USE OF BASEMENT IN PASSIVE COOLING OF AN ADMINISTRATIVE BUILDING IN SION (SWITZERLAND)

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ABSTRACT. This study presents the measurement and the analysis of a passive cooling in an office building. Dividing the cooling plant into three subsystems, we model the whole system in order to determine which parameters are the most influential on the system efficiency.This paper discusses the possibility to use the basement in passive cooling.

1. Introduction

In an urban context, even in countries with a moderate climate like Switzerland, cooling is often necessary in administrative buildings when considering effects like : urban microclimate, solar gains through windows, lighting and internal gains. In a well designed building, cooling needs are not high enough in intensity and time to justify the investissement cost and the electricity consumption necessary to install and to run a standard air conditionning system. Because these buildings generally include several underground floors, we are investigating the possibility of using the fresh air from the underground floors to cool down the offices.

2. Plant description

We have studied a simple case in order to acquire a good know how for such systems. The chosen building is located in the city of Sion, which lies in the Rhône Valley, in the Alps. Built in the 19th century,it was renovated in 1989 and devoted to administrative offices. In summer time the outside temperature can easily reach 30°C and even if the building is properly insulated, the last floor (mainly garrets under a slated roof) can reach more than 28°C. It was then desirable to install a cooling system for this last floor. The building includes wide and deep cellars about 10 meters underground, as seen in figure 1. The air used to cool the last floor was brought from these cellars thanks to a fan. The main characteristics of the plant are :

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cooling source : cellar
deepth : 10m
volume : 300m3
walls + ground area : 500m²

Air distribution network
fan : 1000m3/h, 400W
ducts : steel, not insulated, 8m before fan and 23m after.

Cooled area
total area : 200 m²

Monitored office
South-West orientation
.wall insulation : 0.10m
.roof insulation : 0.16m
.area : 17.5 m²
.volume : 44.5 m3
.window : double glazed
.skylight window area : 1.1 m²
.shell window area : 0.4 m²
.changing air rate : 4.5 per hour
.internal loads : 78 W (1 pc on 24h/24)
.employees : 1-2

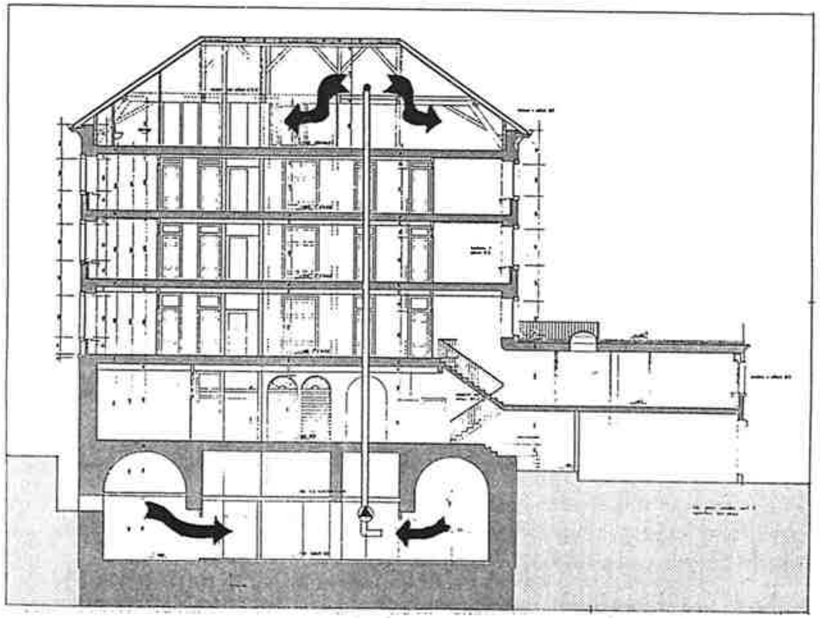
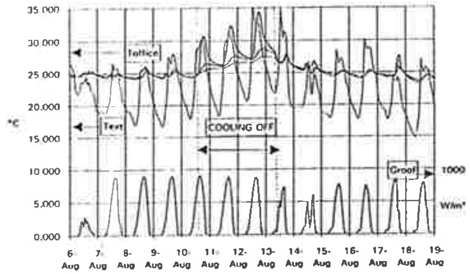


Figure 1. Passive cooling system.

3. Monitoring and results.

We recorded data (mainly temperatures) during the summer 1989, in order to characterize the building without cooling system. The passive cooling plant was completed during the spring 1990. We then started the monitoring of the building to evaluate the performances of the cooling system. The data deal with hourly measurements on 40 channels such as temperatures, humidities, solar radiation, air flow rate, electrical consumption and other parameters. We mainly focus on the largest cellar and the most overheated office (located South-West).

Good comfort was reached during summer 1990 thanks to the passive cooling system. Figure 2 shows the meteor data for two weeks in August and the corresponding South-West office temperatures at three different levels : 0.1 m (close to the floor), 0.9m (working place) and 3m (under the roof). The fan has been switched off during 3 days (from August 11th to 13th) to confirm its effects and an immediate stratification of temperature appears.



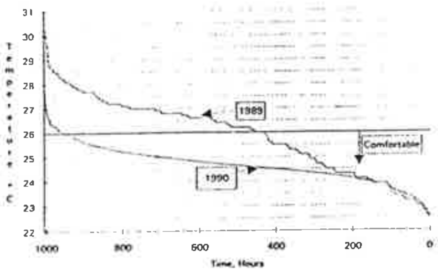


Figure 2 . Temperatures and meteor data versus time — Figure 3 classified temperatures
Temperatures in the South-West office, from August 6th to August 19th.

Figure 3 shows the classified hourly air temperatures of the South-West office at the working place during 1989 (without cooling), from July 27th to September 9th, and during the same period in 1990, with cooling but with 70 hours without cooling, as seen in figure 2. In the summer of 1989, which was cooler than summer 1990, the South-West office was inoccupied for most of the month of August.

4. Modelisation of the system

4.1 THE COOLING SOURCE : THE CELLAR

The measurements show that,when applying daily values, the cellar output air temperature can be described as a mixture of two air flows, one at the cellar structure temperature and one at the mean daily outside temperature (see figure 4).

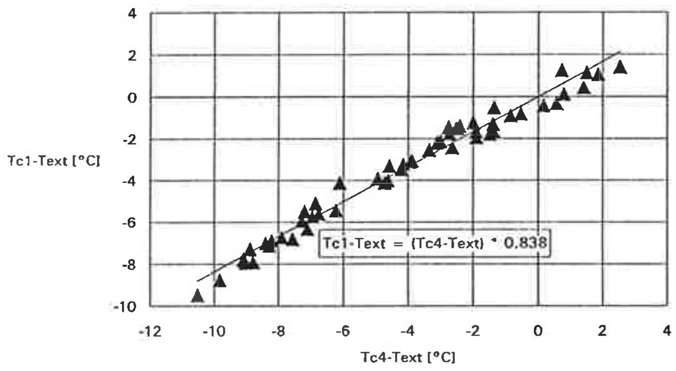


Figure 4. Correlation between the temperatures of the outside air (Tex), of the cellar structure (Tc4, 50 cm under the ground) and of the cellar output air (Tc1). Daily values.

4.2 FAN AND DUCTS

The signifant sources of heat gains were :

. the fan, because the motor is inside the duct,

. the friction losses in the duct,

. the heat transfer through the wall ducts,

. the air infiltration before the fan.

The relative importance depended of many parameters and the modelling of this part was long. An example is given in figure 5.

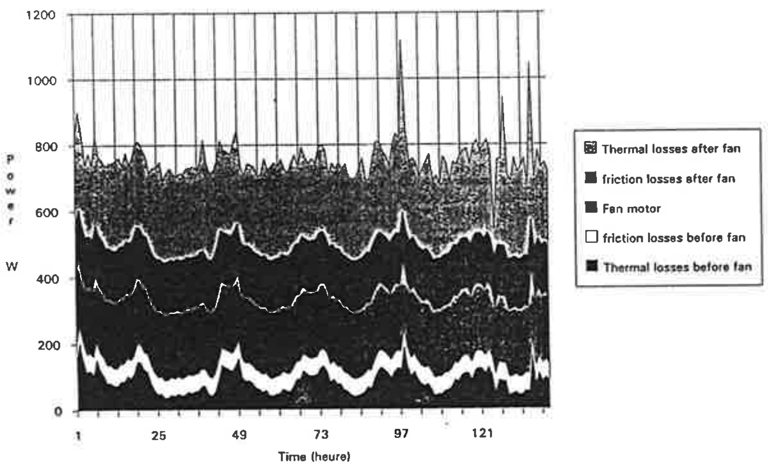


Figure 5. Heat gains in the air distribution network.

4.3 SOUTH-WEST OFFICE

For this office, we used a simplified method with one node thermal diagram. In fact, the most important cause of discrepancies of the model was the bad knowledge of parameters like : incline of internal blind strips and the corresponding solar transmission, heat transfers from the other rooms in relation with the opening of the door, the number of people in the office, air infiltration through the open window,... All these parameters are very difficult to deal with and we preferred to use simple but reliable parameters including all these effects and determined with daily value analysis (see [1]):

. total heat loss factor U =2 to 27 W/K,

. total effective area for solar gains Aeff = 0.3 to 0.45 m² (0.2 m² was due to the skylight window, 0.1 m² was due to the roof transmission and 0.1 m² was due to the shell window).

Dynamic model for the office temperature with this one node diagram gave good results, specially when considering classified temperatures during the summer time. Parameters used in this model are hourly values of outside temperature and of solar radiation on the roof, heat loss factor = 27W/K, effective area for solar gains = 0.4m² and heat capacity of the office but with respect with the air temperature variation = 1500 Wh/K (see [2]). We recall that the main cause of errors was not the simplicity of the model, but was due to the difficulty in estimating the parameters.

4.4 RESULTS OF SIMULATION

Thanks to these models, we were able to describe the whole system and to carrefully study the effects of each parameter. We gave the quantitative results, described in details by [1] and [3] and we only focus on the qualitative consequences in the next section.

6. Discussion : use of basement in passive cooling

The use of basement in passive cooling and in urban context is possible but has several implications :

Site implication :

.In addition to the existence of fresh undergrounds, the air must be clean and safe. Radioactive pollution with radon is to be considered carefully. In our case, we measure a very low content of this gas in the cellar (24 Bq/m3). When a problem of air pollution occurs, a air air heat exchanger will be used, but simplicity and low cost are partially lost.

Architectural implications : such a system needs :

.a very good insulation of the roof (decrease of solar load)

.a very good solar protection

.a good thermal inertia with good thermal coupling between thermal mass and inside air,

.a space to install the duct (from undergounds to the last floor!) in case of retrofitting,.

.a limited area is to be cooled (for instance, the last floor under the overheated roof). For greater areas, it would be more complexe and expensive.

Technical implications

.good fan, with external motor, and low friction losses (well designed ducts)
.no duct in depression in order to avoid warm air infiltration,
.good insulation of the ducts in warm conditions

User implications

.good comfort if good management of solar protection, lighting and electricity use.

7. Conclusions

The passive system we have studied in detail runs very well and the same comfort as a standard climatisation is obtained, but requires half of the investissement and less than 25 % of the operational costs [1]. The use of underground in passive cooling in an urban context is often possible, in new buildings as well as in retrofitted buildings, but needs special attentions. Note that other cooling sources could be used : river, underground, ...

8. References

[1]. R. Meldem, B. Lachal, C. Ançay, W. Weber, O. Guisan, Rapport final : Climatisation passive du Bâtiment Aymon à Sion, to be published in June 1991, Geneva University.

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