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HISTORICAL STORAGE CELLARS IN BUDAPEST

THE ARCHITECTURAL HISTORY AND FUNCTIONAL OPERATION OF AN INDUSTRIAL BUILDING IN 19TH-CENTURY HUNGARY

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The Kőbánya district of Budapest is situated on the eastern margins of the Hungarian capital city. Beneath Kőbánya there is an extensive limestone layer, in which tunnels and passages have been made, some of which appear to date from the 13th century. In the 19th century, the limestone caverns of Budapest-Kőbánya were used for the refrigeration of perishable goods in large quantities. The caverns represent one of Budapest's historical industrial landmarks, although their architectural history has not been documented in full. This article analyses the architectural development of these evidently low-tech facilities, while also exploring their significant role in the city's urbanisation. The technical functions and structure of the system of caverns may be useful as a resource for society in the future when the supply of fossil fuels runs out. The effectiveness of the caverns as places for refrigeration can be demonstrated through climatic calculations. The cavern system has significant energy capabilities, given that there is a constant air temperature throughout the year. The vast amount of geothermal energy could be used to cool heat pumps or heat exchangers. The results of measurements taken in preparation for this article are presented.

Keywords: historical industrial architecture, Budapest, cavern system in Budapest-Kőbánya, First Hungarian Brewery Share Company, ice refrigeration PCM – phase change materials

REFRIGERATION PLACES AS A PREREQUISITE FOR URBANISATION

Until now, architectural historians have tended to ignore the technical establishments used in the 19th century for refrigeration purposes. Evidently, one reason for this is that the functions of these buildings were hidden from the public and conducted in a concealed manner. It is thus understandable that they have never been at the focus of attention. Still, alongside sewerage facilities and other public utilities, places of refrigeration represent, as an aspect of infrastructure, an inseparable part of the process of urbanisation that took place in what is now Budapest. Without them, the city's urbanisation would not have occurred [23], for it would not have been possible to ensure the food supply of the city's rapidly growing population without a large-scale grocery sector with the necessary hygienic conditions. Further, in the late 19th century, Hungary was a country with a strong agricultural sector; it is no surprise, therefore, that as Pest-Buda grew into a large city (becoming known as Budapest from 1873), food processing developed into a major branch of industry [24]. In order to avoid shortages of certain foods and to cope with the overproduction of perishable foods in certain seasons, there was a need to store perishable goods and build up inventories. In the course of such efforts, various foodstuffs had to be kept fresh through storage at the appropriate temperature. However, refrigerators, operating on the basis of the principle of gas cooling and produced in industrial quantities, became widespread in Hungary only after 1887 [2]. Prior to this, cooled buildings were used, employing the insulating effect of building materials with natural ice as the cooling agent. For example, the Municipal Slaughterhouse and Cattle Market, which opened in Budapest in 1872 and was designed by Julius Hennicke and von der Hude, initially utilised an "American-style" insulated refrigeration chamber. This had a main beam of iron, the refrigeration of which was provided by a layer of ice almost four metres thick [10]. This meant the Municipal Slaughterhouse was in possession of the most modern refrigeration equipment of the era [11].

Natural caverns were an alternative to cold storage houses; caverns were used first and foremost in the beer brewing industry. The caverns of Kőbánya had been carved into the limestone. These "low-tech" constructions may be regarded as an archive of earlier design and construction techniques – ones that are no longer used today. They also represent an overlap between architectural history and technological history, and offer interesting opportunities for the study and documentation of caverns [24]. The knowledge arising from such studies will be useful as an intellectual resource when finite fuel fossils are no longer accessible. Bearing in mind the attitudes and mentalities that influenced the building of these objects, the architects and engineers of the modern era actively cooperated in efforts to resolve the challenges of the environment and energy efficiency. Seen from this perspective, these historical constructions with their simple technical requirements may, even today, be regarded as very modern buildings.

In what follows, I shall examine the architecture and functional operation of these technical buildings and analyse them using an interdisciplinary approach. In the first part, I shall analyse, from an architectural perspective and based on examples, the operational mechanism of the system of caverns in Kőbánya, which were also used as refrigeration places for breweries. Then, in the second part of the study, I shall examine the refrigeration mechanism of the storage cavern of the First Hungarian Brewery Share Company, doing so from a building engineering perspective and with the help of a digital model.

TECHNOLOGY TRANSFER IN THE BREWING INDUSTRY

Within the food and beverages industry, breweries were the first plants to switch from artisan production to industrial large-scale production, whereby a large amount of perishable goods were produced. Furthermore, the storage of beer for longer periods of time and under specific temperature conditions is an integral part of the production process. Indeed, it is the final stage – the most essential stage in terms of the beer's taste. This development was the result of the switch in the brewing technique from top-fermented beer brewing to bottom-fermenting after 1845. Until that time, the new technique had been used exclusively in Bavaria [19]. The know-how-transfer of this brewing technology to Hungary was begun by Péter Schmidt in 1844. Schmidt brought the bottom-fermenting technique to Budapest after studying in Munich. Indeed, he founded his own brewery in Budapest. The innovation required the use of caverns in natural stone for the storage of beer for the length of the fermentation process. Schmidt brought the technique to Hungary from Bad Tölz in Bavaria [13]. The "lager" beer stored in this manner was based on a production process more complex than that used in the production of top-fermented beer, which was much simpler [14]. The new method also required larger working spaces, which were added on in accordance with the work process. This led to the development of the linear construction principle that is so characteristic of historical breweries [12]:

1. The malthouse
2. The brewhouse
3. The caverns

The bottom-fermenting technique required the presence of storage facilities where the beer could be fermented at a low temperature (approx. 3 °C) and under constant humidity for six months, resulting in its optimal taste. In technological terms, the construction of large-scale storage spaces – walled cellars – was expensive and time-consuming. Figure 1 shows the storage cellar established around 1860 at the Rath Brewery in the Angyalföld district of Budapest *(Fig. 1)*.

KŐBÁNYA: THE SYSTEM OF CAVERNS AS A FACTOR IN THE CHOICE OF A SITE

The existing system of caverns in Kőbánya, which were formed in the limestone through underground stone-mining, represented an alternative to the constructed fermentation caverns. The tunnels and passages provided ideal temperature and humidity conditions. At little cost and with minimum effort, they could be transformed to meet the needs of the larger breweries. Concerning the system of caverns, Borsodi-Bevillág wrote the following:

> "*In Kőbánya there were initially vineyards, and the caverns were used as wine-cellars. For this purpose, the tunnels were divided up into cellars through the construction of walls. The constant temperature and humidity had a favourable impact on the fermentation of the wine. In the mid-19th century, several poorer families also moved into the caves [4].*" [7]

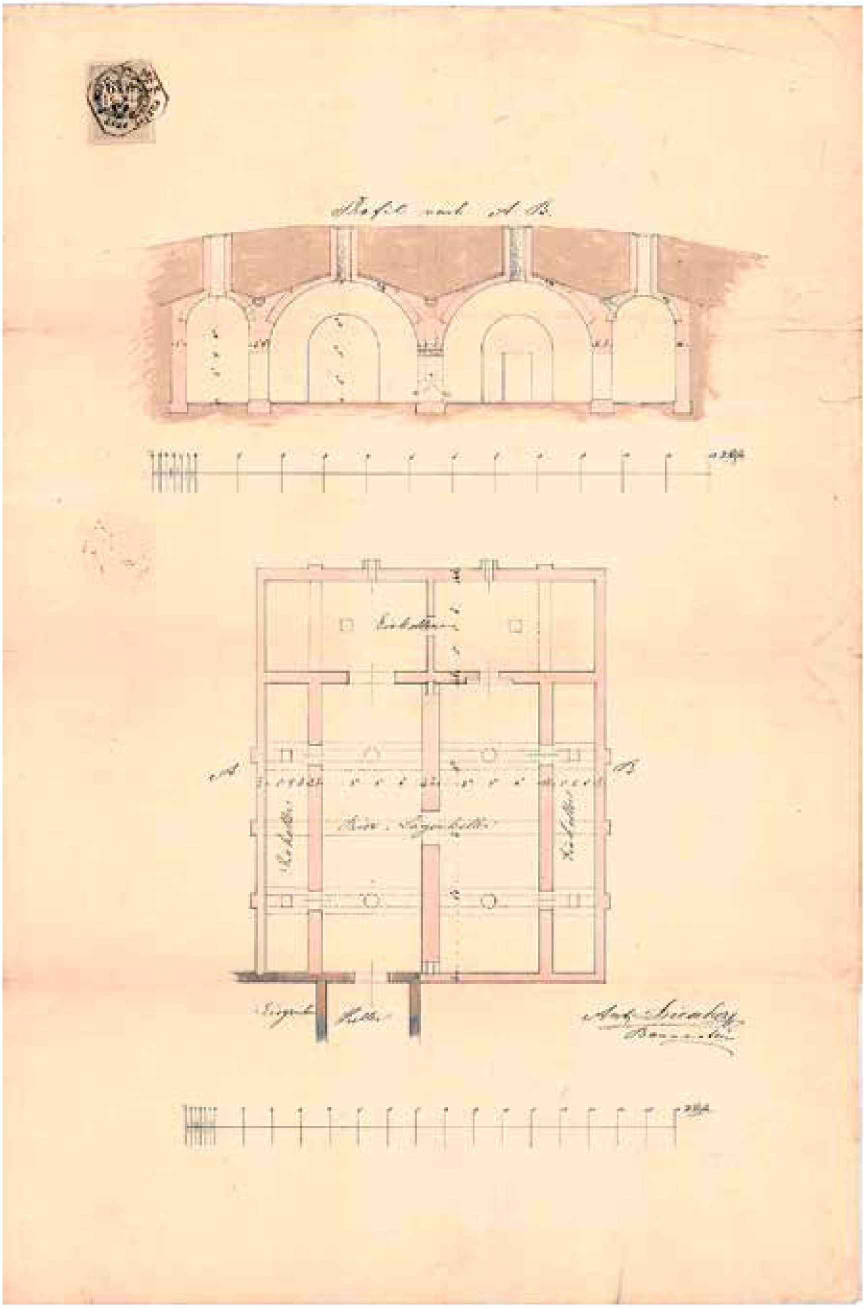

Figure 1. The storage cellar at the Rath Brewery in the Angyalföld district of Budapest, which was established around 1860 (Source: BFL [BFL: Budapest Főváros Levéltára/Budapest Municipal] Archives 15_17_b_300_szb_18099)

On the same topic, János Lukács noted the following:

"*In 1244, King Béla IV gifted Kőbánya to the City of Pest. We find in the document the following names: Kewerfelde, Kuerfelde, Küer and Kőér. The area named Kőérfölde was, with its soft sandstone, very suitable for stone-mining. Thus, over the centuries, there arose the system of long passages typical of the cavern system in Kőbánya. The direct benefit of the stone-mining was as follows:*

1. *The material mined here was used in the construction of public buildings: Among others, the Hungarian Academy of Sciences, the basilica, the wall of the Tunnel and the upper part of the columns of the Chain Bridge together with the lions, were made from Kőbánya stone.*
2. *The caverns thus created were then used as wine-cellars.*

The undulating terrain was favourable for wine-growing, and so it was regarded as valuable in itself. This explains why they mined the limestone from underground. In this way, there developed a fundamental relationship between the production of the wine and the artificial geological forms." [16]

THE STORAGE CAVERN IN THE LIMESTONE – FRONT ICE SYSTEM, MIDDLE ICE SYSTEM AND SIDE ICE SYSTEM

Following Schmidt's example, an increasing number of breweries began using the underground limestone passages with their ideal climatic conditions for the fermentation of beer *(Fig. 2)*. The selection of this site by the Budapest brewing industry was strongly influenced by the geographical location of the cavern system in Kőbánya. Various prerequisites for beer brewing were present in Kőbánya, and there was also a free supply of water.

The caverns were very long, and so they were placed underneath the brewery site. The storage caverns were initially accessed by way of a cavern courtyard. Later on, lifts were also installed. The long cooling passages were approached by way of the tunnel-like entrances; they contained storage barrels. At the end of the cooling passages, there were walls reaching halfway to the ceiling. The chambers formed in this way were filled with natural ice. In order to ensure a constant temperature in the extensive storage areas, an effective ventilation system was required. To this end, in some cases (not in the case of the cavern examined in the study on the First Hungarian Brewery Share Company) the floor of the ice chamber was raised somewhat higher than the floor of the cooling room. In this way, the colder and thus heavier air flowed downwards and pushed the warm air out. Owing to the positioning of the ice chamber at the end of the cooling passage, the system was called the front ice system. A series of openings ensured the equal distribution of the cold air throughout the storage cavern. In general, the ice chamber occupied one-quarter of the total cavern area [18]. When calculating the amount of ice required, it was assumed that 1,250

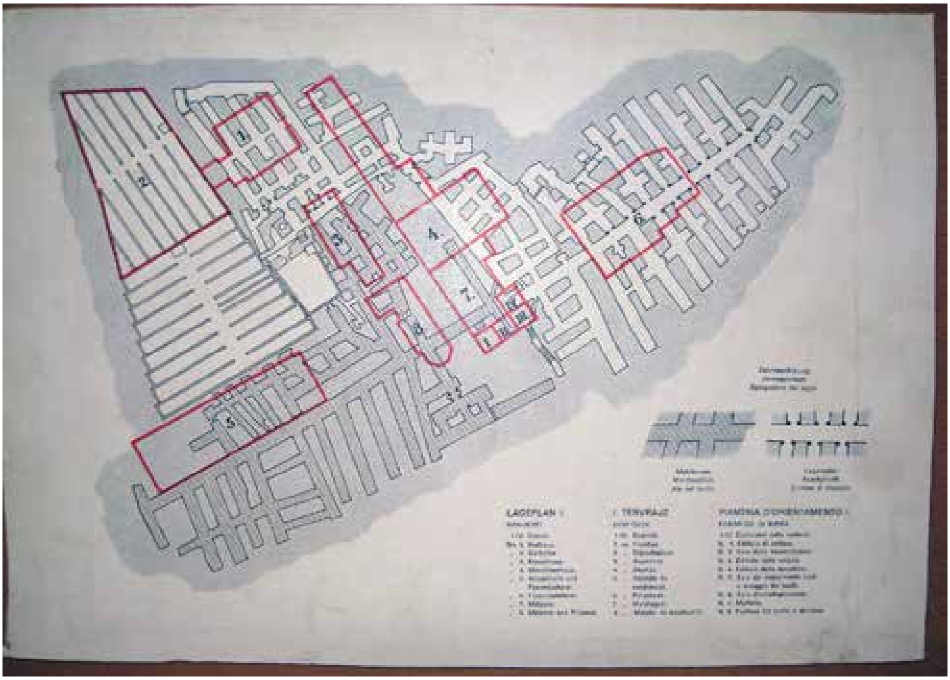

Figure 2. The historical storage cavern of the First Hungarian Brewery Share Company (Source: Archive of the Dreher Brewery Museum, Budapest)

tonnes of ice would be needed for the production of 10,000 hectoliters of beer. For instance, in 1877, the production of the First Hungarian Brewery Share Company amounted to 91,500 hectolitres, which means the demand for ice was 1,250 tonnes × 9.15 = 11.50 tonnes.

Alongside the front ice system, there existed the following options for a cooling cavern:

– *The middle ice system*
In this system, the ice chamber was placed in the middle of the storage room.
– *The side ice system*
In this system, the ice chamber was placed in a neighbouring storage space.
– *The combined system*
In this system, the side ice system was combined with the front ice system.

When production declined, the size of the storage cellar was reduced through the construction of a wall at the back. This gave rise to a flexible system of storage spaces, whereby it was possible to control the amount of ice needed and thus ensure operational efficiency. As the ice gradually melted, water was drained to a collection basin along grooves in the floor. The water was subsequently removed using a pump.

At the same time, the melted ice also resulted in increased humidity levels in the cellar, leading to condensation on the walls and ceilings. To prevent dripping, the condensed water was led off in a controlled fashion along drainage eves. This technique prevented harmful bacteria and fungi in the non-sterile melted ice from spreading in the cellar, as this would have ruined the beer. Meanwhile, in line with the strict regulations, ventilation measures were realised, whereby in winter the relatively warm air of the cellar flowed outside along a ventilation shaft.

1. Ventilation in winter (release of warm air from the cellar)
   In winter, cold air was allowed into the storage cavern, which then sank to just above floor-level. The warm air rose and flowed outside along a ventilation shaft.

2. Cooling in summer (closed-cycle cooling)
   The ice cavern was placed higher than the storage cavern. The ice-cooled air sank to just above floor-level. The relatively warmer air was directed along the ceiling back towards the ice, where it cooled once more. The ventilation shaft was closed, creating a closed-cycle cooling system.

OBTAINING THE ICE

Until the widespread introduction of cooling aggregators, natural ice was the only cooling medium available for use in the caverns. The collection of ice was carried out during the colder winter months. There were various options for obtaining ice:

1. *Collecting ice from natural waters:*
   Ice blocks were carved out from ice on frozen lakes and rivers.
   In 1864, the Dreher Brewery requested permission from the Municipal Council to cut and remove ice from a section of the Danube River in Soroksár [3]. A drawback of this method was the relatively great distance from the Danube to Kőbánya – the long transport route.

2. Collecting ice from suitable frozen lakes:
   To reduce transport times, artificial pools were established in the vicinity of the brewery.
   The Barber-Klusemann Brewery, for the purpose of producing ice as a cooling medium, established an artificial pool close to the brewery as early as 1856 *(Fig. 3)* [6].

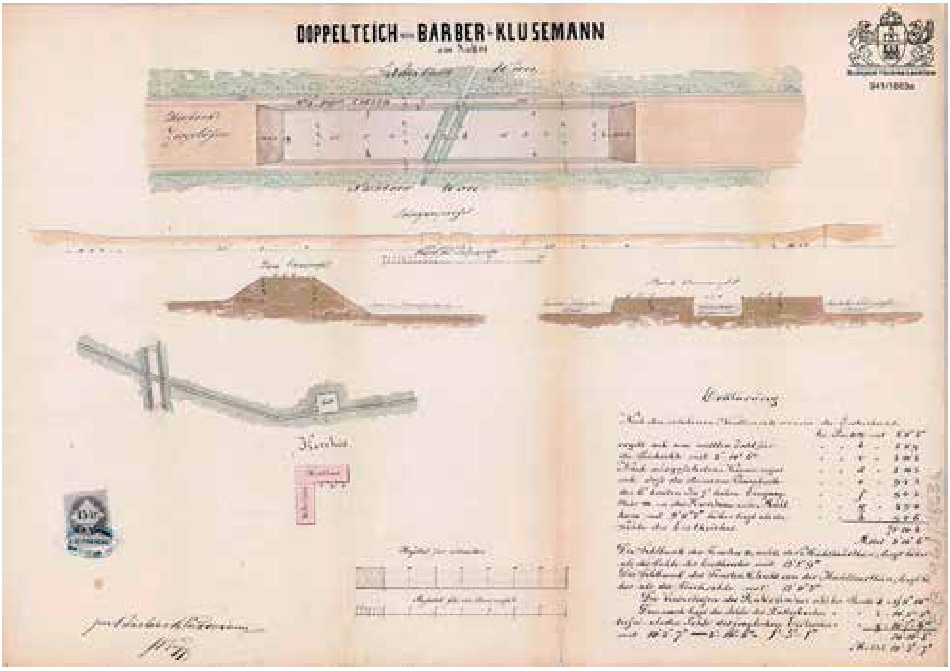

Figure 3. The double lake of the Barber-Klusemann Brewery, 1863
(Source: BFL 15_17_b_312_szb_1863a)

This artificial lake consisted of two pools, at the centre of which there was a channel for running water into the pools. The division of the artificial lake into two parts enhanced flexibility when it came to meeting demand for ice. A system of dams and high-water levels served the function of protecting the surrounding environment from possible flooding. Depending on temperature conditions, ice could be cut from the lake on one or more occasions during the winter. In the course of a single freezing, 3,600 cubic metres of ice could be obtained from the two artificial pools:

Size of the pools:
length, (L) = 120.00 metres
breadth (B) = 60.00 metres
thickness (height) of ice (H) (variable): 0.25 metres
number of pools: 2

$L \times B \times H \times 2$
$120.00\ \text{m} \times 60.00\ \text{m} \times 0.25\ \text{m} \times 2$
$= 3{,}600\ \text{m}^3$

This amounted to approximately 3,200 tonnes in volume. When calculating this estimate, we did not take into account the possibility of variations in the height of the ice (it could be 30 percent less) [1]. Given the possibility of a mild winter with little ice, in any given season the amount of ice cut and stored was twice the required amount for that year.

THE ICE HOUSE

For the purpose of storing the ice, containers (ice houses) were created in the ground. The ice houses were sided by walls, but the top closure was a simple gable roof, whereby the gable sloped towards the entrance. To protect the ice houses from sunshine, they were usually built on the northern side of buildings [18]. The two ice houses constructed by the Budapest builder Anton Diescher each consisted of 100 cubic metre tanks, with the thickness of walls decreasing upwards [5]. The cylinder shape meant that there was a favourable ratio between surface and capacity and a favourable resistance to pressure from the sides *(Fig. 4)*. To drain away any melted ice, a dehydration system was installed in the soil.

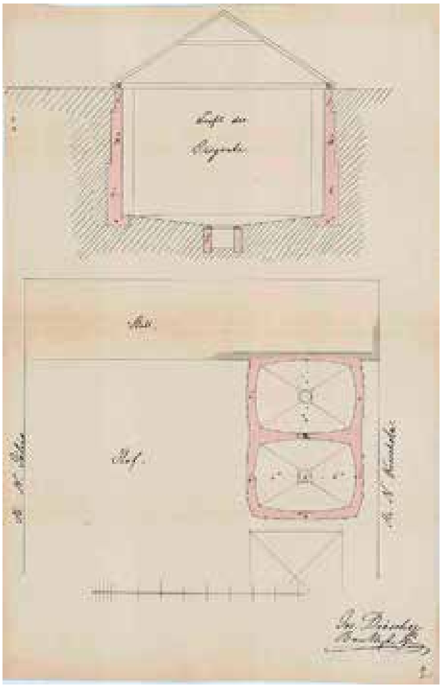

Figure 4. Ice house
(Source: BFL XV_17_.b_.311_.SZB_09767)

DIGITAL MODEL OF THE COOLING MECHANISM

In what follows, a digital model of the historical storage cavern of the First Hungarian Brewery Share Company is employed as a means of examining the cooling mechanism achieved through the use of natural ice *(Fig. 5)*. The limestone cavern under investigation forms a part of the extensive system of caverns in Kőbánya. These caverns appear to have been used for multiple purposes between 1867 and 1900. In addition to the malthouse, other caverns were used for fermentation and storage purposes. The ground plan shows a complex system reminiscent of urban structures and comprising storage areas, paths, courtyards, wells, passages and stairways.

The cooling of the 19th-century fermentation and storage caverns in Kőbánya was based on the ice cooling system described above. The mechanics of ice cooling were based not only on the thermal transfer stemming from the warming of a cold substance but also from the latent heat required for melting a solid material, which is taken from the surrounding environment during the course of the melting process. The change in the energy content of the ice is accompanied by a change in the solid/fluid ratio, whereby latent energy is released or absorbed, with an energy transfer from the surrounding storage cavern.

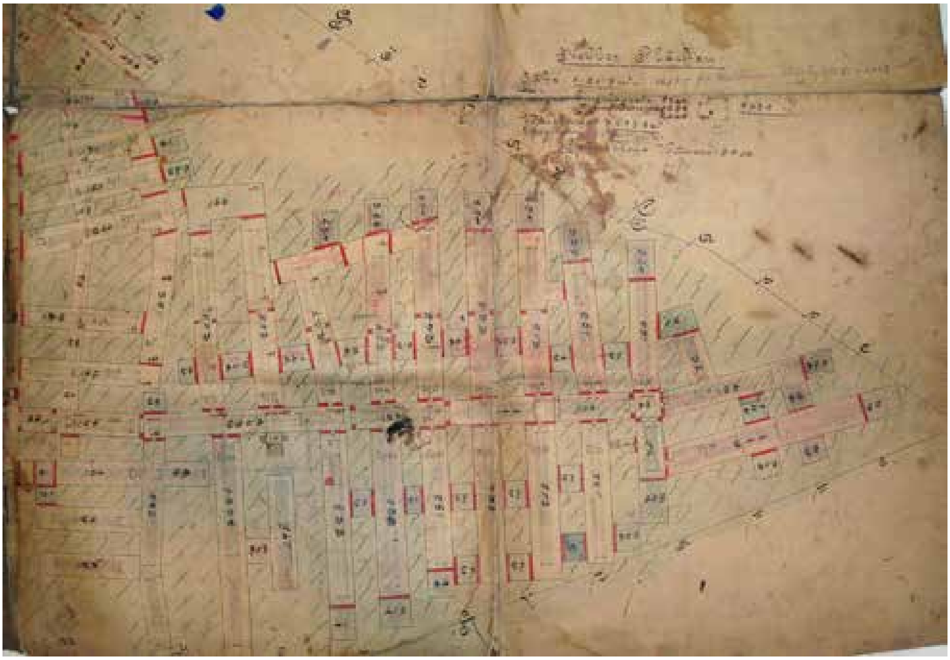

Figure 5. The historical storage cavern of the First Hungarian Brewery Share Company, Kőbánya, 1890 (Source: Archive of the Dreher Brewery Museum)

INPUT PARAMETERS OF THE NUMERICAL MODEL

The storage and fermentation caverns of the First Hungarian Brewery Share Company – now known as the Dreher Brewery – originating from the 1880s are situated on Jászberényi Street. The total length of the Kőbánya caverns is more than 32 km, with a floor space of around 180,000 square metres. We partly explored and examined a separate part of the middle floor *(Fig. 6).* The cavern system was surveyed on July 26, 2013. During our investigation, we carefully examined the main branches of the tunnel system, concentrating on the architectural and building-physics related properties of the structure.

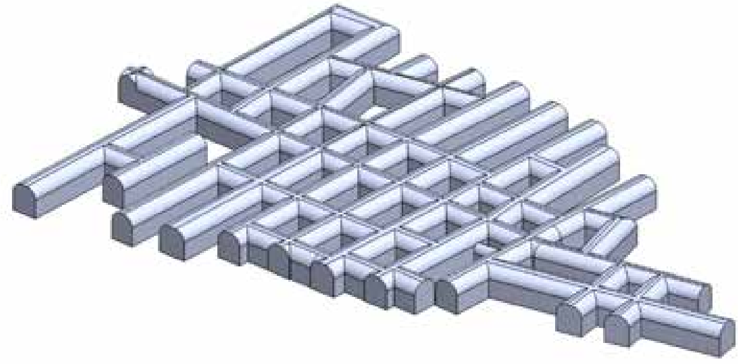

Figure 6. Model of the cellar system

ARCHITECTURAL PROPERTIES

The terrain in which the tunnel system was carved mainly consists of Sarmatian limestone formed in the Miocene era. The limestone rock is able to withstand sub-zero temperatures and gets harder when exposed to air. The walls are only plastered in smaller areas, to protect from deterioration. [21] The length of the examined tunnel system is approximately 1,170 metres and the width is about 6 metres. Thus total floor space is in excess of 7,000 square metres. The height of the caverns varies between 5 and 8.5 metres. Volume is approximately 52,000 cubic metres. Based on contemporary map data, the area designated for ice storage is about 2,850 square metres. The area of contact surface between the air and the walls of the cavern system is approximately 26,400 square metres. The volume of air inside the tunnels is about 46,500 cubic metres.

The ice storage area is separated from the storage space where the barrels were placed *(Figs. 7–8)* by a solid wall up to 4 metres in height, built of small bricks. [22] We determined the height of the solid wall, which has been demolished, on the basis

Figures 7–8. Photograph and model of the wall next to the ice
(Photo: the authors – Zsuzsanna Nádasi-Antal and Martin Pilsitz)

of the evidence to each side. The wall above 4 metres (up to the arched ceiling) was porous, consisting of small bricks with gaps to ensure good ventilation and more efficient cooling.

In our calculations, the ice reached up to the top of the solid part of the wall, and so the capacity was almost 6,000 cubic metres of ice *(Fig. 9).*

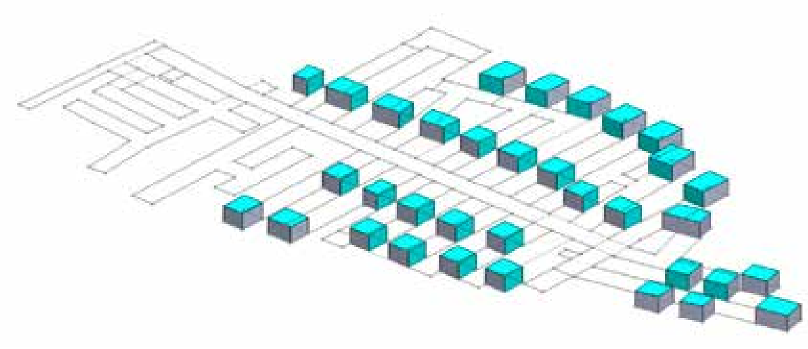

Figure 9. Illustration of the maximum use of ice – model of the ice storage area

MICROCLIMATIC PROPERTIES

Regarding the outer environmental temperature, we obtained information from the local weather bureau. The day when we visited the brewery the temperature was 29 °C and the sea-level air pressure was 1016 hPa. The altitude of the land above the caverns varies between 129.7 and 130.3 metres above sea level. The floor level of the tunnels is between 116.2 and 118.2 metres above sea level, so that the temperature in the tunnels can be considered constant throughout the year. The three important building-physics parameters measured: the surface temperature of the floor and walls, the air temperature, and humidity. The measurements were undertaken using calibrated instruments. We measured an average surface temperature of 10.7 °C, an air temperature of 12.3 °C, and 95% as relative humidity. [23] The beer in the tunnels was kept in barrels with a capacity of 10 or 15 cubic metres. Presumably, the temperature of the beer was 3 °C. We assumed that the average temperature of the ice was minus 5 °C. Researching the coolant system in the tunnels, we concluded that the heat transfer between the limestone wall, the barrels and the air holds the thermal equilibrium with the gradual warming of ice at a temperature of between minus 5 °C and 0 °C, and the melting of the ice and the warming of the melt water at between 0 °C and 3 °C [24].

ENERGY CALCULATIONS

Examining the ice as a material containing latent heat, we performed energy calculations for the whole tunnel system under investigation [25]. The density of the ice is 900 kg/m^3, and so the whole weight of ice which can be stored in the system is approx. 5,220 tonnes. Thus, the enthalpy of fusion of this quantity (assuming 337.7 kJ/kg specific heat of fusion for ice) is 1,762,794,000 kJ. The water produced by the fusion of ice was gathered in channels leading to a water container, from where it was pumped to the surface. [26] Heat transfer between the air and ice during the gradual warming of the ice from minus 5 °C is 32,886,794,000 kJ. The gradual warming of water produced by the fusion of ice from 0 °C to 3 °C required 65,568,420 kJ of heat. The three quantities above in sum give the total energy absorbed by the ice placed in the storage room under investigation. If we base our calculations on an electric coolant system (assuming a COP value of 3), the energy costs alone would amount to approx. EUR 20.800 – based on the average cost of electricity supplied by the local electricity company [27].

	Energy [kJ]	Cost of electricity [Ft]	Cost of electricity [EUR]*
From the melting of ice	1,762,794,000	6,161,618	19,760
Warming of ice (–3 °C –> 0 °C)	32,886,000	114,949	369
Warming of water (0 °C –> +3 °C)	65,568,420	229,186	735
Total	1,861,248,420	6,505,753	20,864

*HUF/EUR rate of exchange: 311.82 Source: National Bank of Hungary, 27 April 2017 [28]

NUMERICAL SIMULATION

Our purpose with the FEM modelling and CFD analysis was partly to reconstruct the original parameters, and to find out if the instructions and methods documented on the original plans were correct and capable of facilitating the design and building of a storage space with the capacity to enable this amount of beer to be stored cor-

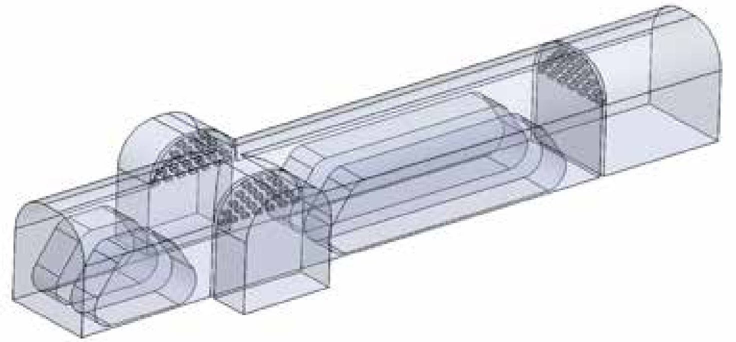

Figure 10. Model of the tunnel used for simulation

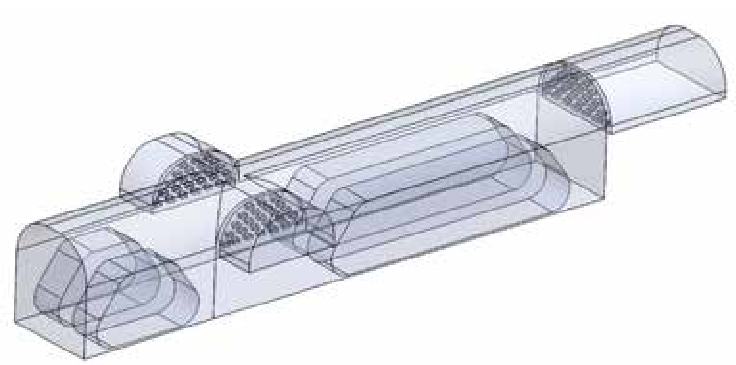

Figure 11. Spatial capacity model

rectly. The current simulation is not meant to produce quantitative results, its main purpose is to inspect how the shape of the cavern guides the air flow around the barrels. We separated a single tunnel for modelling *(Fig. 10)*. We treated the barrels as one block matching the outer dimensions of the stack of barrels. On the model, the ice covers 86 square metres. The surface area of the walls is 1,380 square metres. The ice fills the ice containing room up to a height of 4 metres, to the very top of the solid part of the separating wall.

We performed a *steady-state analysis* to plot the speed and temperature distribution of the volume *(Fig. 11)*. The model used for the simulations was built according to contemporary maps and our field measurements. We set the temperature of the surrounding structure to 12 °C, steady-state surface temperature of the walls to 3.5 °C. We did not set up any heat transfer between the ice block and the walls touching it because we did not have any information how solid the ice really was. Furthermore, the melting was much faster next to the wall, compared to the inside of the ice block.

The general mesh size on the model of examined air volume is 0.30 metres. On the porous part of the 4.00 m high separating wall the mesh has been refined; its size here is 0.10 m *(Fig. 12)*.

Between the wall and the air we set a heat transfer coefficient of 8 W/m^{2}K between the ice and the air, the value was set to 6 W/m^{2}K *(Fig. 13)*. We performed the simu-

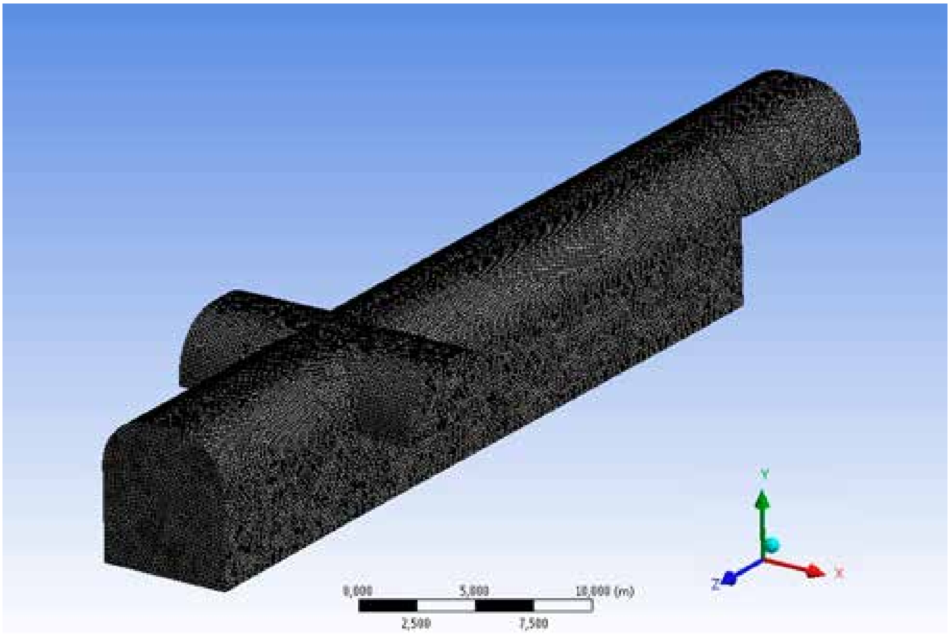

Figure 12. Spatial net

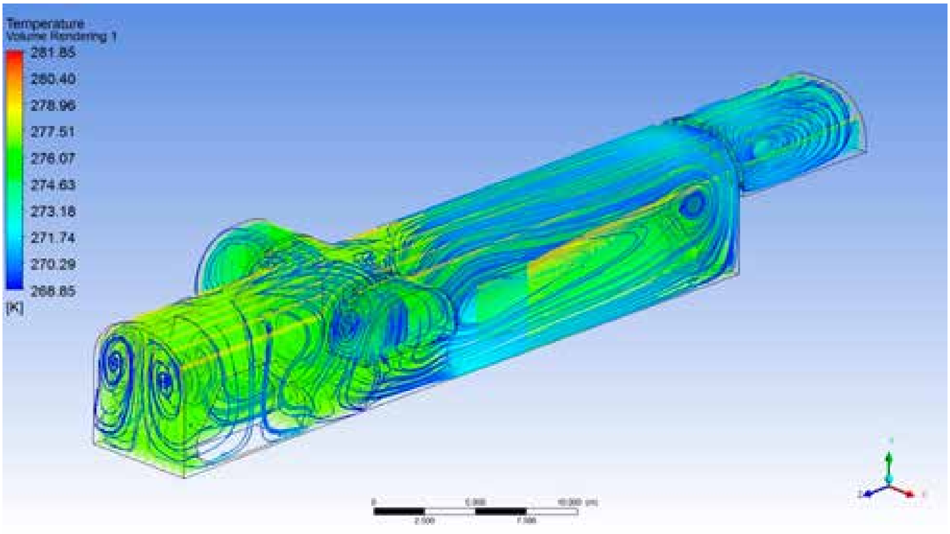

Figure 13. Temperature distribution in the air

lation with the fluid flow CFX module of Ansys software. The initial condition was *heat transfer*. Air temperature is around 3 °C, but in some places this goes up to 7 °C, mostly under the vaulted ceiling.

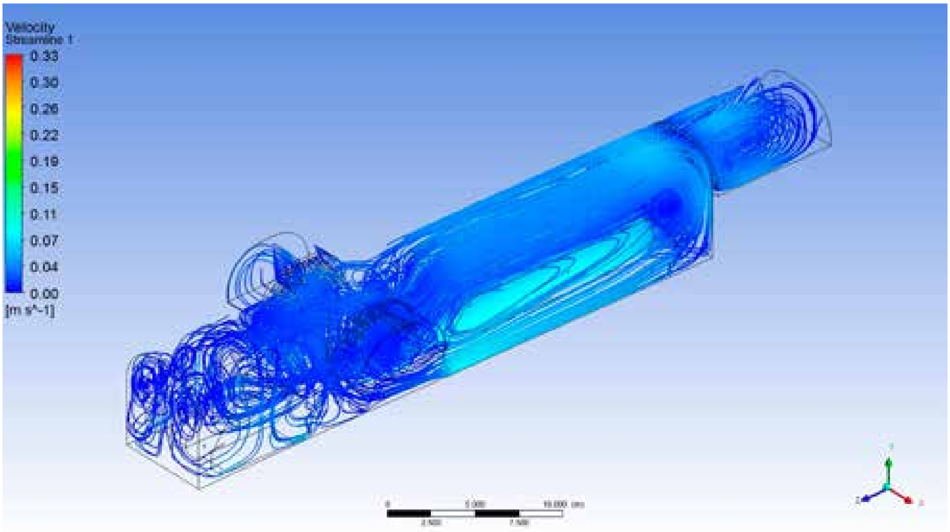

Figure 14. Velocity distribution in the air

The characteristic of the air-flow forming in the examined air volume is laminar; it does not require any driving force and it evolves as an effect of temperature differences *(Fig. 14)*. In case of a laminar flow, the speed vectors of particles are parallel, with a parabolic distribution in magnitude. The speed values are relatively low, not exceeding 0.07 m/s. Due to the extensive amount of uncertainties in the inputs, results listed above may contain significant errors quantitatively. However, the character of air flow in the chamber can be observed, and this shows that the barrels are well placed and cold air streams surround them well.

The builders made great efforts to establish a contact surface between the air and the ice, with this surface being large enough to ensure the required heat transfer, but not too large to make the caverns colder than necessary. The size of contact surface was based on strict calculations, which were possible in view of the empirical data available.

RESULTS

The oldest known material capable of containing latent heat is ice. The effectiveness of the 19th-century cooling and fermentation caverns is clearly shown by our calculations: the energy absorbed during the phase shifting of ice is over 18 times more than the energy needed to warm up ice and water. Nowadays, reflecting ecological demands and construction energy requirements, phase change materials (PCM) are receiving increasing attention, being used for the storage and transportation of cold energy. Concerning latent heat containing materials, it is also possible to increase the heat capacity of building structures, thereby avoiding the typical, summer-time overheating of light structure buildings. At first sight, the utilization of PCM materials may seem easy, given that their melting point can be adjusted in a chemical way. However, it can be difficult to ensure constant thermal properties.

SUMMARY

This research was undertaken as part of an interdisciplinary cooperative project, which aimed to examine the historical cavern system of Kőbánya from a technological perspective and to represent it by means of numerical simulations, as the working storage and coolant system of the First Hungarian Brewery Share Company [29]. This object, similarly to other industrial structures, represents a very important aspect of urban development in Budapest. Besides the architectural typological and spatial issues, we also examined the building service solutions of historical industrial buildings. This could provide insights into how the system could be used in the future when access to fossil fuels and other finite energy sources becomes limited. The question of how this cavern system could be reused cannot be answered definitively, because it raises a number of rather complex issues, including safety and legal concerns. At the same time, the cavern system has significant energy capabilities, given that there is a constant air temperature of 10.7 °C throughout the year. For example, the vast amount of geothermal energy could be used to cool heat pumps or heat exchangers. To discover ways of using the tunnel system, a separate study is required.

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A KŐBÁNYAI TÖRTÉNETI PINCERENDSZER

A BUDAPESTI IPARI ÉPÍTMÉNY ÉPÍTÉSTÖRTÉNETE ÉS MŰKÖDÉSI MECHANIZMUSA

Összefoglalás

A kőbányai pincerendszert a 19. században romlandó áruk nagy mennyiségben történő hűtött raktározására használták. A Budapest történeti ipari létesítményei közé tartozó műszaki objektum építéstörténete azonban még nincs véglegesen dokumentálva. A jelen tanulmány ennek a low-tech létesítménynek az átfogó építészeti kialakítását elemzi, és egyben utal a város urbanizációs folyamataiban képviselt fontos szerepére is. A pincerendszer műszaki funkciói és szerkezeti kialakítása később, amikor fosszilis energiahordozók már nem állnak a társadalom rendelkezésére bármikor és látszólag korlátlan mennyiségben, szellemi erőforrásként is hasznosítható lehet. A hűtőpince hatékonysága beltéri klímaszámítások segítségével is igazolható. A tanulmány keretében végzett mérési eredmények digitális modell formájában kerülnek bemutatásra.

Kulcsszavak: pincerendszer, Budapest, Kőbánya, történeti ipari építészet, Első Magyar Részvénysörfőzde, jéghűtés, PCM

DIE HISTORISCHEN FELSENKELLER IN KŐBÁNYA

BAUGESCHICHTE UND FUNKTIONSMECHANISMUS EINES INDUSTRIEBAUWERKES IN BUDAPEST

Zusammenfassung

Im 19. Jahrhundert wurden die weitläufigen Felsenkeller in Budapest-Kőbánya als Kühllager großer Mengen verderblicher Waren genutzt. Dieses technische Bauwerk gehört zu den historischen Industrieobjekten in Budapest, die hinsichtlich ihrer Bauhistorie noch nicht umfassend dokumentiert sind. Der Artikel fasst eine Studie zu diesem low-tech Bauwerk zusammen, wobei zunächst die architektonische Entwicklung aufgezeigt und auf Wechselwirkungen mit der Stadtentwicklung eingegangen wird. Danach wird die technische Funktion und die konstruktive Gestaltung dieses historischen energieautarken Bauwerkes erläutert. Möglicherweise können solche baulichen Konzepte in Zukunft, wenn fossile Energieträger nicht mehr in scheinbar unbegrenzter Menge zur Verfügung stehen, Teil einer Gesamtlösung darstellen.

Schlüsselwörter: Felsenkeller, Budapest, Kőbánya, Historische Industriearchitektur, Erste Ungarische Aktienbrauerei, Eiskühlung

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