). The relatively low indoor temperatures are primarily a result of the ground temperature that makes it possible to maintain an air temperature of between 12°C in winter and 22°C in summer thanks to an uninsulated concrete floor.
This principle is based on the so-called *Danish model*, the most important features of which are an uninsulated concrete floor slab, solar panels, a highly insulated façade and roof (R value of 10 m^2K/W) and a very airtight building.[132]
Modelling the indoor climate indicated the need for dehumidification in summer. Despite the Danish experience and the modelling, the parties involved ultimately opted to actively control the temperature and relative humidity in the storage facilities.
The compartments were fitted with a system for cooling, heating and dehumidification, which is used to continually recirculate the air.
The Kolleksjesintrum project more or less coincided with the launch of two other major projects. They resulted in the completion of two very different buildings in 2020.

[132] Rasmussen, M.H. (2007). Evaluation of the climate in a new shared storage facility using passive climate control. Museum microclimates, contributions to the Copenhagen conference 19-23 November, 207-212.



		Metaalhof	Naturalis Biodiversity Centre	National Maritime Museum	Stedelijk Museum Amsterdam	Amsterdam Museum	Collection Centre Friesland	Collection Centre Netherlands	DePot Boijmans Van Beuningen
City		Rotterdam	Leiden	Amsterdam	Amsterdam	Amsterdam	Leeuwarden	Amersfoort	Rotterdam
Abbreviation		MH	NBC	NMM	SMA	AM	CCF	CCNL	DBVB
General									
Year		1979	1997	2001	2009	2010	2016	2020	2020
Number of users		5	1	1	1	3	3	4	1 + various tenants
Location		Offsite in industrial area	City center	City center	Offsite industrial area	Offsite industrial area	Offsite industrial area	Offsite living area	City center
Commisioned		Municipality	State	State	Municipality	Municipality	Province	State	Municipality
Functions									
Collection		Mixed collection	Natural history collections	Maritime collections	Contemporary art collection	Mixed collection	Mixed collection	Mixed collection	Contemporary art collection
Functions other than storage		Workspaces, photography (limited)	Labs, photography, workspaces	Workspaces, photography	Labs, photography, workspaces	Labs, photography, workspaces	Labs, photography, workspaces	Labs, photography, workspaces	Labs, photography, workspaces
Building									
Storage surface area	[m^2]	10,000	8,846	4,000	9,000	6,000	1,920	25,000	4,674
Ration SSA/GFA [1]	[%]	86.7%	53.3%	52.7%	61.1%	52.3%	63.7%	74.6%	30.1%
Ration NFA/GFA [1]	[%]	88.8%	Unknown	94.07%	Unknown	80.0%	91.69%	87.62%	Unknown
Object density	[m-2]	29	3750	181	16	27	209	29	32
Building cost (GFA)	[€/m^2]	Unknown	Unknown	1,479	1,375	1,717	1,310	1,320	3861
Building cost (NFA)	[€/m^2]	Unknown	Unknown	1571,998984	Unknown	2146,821429	1428,889373	1506,134969	Unknown
Energy use (SSA)	[kWh/m^2/ year]	40.84	Unknown	173.61	Unknown	Unknown	35.25	42.70	Unknown
Building physics [2]									
Thermal quality building evelope	[m^2K/W]	n/a	n/a	n/a	2.5-3.0	Unknown	10	n/a	n/a
Insulation thickness roof	[cm]	5	4-14 + 9 (FG)	14	12	Unknown	36 (MW)	30-100	16,5-27 (EPS)
Insulation thickness outer walls	[cm]	5	9 (FG)	8-14	10	Unknown	36 (MW)	20	12 (PIR) + 2 (MW)
Insulation thickness floor	[cm]	2.5	n/a	10	10	Unknown	0	0	13 (EPS)
Installations									
Air handling [3]		HE/CO/HU/DE	HE/CO/DE	HE/CO/HU/DE	Unknown	HE/CO/HU/DE	HE/CO/DE	HE/DE	HE/CO/HU/DE
AER [4]	[h-1]	0.3	0.1	0.14	0.25	0.1	0	0.03	0.2
Controls									
Set point T	[°C]	20	18	25	20	18-22	>10	17-23	18
Acceptable fluctuation T	[°C]	5	1	2	2	1	0	0	2
Set point RH	[%]	50	50	55	51	48-52	<55	50	52
Acceptable fluctuation RH	[%]	5	5	2	2,5	3	0	8	2
Seasonal adaptations		No	No	No	No	Yes	No	Yes	Yes

(1) GFA: Gross Floor Area, NFA: Net Floor Area, SSA: Storafge Surface Area
(2) AER: Air Exchange Rate
(3) HE: heating, CO: cooling, HU: humidification, DE: dehumidification
(4) EPS: expanded polystyrene, PIR: polyisocyanuraat, MW: mineral wool, FG: foamglass

Figure 4 *General background information, building physics and climate control data from the storage facilities discussed in this article. Image: Marc Stappers*

Two types: Sustainable or open?

In collaboration with the Royal Palace Museum Het Loo, the Netherlands Open Air Museum (*Nederlands Openluchtmuseum*) and the Cultural Heritage Agency of the Netherlands, Amsterdam's Rijksmuseum developed the CollectieCentrum Nederland, or CCNL. The CCNL will house approximately 675,000 objects. This huge building separates three functions into a head-neck-torso model. The torso is used to store the objects, the neck is designed to enable work on the collection and the head is open to the public. Sustainability was a key aim of this project, which was ultimately awarded an Outstanding BREEAM certificate, the highest possible for new buildings. The storage facility (the torso) is airtight, the 30 cm concrete walls are very well insulated (20 cm), as is the roof (30-100 cm), but the floor slab is not; similar to the Kolleksjesintrum Fryslân and in line with the Danish model. Starting on the first floor, the concrete floors and the roof feature so-called *concrete-core activation*, making it possible to maintain a relatively low temperature with the help of water from the thermal energy storage system. The roof of the building is fitted with 24,000 m^2 of solar panels. Control of relative humidity is activated whenever the relative humidity falls below 42% or exceeds 58%.

In the same period, the City of Rotterdam created an eye-catching building alongside Museum Boijmans Van Beuningen; see the article by Wout Braber. This storage building has an iconic appeal that connects the museum with the city and its inhabitants. The building features rooms for events and study and the roof restaurant affords panoramic views across the city.[133] Individual visitors can also take guided tours through some of the storage facilities. Storage space is also offered for hire to private collectors. The design of the building focused on the accessibility of the collections.
The construction of this building also included some sustainability measures, such as solar panels and a thermal energy storage system. The roof, outer walls and floors have been insulated. Acclimatized air is generated by means of a new technology combining three separate streams of cold, warm and dry air that are mixed based on readings taken in the storage facilities. Although the schedule of requirements was developed for a traditional storage facility, it has resulted in an open storage building located at the heart of the city that can be visited by the general public. This major change is a result of the interests of stakeholders who provided funding based on an alternative business case.[134]

133 Kisters, S. (2021). A New typology? The depot of Boijmans Van Beuningen in Rotterdam. Museum International (73), 74-85.

134 Minutes, Rotterdam City Council (2011, 29 June). Consulted on 20 August 2021 via https://rotterdam.raadsinformatie.nl/document/225153/2#search=%222011%20boijmans%20van%20beuningen%22.

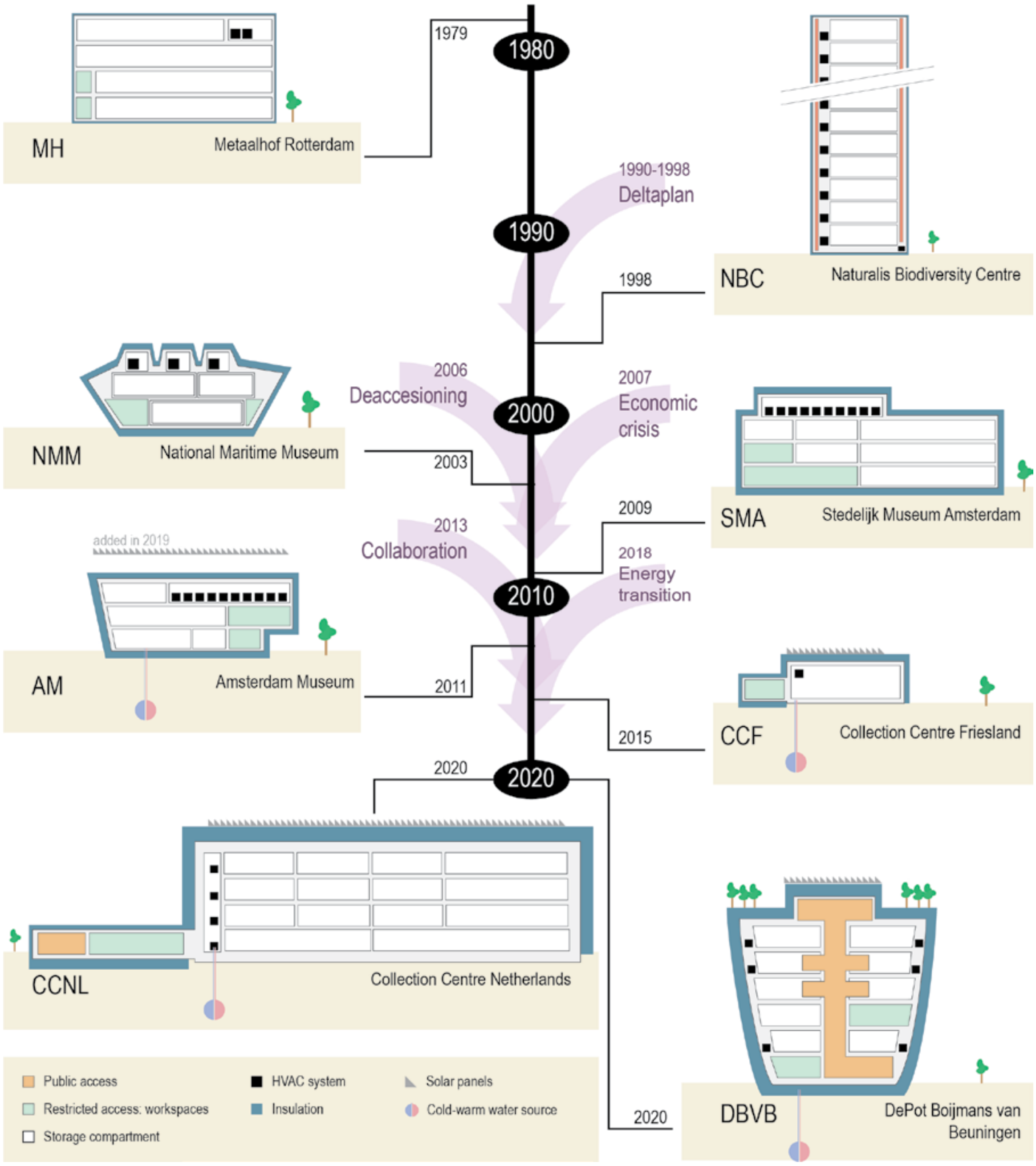


Figure 5 *Timeline charting the storage facilities investigated, focusing on the storage zones, publicly accessible areas, working zones, climate control and some aspects of building physics. Image: Bart Ankersmit*

A Dutch model?

Retrospectively, it has become clear how much the most recently constructed storage facilities differ from those developed in the past, see Figure 5. A few decades ago, a storage facility was treated like a warehouse and the building considered to be fit for purpose as long as it ensured high-quality conditions for conservation and preservation. In recent decades, the objectives have changed dramatically. Storage facilities are now collection centres. These buildings are not only developed for the storage of objects, but primarily to enable optimum collection management and even provide access to a wide public.

A comparison of Dutch storage facilities based on energy consumption (see the article by Merel van Heesewijk), access to collections, climate control and location reveals that there are no general criteria that can be deemed to make a storage facility good, better or best. In themselves, all of the storage facilities investigated can be seen as good, although ultimately this will depend on the specific ambitions and objectives of the user and/or owner.
For example, a storage facility that offers good conditions for conservation may be seen as sub-standard if there are no opportunities for working with the collection, no quarantine area or no possibilities for receiving external users. The average lifespan of a non-residential building in the Netherlands is 30 to 50 years.[135] Over that time, the goals and ambitions of users will change and the same applies, possibly more so, to the objectives and ambitions envisaged for a storage facility. The objectives of today's museum staff for managing stored collections in storage facilities are very different than they were 40 years ago. At times when ambitions are evolving rapidly, satisfaction with a storage building can soon turn to dissatisfaction before the end of its theoretical lifespan. This is why it is extremely important when developing a new storage facility to anticipate far in advance and develop the objectives for the future.
This can only be achieved in consultation with staff, management and other stakeholders. In general, it is possible to identify six key themes that have an effect on the future potential of the storage facility building:

1. Mission and vision of the heritage institution and the role its collection plays in society;
2. Risk and collection management;
3. Logistics, space and accessibility;
4. Energy and building physics;
5. Architecture;
6. Finance and project management.

The best building would be the building that best reflects the objectives for these six themes over a long period of time. During the development process, any decisions will continually need to be tested against these objectives. These themes can possibly also be prioritized in order to provide guidance on choices to be made. In the case of most Dutch storage facility projects, specialists and staff in each of these six areas are involved in decision-making throughout the entire process, from the definition of ambitions through to the relocation of the collection. Although initially time-consuming, this process delivers a high return on the investment since it helps to develop a storage facility that remains useful for longer.

Conclusions

Over recent decades, very different storage facilities have been developed, each applying the best knowledge and loftiest of ambitions. Looking back, it is clear at a glance how much variety there is. Why is it that such different storage facilities have been developed in the Netherlands? Our evaluation has attempted to identify more clearly what the key principles are for the different buildings and the extent to which they meet the specifications and requirements that formed the basis for the initial design. The socio-economic and political factors during the development of the storage are key determinative factors. Shared storage facilities were the result of political and economic forces, driven by the need to enable work on the collections.
In the period of major government cutbacks when energy consumption became a global problem, there was a trend towards energy-efficient buildings. In this process, a shift from preventive conservation to risk-based decision-making played a significant role and the efficient use of resources, space and budget became increasingly important. Over time, sustainability became much more than a mere focus on energy consumption and finding alternatives to the use of fossil fuels. Museums also became more aware of their role within society and their responsibility as custodians of the national heritage. They opened their vaults and created

[135] W/E rapport (2013). Richtsnoer 'Specifieke gebouwlevensduur': Aanvulling op de Bepalingsmethode Milieuprestatie, Gebouwen en GWW-werken (MPG). Consulted on 20 August 2021 via https://milieudatabase.nl/wp-content/uploads/2019/05/Rapport____Richtsnoer_Specifieke_gebouwlevensduur___.pdf.

collection centres in order to increase collection mobility for a wide public.

These Dutch examples show how a shift has taken place from high-quality storage of cultural resources towards facilities in which the collection is stored sustainably and featuring everything needed for the collection to be studied, restored, loaned and brought into contact with a wide public. The most recent storage facility that was opened even added extra functionalities such as possibilities for visits, auditoria, a restaurant and educational facilities.
As a result, it is possible to identify three key trends in Dutch storage facilities over the course of time:

1. Institutions have increasingly chosen to collaborate and combine collections in a single building;
2. The storage buildings are becoming increasingly sustainable;
3. The collections in the collection centres are becoming more accessible to a wider public.

Because environmental factors and the wishes and requirements of stakeholders change over time, what is initially a state-of-the-art storage facility has a relatively short lifespan. This is why it is advisable for the development of any new storage to go hand-in-hand with a long-term vision based on the social, economic and financial framework. We hope that the overview we have presented will provide inspiration for that challenge.

The open storage of the Open Air Museum in Arnhem in 2009. Photo: Bart Ankersmit

The European DIPOT project – a 360-degree view of collections in storage

Marzia Loddo– Postdoc, Delft University of Technology (TU Delft)

Introduction

Museums have always been interested in finding new ways of entertaining the public and informing them about their activities. One of these new ways is digital technology, such as 360-degree photography, computer games, virtual reality (VR), augmented reality (AR), mixed reality (MR) and so on. VR and AR are very different. The first offers total submersion in a virtual reality whereas the second shows reality alongside an augmented digital version. In order to use AR, you need a device such as a smartphone or tablet and have to download apps. For VR, you need software and a headset with a built-in screen combined with controllers to navigate the virtual environment. MR combines aspects of both AR and VR and enables users to manipulate and interact with elements from both the real and digital worlds.[136] It might be possible, for example, to take a virtual box out of a real bedside table, open it and look at what is inside. MR is a more captivating form of AR without the limitations of a screen. AR, conversely, uses special equipment: a headset or visor with controllers.

In recent years, museums and libraries have increasingly begun to focus on digital access to their collections and many have been investing in virtual reality for several years, often with impressive results. Inspiring examples include the reconstruction of historic settings and period rooms,[137] enabling interaction with one or several objects in the collection,[138] creating interactive and compelling experiences in the museum[139] and a virtual museum collection.[140] In early 2019, the European Union awarded funding for the Digital Depot (DIPOT) project. Part of this project, involved experimenting on a wide-ranging, interdisciplinary audience with the use of 360-degree photography and video and VR technologies. Participants provided feedback and notes on the experiences were compared. In the project, it was investigating how digital technologies can raise awareness about museum storage facilities, improve future museum designs, educational and curatorial activities, and develop exciting projects. The experiences acquired can be applied to future management and to improve building design by means of in-depth qualitative research and the integration of VR technologies within education.

In this article, the provisional results of a project are described in which the digital representation of real objects and their surroundings is being tested on international architecture students at TU Delft with the help of 360-degree photography and video and VR technologies. The research methods combined qualitative and quantitative approaches to museums and cyberethnography, including interaction, surveys, interviews and visual devices. The results show how digital tools influenced students' awareness of museums and architecture and inspired them to explore certain topics in more detail. During workshops, students became more motivated and engaged with the subjects. They were able to compare different digital methods and learn from them, delivering valuable results.

Background of VR in design education

In the design process, architects constantly need to be creative and to think outside of the box. Designers sketch, draw and make models and mock-ups. As such, they are accustomed to working in a virtual world. Architecture as virtual reality existed long before the term was made popular by Jaron Lanier in 1989. However, the earliest experiments with a VR head-mounted display (VR-HMD) were actually done in 1965, but the helmets were too heavy to wear.[141] The use of VR in design education was first pioneered in the 1990s,[142] focusing primarily on the use of a VR interface as a means of involving users in the assessment of designs during the design process.[143] With the increasing popularity of video

[136] Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems* 77 (12), 1321-1329.

[137] Modigliani VR: The Ochre Atelier (2017). Consulted on 1 March 2021 via https://www.tate.org.uk/whats-on/tate-modern/exhibition/modigliani/modigliani-vr-ochre-atelier. Force Field (2017). *Meeting Rembrandt: Master of Reality*. Oculus Studios. Consulted on 21 March 2021 via https://www.oculus.com/experiences/gear-vr/1297352360374984/?locale=en_US.

[138] Vive Arts (2019). *Mona Lisa: Beyond the Glass*. Musée du Louvre, Paris. Consulted on 27 March 2021 via https://arts.vive.com/us/articles/projects/art-photography/mona_lisa_beyond_the_glass. Hills-Duty, R. (2018). *National museum of Finland offers virtual time travel*. Consulted on 26 March 2021 via https://www.vrfocus.com/2018/02/national-museum-of-finland-offers-virtual-time-travel. Bone Hall (2017). A *hall through new eyes*. Washington: Smithsonian Museum. Consulted on 24 March 2021 via https://naturalhistory.si.edu/exhibits/bone-hall.

[139] Grande Galerie de l'Évolution (2018). *A permanent room dedicated to virtual reality housed in the gallery of evolution*. Consulted on 30 April 2021 via https://www.mnhn.fr/en/visit/lieux/cabinet-realite-virtuellecabinet-virtual-reality.

[140] Pottgiesser U., Dragutinovic A., & Loddo M. (Eds.) (2021), *Momove Modern Movement and Infrastructure*. 18th Docomomo Germany Conference, Dessau, Bauhaus: Technische Hochschule Ostwestfalen-Lippe, pp. 12-17. Lierop J. van, & Kremer, G. (2019). *Kremer Museum*. Consulted on 28 February 2021 via https://www.thekremercollection.com/the-kremer-museum.

[141] Faisal, A. (2017). Computer science: Visionary of virtual reality. Nature, 551 (7680), 298-299.

[142] Achten, H., W. Roelen, J.-Th., Boekholt, A., Turksma, & Jessurun, J. (1999). Virtual Reality in the Design Studio: The Eindhoven Perspective. *Architectural Computing from Turing to 2000, eCAADe Conference Proceedings*, 169-177.

[143] Fernando, T., Wu, K.C., & Bassanino, M. (2013). Designing a novel virtual collaborative environment to support collaboration in design review meetings. *Journal of Information Technology in Construction* (18), 372-396. See: http://www.itcon.org/2013/19.

games, the creation of Oculus VR in 2012 and the introduction of affordable VR cardboard headsets in 2014, the use of VR has quickly become mainstream.[144] Users now have the possibility of easily exploring virtual environments using cheap software and gaining access to digital modelling tools, allowing for the integration of VR into architecture and design studios.[145] Students can use the virtual environment to visualize their projects and improve their spatial understanding, in order to achieve a better design.[146]

Architecture courses often include assignments that involve formulating the transformation framework and principles for designing a museum. Students are asked to present a final design that demonstrates their knowledge and understanding of interactions between an architectural and structural concept. They are tasked with developing and fleshing out sustainable technical aspects, such as refurbishments of existing buildings, the construction of new buildings and strategies for the conservation of heritage. However, the available literature on the subject of museum design does not encompass all of the aspects that are important for the way in which a museum functions, such as practical information about facility management, conservation and storage facilities. Moreover, professionals invited to lecture about practical insights do not always touch on these aspects. In spite of this, the final assignments are highly specific and students are often asked to come up with a new museum setting that must include such elements as permanent and temporary exhibitions, offices, archiving, conservation studios, storage space and installation areas. To this end, it can be important to know how many objects a permanent collection includes, how many of them are exhibited and how many are in storage. It would also be useful to know how many people generally work in the museum.
This information is often lacking in course assignments, but how can a design be efficient if students do not take account of these basic requirements? In design studios, students learn how they should tackle problems.
Digital tools, such as AR and VR, allow for an in-depth analysis of designed environments that are impossible using traditional presentation methods, such as models, because they enable designers to immerse themselves and visualize and explore spaces during different design phases before the designs are built. For this reason, students should be able to use these technologies to learn more about different aspects of a museum (and of other building typologies). VR museums, which are appearing in increasing numbers, and exhibitions usually focus more on achieving a good representation of artworks than on architecture.[147]

Below are some examples of 360-degree photography and VR representations of museum storage facilities that have been used to raise students' awareness of VR technology in order to improve their future designs, but also of new VR technology in order to improve the user experience.

Methods used

On 9 November 2020, in a workshop as part of the TU Delft Bachelor's minor Heritage & Design, 20 students experimented with the use of 360-degree technology and VR representation of a museum storage facility. Two case studies were used for the 360-degree representation: the CollectieCentrum Nederland (CC NL) and the special collection storage facilities of the Royal Library of the Netherlands (KB). Beforehand, I used a 3D camera (Insta360 EVO) to record the storage rooms prior to editing the images, adding interactive elements and making them available via the technology platform ThingLink. The KB, for example, had links to copies of digitized books, a conservation report, additional images and other materials (see Figure 1)[148] and the CC NL linked to technical information about the building, storage and artworks, information about preventive conservation and collection care and hyperlinks to external sources, literature and detailed images (see Figure 2). Interestingly, it took four hours to photograph a storage facility. Since this was an academic project, ThingLink was used, but it is advisable to adapt the platform to reflect the museum's needs, for example for reasons of privacy, to arrange access or facilitate updates, and to develop a platform specifically for the museum or purchase one.

[144] Coates, C. (2020). *Virtual Reality is a big trend in museums, but what are the best examples of museums using VR*. Consulted on 24 March 2021 via https://www.museumnext.com/article/how-museums-are-using-virtual-reality.

[145] Angulo, A. (2015). Rediscovering Virtual Reality in the Education of Architectural Design: The immersive simulation of spatial experiences. *Ambiances. International Journal of Sensory Environment, Architecture and Urban Space* (1), 1-23; Bartosh, A., & Anzalone, P. (2019). Experimental Applications of Virtual Reality in Design Education. In K. Bieg, D. Briscoe, & C. Odom (Eds.), Ubiquity and Autonomy - Paper Proceedings of the 39th Annual Conference of the Association for Computer Aided Design in Architecture, ACADIA 2019 (pp. 458-467).

[146] Milovanovic, J., Moreau, G., Siret, D., & Miguet, F. (2017). *Virtual and Augmented Reality in Architectural Design and Education: An Immersive Multimodal Platform to Support Architectural Pedagogy*. 17th International Conference, CAADFutures.

[147] Idem note 5

[148] Loddo, M., Boersma, F., Kleppe, M., & Vingerhoets, K. (2021). Experimenting with 360° and VR representations as new access strategies to vulnerable physical collections: two case studies at the KB, National Library of the Netherlands. In *IFLA Journal*. 29 June, 2021 [https://doi.org/10.1177/03400352211023080]

In March 2020, ICOM Belgium Flanders and the Turnhout Museum commissioned 3D scans of their storage facilities for a VR tour that can be accessed on a computer with or without a VR headset (see Figure 3).[149]
The 360-degree representations and VR presentations were also shown to students during the workshop.
One of the assignments on the course was to restructure the exhibition spaces in the Prinsenhof Museum in Delft. There was also a workshop and a lecture about storage facilities, the history of the museum and preventive conservation in order to prepare students for the design phase of the course. The research methods used comprise a combination of open questions and multiple-choice questionnaires, both for the questions and the experiments. The students then had an opportunity to spend 20 minutes on the website with 360-degree representations working with the VR tools and gaining experience of visualizations using the VR model (the scale, building geometry, space (structure), etc.).
After the workshop, the links to both the VR and 360-degree photography were made available for further use. During the workshop and lecture, the students were also able to ask questions and raise issues that were relevant for their projects.

For the workshop, two surveys for different purposes were designed, including understanding how students can use digital technologies in different phases of the design process and how 360-degree visualizations and VR tools can help to raise awareness about museums and storage facilities as a means of improving future designs. The first survey was put to students two weeks before the workshop and the second was completed after the workshop. The qualitative data were analysed by adding coding (labels) using the software ATLAS ti.[150]

149 See: https://my.matterport.com/show/?m=Pm4cFdDpC6P.

150 See: https://atlasti.com.

Figure 1 *Frame from the 360-degree photograph of the Royal Library of the Netherlands in The Hague. Photo: Marzia Loddo*

Figure 2 *Frame from the 360-degree photograph of a storage facility in the CC NL in Amersfoort. Photo: Marzia Loddo*

Figure 3 *Frame from the 360-degree photograph of a storage facility in the Museum Turnhout, presented by ICOM Belgium Flanders. Photo: screenshot taken by Marzia Loddo*

Survey results

The results of the first survey showed the extent to which students were engaged with the museum surroundings, the collections, staff and visitors. On a five-point Likert scale, students replied that they visit museums once a year (two students), once every three months (14 students), once a month (three students) and two to three times a month (one student). They all knew which professionals generally work in a museum, although quite a few respondents were unfamiliar with the position of registrar. Other questions aimed to gain an insight into students' familiarity with virtual museums and exhibitions and how frequently they make use of digital archives and libraries. A total of 80% of students had never visited an online museum. On a five-point Likert scale, the results showed that, before the COVID-19 pandemic, students were more likely to have visited physical libraries for research and study purposes than digital ones. They had rarely or never used a physical and digital museum archive. Some questions in the first survey were repeated in the second to identify how students respond to the same questions after attending the lecture. Four of them had visited a museum storage facility and the majority were unaware of what its precise function was. In the first survey, four students were unaware where the storage facility was located; 16 thought it was in the cellar of the museum and one outside the museum. They were also unaware of the fact that there may be more than one storage facility. In the second survey, held after the workshop, students knew more about the storage location and the number of locations.

The qualitative results showed students' views concerning the usability and difficulties experienced with 360-degree and VR tools in order to test how they can help in understanding and resolving design problems.
They found both tools easy to use. With regard to the

360-degree platform, they appreciated the interactive pictograms providing information and explanation about the building and the object, supported by additional photographs and hyperlinks to external data. The VR lacks this support, which is important for the learning process, but they appreciated the captivating experience and visualized the model 'as a doll house'. Some of them felt 'as if they were really in the building' and this enabled them to effectively visualize the shape of the space, the scale and routing.
According to the students, the 360-degree tool does not offer the same captivating experience and visualization as VR. With one exception, they all agreed about the use of these instruments as a means of improving the future design. Some of them appreciated being able to visit existing places that are not accessible, but continue to attach value to pen and paper and are not totally convinced about switching to a completely virtual design. Others can see the potential of virtual designing as a means of identifying problems in advance, providing insight into spaces and experiencing the space before the building is constructed.

Conclusion

Using various examples, I have presented an overview of available digital technologies and their potential for application in architecture- and heritage-related issues. Despite the challenges of working during the COVID-19 pandemic and being unable to organize fieldwork, the adapted methodology for the course served as an effective alternative to promote the critical and creative telling of digital stories. The use of these technologies has helped boost understanding of the various aspects and layers of museums. It helps students in the ultimate realization of one of the subjects of the course: a case study of the Prinsenhof Museum in Delft and improving the configuration of the exhibition, storage and adjacent rooms. It also boosted students' engagement with the museum.

Of the two technologies evaluated, VR so far appears to be the only design representation method offering a captivating experience and visualization of design elements. Above all, VR makes it possible to move through a digital representation of a room and has the significant advantage of increasing spatial understanding and visualization of architectural projects. 360-degree visualizations offered a less captivating experience, but also proved useful in providing students with the right tool and information to improve their projects. Students suggested combining both experiences and adding interactive pictograms to the VR representation and the option of greater communication with the VR scene, for example by being able to open drawers and furniture, having movable objects and including a part of the building. Although the focus of this study was on museums, this highly promising technology can also be applied to different subjects and used or tested in different courses. In the coming years, these approaches will be repeated and improved in order to offer students the tools they need for the digital transition towards a likely blended educational future.
Another potential area of application involves researching how the museum sector can improve the work of designers and lecturers in design and ultimately raise the design's quality and creativity by:

- offering structured access to collections;
- presenting design innovations;
- encouraging discussion about design;
- creating better public awareness and understanding of design culture;
- collaboration with the creative industry.

Heritage professionals and academics are the people most likely to visit storage facilities, but they may not always have the opportunity to do so. Storage methods are changing depending on the type of collection, offering a different structure that can be of interest to the public, such as painting racks, drawers and shelves filled with objects, set in an atmosphere that is different from an exhibition. In view of the sensitive nature of storage facilities of this kind, with their fragile objects and because of the indoor climate and security, conservation has often taken precedence over open storage with access to a wider public. Digital technologies, such as VR, AR, 360-degree photography and games, can help heritage institutions to improve their collections and encourage more of the public to engage with them. The security issues concerning what is shown to the public, for example on museum websites and in communication campaigns, can be solved by taking additional design measures. The challenges may not be easy to overcome, but by continuing research in this area and tackling new challenges in education and design projects, museums and other cultural institutions can be more inclusive and the use of digital technologies can allow for more of the cultural heritage currently kept in storage to be shared with a wide community.

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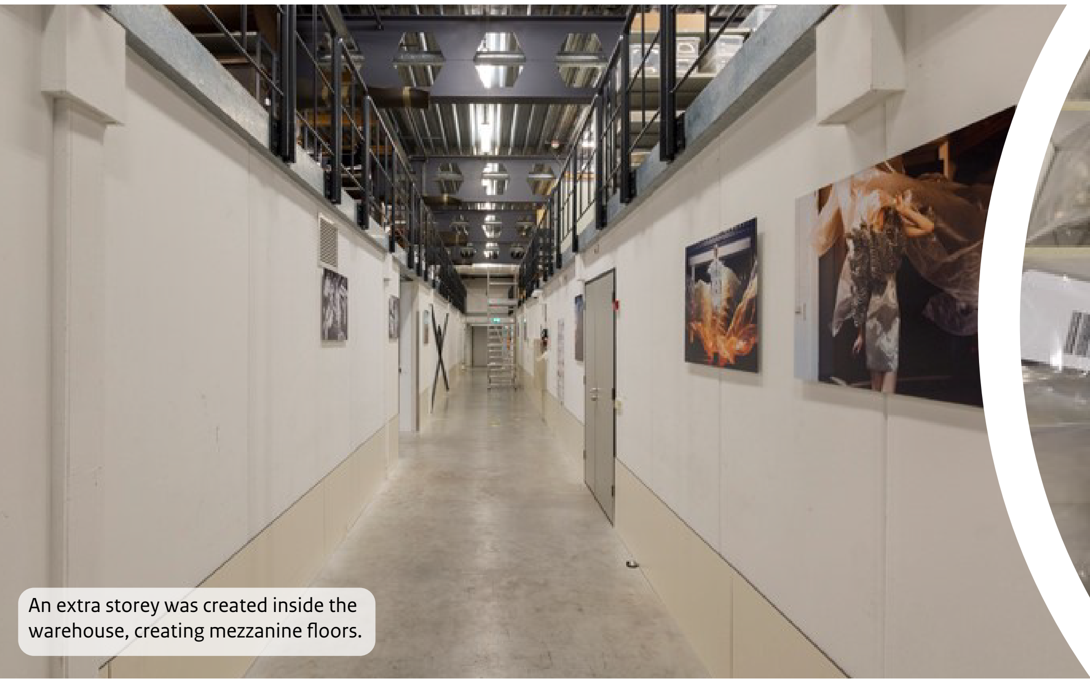
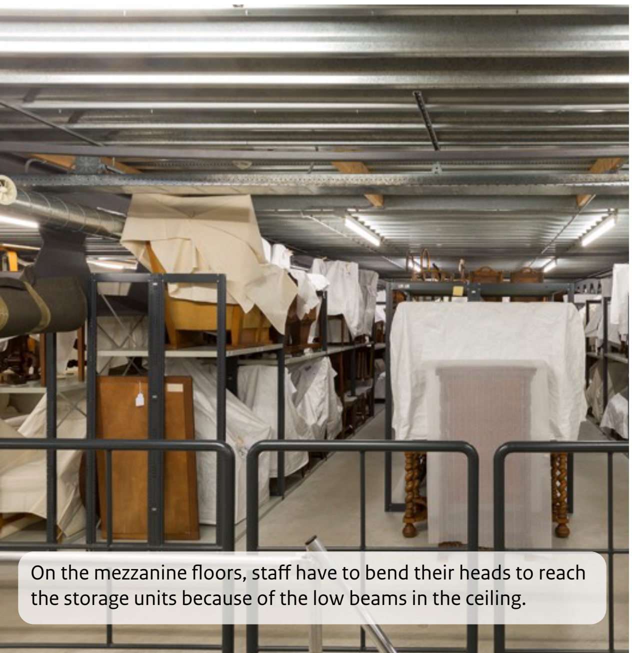
Centraal Museum storage facility in Utrecht

Marije Verduijn - Head of Collection Management, Centraal Museum, Utrecht

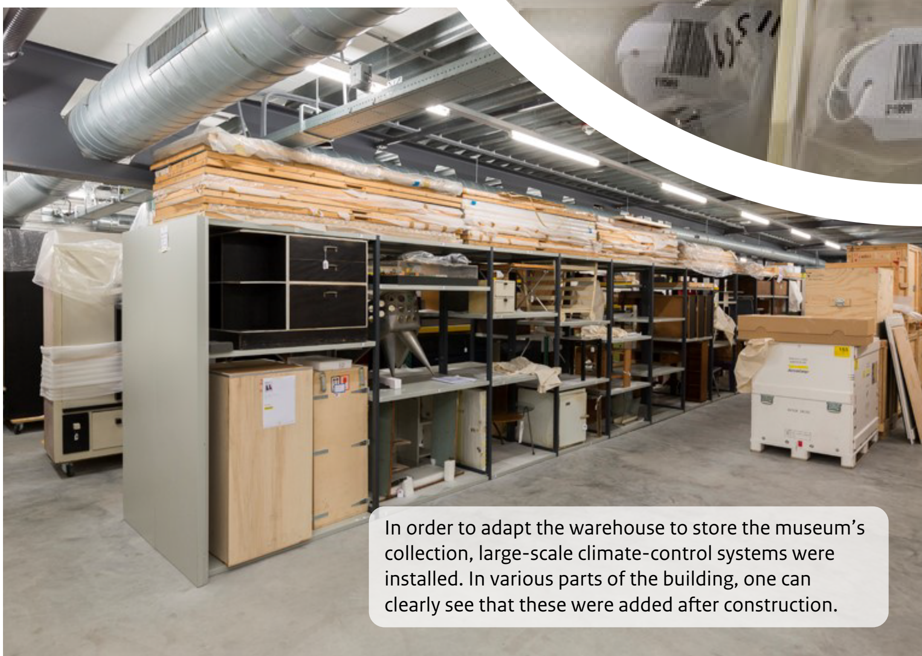
The Centraal Museum started to use an old warehouse of a removals company as a storage facility in 1996. At the time, it was one of the first museum storage facilities on a suburban business park. For the first time since the museum had opened in 1838, it was possible to store all of the collections together under one roof.



An extra storey was created inside the warehouse, creating mezzanine floors.



On the mezzanine floors, staff have to bend their heads to reach the storage units because of the low beams in the ceiling.



In order to adapt the warehouse to store the museum's collection, large-scale climate-control systems were installed. In various parts of the building, one can clearly see that these were added after construction.

In 2016, a new storage unit for the metal collection was installed. The mesh partitioning in the back separates the Centraal Museum's collection from that of Utrecht's Municipal Heritage Department.

Conventional air-conditioning with humidification and dehumidification and heating and cooling delivers the desired temperature of between 16°C and 20°C and keeps humidity levels between 52% and 60%.

In recent years, the museum has been working hard to barcode the whole collection, made up of over 60,000 objects, in anticipation of the move to the new storage facility.

The relative humidity in the metal storage is kept as low as possible.

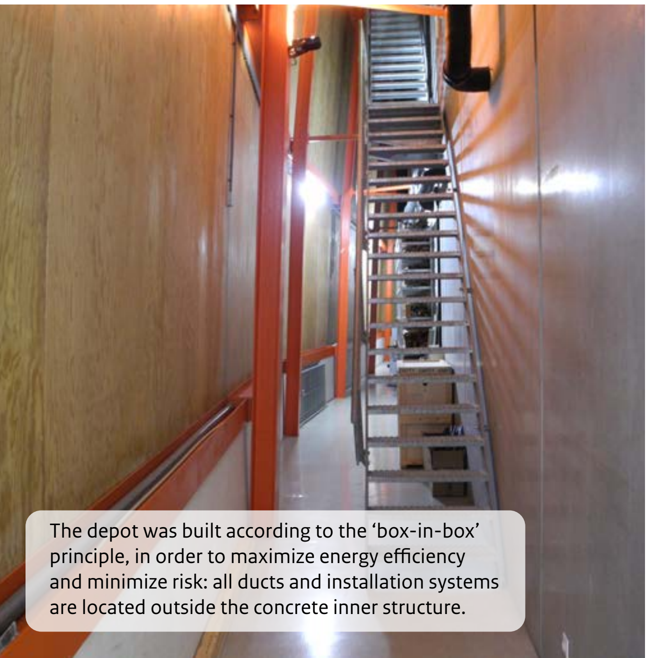
Fortunately, the plans for the new storage facility also include a warehouse. These mannequins, currently hidden away in forgotten nooks and crannies in the buildings together with boxes and objects from the study collection, will soon be moving to a nice new home.

National Maritime Museum in Amsterdam

Frans van den Hoven - Head of Collection Management, National Maritime Museum (Het Scheepvaartmuseum)

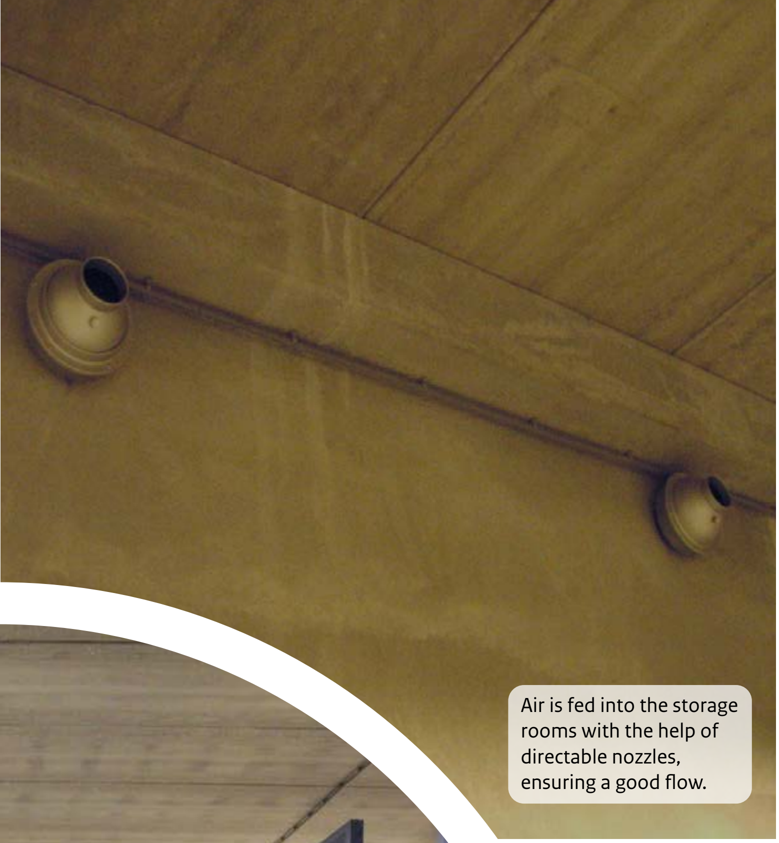
The National Maritime Museum's storage depot (named the Behouden Huis) was designed in 2002 by Liesbeth van der Pol from Dok Architecten. The building is 90 m long, and clad in titanium.

The building houses six storage units and eight work spaces connected by a central corridor. The cavity space between the inner structure and the titanium shell is temperature-controlled only.



The depot was built according to the 'box-in-box' principle, in order to maximize energy efficiency and minimize risk: all ducts and installation systems are located outside the concrete inner structure.

The silver collection is given extra protection through storage in locked cabinets.



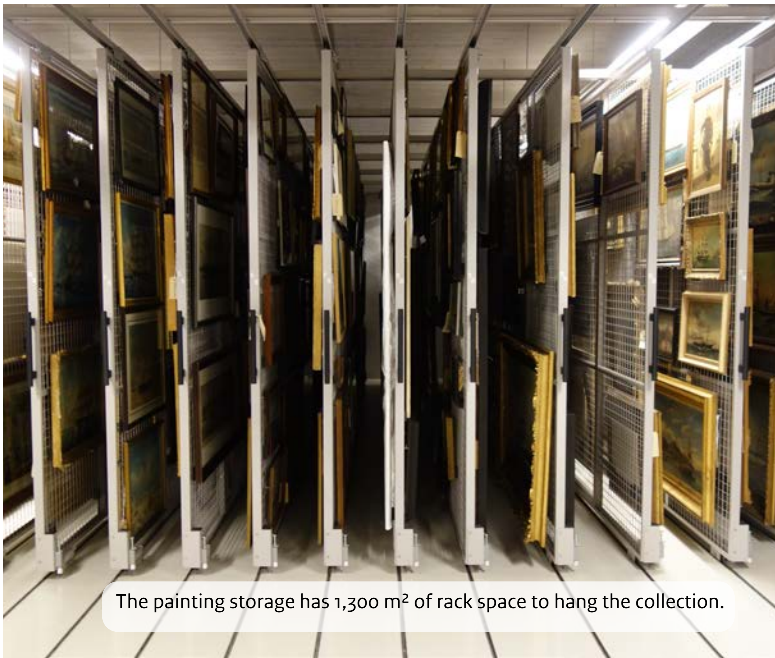
Air is fed into the storage rooms with the help of directable nozzles, ensuring a good flow.

All photographic materials, films and negatives are kept in a separate integrated cold storage unit at a temperature of 3-6°C and a relative humidity between 33% and 37%.

On the first floor, there is a large storage space with fitted storage units for the collection of fragile ship models.

Air-conditioning systems installed at the top of the building provide an air temperature of 18°C in winter to 20°C in summer with a fluctuation of 2°C and a relative humidity of 50% in winter and 55% in summer with a maximum fluctuation of 5%.

Less vulnerable objects are stored in mobile shelving units.

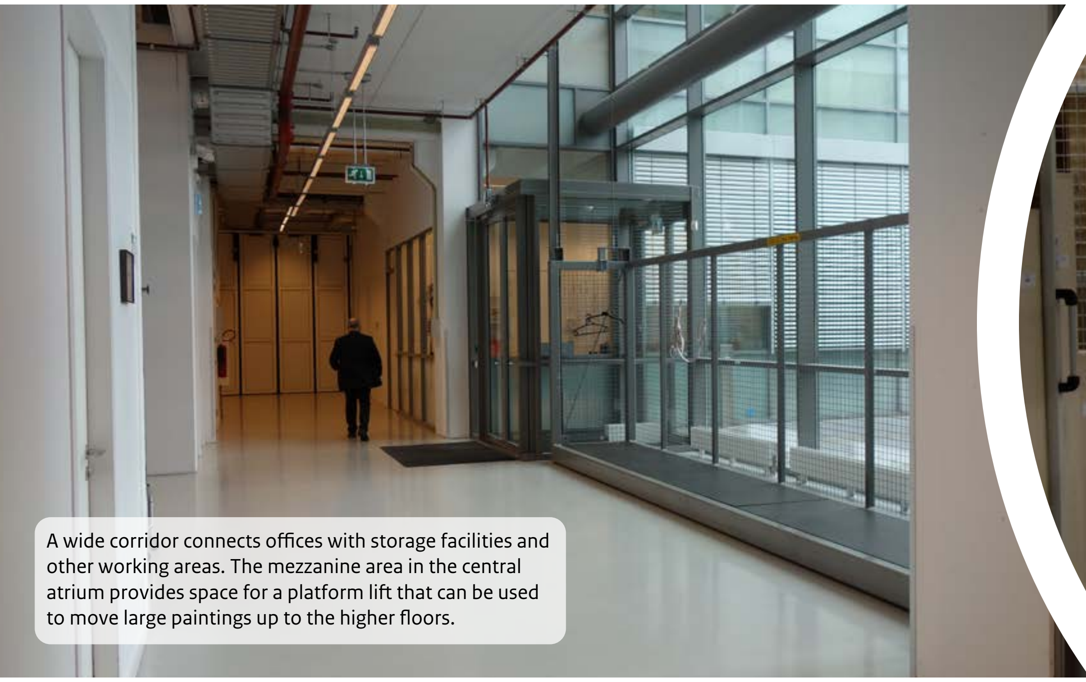


The painting storage has 1,300 m² of rack space to hang the collection.

Stedelijk Museum Amsterdam storage facility

Roel Prins - Storage Facility Coordinator, Stedelijk Museum

The Stedelijk Museum opened its storage facility in Amsterdam West in 2010 The building contains 19 different storage rooms and five workshop areas. The total floor area is 8,000 m², of which 80% is used to store the collection.

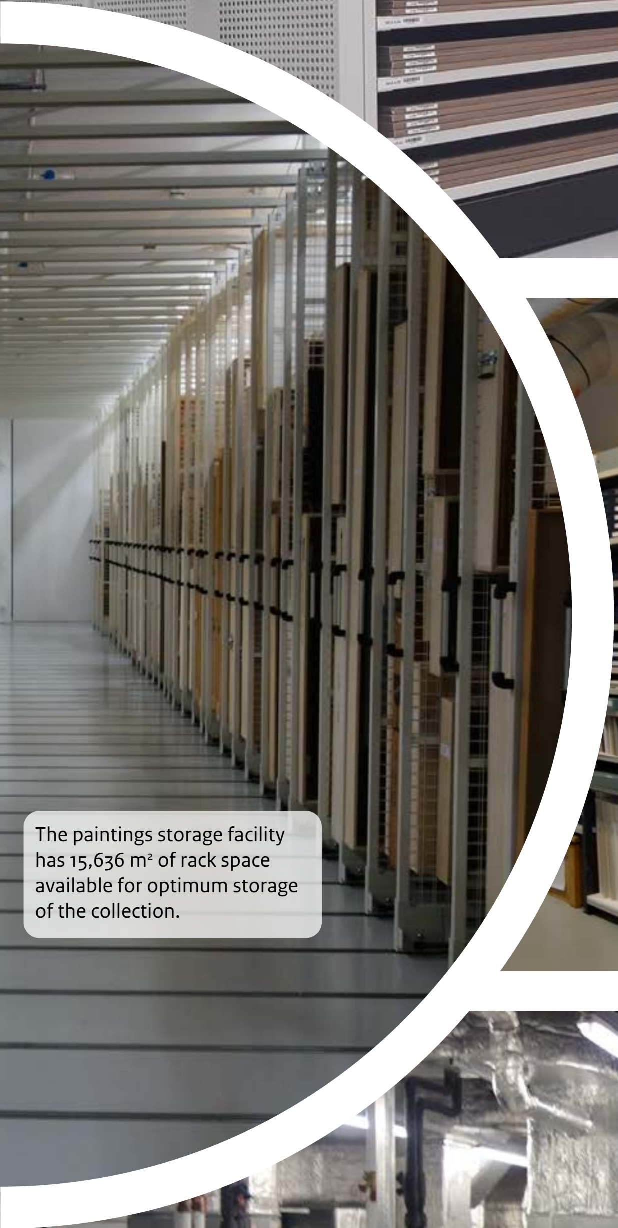


A wide corridor connects offices with storage facilities and other working areas. The mezzanine area in the central atrium provides space for a platform lift that can be used to move large paintings up to the higher floors.

On the ground floor there is a high-ceilinged storage facility for large objects. If objects are fragile, they are stored in shipping crates.

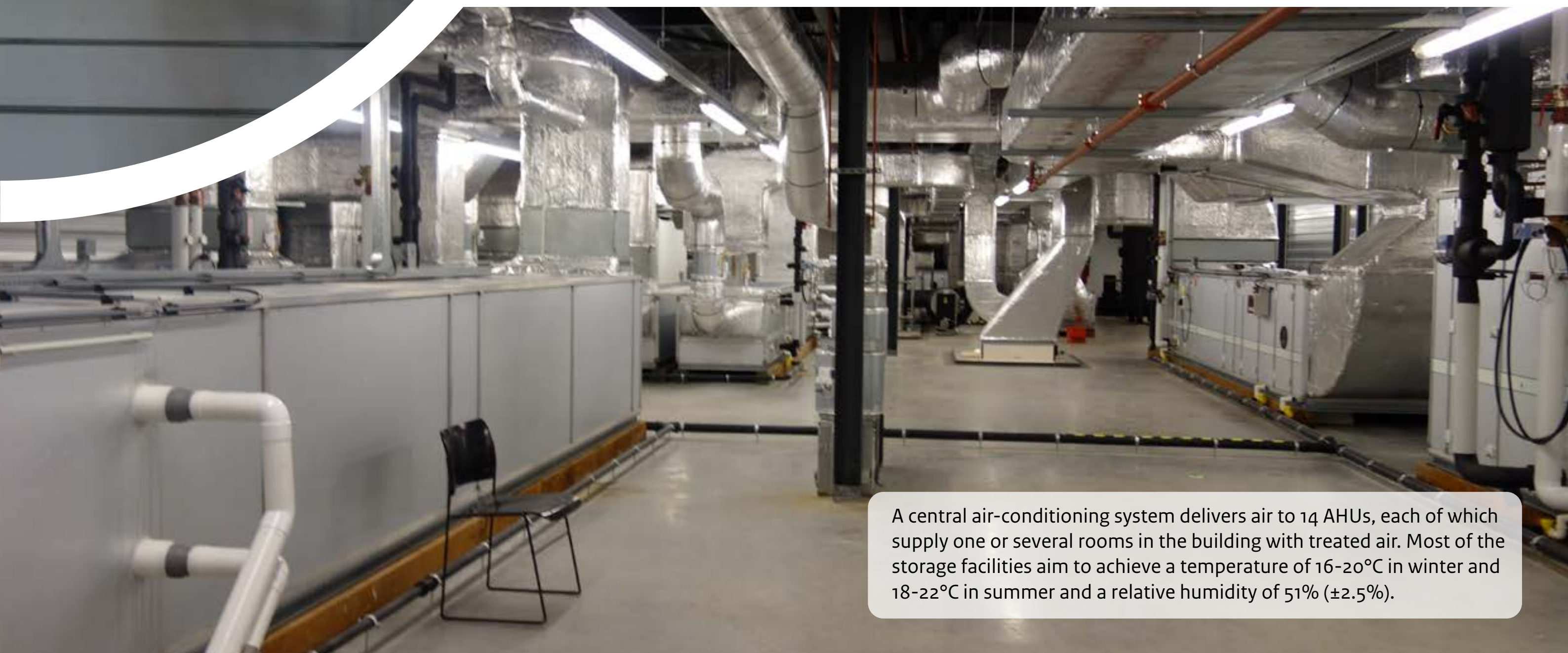
The furniture collection is kept in high density mobile shelving that provide very efficient storage.

The Stedelijk Museum has a sizeable collection of posters in various formats. These were recently repacked into folders, allowing for more efficient use of the available space.



The paintings storage facility has 15,636 m² of rack space available for optimum storage of the collection.

Unstable colour photos are kept in a separate integrated cold storage unit at a temperature of 3-6°C and a relative humidity of 33% and 37%.



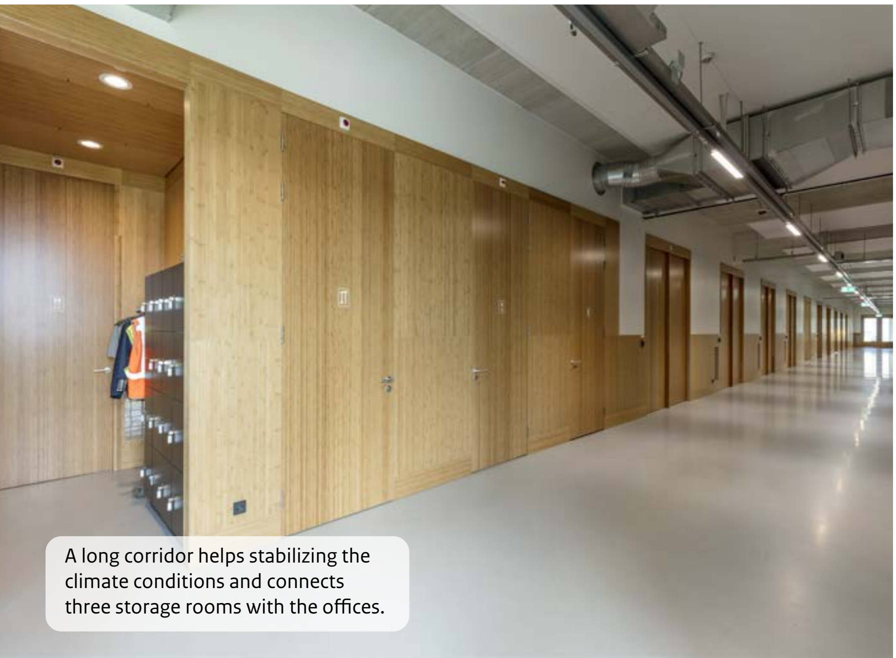
A central air-conditioning system delivers air to 14 AHUs, each of which supply one or several rooms in the building with treated air. Most of the storage facilities aim to achieve a temperature of 16-20°C in winter and 18-22°C in summer and a relative humidity of 51% (±2.5%).

Kolleksjesintrum Fryslân in Leeuwarden

Bart Ankersmit - Researcher, Cultural Heritage Agency of the Netherlands

The storage facility sits on a plot of 6,885 m² and has a gross floor area of 3,007 m² and a usable floor area of 2,757 m². The façade has an aluminium sheeting finish.

In order to achieve an insulation value of R_c = 10 m²K/W, the external walls and roof were given a double coating of insulation.



A long corridor helps stabilizing the climate conditions and connects three storage rooms with the offices.

16 km of shelves and drawers
2 km of textile storage
2,600 m² of mesh racks for paintings
2,000 m² for large objects
350 energy-efficient LED fittings

There are three storage rooms in the building, with a total floor area of 1,915 m^2. The rooms are 5.8 m high (total volume = 11,107 m^3).

Access to valuable collections is restricted. These are separated from the main area by a fence.

In two of the storage units, electric double-decker mobile shelving has been used. The upper level can be accessed by stairs.

The floor grating enables the air to circulate freely between the storage units and in the upper zones of the space.

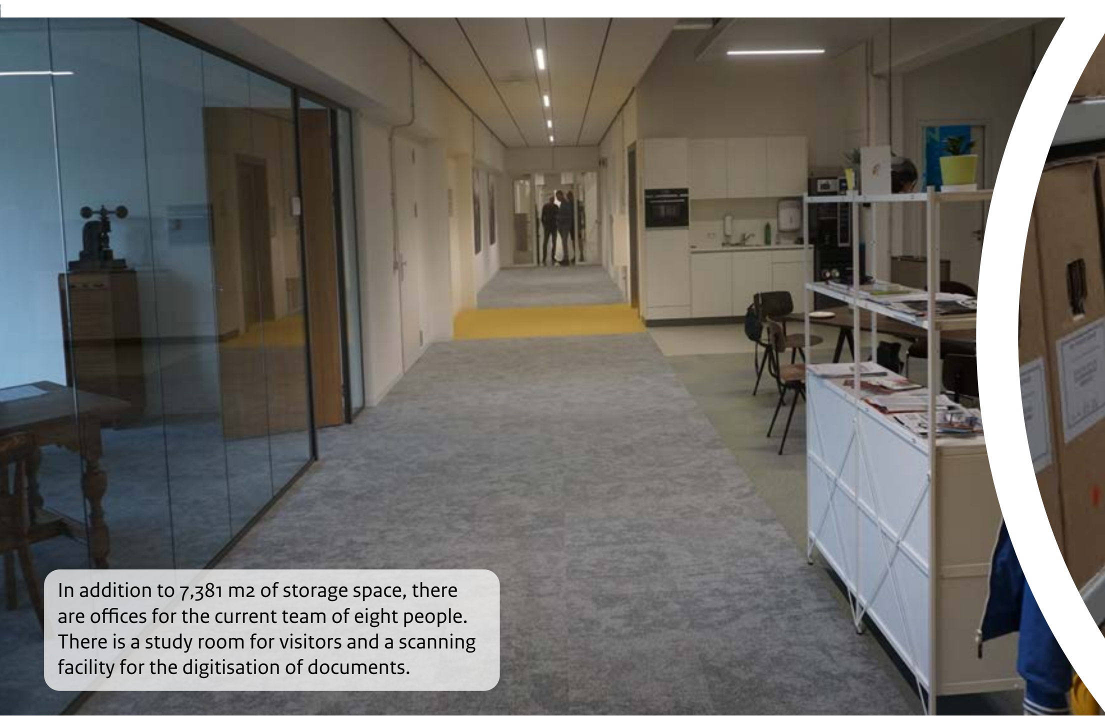
Conditioned air is blown into the storage room via two air bags located directly beneath the ceiling alongside the two long walls.

The climate system recirculates the air. There is no ventilation. The system can be used for heating and dehumidification. With the help of a heat pump, the heat produced by dehumidification is added back to the dried air. This ensures minimal changes of the room temperature.

National Archives of the Netherlands in Emmen

Gabriëlle Beentjes – Sr. conservation specialist, National Archives of the Netherlands

In 2019, the National Archives of the Netherlands based in The Hague opened an additional storage facility for 95 km of permanently-stored national archives. Originally housing the Topographic Service (Topografische Dienst), the building already had 11,578 m2 worth of high load flooring, making it very suitable for archive storage.



In addition to 7,381 m2 of storage space, there are offices for the current team of eight people. There is a study room for visitors and a scanning facility for the digitisation of documents.

Archived documents are stored in acid-free boxes. These boxes form an additional barrier to protect against pollution and fluctuations in relative humidity.

A special feature of the building is its deacidification machine. This is primarily used to treat war archives, doubling the expected lifespan. Although expensive, the investment was justified by the importance and emotional value of the documents.

Just like the rest of the building, the corridors in the storage section are spacious and bright.

In order to minimize the risk of fire, manually-operated moveable shelving units are used instead of electric ones.

The storage units and air ventilation have been positioned in such a way that they ensure the free movement of air throughout, minimizing the likelihood of microclimates.

Air in the depots is treated and cleaned in accordance with the stipulations of the Archive Regulation 2009. External air is pretreated in a central air-conditioning unit. The air is post-treated in each individual storage facility and mixed with 90% of the existing air (recirculation). A second system is used for climate control in the communal areas. There, the temperature is regulated by means of a climate ceiling system, which enables a flexible layout of the different rooms.

The energy needed to power the building is generated using two heat pumps and 780 solar panels on the roof. The combination of effective insulation and power generation ensures the energy--neutral operation of the building, which has an A++ energy label.

Photo credits of the photo spreads

Kolleksjesintrum Fryslan in Leeuwarden
Photo showing the building: Marcel van der Burg photography
Photo showing insulation on the outer facade: Luc Schaap
Photo showing the corridor: Marcel van der Burg photography
Photo showing painting storage: Marcel van der Burg photography
Photo showing electric double-height mobile storage system: Marcel van der Burg photography
Photo showing overview in storage: Bart Ankersmit
Photo showing the fence separation: Bart Ankersmit
Photo showing floor grating: Marcel van der Burg photography
Photo showing the air inlet bags: Bart Ankersmit
Photo showing HVAC: Bart Ankersmit

National Maritime Museum in Amsterdam
Photo showing the building: Bart Ankersmit
Photo showing the corridor: Bart Lahr
Photo showing box-in-box: Bart Lahr
Photo showing silver collection: Bart Lahr
Photo showing fixed furniture: Bart Lahr
Photo showing air inlet: Bart Ankersmit
Photo showing cold storage room: Bart Lahr
Photo showing HVAC system: Bart Lahr
Photo showing movable shelving: Bart Ankersmit
Photo showing painting storage: Bart Ankersmit

National Archive of the Netherlands in Emmen
All photos: Bart Ankersmit

Central Museum storage facility in Utrecht
All photos: Adriaan van Dam

This publication is intended as a source of inspiration for colleagues working in the heritage field who are optimizing or building a storage facility. In it, Dutch heritage professionals present their experiences in developing, managing or researching a heritage storage facility. Across 21 contributions, the challenges involved in heritage storage, from design through to everyday management are explored.