Building Advanced Ventilation Technological examples to demonstrate materialised energy savings for acceptable indoor air quality and thermal comfort in different European climatic regions.

Advanced Ventilation Technologies

Photo: architect N. Nikolaidis

Case Study No 3

PAPER WAREHOUSE AND OFFICES AGGELIDIS – GEORGAKOPOULOS A.E.B.E. ATHENS, GREECE

Supported by

Intelligent Energy Europe

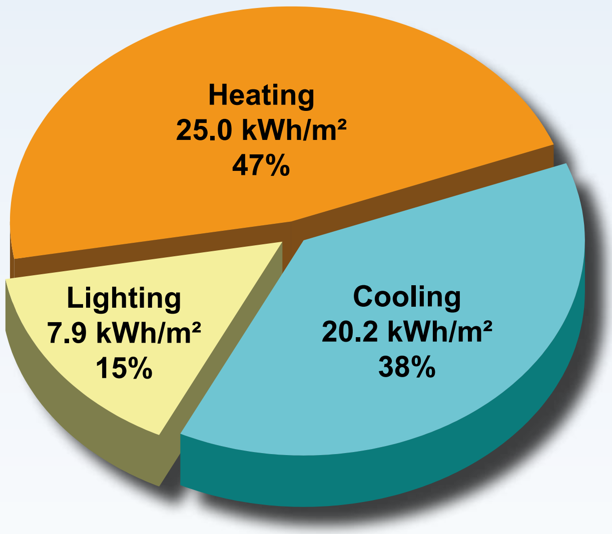
INTRODUCTION

The building is located in an open area, next to a national highway. It is exposed to high external noise levels and exhaust fumes that restrict the use of natural ventilation. It is a free-standing building with no any other built structures close to it.

Summary Table of key design parameters.

Building data	
Building type	Paper warehouse and office building.
Total floor area	10 400 m², of which offices 900 m².
Mean occupant density	16 m²/person (offices)
Occupied hours	2 300 hrs/year
HVAC data	
Ventilation system type	Hybrid ventilation – mechanical ventilation in conjunction with openable windows controlled by CO_2 level.
Heating / cooling system	Multi-zone VRV air-conditioning
Total ventilation rate	28.8 m³/person (building code)
Heat recovery efficiency	64% to 75%
Building fabric data	
Window U-value	2.7 W/(m² K)
Window g-value	0.75
Exterior wall U-value	0.5 W/(m² K)
Base floor U-value	0.45 W/(m² K)
Roof U-value	0.6 W/(m² K)
Climate data	
Design outdoor temperature for heating	2°C
Design outdoor temperature for cooling	34.5°C
Heating degree days (include base temperature)	1 428 days (base 18°C)
Cooling degree days (include base temperature)	186 days (base 25°C)

The building is situated in a climate zone with a high cooling load.



Annual energy use.

BUILDING DESCRIPTION

The building was constructed in 2003. It houses areas for printing, paper treatment, paper storage and office areas. The building has a total floor area of 10 400 m² arranged on three levels:

- **Basement with storage area, sixty parking places and central mechanical equipment**
- **Ground floor with the main storeroom and lifting platforms.**
- **First floor with special products storeroom, platforms and offices**

The office area is approximately 900 m² with approx 55 working places. Figure 1 shows a plan view of the First Floor. The offices are occupied from 08.00 to 17.00.

DESIGN SOLUTIONS

The design brief required that the building should have the minimum possible energy consumption consistent with optimum indoor environmental conditions and allowed for the advanced building services technology and electronic control systems necessary to achieve this.

The building is constructed using a steel framework with reinforced concrete slabs. The building envelope has a high level of thermal insulation with the installation of polyurethane panels, coated with additional mineral wool and gypsum board in the inner side of the external walls, 80 mm thick mineral wool in the roof and 25 mm thick mineral wool in the suspended ceilings. Low emissivity double glazing, with a sound trap, is installed in all openings of the office areas in order to minimize the thermal losses

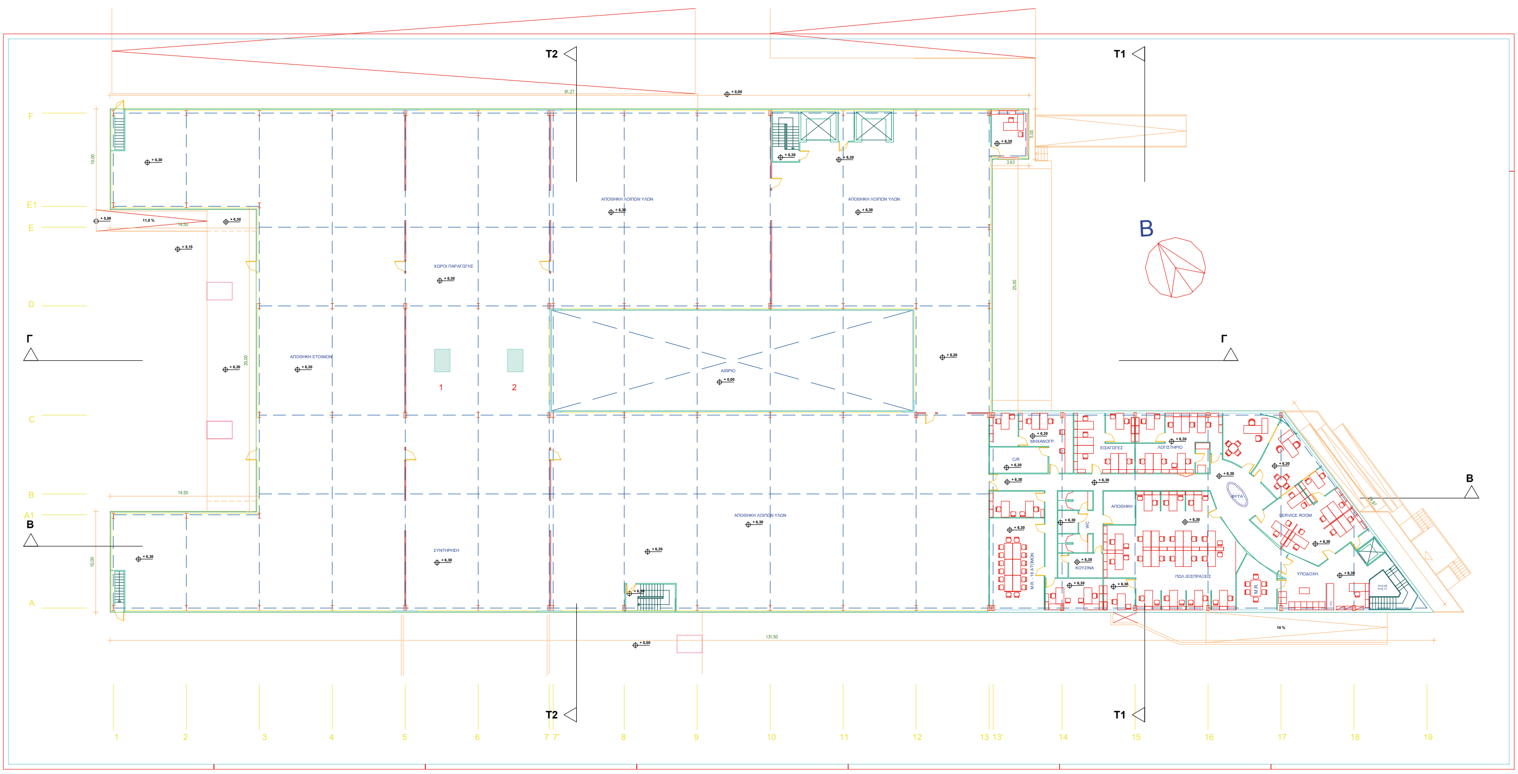


Figure 1. Plan view of the First Floor, showing production area and offices. [Source: Nikolaidis, 2005]

and to reduce the external noise. Perforated aluminium panels are used as external cladding for the office areas.

The building incorporates a number of energy-efficient systems. Ground heat exchangers are installed for the cooling the air supplied to the work areas on the ground floor. In the offices on the first floor, a multi-zone VRV air conditioning system, consisting of nine external units and sixty four interior units provides heating and cooling (Figure 2). Every external unit has an inverter that adjusts the performance of the system according to demand. In addition, ceiling fans are installed to improve thermal comfort. Sensors in each office area control the level of the artificial lighting according to the available daylight. The distribution of daylight is enhanced by the use of reflecting surfaces near the windows. Also, sensors open or close the window blinds. Overall control and monitoring of the building services is provided by a sophisticated building management system (BMS).

VENTILATION STRATEGY

The ground floor houses a large warehouse with constant traffic of delivery vehicles. Staff working in this area are potentially exposed to external temperatures which can vary from an average in February of 5.5°C to an average of 31.7°C in July. Combined with the need to optimize paper storage conditions, this led to the incorporation of ground to air heat exchange to temper incoming ventilation air (Figure 3). Incoming air is drawn at a rate of 4 500 m³/h through 20cm diameter ducts set at a depth of 2.5 m in the ground by a 300 W fan. The relatively stable temperature of the ground at this depth allows the incoming air to be pre-heated in winter to a mid-temperature of 13.1°C in winter and pre-cooled to 21.7°C in summer.

The central ventilation system of the office areas is equipped with eight UMA type heat recovery units that can achieve a 64%-75% reduction in the temperature difference of the air entering the building. These units have variable fan speed, can pre-heat or cool delivered air and operate under a range of controls, including the central BMS system and time switch.

PERFORMANCE

(i) Energy performance

The data monitored by the BMS for the year 2005 shows that the total annual energy consumption was 53.1 kWh/m² of which 20.2 kWh/m² is at-

Figure 2. Outlet of the air-conditioning unit. [Source: Niklaidis, 2005]

Figure 3. Installation of ground heat exchanger. [Source: Nikolaidis, 2005]

tributed to cooling, 7.9 kWh/m² to lighting and 25.0 kWh/m² to heating.

Figure 4 shows the performance of the building before and after retrofit using the energy rating system included in the EU-funded EPlabel Project. This demonstrates that the building has an A rating and performs considerably better than a best practice air-conditioned building and considerable improvement, although the rating still falls below the benchmark for best practice office buildings.

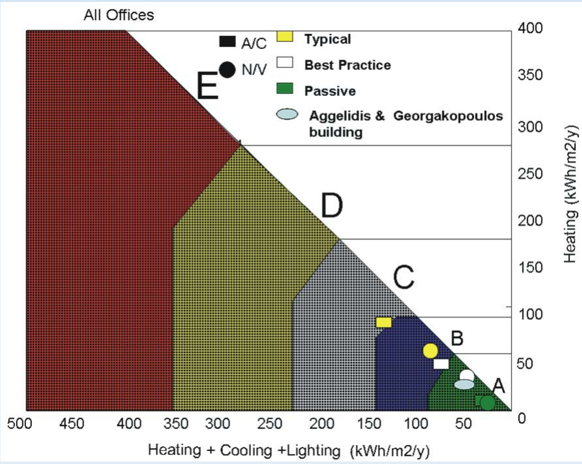


Figure 4. Energy rating for the Aggelidis & Georgakopoulos building [using the system included in the EPLabel Project (see references)].

(ii) Indoor environment performance

(a) Thermal

During the monitoring period, the average internal temperatures in the office areas varied from 26.4°C to 29.7°C. In the summer internal temperatures were 10°C lower than the external temperature than peak external temperatures which reached values as high as 38.2°C. As a result of the operation of the ground heat exchangers serving the ground floor a mean reduction of 2°C in internal temperature was achieved in the summer months and a mean increase of 1.5°C in the winter months. The measured mean temperature reduction of the air entering from the ground heat exchange ducts in summer was approximately 5°C. Figure 5 shows the distribution of internal temperatures in the warehouse during the summer period.

(b) Ventilation

Measurements were carried out in five representative office areas of the concentrations of carbon dioxide (CO_2), carbon monoxide (CO), particulates (PM10, PM2.5 and PM1) and volatile organic compounds (VOCs). The results for CO_2 concentration are shown Figure 6.

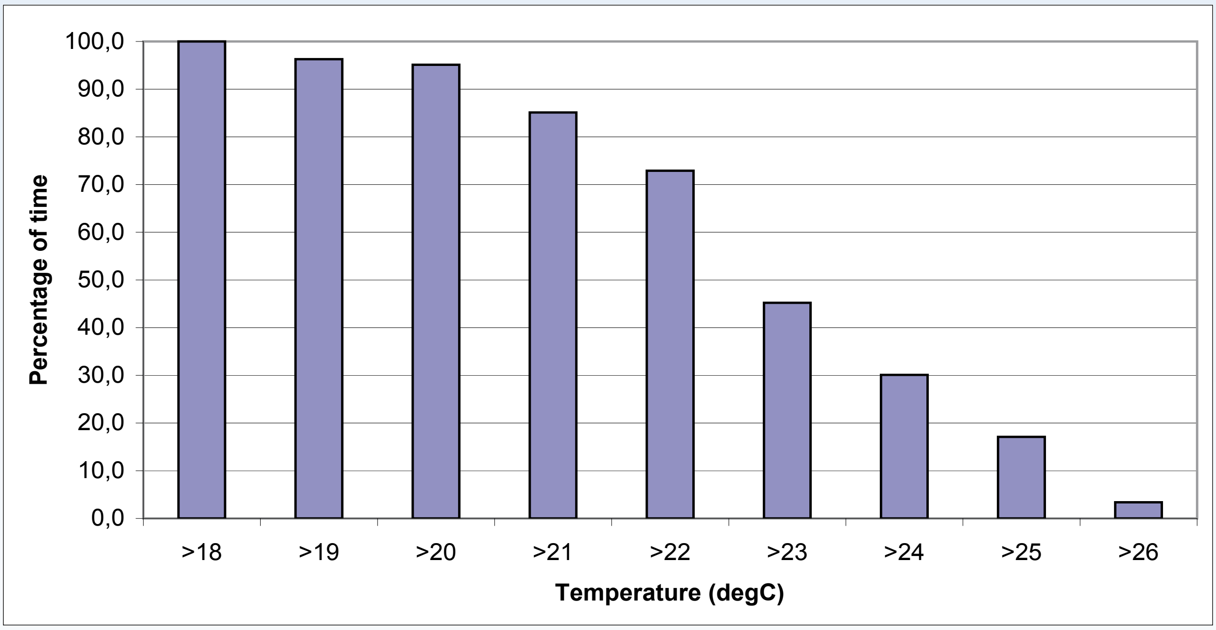


Figure 5. Frequency of measured internal temperatures in the warehouse (ground floor). [Source: Santamouris, 2006]

During the whole monitoring period CO_2 concentration was below the 8-hour exposure level of 1000 ppm proposed in ASHRAE Standard. The measured concentrations of CO never exceeded the ASHRAE standard the limiting 8-hour exposure for CO is 9 ppm.

(iii) Occupant assessment of performance

A survey of occupants' assessment of the indoor environment was carried out by questionnaire in 2008. Only a relatively small proportion of occupants, 16 in total, participated. The survey showed that only 38% of respondents expressed satisfaction with the overall indoor environment in the building for both summer and winter periods. Dissatisfaction was mainly due to large temperature variations, stagnant air and draughts. Satisfaction with the specific characteristics, indoor air quality and thermal environment, were higher in winter, at 56% and 75% respectively, than in summer, at 44% and 33% respectively. Lighting and the acoustical environment were generally found to be satisfactory.

Outlet of the ground heat exchanger. [Source: Nikolaidis, 2005]

DESIGN LESSONS

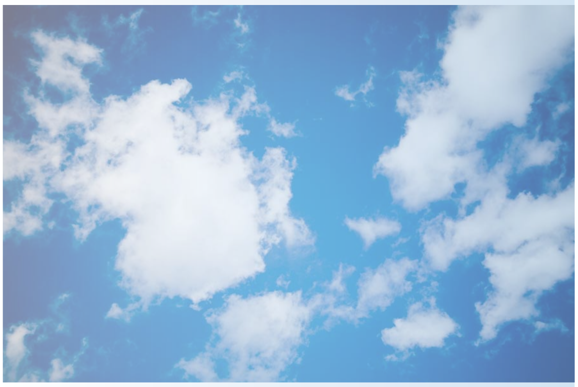
The building is characterised by its high architectural quality in conjunction with an excellent energy and environmental performance. The cladding of the building envelope combined with the system of the earth to air heat exchangers performs well in the paper warehouse and provides acceptable indoor environmental conditions, even during the days with extreme climatic conditions. Additionally, the HVAC system of the office areas equipped with heat recovery results in very low energy consumption.

The paper warehouse. [Source: Nikolaidis, 2005]

Ceiling fans in the office areas. [Source: Nikolaidis, 2005]

Table 1.
Summary of occupant assessment of the indoor environment.

	Summer %	Winter %
People finding the **overall indoor environment** acceptable	38	38
People finding the **thermal environment** acceptable	38	75
People finding the **indoor air quality** acceptable	44	56
People finding the **acoustic environment** acceptable	75	75
	Artificial %	**Natural %**
People finding the **lighting** acceptable	63	81



Design team information
Designers and contractors

Tenant	Aggelidis & Georgakopoulos
Architect	Nikolaidis Nikolaos
Civil Engineer	Alexopoulos Alexandros
Mechanical Engineer	Konstantoulis Konstantinos
Elecrical Engineer	Margaris Ioannis
Energy Consultant	M. Santamouris, Associate Professor, Group Building Environmental Research, National and Kapodistrian University of Athens
Main Building Contractor	J. Kloukinas – J. Lappas S.A.

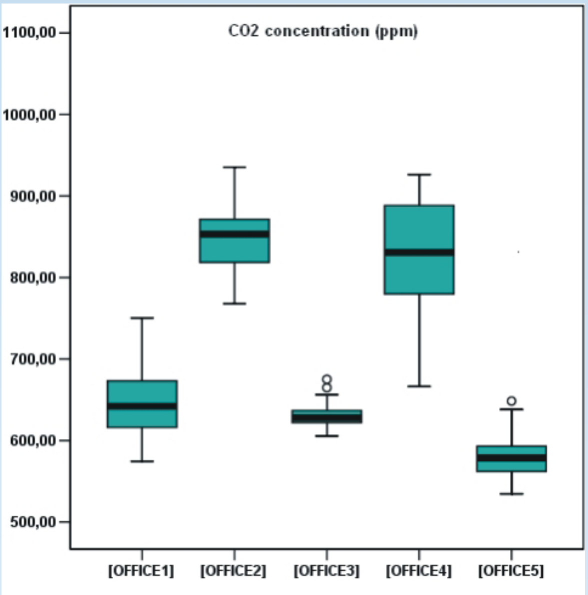


Figure 6. Monitored CO_2 concentration (ppm) in representative office areas.

GENERAL

(i) Key points concerning the design

A low energy office and paper storage building that employs earth to air heat exchangers, shadow cladding and VRV (Variable Refrigerant Volume) type heat pumps, combined with simple ceiling fans for comfort in the office areas.

REFERENCES

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EPLabel project, Save project, supported by Intelligent Energy Europe, duration 1st January 2005 – 28 February 2007, WP2: Overview of Country Surveys, available in www.eplabel.org.

Brochure authors: M Santamouris and I Farrou, National and Kapodistrian University of Athens.

BUILDING ADVENT

Full title of the project: Building Advanced Ventilation Technological examples to demonstrate materialised energy savings for acceptable indoor air quality and thermal comfort in different European climatic regions. Building AdVent is funded by the European Commission, Directorate-General for Energy and Transport as part of the Intelligent Energy - Europe Programme.

It is estimated that energy consumption due to ventilation losses and the operation of fans and conditioning equipment is almost 10% of total energy use in the European Union and that about one third of this could be saved by implementing improved ventilation methods. A number of projects have been undertaken under the auspices of the European Union (under the SAVE and ALTENER programmes) and the International Energy Agency (Energy Conservation in Buildings and Community Systems Annexes 26 and 35) to identify and develop improvements in ventilation technology.

The AdVent programme is intended to build on these and has three principal objectives:

- Classification of existing building ventilation technologies as applied in built examples and collection of information on building performance.
- Identification of barriers for future application.
- Preparation of case-studies in a common format, together with training material

BUILDING ADVENT PARTICIPANTS

Coordinator

Buro Happold Consulting Engineers .... UK

Participating Organisations

Brunel University .... UK
National and Kapodistrian University of Athens .... Greece
Helsinki University of Technology .... Finland
Aalborg University .... Denmark
Faculdade de Engenharia da Universidade do Porto .... Portugal
International Network for Information on Ventilation and Energy Performance (INIVE) .... Belgium

Major Sub-Contractors

Federation of European Heating and Air-Conditioning Associations (REHVA) .... The Netherlands
International Union of Architects .... France/Greece
—Architectural and Renewable Energy Sources Work Programme (UIA - ARESWP)

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