Sustainable natural ventilation and cooling of museums

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ABSTRACT

In most museums without air conditioning the situation is very similar: room temperature in summer often exceeds limits of about 26°C which are not favorable for artifacts and people in the museum.

A far better, simpler, cheaper and more sustainable solution than installing fan coils in warm summers would be to use well filtered cold outside night air in order to pre cool at night the building masses of the exhibition rooms to compensate for accumulation of heat during the day. Normally in historical buildings this could be done with a minimum of investment if there are historical shafts or chimneys available.

Keywords

Natural ventilation; sustainable cooling; night cooling of museums; green museum, microclimate

1. Introduction

Most museums mechanically cooled or not, often have the same problems: during hot summer periods heat accumulation will rise inside temperature above the acceptable 24°C. Often mechanically chilled museums have the same problem, because shading systems are often mounted wrongly inside the windows. Therefor of little effect against the sun's rays in summer.

With best possible shading systems and night cooling in the sense of "natural" ventilation, there are simple and efficient tools to keep museums cool during hot summer periods.

The origin of this idea is the awareness that only in 2 critical months per year, June and July, 30% or 50% of the time, outside absolute humidity is above 13gr/m³. That means, outside air could not be used for drying inside air in a museum or for lowering room temperature by cooling the building masses The rest of the year you can always dry excess inside humidity with drier outside air. During this period of the year, if outside air is cooler than inside air, you also can cool the building with a double air exchange rate at the lowest.

Principally there are two major approaches to achieving best possible results for night cooling:

- Either by using ventilators in windows, which are not seen from outside and well hidden from inside,
- Or by using existing shafts in historical buildings for night cooling ventilation,
- Or by installing air handling units to have a double air exchange rate during cold summer nights to lower room temperature in warm summers in exhibition rooms.

The following graph shows this relationship.

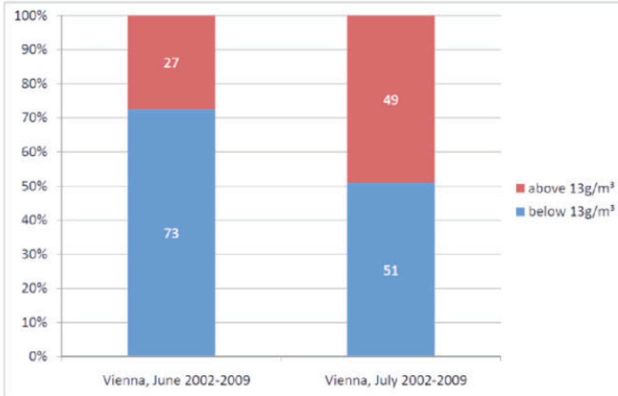

Figure 1 Frequency distribution of absolute humidity in summer in Vienna.

After having reduced sunshine loads by using the best possible outside shading and also internal loads by choosing light with a minimum of heat, often windows can be used for night ventilation. An air intake is chosen, if possible, from a northern window, leading the air with a minimal overpressure to windows situated on the opposite side, where an exhaust fan, installed in a window as well, will provoke at least a double air exchange rate for cooling building masses of the museum.

A possible solution of cooling with chilling units (fan coils) is not the right approach because of the costs for machinery and running costs, not to mention esthetic problems and dust pollution.caused by installing the fan coils

The following 7 examples in Vienna (A), Hamburg (D), Eisenstadt (A) and Mauthausen (A) will show and prove the simplicity of these "natural" ventilation systems.

In literature natural ventilation together with night cooling is not often discussed. Also there are very rare proposals for external shading systems which comply with the demands of monument authorities.

Generally, the following measures will help to improve the situation:

- First of all a museum has to be "airtight", that means firmly closed windows, closed shafts and buffer zones in order to reduce air infiltration from outside with the consequences of dust and dry or humid air.
- In order to get rid of external loads, glass roofs and windows have to have outside shading systems, all other solutions are inacceptable – except in cases when there is a possibility of exhausting inside from the windows with those "wrongly" situated inside shading

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systems. The hot air which is created inside the window through the "glasshouse effect" can be exhausted by an air handling unit.

- Installing (LED) lighting which results in the best possible lighting for the artifacts with a minimum of heat.
- Creating a night air exchange rate of 2 in hot summer periods by using either natural forces of wind or by shaft effect by using differences in temperature or by differences in the building by luv and lee or using finally mechanical air handling units.
- A control unit which activates natural or mechanical ventilation by comparing inside and outside temperature and absolute humidity in order to leave an unfavorable climate outside the building.

The lack of night cooling and ventilating systems always show similar effects: Daily heat accumulation even only of 0,5°K in warm periods results in much warmer exhibition rooms than those rooms which were continuously ventilated and cooled naturally. This is the result of installing a natural ventilation system in the Museum of Applied Arts in Vienna. The proof of logged room temperature data will be given, when the first data are available.

2. Hofburg, Vienna, Corps de Logis

Originally "natural ventilation" was learned and studied by the author while reactivating the "natural ventilation system" in "Corps de Logis" in the "Hofburg" in Vienna (A) during refurbishing works.

In the "Hofburg", a historical building of the late 1890, a natural ventilations system was installed.

Figure 2 View to historic Hofburg.

As shown in the following plans (Fig. 2) from the garden through huge air intakes, outside air was led into the brick labyrinth tunnels in the basement.

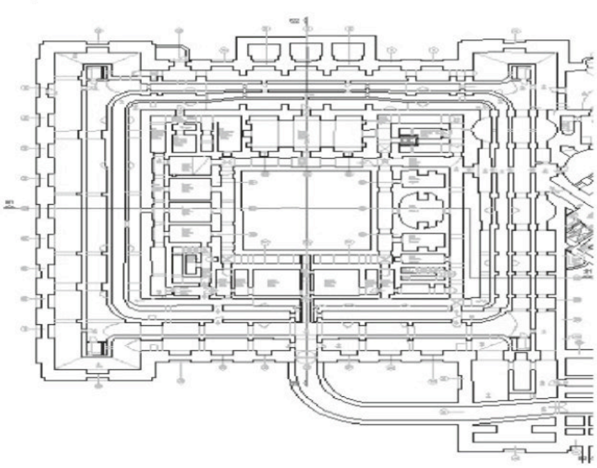

Figure 3 Plan of the basement.

From the basement in 1 of 2 shafts in all 4 corners, altogether 8 shafts, cold air in summer (and warm air in winter) was led into the exhibition rooms. At the end of the rooms on one floor, which were connected by air ducts, the second shaft had an opening to the outside in the loft, which ended with a mechanical flap which opened onto the outside when natural driving forces were enough due to difference in temperature. If not a historical American "Blackman" ventilator of 1905 created enough under pressure to transport air in the shafts from the basement through the rooms towards the outside. The outside air guided through the tunnels and the rooms was transported by the stack effect to the vertical shafts in the corner and sucked through the rooms by stack or – if lacking – by the historical ventilators. The following scheme shows the air flow.

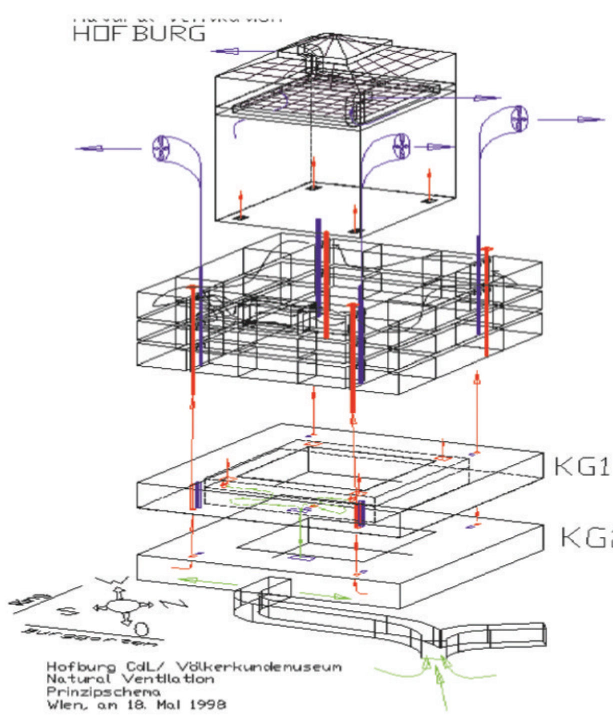

Figure 4 Scheme of air flow.

3. Schönbrunn Castle, Vienna

This historic system of natural ventilation was applied in Schönbrunn Castle since every summer complaints of too warm show rooms were to be heard.

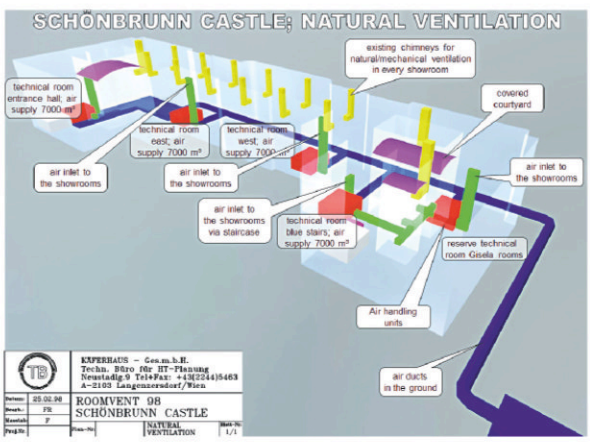

Figure 5 natural ventilation in Schönbrunn Castle.

When a 200 m long historic underground tunnel (80/150cm) 1 m below the surface was found, made of clay bricks and pointing in a western direction in the park, the decision was taken to use the cooling effect in summer to pre-cool the exhibition rooms during the night (and inversely to pre-heat ventilation air in winter).

Therefore, some years ago a huge connecting tunnel (diameter 80cm) was dug and pushed beneath the castle in order to bring outside air through the historic tunnel into the basement where the air handling unit (about 7.000m³/h) was installed to ventilate the western wing of the castle through existing shafts.

In these shafts, horizontally mounted ventilators were installed together with flaps against smoke and fire. These flaps also interrupted all natural ventilation through shaft effect when not necessary or not favorable. These shaft ventilators were used as generators when spinning only by shaft effect, showing by means of a meter the naturally transported amount of air. When more air had to be transported through the rooms, electric power was given to the ventilators according to the calculated necessary amount of air to be transported.

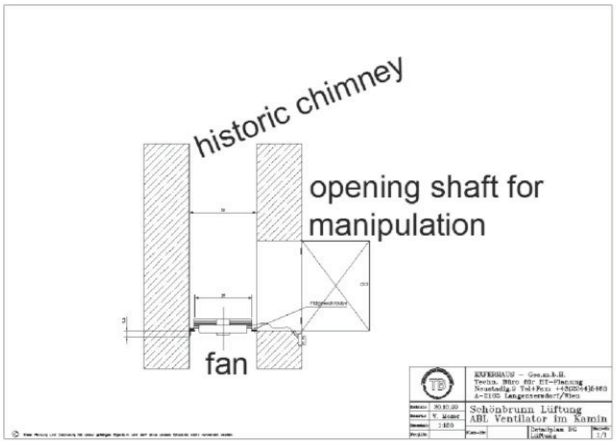

Figure 6 Ventilator in historic shafts.

This natural ventilation system in the historical tunnel without chilling or heating machinery resulted in a heating capacity of about 54 kW. The chilling effect in summer was about 64 kW cooling power. This was the result of dynamic simulations which were confirmed by measuring campaigns in the following year.

For the western part of Schönbrunn Castle the natural ventilating and cooling effect was enough to keep the complaints of visitors and employees under control.

To serve the rest of the castle with conditioned air a new air exchange tunnel in concrete with brick walls across direction of air flow was built in the earth beneath eastern "Lichte Allee" with a capacity of about 14.000m³/h.

4. Academy of Fine Arts, Vienna

In the historical building of the Academy of Fine Arts, Vienna, (A) the south oriented "Hansen-exhibition room" of the famous painting gallery was naturally ventilated through existing shafts in outer walls in which ventilators were installed to lead filtered outside cold night air into the room with precious "Dürer" engravings. In this room another shaft towards the roof exists which was used to get rid of the cooling air only by means of an autorotation ventilator, which was working on top of the shaft on the roof only by stack effect as a consequence of difference in temperature.

An intelligent control unit, operating especially at night, starts the ventilators by comparing absolute humidity inside and outside and also temperature in order not to bring harmful climate from the outside into the exhibition rooms.

The following systematic sketch shows the simple installations of the natural ventilation in the painting gallery which helped at night, during hot summer periods, to keep accumulation of heat under control in order to limit room temperature in summer to about 24°C.

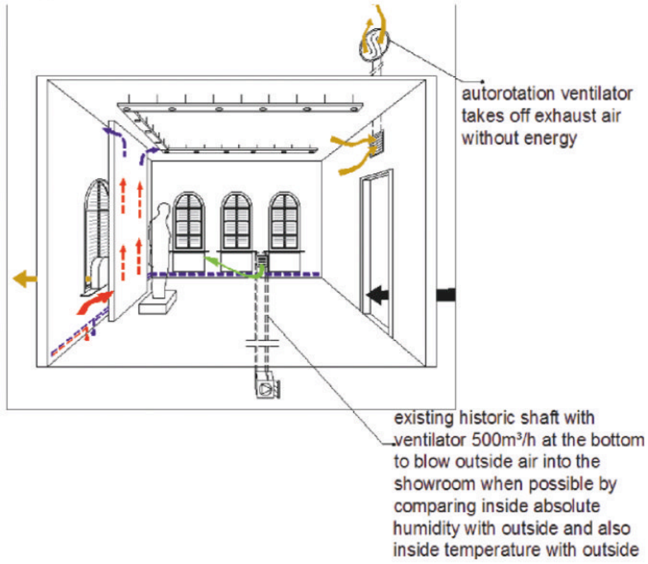

Figure 7 System of natural ventilation in the Academy, Vienna.

5. Burgenländisches Landesmuseum, Eisenstadt

In the "Burgenländisches Landesmuseum" in Eisenstadt (A) a similar situation was found:

Insufficient shading systems, far too "hot" lighting in the exhibition rooms and strong southern sun, slowly increased room temperature to above 26°C due to heat accumulation in the outside walls.

Figure 8 View to the Landesmuseum, Eisenstadt

A simple system of natural ventilation through windows was installed after having improved shading and lighting. On the northern side of the museum, in the courtyard, a window ventilator with an efficient filter of about 2.000m³/h was mounted on a wooden board instead of the glass.

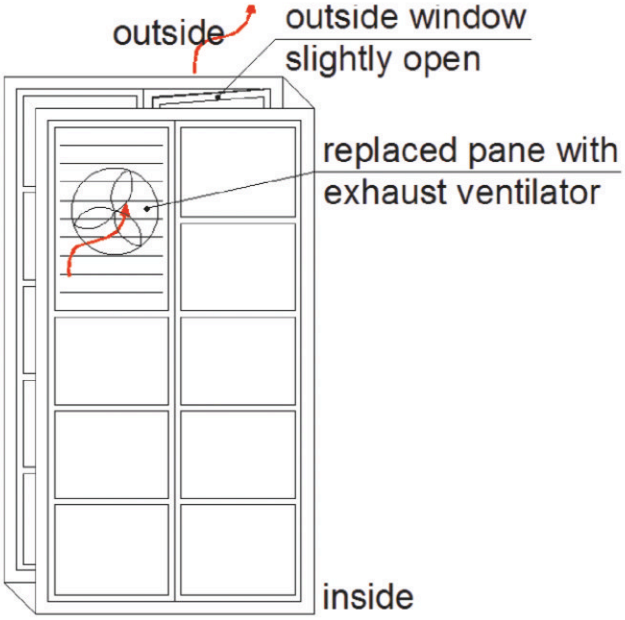

Figure 9 Ventilator, mounted in a box window.

On the southern façade, a window ventilator was installed as an exhaust system in a box window. The ventilation system is controlled by temperature and absolute humidity and will be activated at night (and sometimes also at daytime) when all parameters are favorable to cooling. Also this system is driven by small overpressure of about 10 Pa.

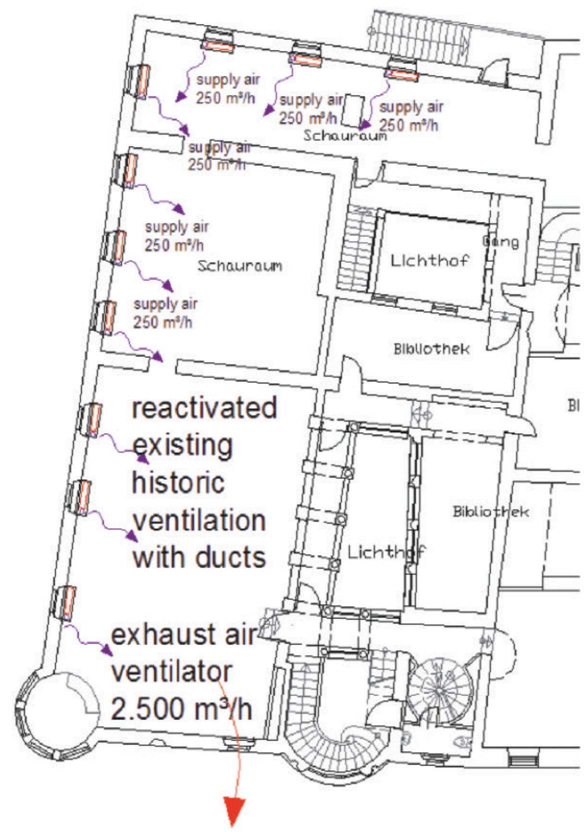

Figure 10 Floor plan of "natural" ventilation.

6. Maritim Museum, Hamburg

The very famous "Maritim Museum" in Hamburg (G) had a similar problem:

Always in summer, exhibition room temperatures exceeded 26°C, especially on upper floors.

Figure 11 Maritim Museum, Hamburg, D.

Moreover, there was another major problem: the ventilation of the museum was based on leaky windows with the negative result of dust pollution in the exhibition rooms and entrance of outside climate in winter (dry and cold outside air) and humid air in summer, due to a large uncontrolled air exchange rate.

Furthermore, there was a anti smoke ventilation system installed in the museum in case of fire.

The first step to improve climate stability and dust pollution in the exhibition rooms was to stop uncontrolled air exchange through the gaps of the windows by sealing them. Then the anti smoke ventilation system and the flaps on top of the museum were activated during hot summer periods when night temperature was significantly lower than day temperature, controlled by comparing not only temperature inside and outside the museums but also absolute humidity.

The result was a significant improvement of summer room temperatures of about 24°C without installing big machinery, but only by sealing the windows and changing the commands of the rescue ventilation system (according to official prescriptions!), which was done by museum personnel

7. Museum of Applied Art, Vienna

The "MAK" in Vienna (A), the "Museum of Applied Arts" has similar problems: Despite 3 chilling units, 2 for depots in the basement and one for the "Weiskirchner Wing", the rest of the museum along the famous "Ring street" in Vienna has no ventilation system at all. The result in summer is felt in the exhibition room temperatures far above 26°C, which is unbearable, both for artifacts and for visitors.

The reason for the heat accumulation in this museum are glass roofs, which were refurbished with insulating glass and inside shading resulting in tremendously hot exhibition rooms in summer.

Even a ventilation of the lofts of the museum of about 12.500m³/h each was no relief, since the control unit for ventilating, situated beneath the room was wrongly programmed.

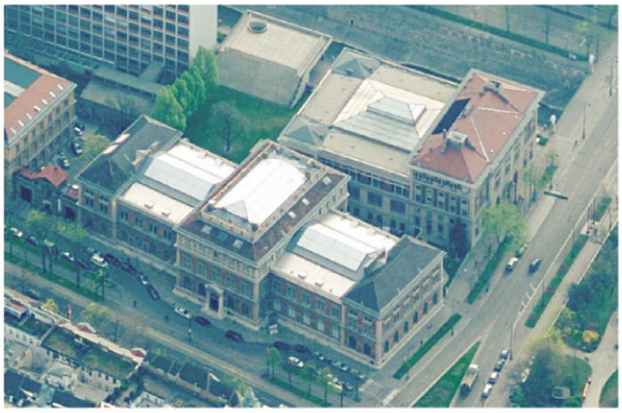

Figure 12 View to the glass roofs in MAK, Vienna.

In order to improve the situation the following steps were planned, accepted by the management and begun. The improvements will be measured by a measuring campaign when the refurbishment is completely finished to justify the investments made.

- Mounting of an outside shading system made of expanded aluminium sheets, which reflect high summer sun and allow low winter sun into the loft of the museum beneath the glass roof
- Improving the existing ventilation system for the room below the glass roof by blowing outside air, when cooler than inside air, along the glass roof and building a new exhaust duct to collect hot air outside the room under the glass roof. In addition, the algorithms of the control unit were improved.
- The existing ventilators for ventilating the roofs with 5,5kW were changed into state- of-the- art ec-motors with 1,5 kW, resulting in a significant electric power saving. Together with these improved ventilators, additional ducts and nozzles were installed in the exhibition rooms producing a night cooling of the northern part of the museum; as shown in the following plan.
- To have an additional cooling effect during very hot summers in case night cooling is not sufficient, a small Danish ventilation and chilling unit of about 25 kW and 5.000m³/h can ventilate and cool the northern rooms.
- The exhibition room of carpets needed to be protected from dust and cooled in summer. Dust reduction was achieved by new glass doors. By a very simple means the existing floor heating in this room was used to bring in the room chilled water above 16°C (to avoid condensation) from the nearby chilling unit in the basement and the connecting buffer. So very simply the room could be kept at a constant cooler temperature in summer.
- Finally, the existing shading system in the southern box windows was improved and naturally ventilated by new little handles in every window which ventilate the box of the window by creating a little gap without letting rain through the window. With this simple construction, hot air inside the box window is ventilated to the outside thereby lowering the surface temperature of the inside windowpane by about 10°C compared to the southern box windows not ventilated or "cooled" in this way.

The handles have to be opened and closed twice a year: in spring before the hot season and closed in autumn to use the buffer space in the box window as a protection against the cold.

8. Book shop in Mauthausen Memorial

The last example of intelligent simple "natural" ventilation by night cooling, using the big masses of concrete buildings is the bookshop of the Mauthausen, a museum in Austria.

The shop is a building with a huge glass façade facing south, 26m long with a width of about 6 m and a height of 6,5m. The roof is partly glass. There isinside shading by vertical wooden bars in front of the large window, which is useless. The shop has no basement and no floor above it.

There is ventilation and a cooling system, which does not work as planned. It is so inefficient that there is no cooling effect. The heat is unbearable.

There was an existing ventilation system of double air exchanges rate blowing from the colons into the room. On top of the large window, a new air exhaust duct was mounted and connected to the exhaust air duct in the ceiling. This duct extracts warm air from the window, since behind the duct a curtain of heat reflecting lamellas transforms the ultra violet sunrays into infrared heat rays (glasshouse effect). During cold summer nights outside air will be ventilated and circulated through the shop with double air exchange rate, using the concrete building masses to pre cool the shop for the next hot day.

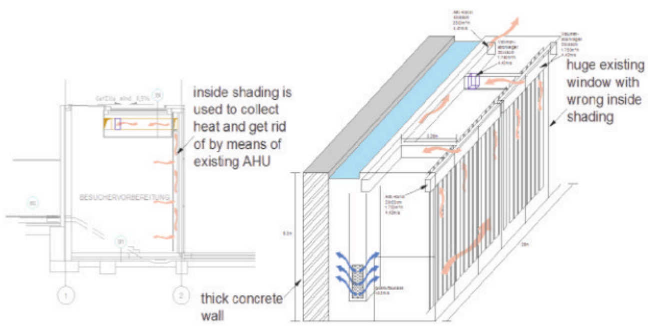

Figure 13 Scheme of improvements against summer heat

With these simple installations the bookshop is usable year round, since in colder periods the lamella curtain is opened to exploit the sunrays, whereas in winter at night the curtain is closed to create a buffer zone inside which helps to reduce heat losses or rises comfort in winter in front of the cold window pane.

9. Conclusions

All these examples have shown how simple it is to avoid overheated exhibition rooms in museums during the hot summer months. They show some proposals of how to improve such critical situations by means of "natural" ventilation.

10. References

[1] KAEFERHAUS, J. Nachhaltige Renovierung museum aktuel, München, (2010), Seite 25-28

[2] KAEFERHAUS, J. Quo vadis Austria museum aktuel, München, (2005), Seite 62-66