Low energy cooling in historical library office hall

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ABSTRACT

Requirements on working environment in office buildings according to Czech law express optimal air temperature, globe temperature, humidity and air velocity. In the case of historic library office hall with skylights, located in the centre of Prague the main problem was overheating during summer period. Paper describes problem analysis using CFD tools, measurements and building energy performance modelling tool, design of energy efficient and sustainable measures and evaluation of results.

1. INTRODUCTION

Historic library office hall, built in the beginning of 20th century, is used to service library users with catalogues, administration and library front office services (Fig. 1). Due to technology development in recent years (computers, copy machines) there was significant growth of internal heal loads simultaneously with exacting of indoor environment requirements. Next major heat load source are sky lights. The hall is designed as single zone cast concrete hall 20*40*8 m with 6 double pitched sky-lights in the flat roof. Total area of skylights is 240 m^2, glazing with no reflective sheet (r = 0,9). There is warm – air ventilation system installed with no cooling, built in last century. Because the only existing way of cooling of such space is fresh outdoor air ventilation, the basic problem of the hall is overheating in summer period, when indoor resultant temperature exceeds required 26°C. This study describes possible solution of improvement of indoor environment, respecting the historical value of the building, using simulation and engineering approach.

Figure 1: Library hall.

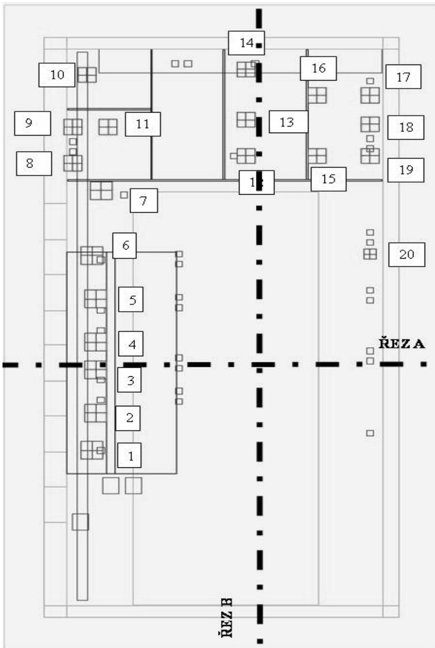

Figure 2: Working places layout.

2. METHODOLOGY

First idea to solve the summer overheating was to install traditional air cooling system, but due to high heat gains (over 140 kW) and limited possibilities of existing duct size increase this solution was cancelled. After deeper problem analysis (Novoselac and Srebric, 2002) together with architect, client and historical authority representative the integrated solution has been accepted. First step has been aimed to decrease exterior heat load from skylights. To achieve that, existing glazing has been covered by additional reflex film layer with shading coefficient s = 0,4. This step decreased heat load in critical summer period from 140 to 70 kW. In spite of reduced heat gains, existing ventilation system with no cooling was not able to ensure thermal comfort in working zone. Next step was to improve microenvironment at the working places of permanent employees, which are located generally at hall perimeter (Fig. 3 marked with boxed numbers). There was accepted technical solution based of installation of radiative cooling ceilings below the lowered gallery, which runs along three sides of hall. Radiative cooled ceiling, designed for temperature gradient 17/20°C on the area 70 m^2 has design cooling output 6 kW, which covers only less than 10% of total heat gains (ASHRAE, 2001). This solution of course does not create thermal comfort in entire space of the hall, but according to engineering practice should improve thermal comfort locally, at the fixed working spaces. To evaluate this engineering prediction, CFD model of the hall has been created to simulate expected thermal behaviour and thermal comfort.

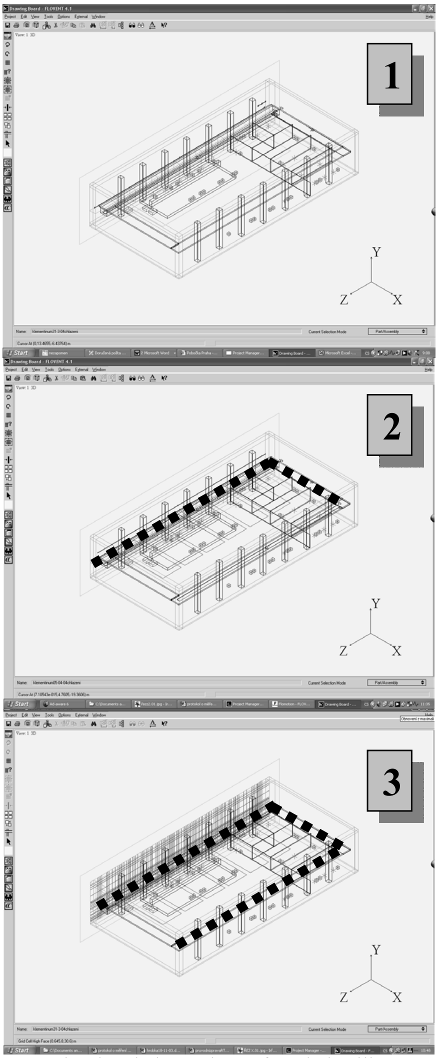

Figure 3: Simulated alternatives of cooled ceilings.

3. MODELLING AND SIMULATION

To model solved hall, we used CFD package Flovent (Flomerics, 2001; Kabele and Kabrhel, 2003).

3.1 Model

Based on optimisation of detail level, computing time and computing stability we described problem with a grid of 122 240 cells covering the simulated space with variable density. Simulation runs under turbulent air flow model k-ε and static boundary condition, describing critical situation, when ambient temperature is +32°C.

There were three alternatives simulated (Fig. 3):

- Alternative 1 - reference, describes existing situation with no cooling ceiling installed.
- Alternative 2 describes situation, when cooled ceiling is installed along 2 sides of the hall.
- Alternative 3 cooled ceiling installed along all three sides of the hall).

Cooling ceiling is installed in the height 2,45 m above floor level, width of the active zone is

0,6 m at the longer sides and 1,6 m at the shorter side of the hall. Surface temperature was set to constant +19°C to avoid air moisture condensation.

3.2 Results

CFD simulation method results into set of data, describing air velocity vectors and temperature scalars in each of grid cells. To select conclusive data from this huge data set (more than 40 MB of values for each simulated alternative) we used air temperature data presented by comparative graphs for monitored working places (Fig. 4) and spectral air temperature and vector velocity analysis in cross-over sections of the hall (Fig. 5).

Above described mathematical model was compiled to find out the influence of synergic action of thermal radiation and convection on the final state of internal environment in an office hall from the view of operative temperature and air temperature in local workplaces. Modell compared the current situation and the designed one, where two positions of cooling ceilings were designed (Kabele and Dvořáková, 2004). Applied method of CFD (computational fluid dynamics) provides an idea of three – dimensional layout of temperatures and speed vectors of air flux in studied interior. In our case a static model was applied using external conditions currently used to desing air-conditioning in summer period covering external air temperature influence and solar radiation with values for the noon of 21st July, next the influence of the floor being on the ground and the northern wall bordering the complex of massive buildings of the library. Concerning iternal sources thermal gains from office equipment (computers and copiers) were involved in computation installed according to the investor´s assignment. The main task was to reach the idea of the cooling ceilings´ impact on microclimate in a critical situation therefore no working air-conditioning (assigned just for ventilation not for cooling) is improving thermal balance of the examinant space.

Examined alternatives – positions of the cooling ceiling on two or three sides of the hall below the lowered galleries – clearly show the ifluence on the reduction of the operative temperature in the working places of the library during summer period. Alternative 2 – position of the cooling ceiling on three sides - proves better temperature distribution and heat load reduction in monitoring places. Negative

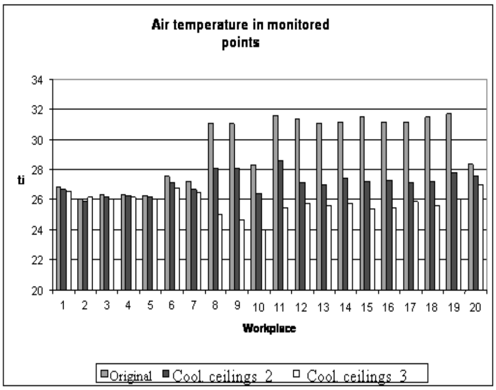

Figure 4: Comparison of air temperatures in monitored working places.

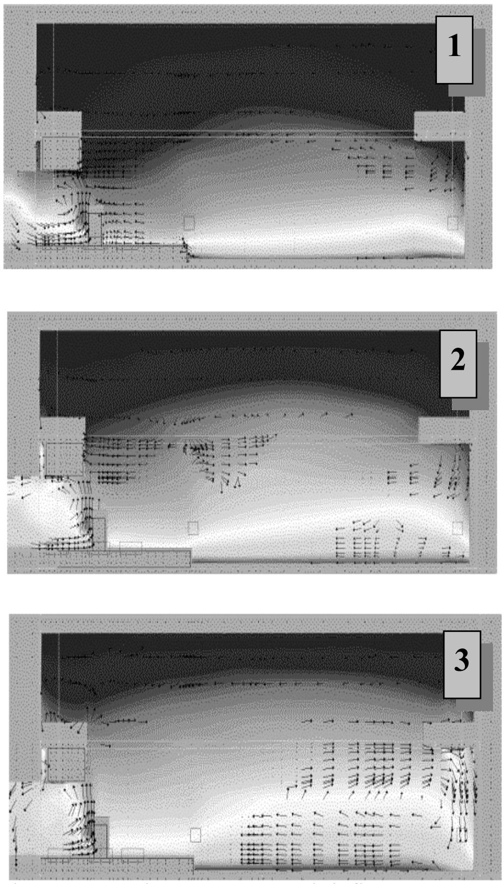

Figure 5: Operative temperature and air flow patterns – alternatives 1, 2, 3.

radiation of cooling ceilings in these places causes the decrease of operative temperature as well as the decrease of air temperature by the influence of convective flows so that according to the conditions mentioned above the maximum of air temperature in monitoring points reaches 26,9 °C.

It is necessary to warn that this solution doesn't provide any elimination of heat loads or any temperature reduction in the whole space of the hall, but it only provides improvement of conditions on a local level in working places so that the working environment reaches the requirement of NV 178/2001, where the operative temperature in closed workplaces during the summer period is set to be 20-28 °C at the air flow speed of 0,1-0,2 m/s.

Advantage of this solution is in low energy demand on the cooling source - capacity runs into 6 kW in maximum, which is approximately 11 % of heat loads of the entire place of the hall, reduced after the shading of glazing to 75 kW.

4. CONCLUSION

The presented case study shows possible uses of the method to decrease energy consumption in the office hall using local cooling. The development of application of the methods of computer simulation opens up a large space for future research in the field of optimization of the building energy performance.

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