Restoring the greenhouse at Lednice chateau

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ABSTRACT: During 1999–2003 years was progress global reconstruction of palm greenhouse in the state chateau Lednice in Czech Republic. Structure is a part of Lednice-Valtice precincts, UNESCO landmark. Greenhouse is one of the largest withal the oldest on European continent. It was designed by architect George Wingelmüller for the Alois Joseph II from Liechtenstein date 1845.

1 INTRODUCTION

The greenhouse was built on the site of a previous, obsolete orangery, which was torn down. The new greenhouse connects to the eastern wing of the chateau via the floral hall, while to the east of the greenhouse lies a terrace at ground level, and below the terrace is a subterranean space called the catacomb. This also connects to the greenhouse via a stairway. The greenhouse served in its original condition until 1939, when an extensive reconstruction took place. That reconstruction partially altered the character of some of its elements. During 1995 year planning work began for an overall historical restoration, as the support construction and ornamental elements alike had reached the state where the safe functioning of the greenhouse (as to both structure and vegetation) was immediately threatened.

From the start of the historical restoration of the Lednice chateau greenhouse, the priority was not to allow damage to the plants growing in the greenhouse. For this reason, all the ongoing work was consulted with horticulture experts.

The first necessary part was the reconstruction of the greenhouses heating system. This reconstruction took place 1997–1998. In 1998 the renovation of the greenhouse continued with the completion of the required studies, and work began on restoring all five entry portals to the greenhouse. At the end of 1998 the vegetation was removed from the part on the greenhouse between the chateau and the first set portals as preparation for construction and restoration work planned for 1999.

In 1999 a complete historical restoration was done on all elements in the cleared section, and at the end of the years preparation was done for work in 2000, that is, the removal on the vegetation between the first and second set of portals.

In 2000 a complete historical restoration was done on the cleared section, and the last part of the greenhouse was cleared between the second set of portals and the portal on the end of the greenhouse. Here restoration work was done in 2002. Work on the interior of the greenhouse was finished on 1 November 2001, and by April of 2002 all vegetation in the greenhouse had been restored.

The insulation system on the north side and shading system on the south side were also part of the restoration. The insulation system was completed in fall 2001, the shading system was completed in 2003.
2 GREENHOUSE STRUCTURES

2.1 Support construction of vault

Support construction is created by 22 couples of support columns holding up the vault constructed from metal ribs and glass tiles. The distance between the columns is 3.9 m lengthwise and 4.3 m in the directions across. The support columns are formed with a core made of steel Ø 74 mm. The core is surrounded by cast iron sleeves, which create the outer surface. The space between the cast iron sleeve and the steel shaft was originally filled with plaster. Both heads and bases of the columns are decorated with zinc foliage.

First, the cast iron sleeves were removed and the metal cores had to be cleaned, afterwards they were tested using non-destructive methods – magnetic dust method and ultrasound.

43 shafts underwent these tests; one was cut into pieces for the restoration study. In all, only one pole did not comply with load-carrying capacity, and had to be replaced with a stainless steel pipe 73/7.1. The support shaft cut up for samples for the restoration study was also replaced. The shafts were cleaned and zinc galvanized, the cast iron removed, and missing parts were replaced with new ones. The decorative zinc foliage was renewed as well.

2.2 Vault ribbing

The metal ribs of the vault were sandblasted, after glass had been removed. The damaged parts were replaced with new ones of the same shape; bent parts were straightened.

In meeting place of the support columns and the vaulting (3.9 m lengthways) there are double supporting metal ribs anchored into the base. At a distance of the width of a glass tile 250 mm, between these two double ribs there is a simple holding rib anchored only into the marble curb atop the stone base. To anchorage the ribs, poured lead was used. The ribs – in the upper parts – are fixed into a lengthways-metal support beam running at the level of the heads of the columns.

2.3 Stone base wall

Into a stone base wall, the metal support structure of the greenhouse vault is anchored. The wall lies on a brick foundation approx. 0.3 m below the level of the terrain.

The structure is partly above a cellar; also a service corridor runs under the greenhouse, and around the outside perimeter, a ventilation and drainage canal are to be found. The connecting canals between the corridor and the outdoor perimeter canal were stopped up sometime in the past.

Analyses of stonewall found severe dampness – around 80–90% saturation of the pore system. The dampness damaged the stone surface.

During the restoration of the stone base wall into which the ribs are anchored, the base was made of a limestone curb, and a stem upon which the marble ledge rests. It came out that the marble was originally grey-black with white veins, not white as it had been expected before cleaning. Its colour similarity with the portals was verified by the analyses of fragments of the grey-black colour. Chemical cleaning of the stone surface alone is not convenient because of its uneven effect. Thus, it was opted for a gentle mechanical cleaning with moistened flexible diamond sandpaper to the point of a dull shine. Before each brushing, flaws in the form of crevices and gouges were filled with a polyester resin made for restoring marble.

Figure 2. Greenhouse interior during vegetation renovation.

Figure 3. Cross section of greenhouse.
Only corrosion spots were treated chemically. The cracks between the blocks were filled with silicon putty of the stone colour. The restoration of the ledge was completed with hydrophobization. The restoration of the limestone parts was divided into two stages because of the different phases of eliminating the causes of moisture penetration. At the moment the wall stem has been restored inside, where the new floor surface including insulation were laid. After dirt and the cement lining were mechanically removed, a chemical barrier was injected into the lower part of the wall to protect it from rising dampness. Artificial stone replaced the missing material, and the surface smoothed to conform to the original.

The outer side of the wall is planned to be restored in 2004.

The injection bores put in just below the stone wall had the diameter of 16–18 mm according to the drill bit used. To spare the heating canals and thus the lack of room to work, the holes were drilled at an angle of about 23°, 8–10 cm deep from the inside of the wall (60 cm), axial distance 12 cm. To dry out the wall, the work was halted for a period of about 1 month. The special equipment IDEA INJEKT was used for pressure injection, with working pressure of 15–30 BAR handled by a specialised firm. To eliminate considerable dampness, the Aida Mauerinjektion silicone microemulsion was dissolved in water at a ratio of 1:4. The bore holes were filled with a special non-shrinking cement suspension Aida Bohrlochsuspension. On the interior of the stone wall – up to floor level, the surface of the wall received a sulphur-resistant mineral insulating treatment Aida Sulfatexschlamm connected to the injection material. A necessary part of the horizontal insulation of the base wall was to provide the hydro-insulation of the exterior face of the foundation wall from the level of the bore to the level of the terrain.

Aida Mauerinjektion is a water-silicon microemulsion (concentrate) with particle size measured in nanometers. For this reason, it permeates through normal pores and capillaries even in case of a high level of water saturation. The preparation is suitable for damp and porous building materials, it contains no solvents, salts, etc. Mixed with water, it stays neutral and has no harmful effects on building material or the environment. During the short reaction time, its hydrophobic effect appears rapidly. The base may be damp or dry, with a relatively high salt content.

2.4 The floor

After the plants and the garden soil were removed, a subsequent study of the floor was done. It resulted in discovering new elements. The system of paired water reservoirs with grating in the floor, always placed in the middle of the field between four columns was of a particular interest.

At the base of every pole on the side toward the outer hull, small hexagon-shaped underground tanks about 45 cm deep were found. They probably served as water reservoirs for plants by the column, and also,
as it was discovered later, as an aid to dismantle and remount the columns. Lowering the pole down into the tank allows it to be tilted out and removed from the upper support beam.

All of the newly discovered elements were to be cleaned, covered with hatches, and preserved below the floor and insulation system.

2.4.1 Water areas
Two other elements directly related to the reconstruction of the greenhouse floor are the oval and round pools.

Before the restoration, the oval pool was subjected to archaeological study so that the evidence of the original pool, and its drainage trough were found. Then, these structures could be rebuilt to their original historical form.

2.4.2 Insulation against earth damp
The original horizontal insulation – a simple layer of poured asphalt – was severely disrupted over most of its surface by the roots of the plants.

To restore the insulation, it was necessary to remove the original poured asphalt, clean the surfaces and openings, cover the openings using concrete slabs, galvanized steel profiles, and galvanized sheet metal. Afterwards, the bases of the columns had to be wrapped in PE-foil and secured with bituminous putty.

Thin layer of concrete was applied to achieve 3% grade toward the heating canals, the surface was impregnated, the hydro-insulation layers of DERBIGUM system were applied, DERBIGUM GC AR 4 mm layer around the bases of the columns was melted, and the poured asphalt about 30 mm thick was laid.

2.5 External glass areas
The analysis of the greenhouse glass body carried out in 1998 was supposed to deal with an appropriate approach to its disassembly and subsequent reassembly. The study began in a pre-selected area on the outer shell (width 4 m, height 2.5 m).

Of a total of 323 glass tiles, 184 pieces, i.e. 56 per cent, could be reused; 139 pieces were ruined either prior to or during removal. Further study showed that also the condition of other components of the outer shell, above all anchoring elements (putty, pegs, metal connecting strips) was extremely bad. The quality of the glass, including the thickness of the tiles, proved variable. The original hand-made light-blue glass tiles from 1842 were 4 mm thick, while the thickness of clear glass from 1939 was 5 to 9 mm. During subsequent repairs, glass of different type, colour and quality was used, mostly 3 mm in thickness.
The analysis found that the glass hull, including all four anchoring elements (putty, silicon, pegs, and strips), had to undergo an urgent restoration, be restored as soon as possible, since it was possible that a strong wind might cause local detachment of tiles.

The study consisted of a series of analyses and tests of the individual components composing the glass hull, that is, the glass tiles, putty, silicon, pegs, or connecting strips. Laboratory tests on the glass were done in the glassmaking institute in Hradec Králové, where faults and bubbles in the glass were found out. Other analyses determined the chemical composition of the glass and its resistance to water at 98°C. Another set of tests and analyses were done at VÚSU a.s. in Teplice, where spectral analysis to establish the chemical properties of both the glass and the original putty was carried out. At the Crystalex, a.s. laboratory in Nový Bor, tests were requested to determine the spectral permeability and colour of the original glass. Not only original glass tiles but also samples that had been cleaned using the prescribed techniques were examined.

The chemical analysis results showed a sodium-calcium glass with an elevated content of Al₂O₃ exceeding today's pane glass standards. Such content severely impedes melting, but increases the chemical resistance of the glass to water, which was desirable for greenhouse glass. The content of Fe₂O₃ was also high compared to today's glass.

To be able to restore the glass body of the greenhouse using plate glass tiles, we searched for a product to replace the original glass based on several important aspects.

The most significant factor was the effort to approach the chemical composition of the original glass, and thus its physical properties, as much as possible. Another aspect was to preserve the "historicity" of the production. Finally, a glass of 5 mm thickness made in Belgium was selected for the greenhouse.

The potential large producers of industrially manufactured glass, and small producers of hand-made, individually ordered glass were contacted. Attention was not paid only to domestic sources and potential producers alone, foreign firms were addressed as well.

Elements anchoring the glass tiles to the outer body presented another problem. These are pegs set along the length of the ribbing at regular intervals into pre-drilled holes, hooks hung on the pegs, and putty.

The original metal pegs were two millimeters long. Most of the pegs had been damaged by corrosion. The new pegs are made of brass.
To set the load-bearing capacity of the hooks, the tests of zinc-galvanized and titanium-zinc-galvanized metal and the pliability of the hooks were carried out. The maximum load borne by the zinc-galvanized hooks was about twice that of the titanium-zinc-galvanized hooks.

The putty samples were submitted to spectral analysis. The samples were dark in colour, and contained around 85% dolomite limestone, 6.6% red lead, and the remainder consisted of varnish. The composition of the putty corresponded to that of glassmaker's putty of the last century, i.e. a mixture of whiting CaCO₃ and linseed oil. Red lead was added to the mixture for quicker hardening.

To avoid the situation where the metal ribs would be left free on one side the disassembly proceeded horizontally. The strip of glass tiles fixes the ribs and prevents the danger that a large number of tiles would fall out at once.

In sorting the tiles, priority was given to preserving the existing historic glasses (up to 1939). The dismounted tiles were sorted into the following groups:

a) historic glass up to 1939 (undamaged)
b) historic glass up to 1939 (damaged)
c) glass used after 1939

Glass tiles of groups a and b were marked for cleaning. Glass in group c was slated for liquidation. The actual installation of the glass was carried out in a standard way. Cleaned panes were remounted, or in individual places replaced by new 5 mm glass panes.

The tiles were overlapped by 10 mm, while maintaining the horizontal level of the tiles over the entire length of the glassed area.

3 HEATING AND VENTILATION

3.1 Principles of heating and ventilation connecting with structure

The source of heat was situated in the basement and the heat was distributed to the greenhouse by underground canals which are located along north and south side of greenhouse. Historical heating system from 1846 used steam and iron and copper distribution pipes. Hot surface of steam pipes was used for indoor air humidifying during vegetation watering.

Shape of glass envelope and orientation of structure was designed to optimize utilization of solar radiation. Solar energy help to heat up space and create good lighting for vegetation. For energy saving during winter time was installed additional thermal insulation on north glass envelope every year. For solar radiation protection due to space overheating and against high surface temperatures of vegetation was every summer time installed shading system.

Space ventilation is based on natural venting. There are several types of opening on both longitudinal sides at different height levels. For natural ventilation are used both principles - air temperature difference and wind effect.

During greenhouse renovation process was respected all historical principles of structure connected with indoor climate creation.

3.2 Heating system restoration

In 1997 the old furnace was replaced with a gas burner. Until that time the chateau had not been hooked up for natural gas. At present there are two furnaces working in the boiler room, each with an output of 165 kW. The entire system has been given an automatic control system that was connected to the previously-existing year-round monitoring system. The heat transfer medium is now hot water (the design temperature drop is 90°/70°C). The system also serves to warm up water for watering the plants during the winter. The heating emitters are constructed from the pipe heating coils. As per the wishes of the client, all of the heating surfaces (except the small defrosting pipes) were laid in the old heating canal, thus limiting to the maximum possible extent of the total surface area of the heating system registers.
3.2.1 Heating canal – positioning of the heating elements
To achieve water evaporation and humidification, and also to increase the efficiency of the elements in the canal below floor level, a support ventilation system was also designed in order to force the air from out of these canals. The speed of the air flowing over the surface of the water will be about 1 m/s. The air forced through these canals comes from inside the greenhouse.

3.2.2 Support ventilators
Along the total, straight length of the heating canal (140 m), evaporation comes to about 100 kg/h during full operation of the system. In the greenhouse, which has a volume of 14,343 m³, this results in an increase in humidity of 7.5 g/h per 1 m³ of air. However, it is necessary also to take into account the fact that part of the supplied heat is consumed in evaporating water, and to add water to the canal to replace it. The results shown are therefore only approximate, because they are based on the assumption of a constant state of evaporation conditions, and an idealized model of geometric calculations. Regaining water from the heating canals realistically only occurs during the heating season. Even so, the calculation of humidity in the greenhouse provided the information that it was possible to make use of the water surface in the canal to increase humidity during the winter. The theoretical calculation showed that when warm air is passed over such a large surface of water, evaporation is sufficient to maintain the necessary humidity. However, it was necessary to achieve the proper configuration of the canal from a structural standpoint. In the summer the plants must be misted.

3.2.3 Control system
The greenhouse is equipped with equithermal control depended on interior temperature, which makes it possible for the control system to take into account heat gains from sunshine. In each zone the temperature is monitored on several levels vertically, as well as the temperature of the exterior on the northern side of the greenhouse, and the relative humidity. Impulses from the sensors are processed in the control unit located in the boiler room. The system is connected to a computer terminal in the service office. From the computer it is possible to alter the working of the furnace and the system of defrosting pipes; the central PC also monitors the state of repair of the furnace. Another part of the measurement and control system is an archival module that records extremes of temperature and renders them visually in the form of charts and graphs. The archival period is one year.

In taking into account the possibilities for zonal regulation, the heated areas were planted so as to allow for the individual controlling of four parts of the greenhouse:

Zone 1 – from the floral hall to the first couple portal
Zone 2 – from the first couple portal to the middle of the greenhouse
Zone 3 – from the middle of the greenhouse to the second double couple portal
Zone 4 – from the second double couple portal to the back portal at the end of the greenhouse

The primary circuit of the furnace is also regulated independently in accordance with the requirements of the individual zones.

3.2.4 Defrosting circuit
This prevents frost condensation on the outside of the hull of the greenhouse, while at the same time preventing the undesirable occurrence of icing, which could have destructive effects on the glass hull envelope. The pumps of the defrosting system switch on when the temperature on either of two sensors on the shell drops below 5°C. They turn off again when the temperature reaches 8°C.
4 CONCLUSION

At the present time the only unfinished work on the interior of the greenhouse is part of the stone ledge that was delayed due to increased humidity. The estimated date for this part is 2004, after restoration is finished on the ventilation and drainage canals running around the exterior perimeter of the greenhouses base.

In 2001 planning documentation was begun, including restoration studies for the catacomb. This documentation was completed in 2002, 2003 and it is anticipated that construction and restoration work on this stage will be started in 2004.

Monument care of palm greenhouse on Chateau Lednice was awarded by GRAND PRIX 2003 price of architectural associations in category Restoration of structures.

REFERENCES


