Passive cooling techniques as part of energy rehabilitation measures in office buildings in Greece

Ch.J. Koinakis
Technological Educational Institute of Thessaloniki, Greece

ABSTRACT

This paper is focused on passive cooling techniques and especially on natural and hybrid ventilation as part of energy rehabilitation measures during an office renovation project. Natural, hybrid and mechanical ventilation was designed to decrease cooling demands and to obtain acceptable indoor air quality for the various needs. In some cases mixing of indoor and outdoor air was implemented. Air-draft problems were solved rearranging the type and the use of windows and using proper the air-grids. In order to select the proper ventilation type and characteristics, ventilation efficiency tests were performed for each area, according to the area population, taking to account the peak demands per space. The implemented passive cooling techniques include natural and hybrid ventilation during the night and the day and are combined with basic solar shading measures.

1. INTRODUCTION – CURRENT TRENDS

The installed air condition systems in the public office buildings of this category were vastly increased in Greece after 1986. Based on a brief survey in 2002 the air-conditioned spaces in the above-mentioned buildings have increased over 650 percent in the years 1986-2002 (Koinakis, 2001). This is a combined result of the trends in the Greek market, the increase of the family income and severe heatwaves after 1985. This increase rate is about 20 times greater compared to the respective trends in the European Union according to I.E.A. (1998), Wittchen and Brandt (2002), and Santamouris (1990).

There is still great potential for future penetration of air conditioning in buildings of this category, since less that 40 percent are air-conditioned and the demand for A/C is very increased. Additionally, the electric peak load in Greece is affected very significantly by the air conditioning since most of the peak load incidents occur during the summer period and especially during hot days. All the air conditioning equipment installed in the examined office buildings, both central plants and packaged plants until 2003, were not fulfill the new directives for non-CF refrigerants and therefore the environmental problems related to ozone layer are also significant, according to Koinakis (2001, 2003).

The potentials for the implementation of passive cooling techniques during retrofitting in office buildings are therefore very promising. These techniques can be easily embedded during the overall process of retrofitting and they can also serve various other demands. For example retrofitting action for night ventilation techniques can be easily combined with hybrid ventilation systems and mechanical ventilation with ducts. These actions also decrease Indoor Air Quality problems reported from the working personnel and the customers (Koinakis, 2003).

2. THE EXAMINED CASE STUDIES

The building presented in the first case study (Fig. 1) is a 7-storey building with a basement, constructed in 1967 in middle density urban environment with a total area of 7120 m^2 with a typical floor of 850m^2. It is located in Thessaloniki the second largest city in Greece. The building is a cubic-shaped building with an in-

Figure 1: Views of the building of the first case study before retrofitting actions. Old split A/C units and windows (left) and old duct A/C systems (right) before the removal and their effect on the building's aesthetics.

ternal atrium in the 4 upper floors; all the facades are exposed. The building was not insulated initially because it was built before the force of the Greek Insulation Code (GTIC, 1979; KOXEE, 1998).

Minor insulation renovations were implemented in the opaque elements of external envelope mainly due to technical and operational difficulties because the building should be in continuous operation. Single glazed wooden windows were placed initially. Double-glazed windows with shading (venetian blinds) and vertical louvers at the eastern and western facades were implemented during the retrofitting scenarios. The mean duration of the heating period is 16 h/day for 5.5 months, due to the two shifts in most of the offices. The building has central heating installation with oil burner and radiators.

An out of date water-cooled A/C system of 200,000 Btu/h (nominal power) with air ducts was initially used for three of the floors. The efficiency of this system was inadequate due to mechanical problems and increased air velocity. Individual old split units were used for approximately the 10% of the rest of the offices. All the A/C systems were replaced by a central VRV A/C system controlled by a Building Management System (Koinakis, 2001, 2003).

Ceiling fans were used in some waiting areas and in some offices and ventilators were used in W.C. areas and corridors to create sub pressure and force hybrid natural ventilation (especially

Figure 2: Views of the building of the second case study during retrofitting actions. Reconstruction of the buildings envelope outside (left) and inside (right).

night ventilation) through skylights at the external openings.

The building presented in the second case study (Fig. 2) is a 4-storey building partly constructed in the late 60's (the concrete structure), with 290 m^2 per typical floor and it was extensively modified in 2000-1.

The building of the second case study is located in Ptolemaida a medium sized town in Northern Greece. It has a northern and eastern orientation and it is located in dense urban environment. The mean duration of the heating period is 9 h/day for 7 months. Among others, new external envelope elements, heavily insulated, were constructed and the heating, cooling and ventilation installations were completely redesigned. Solar absorbent glazing and venetian blinds were also placed. A central heating installation was placed during the retrofitting, including a heat exchanger system supplying hot water to the radiators of the building. The heat exchanger system is supplied by the tele-heating network of the nearby thermo-electric factories. Both floors used as offices mechanical ventilated and air-conditioned, implementing two system types Wall split units are installed in individual offices and air duct units are installed in unified working spaces (Fig. 3, Fig. 4).

Two A/C air duct units of 76,000Btu/h each were installed in each floor and three wall split units from 9,000 to 12,000 Btu/h were selected for individual offices; the split units can also be used for heating. Mechanical and hybrid venti-

Figure 3: Views after retrofitting actions; 1st case study (upper) and 2nd case study (lower). Ventilation grids embedded in the suspended roofs for hybrid and mechanical ventilation.

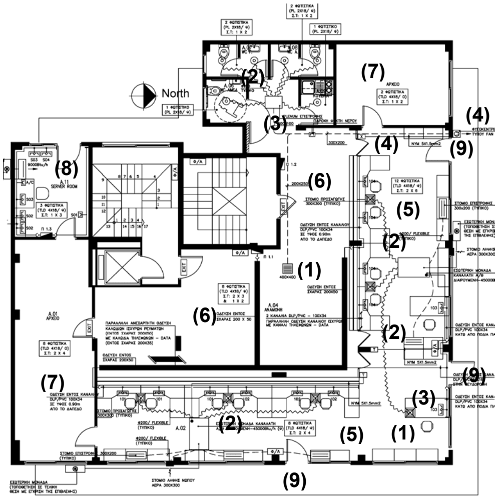

Figure 4: Ventilation installations in the 2nd case study, after retrofitting.
Memorandum: (1): grids, (2): flexible ducts, (3): internal ventilation unit, (4): outlet air duct, (5): working areas, (6): waiting areas, (7): non ventilated spaces, (8): computer room, (9): external openings for night purge ventilation (skylights).

lation was installed individually on each floor for forced air removal also used for night ventilation. The air is removed from the W.C. area on each floor implementing plenum and flexible air ducts (TOTEE, 1986; Koinakis, 2001, 2003).

3. PASSIVE COOLING PARAMETERS DURING RETROFITTING PROCESS

The special constructional and characteristics of examined buildings create certain outcomes during the entire procedure of design - implementation - validation (Fig. 5). Among the most important outcomes, for both case studies, are the following:

- The cooling demands are increased after retrofitting –if no passive cooling techniques are implemented- because of the increased internal gains due to the increase of the IT equipment and the decrease of the U-value of the building envelope. This was confronted implementing hybrid night ventilation and mechanical ventilation. For this purpose special external openings and ventilation ducts were used. Central multi-split VRV units were used which are centrally controlled and programmed implementing building management software in order to eliminate the misuse and the excessive use of the A/C.
- Emphasis was given to the quality of indoor environment (IEQ) as proved during the energy auditing of the examined buildings. The air change rates should be increased without increasing the velocity of the air streams near the working persons. In several cases severe disturb of the working persons was reported before retrofitting. This phenomenon was eliminated implementing adequate duct openings and louvers, and placing the external openings, which are used, as air natural ventilation inlets in high places (Fig. 3).
- Shading was examined in relation with natural and artificial ventilation. Internal louvers

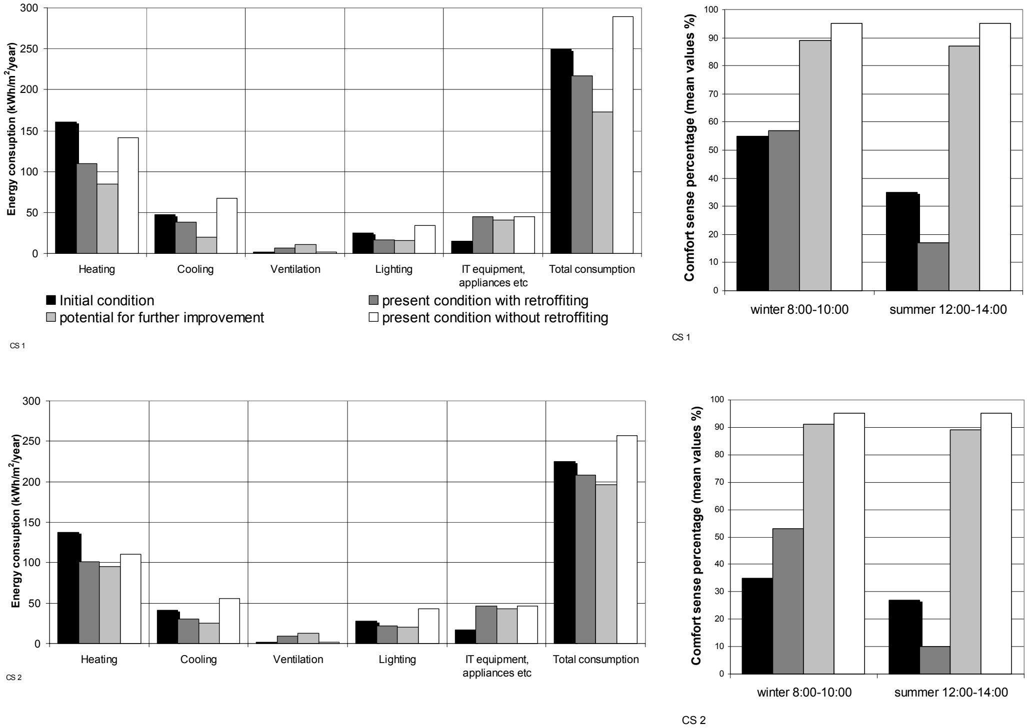

Figure 5: Energy consumption and thermal comfort sense for the examined retrofitting strategies. Above: 1st case study; below: 2nd case study.

were used for shading and for eliminating the dazzling problems during the use of IT equipment when external louvers cannot be used.

- Ceiling fans may contribute to considerable reduction of the cooling demands. According to the thermal comfort standards the use of ceiling fans could increase the acceptable indoor temperature from 27 to 29 °C and consequently the cooling demands could be reduced. For the examined office buildings this could result a 37 to 48% reduction of the cooling demands. A 1 to 2 years amortization period is estimated to be necessary to balance the initial investments and the cooling demand reduction. In several cases the use of ceiling fans was the cause of complaints of the employees due to the relatively increased air draughts especially for long term staying. This lead to the selection of more flexible air handling systems which could combine control capabilities with passive cooling and hybrid ventilation techniques.

In the second case study an air duct network combined with centrifugal funs was used individually in each floor, in order to combine the following:

- The fulfillment of the peak air renewal rate demands for the calculated working places and the maximum predicted customer concentration in the waiting areas (ASHRAE, 1999; TOTEE, 1986).
- The deployment of controllable ventilation by qualitative and quantitative means. In this way it will be possible to adjust the flow pattern according to the specialties of each working spaces (qualitative control) e.g. low air velocity near the working places and increased velocities in the waiting areas and the corridors. The rates of re-circulated and rejected rate could also be controlled (quantitative control).

- Air handling systems should be implemented in order to flexibly combine other passive cooling and hybrid techniques, like night ventilation. For this reason the use of suspended roofs was minimized to the absolute necessary areas (computer rooms and duct covering at the corridors) and the marble or tile floors and the wall remained uncovered and free from heavy furniture with were placed near the internal lightweight partitions. The simulations performed for this purpose resulted a mean decrease of the peak indoor temperature of 1.4 ^{o}C due to night ventilation. This value could be further increased at 1.8 ^{o}C for more cold climates with increased day-to-night temperature variations. The amortization for these cases is estimated to about 3-4 years for the proposed air handling system and could be reduced to less than 2 years if a simpler system is used. Nevertheless, the use of a simpler system could not fulfill the rest of the demands previously described and it was therefore rejected.

Artificial lighting system was proved a major energy consumer of electric energy in the examined office buildings. This was due to ballasts for fluorescent lamps, which consume energy even in the absence of lamps. In the examined buildings the lighting loads were initially up to 72 W/m^2, compared to 20 W/m^2 that are the maximum accepted levels for the lighting loads. These levels were decreased after retrofitting to about 20 W/m^2, as shown in Figure 5.

4. CONCLUSIONS

Passive cooling strategies and especially night mechanical and hybrid ventilation proved to be effective to decrease cooling demand during summer. These techniques were more effective in the building of the first case study due to the exposed eastern and western facades.

Only internal louvers were used for architectural reasons.

It should be noted that if only the IT equipment part of the specific renovation project was applied in these buildings, the cooling demands will be greater that the initial conditions. The thermal losses were significantly affected by the ventilation characteristics (Fig. 6 and Fig. 7).

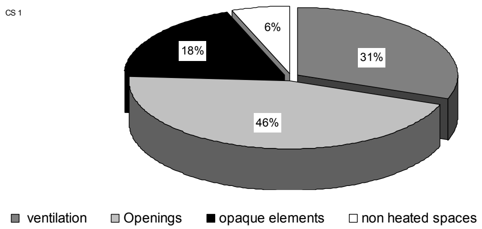

Figure 6: Thermal losses for the implemented mechanical, hybrid and natural ventilation scenario; 1st case study.

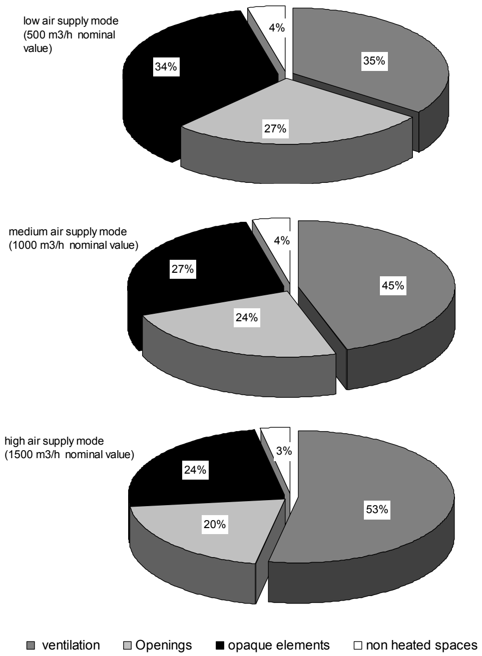

Figure 7: Thermal losses for the three modes of the implemented mechanical, hybrid and natural ventilation scenario; 2nd case study.

The cooling demand was decreased for the first case study to 81% of the initial condition compared to 143% of the initial condition without retrofitting. Cooling demands could be further decreased slightly, at about 55% if extra external shading systems are implemented (programmed as future retrofitting action).

In the building of the first case study the role of natural and hybrid ventilation is more increased, the behavior of the users can often cause malfunctions such as uncontrollable use of external openings and over- or under- ventilation. On the other hand in the building of the second case study malfunctions are almost negligible and are mainly due to misuse of the automations.

In the building of the second case study the direct solar radiation is limited mainly due to dense urban environment and due to the orientation. The night purge ventilation reduces the cooling load at 73% of the initial condition, compared to 137% of the initial condition, if only equipment renovation was implemented and if neither passive nor hybrid cooling techniques are implemented. The benefits of these strategies on thermal comfort were clearly noticeable by the end users as shown in Figure 5 (right diagrams).

The specific energy consumption in the examined case studies (before-after values) were 160-110 and 137-101 KWh/m^2 per year for heating loads and 67-38 and 56-30 KWh/m^2 per year for cooling loads for the first and the second case study respectively.

REFERENCES

ASHRAE, 1999. Standard 62, Ventilation for acceptable indoor air quality, Atlanta, GA.

GTIC, 1979. Greek Thermal Insulation Code (GTIC). Greek Government Gazette no. 362/Δ/4-7-79, Greece (in Greek).

I.E.A., 1998. International Energy Agency, OECD, Energy policies of IEA countries – Greece 1998 review.

Koinakis, C.J., 2001. Internal report of the integrated IT equipment and building renovation project – initial phase. Supervision Team for Northern Greece, Social Insurance Institute (SII), Greece, (in Greek).

Koinakis, C.J., 2003. Internal report of the integrated IT equipment and building renovation project – initial phase. Supervision Team for Northern Greece, Social Insurance Institute (SII), Greece (in Greek).

KOXEE, 1998. Regulations for Energy Efficiency Use and Energy Saving (KOXEE). Resol. 21475/4707/98, Greek Government Gazette no. 880/B/19-8-98, Greece, (in Greek).

Santamouris, M., 1990. Natural cooling Techniques. Proc. Workshop on passive cooling, Ispo, Italy, 2-4 April 1990.

TOTEE, 1986. Technical guide-lines of the Technical Chamber of Greece (TOTEE 2425/86). Technical Chamber of Greece, Athens, Greece (in Greek).

Wittchen, K. and E. Brandt, 2002. Development of a methodology for selecting office building upgrading based on a test survey in European buildings, Energy and Buildings 34 (2002), pp. 163-169.