VENTILATION RETROFITTING OF PUBLIC OFFICE BUILDINGS IN GREECE

Chris J. Koinakis

Laboratory of Building and Construction Physics, Dept. of Civil Engineering, Aristotle University, 54006 Thessaloniki & Social Insurance Institute, Greece, e-mail: chrisko@civil.auth.gr

ABSTRACT

This paper presents aspects of an office renovation project of the Social Insurance Institute (SII), the largest Social Security Organization in Greece. The project refers to small and larger SII office buildings, including various stages of intervention, ranging from the construction of new buildings, to renovation of existing buildings. Construction and electro-mechanical studies for each building were carried out in order to implement the appropriate and feasible actions. Mechanical ventilation was implemented in all spaces, including forced air circulation through wall or ceiling-mounted air ducts and hybrid ventilation. Energy saving strategies were also implemented including shading, solar-absorbent glazing, night ventilation, energy efficient lamps and BMS controlled A/C system. Two case-studies of buildings in the area of Northern Greece are briefly presented. Thermal comfort conditions and energy consumptions are examined for various retrofitting scenarios and results are discussed.

KEYWORDS

Ventilation retrofitting, energy consumption, thermal comfort sense, office buildings.

1. INTRODUCTION

This paper presents aspects of an office renovation project of the Social Insurance Institute (SII), the largest Social Security Organization in Greece. It covers 5,530,000 workers and employees and provides 830,000 pensioners with retirement pensions. This project refers to the renovation of more than 200 SII office buildings throughout Greece, including various stages of intervention. Renovations include complete resettlement of the internal spaces, of counters and furniture of specific types and integrated cable network; they also include linking on-line all desk and back-office positions country-wide. Complete structural and electro-mechanical studies for each building were carried out. The initial budget of the project is 15.000.000 €, not including the construction of new building complexes. The project is mainly funded by the European Union [1], [2].

Within the frame-work of this project, mechanical ventilation of all spaces is implemented, including forced air-circulation, through wall or ceiling-mounted air ducts in each floor independent, and also hybrid ventilation. Two case-studies, are briefly presented, in the cities of Kozani and Ptolemaida in Northern Greece, each one for a specific building. Various HVAC equipment was selected, taking into account the building characteristics and local demands. Both buildings are heated by the tele-heating network of the Kozani prefecture where most of the thermo-electric factories of the Greek Public Electricity Company are established.

1.1. Building characteristics

The building in the first case study is a 5-storey office building with a shopping arcade on the ground floor, located in the center of the city of Kozani, a major town in northern Greece. The 1st to 4th floors are for office use and the basement is used for parking and storing purposes. The building is newly constructed (after 2002) and was built as a commercial building for stores and offices. The retrofitting project began at the concrete frame construction stage. A typical plan view is presented in Fig. 1. A central atrium creates a west and an east wing. The building has a total area of 2.072 m, has extended glazed facades and is constructed according to the Greek Thermal regulation code and the respective HVAC Greek regulations and technical guidelines.

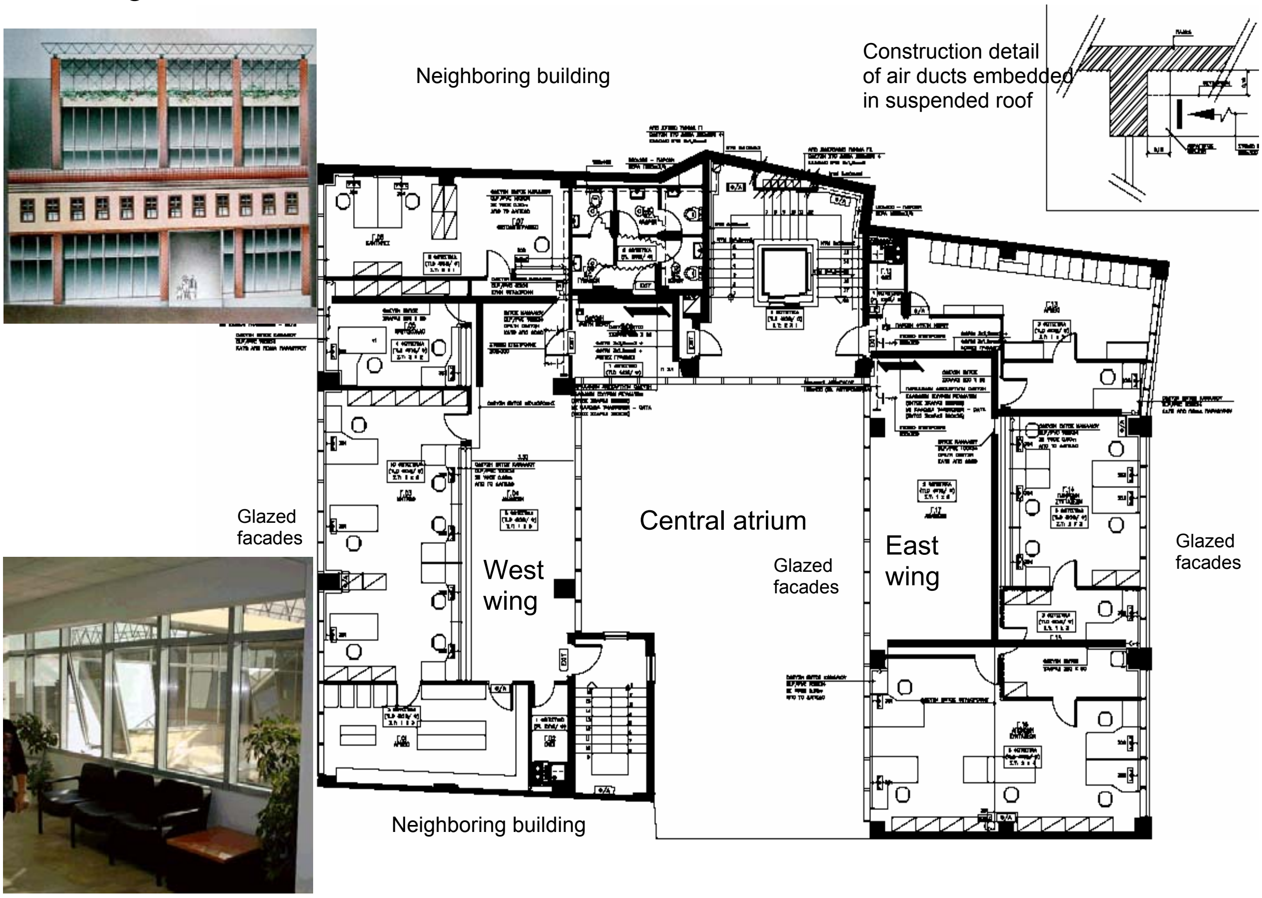


Fig. 1. Above: plan view of a typical floor of the first case study building. Left: views of the building.

The building in the second case study is a 4-storey former apartment house building constructed at late 60's in Ptolemaida a medium-sized town of the northern Greece. Two of the floors were completely reconstructed in order to be used as offices. A new staircase and a new elevator were constructed among others and the HVAC installations were completely re-designed. The building has a northern and an eastern façade and is placed in dense urban environment. A plan view is presented in fig. 2. The surrounding surfaces were reconstructed and solar-absorbent glazing and venetian blinds were used. All the reconstructed elements were insulated.

2. VENTILATION RETROFITTING

Different heating, cooling and ventilation retrofitting strategies were implemented in the two buildings, due to the different configuration, building type and size characteristics.

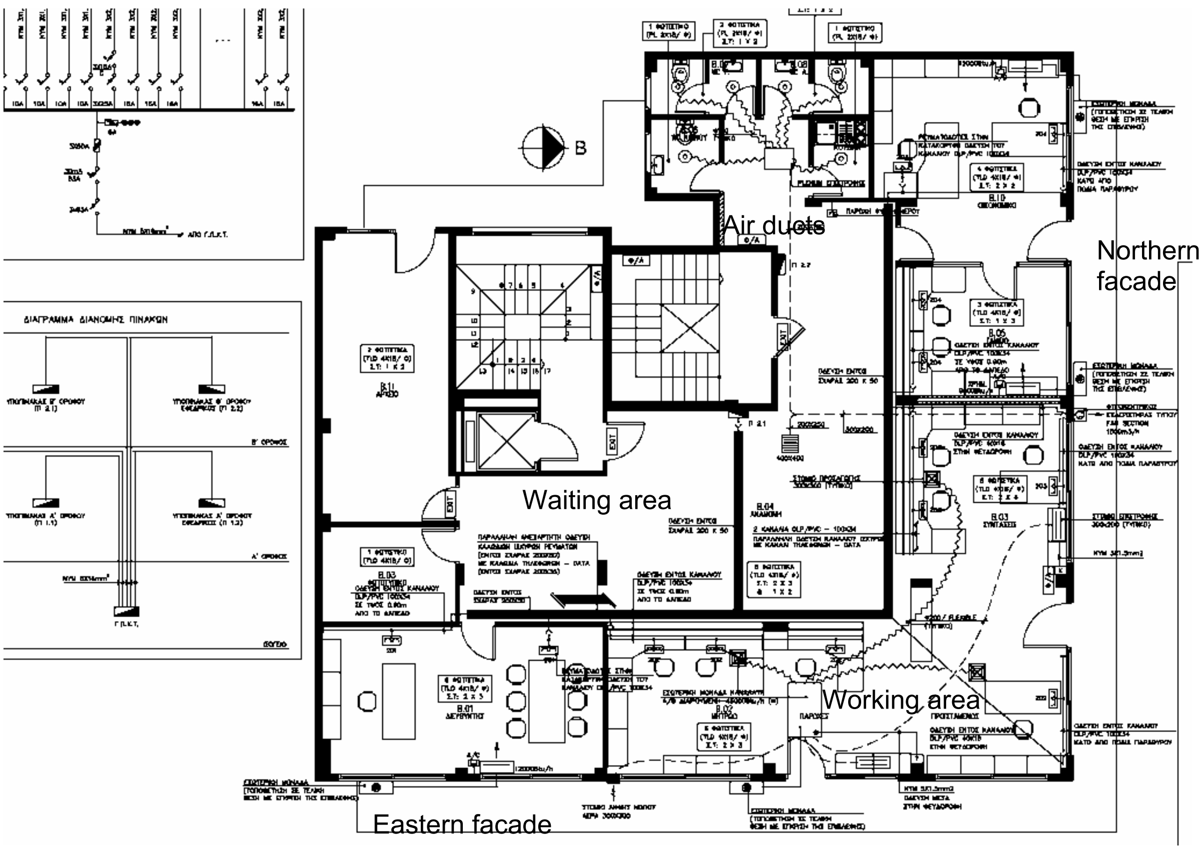


Fig. 2. Plan view of a typical floor of the second case study building.

2.1 First case study

The office building at Kozani has a central heating-cooling installation with a boiler-room at the basement and an external cooling unit on the roof. The central heating installation includes a heat exchange system to cover the thermal demands of the building, supplying the fan coil units of the building with hot water, through a twin-tube system. The heat exchange system is supplied (primary circuit) by the tele-heating network of the thermo-electric factories in the Kozani area and supplies the fan coil units (secondary circuit) with hot water. In the event of supply debility of the tele-heating network an oil boiler and oil tanks could be installed.

For the cooling demands of the building a central cooling system was installed on the roof, including a 500.000 Btu/h air-cooler, the necessary pump equipment and network for the supply of cooled water to the fan coil units of the building. There is no provision for pre-conditioned air and the mechanical ventilation system is designed separately.
In the office building at Kozani, two individual mechanical ventilation systems were installed, one for each wing of the building. There is a separate ventilator unit for each floor of each wing totaling 8 units for the 1st to 4th floors, plus one unit for the separate department of IT services (computer room) and one unit for the basement. The air is removed using plenum and flexible air ducts in the W.C. areas of each wing, which end up at inlets which are placed in the public waiting areas of each level and are covered with grids.

Each unit includes a centrifugal fan (fan section) and the air is carried outdoors, through return outlets and galvanized iron-plated air ducts. The units are placed on the roof of the building near the staircase and ducts are embedded inside the suspended roof. The air enters due to sub-pressure from the external openings of the glazed facades, which are especially designed for this purpose (inclined lintel windows or common, inclined windows). This solution was selected because of the lack of a pre-conditioned air HVAC system in the building. According to the technical guide-lines of the Technical Chamber of Greece (TOTEE 2425/86, tabl. 2.4 & 2.5) [3], there should be air rejection at the rate of at least 25%. The total re-circulated air supply should be at least 6 air changes per hour which is acceptable for office spaces and public waiting rooms. In the examined case, 8 air changes per hour were implemented, taking into account that glazed partitions are used to separate the above-mentioned spaces. Thermal comfort sense in office spaces was carefully estimated by interviewing the staff and by carrying out temperature and air velocity measurements according to the Fanger thermal comfort sense diagrams (Fig 3). The total re-circulated air supply per wing and floor is 3500 m^3/h and the minimum rejected air rate is 875 m^3/h. In order to select the proper ventilation unit characteristics, ventilation efficiency tests are performed for each area, according to the area population, taking into account the peak demands per floor and wing, which is 44 m^2 of the public waiting area and 12 working places. The ventilation demand per person is 30 m^3/h in total, 25% of which (7,5 m^3/h) is fresh air. The peak demands are calculated for 12 working places plus a customer per place, and for the crowded waiting area of 44 m^2, (1 person/1.1 m^2), reaching a total of 64 persons. The lowest total air supply demand is therefore 1920 m^3/h of re-circulated air and 540 m3/h of fresh air. To fulfill the demand of both tests it is necessary to achieve 900 m^3/h minimum rejected air supply. The selected ventilation units are of 1000 m^3/h middle supply and 1500 m^3/h maximum supply.

2.2 Second case study

The office building at Ptolemaida has a central heating installation with boiler room at the basement, including a heat exchange system supplying hot water to ordinary radiators of the building. The heat exchange system is supplied by the tele-heating network of the thermo-electric factories in the wider Kozani area and supplies the radiators with hot water.
The cooling installation in the second case study differs to that in the first case study. Both floors of the office building are air conditioned, implementing two system types. Wall split units are installed for isolated offices and air duct units are installed in unified working places and public waiting areas on both floors. Two 76.000 Btu/h A/C air duct units were selected for each floor and three wall split units from 9.000 to 12.000 Btu/h were selected for the isolated offices. The split units can also be used for heating.

Mechanical ventilation was installed individually on both floors for forced air removal. The air is removed from the areas near the W.C. on each floor, implementing plenum and flexible air ducts and a central air inlet in the public waiting area, for air removal. All ventilation units are placed inside the suspended roof area, including a centrifugal ventilator in a sound-absorbent box (fan section). The air is removed outdoors through air outlets and ducts. The fresh air enters the working spaces through the inlets of the air duct units and through the external openings due to sub pressure. The mechanical ventilation demands are 6 air changes per hour, including 25% of fresh air, according to the technical guidance mentioned before [3]. The total air supply is therefore 3600 m3/h, per floor and the minimum demand of the rejected air is 900 m^3/h. For the selection of the proper ventilation unit, ventilation efficiency tests were performed, taking into account the population of each area.

The peak demands were calculated for 12 working places plus a customer per place and a crowded waiting area of 58 m^2, (1 person/1.1 m^2), reaching a total of 77 persons. The lowest total air supply demand is therefore 2300 m^3/h of re-circulated air and 575 m3/h of fresh air. To fulfill the demand of both tests it is necessary to achieve 900 m^3/h minimum rejected air supply per floor (3600 m^3/h of re-circulation for 6 ach). The selected ventilation units are of 1000 m^3/h middle supply and 1500 m3/h maximum supply.

The energy simulations and the HVAC systems study were performed implementing appropriate software packages (Suncode, EnergyPlus and 3M). Measurements were performed implementing temperate and humidity sensors and a hot-wire anemometer was used for wind speed measurements.

3. THERMAL COMFORT ASSESSMENT

Thermal comfort measurements implementing air and surface temperature measurements, wind velocity and relative humidity measurements, were carried out in both buildings after the completion of ventilation retrofitting,. Winter measurements were carried out during January and summer measurements during July and August. The results are presented in the Fanger diagrams in Fig. 3. The retrofitting of the HVAC systems resulted in a significant improvement of thermal comfort sense with an average of more than 91% satisfaction in all cases. The measurements agreed with the interview questionnaire of the personnel and the public. Some particular problems had to be confronted in-situ, especially the adjustment of the mechanical ventilation outlets near the counters and the relative position of the counter glass partitions and the air outlets. Different diffusion grids were selected and in some cases a re-settlement of the furniture was carried out in order to eliminate local air-draught problems. These problems proved critical for the health of the personnel sometimes resulting serious shoulder and neck problems.

Relative humidity was kept within acceptable values (mean values 49% and 42% in winter and summer respectively in both buildings). Sporadic summer measurements in the crowded waiting areas revealed values above 87% when mechanical ventilation was not operating. Indoor temperatures were kept within tolerable limits. During the summer period the ventilation units were often used in maximum supply (1500 m^3/h in both case studies) resulting in increased air velocity values of more than 50% compared to the respective winter values, reaching 0.24 m/s mean value in highly ventilated waiting areas. Some peak values exceeded 0.65 m/s and efforts were made to confine these to non working or waiting areas. The air change values were increased from 6 ach to more than 8 ach in the summer period. This strategy combines the benefits of roof ventilators and offers the possibility of implementing night-time purge ventilation.

The surface temperatures of the floor and the surrounding walls were kept within the tolerable area in the Fanger diagrams (fig. 3) in most cases due to insulation improvement measures in the floor areas. The different types of office buildings in the examined cased studies, requested different renovation strategies.

4. ENERGY CONSUMPTION FOR RETROFITTING SCENARIOS

The specific annual energy consumption for both case studies is presented in Fig. 5. Heating, cooling, ventilation, lighting, electric appliances etc, are calculated implementing energy simulations for four retrofitting scenarios. “Initial condition” refers to the conditions before the building retrofitting (“old” building) and before the office renovation project. “Present working condition without retrofitting” refers to the implementation of the office renovation project in the “old” building, without intervention on the building envelope or on HVAC equipment. “Present working condition with retrofitting” refers to the conditions after the building retrofitting and the office renovation project, which is the existing condition. “Potential for further improvement” refers to retrofitting measures that was not implemented because of technical and economical reasons or to measures for future implementation.

The heating and cooling set points where 20 °C and 25°C respectively, based on the real working conditions according to the measurements. All the ventilation retrofitting measures as described in the 2nd paragraph were taken into account and the end-users real behavior was simulated. The distribution of ventilation losses for different air supply modes of mechanical ventilation is presented in Fig. 5. The implemented mechanical ventilation schedule was based on the recording of the end-user's behavior. The mechanical ventilation operates for approximately 1.5 hours in winter (at the lower mode) and for approximately 3.5 in summer (at the middle and higher modes). The summer night ventilation taken into account separately.

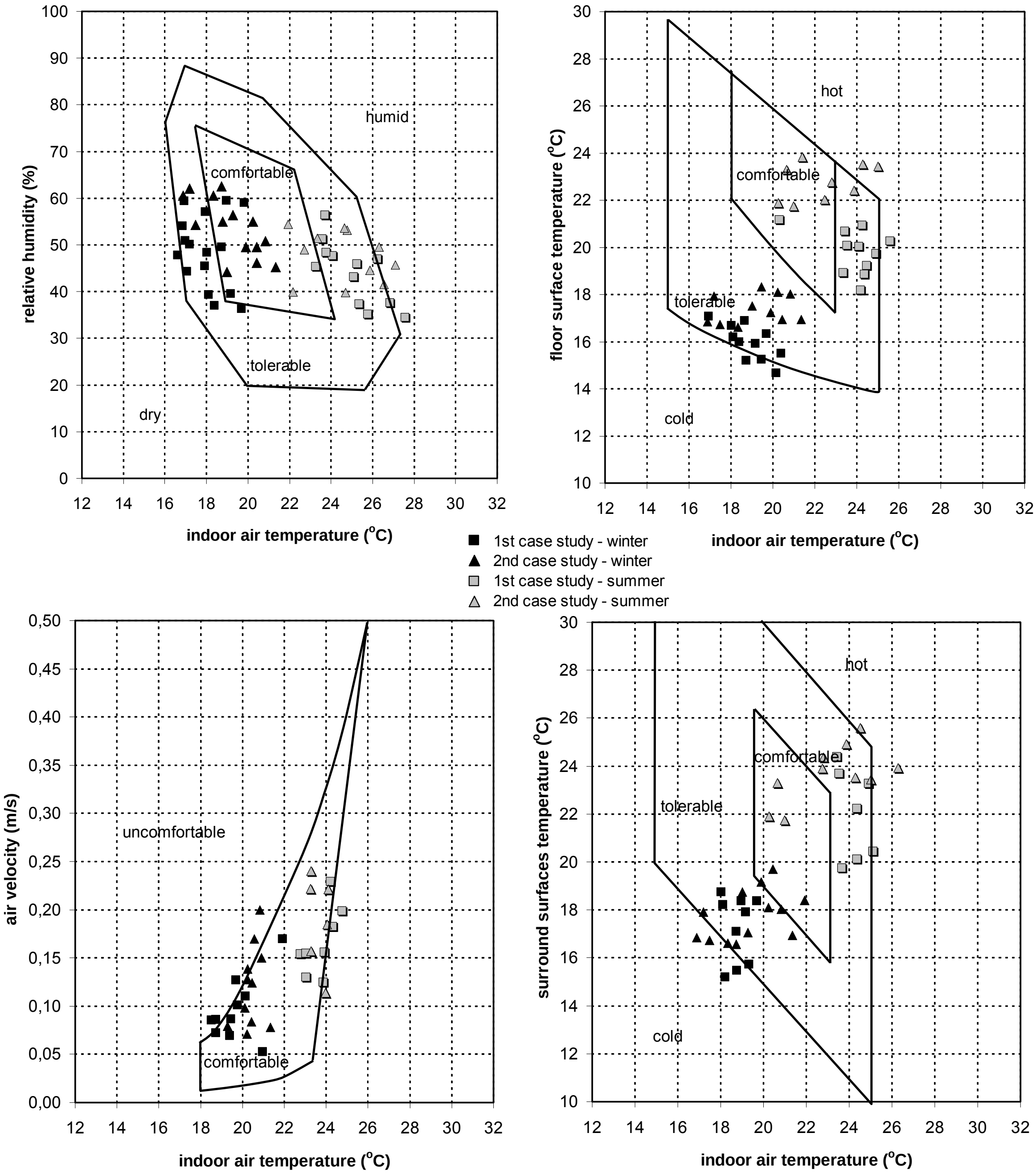
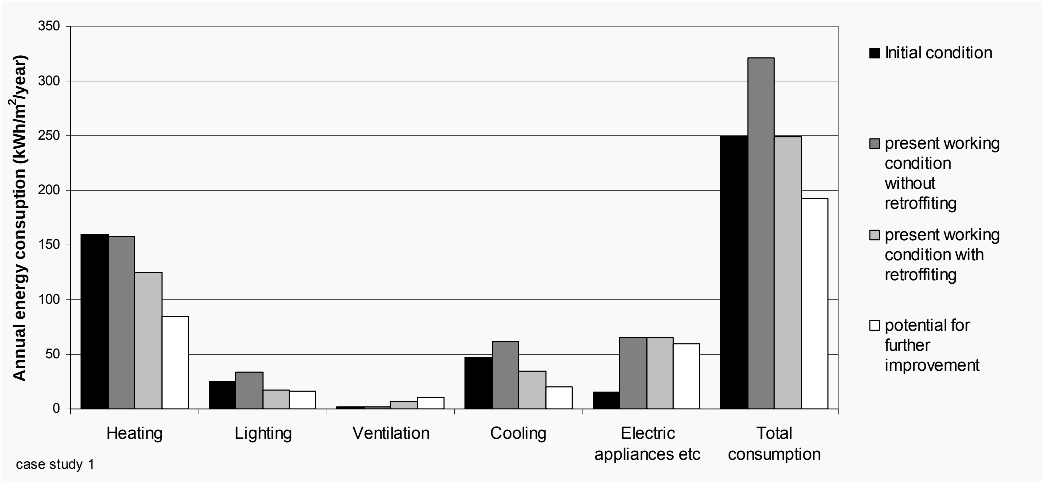
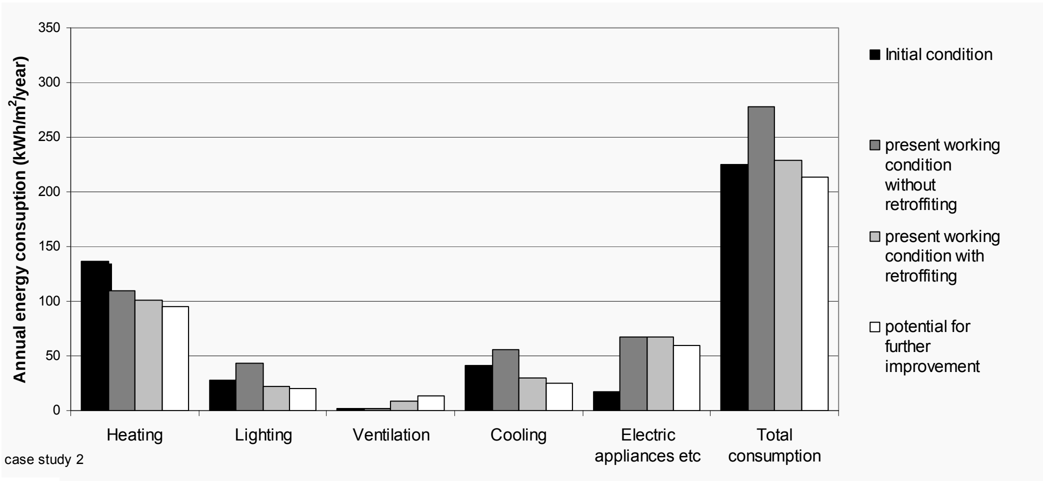


Fig. 3 Thermal comfort sense according to Fanger diagrams, for the two case-studies. Winter and summer measurements.



F/V=0.72 Retrofitting scenario:	energy consumption						comfort percentage	
	Heating	Lighting	Ventilation	Cooling	Electric appliances etc	Total consumption	winter 8:00-10:00	summer 12:00-14:00
	100%	100%	100%	100%	100%	100%	100%	100%
	99%	136%	100%	143%	300%	123%	104%	49%
	78%	68%	350%	81%	300%	93%	162%	249%
	53%	64%	550%	43%	273%	69%	173%	271%



F/V=0.39 Retrofitting scenario:	energy consumption						comfort percentage	
	Heating	Lighting	Ventilation	Cooling	Electric appliances etc	Total consumption	winter 8:00-10:00	summer 12:00-14:00
	100%	100%	100%	100%	100%	100%	100%	100%
	80%	154%	100%	137%	271%	114%	151%	37%
	74%	79%	450%	73%	271%	92%	260%	330%
	69%	71%	650%	61%	253%	87%	271%	352%

Fig. 4 Specific energy consumption and thermal comfort for various retrofitting scenarios. 1st case study (above), 2nd case-study (below).

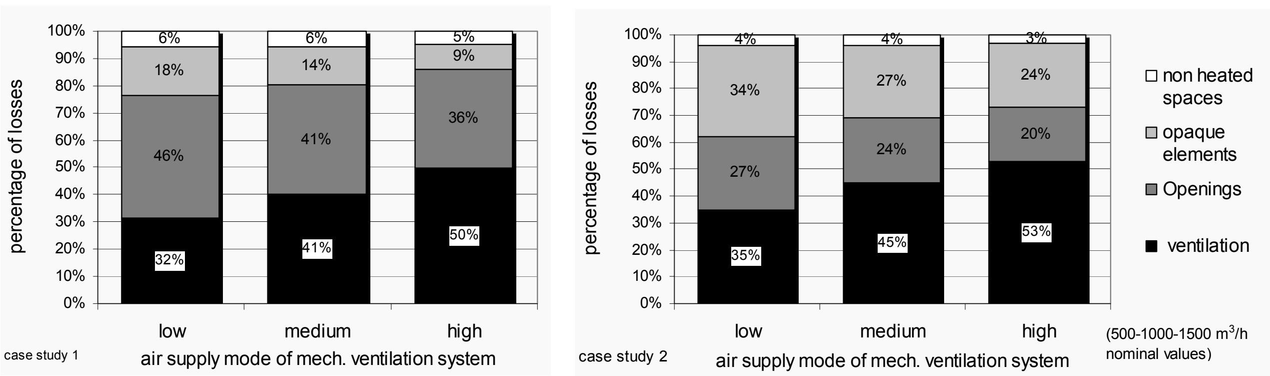


Fig. 5. Distribution of ventilation losses for different air supply mode of mechanical ventilation in the 1st case-study (left) and in the 2nd case-study (right).

5. CONCLUSIONS AND REMARKS

As derived from energy consumption calculations in Fig. 4, the night mechanical ventilation (night purge) proved to be a practical strategy to decrease cooling demand during summer and could be programmable. In the first case study the high building surface to volume (F/V) ratio and the configuration of the building with internal atrium and the extended eastern and western facades resulted in summer overheating problems due to extensive direct solar radiation. Only internal venetian blinds could were used for architectural reasons and the night purge ventilation reduced the cooling demand to 81% of the initial condition, compared to 143% of the initial condition without ventilation retrofitting (fig. 4 above). In the 2nd case study where direct solar radiation is limited due to the dense urban environment and the northern orientation and the F/V ratio is rather small, night mechanical ventilation reduces the cooling demand at 73% of the initial condition, compared to 137% if there was only equipment renovation and no ventilation retrofitting (fig. 4 below). The benefits of this strategy on thermal comfort were immediately noticeable by the end-users. Cooling demand could be further slightly decreased at 61%, if awnings are placed. This solution is generally difficult to implement in these buildings. In the first case study mechanical ventilation should be combined more with natural ventilation though the extended facades and the sometimes end users often cause energy malfunctions such as they open windows near operation fan coils, and they under- or over- use mechanical ventilation. On the contrary, in the second case-study the office building is more mechanically controlled and mal-uses are avoided in most cases.

The specific heating and cooling consumptions in the two case studies were 110 and 101 kWh/m^2 per year for heating and 38 and 30 kWh/m^2 per year for cooling demands for the 1st and 2nd case-study respectively. The most significant factors affecting energy consumptions were, the F/V ratio, the glazing facades and the incident solar radiation. These are the reasons why the newer building has slightly higher consumption, despite the higher energy standards. The energy consumption of the first building could be significantly higher. If the heat transfer coefficient of the 1st case building envelope was the same as the 2nd case-study, the energy consumption would be significantly higher [4], [5].

Taking also into consideration that the major equipment renovation project of SSI increases the thermal and cooling demands, the ventilation retrofitting proved to be a major adjusting factor for energy efficiency and indoor environment design. The total cost of the ventilation retrofitting measures was less than 4% of the total budget and the benefits include a tripling of the percentage of satisfied end-users and the reduction of the cooling demand by more than 40%.

REFERENCES

[1]. 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).*

[2]. 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).*

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

[4]. GTIC (1979). Greek Thermal Insulation Code (GTIC). *Greek State Journal no. 362/Δ/4-7-79, Greece (in Greek).*

[5]. KOXEE (1998). Regulations for Energy Efficiency Use and Energy Saving (KOXEE). *Resol. 21475/4707/98, State Journal no. 880/B/19-8-98, Greece, (in Greek).*