Environmental strategies in retrofitting of educational buildings – The integrated approach

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ABSTRACT

The spatial and material configuration of a building, its dimensions, orientation and fabric are crucial for the choice of the environmental retrofitting strategies to be used. These include innovative daylighting, cooling and control systems, as well as different types of space-related ventilation systems, such as transition spaces, stack devices, ventilation shafts and façade-ventilation, including “double-skin” façade. Most of these systems and their combinations are included in the environmental strategies of the case-studies presented in this paper which come from different European countries as part of an international research program. The projects studied use an integrated approach, resulting in a positive interaction between the architectural features and the environmental retrofitting strategies used, in order to achieve solutions of low environmental impact, well adapted to users’ needs and presenting high levels of air quality and comfort.

1. INTRODUCTION

As existing buildings form a large majority of the building stock, the inclusion of sustainability issues in building renovation could have a considerable influence on human eco-systems. This is not easy to implement, however, since building renovation as a process has many limitations, related to small budgets, building and site drawbacks, service and use particularities and, last but not least, lack of energy conservation experience from the part of decision-makers.

The aim of the I.E.A. E.C.B.C.S. Annex 36 research project “Retrofitting of Educational Buildings - REDUCE” has been to help remedy this situation in the case of retrofitting of educational buildings.

The research deals with the collection and evaluation of retrofit measures and components used for the environmental rehabilitation of educational buildings in 9 European countries and the U.S. The analysis includes factors of cost, environmental benefits, energy savings, design guidelines, lessons learned and user feedback for each retrofit concept used in the case-studies selected.

The final outcome of the project is the development of an “energy concept adviser” for energy-efficient retrofit measures, intended to help decision-makers, appreciate the potential of environmental strategies to be integrated to the refurbishment process.

2. THE CASE STUDIES: TECHNOLOGIES AND STRATEGIES

The collection of 25 case-studies from energy-efficient renovation of educational buildings in the participating countries is part of this project. The case-studies represent a variety of climates, building types and energy conservation principles and technologies which have been designed, implemented and monitored by interdisciplinary design teams in each country. Although quite different in their scope, range and complexity, their evaluation provides useful inspiration and insight on several grounds, some of which are investigated below (Morck, 2003).

Three overall retrofitting strategies have been distinguished in the case studies (Kluttig et al., 2003):

1. The combination of several technologies in an integrated approach, achieving higher energy savings at longer payback time.
2. The emphasis on the implementation of cost-effective technologies only, where short payback times and an immediate return of the investment are achieved.
3. The consideration of the improvement of indoor climate, air quality and lighting comfort as the main retrofitting target, accepting resulting energy savings as additional benefits.

3. THE ARCHITECTURAL DIMENSIONS

3.1 The integrated approach

There are two very important aspects of the retrofitting process that are not explicitly mentioned in most case-studies however. The first one has to do with the role of the existing building both as a space system and as a material configuration in the environmental retrofitting of educational buildings, while the second points to the equally important and often neglected role of the user to achieve high standards of air quality and comfort.

In fact architectural design is a very important part of an integrated approach to environmental design and this is also true for retrofitting. In most of our case-studies, however, environmental design strategies were focused on cost-effective technologies, which were mostly considered as an additive feature to the building.

3.2 Retrofitting strategies and architecture

The air-tightness of the façade, however, often demands a new ventilation strategy-so that better air quality standards are achieved.

At this point the spatial distribution of a building and its dimensions and orientation are crucial for the choice of the natural ventilation strategies to be used. Natural ventilation strategies can be based on morphological characteristics of a building according to its spatial configuration (Mansouri et al., 2002), so that different types of space-related ventilation systems can be distinguished, such as: a) transition spaces, b) stack devices, c) ventilation shafts and d) façade-ventilation, including “double-skin” façade.

Most of these space-related ventilation systems and their combinations are included in the environmental strategies of the case-studies presented, combined with innovative daylighting, cooling and control systems.

The projects discussed below use a holistic approach, resulting in a positive interaction between the architectural features and the environmental retrofitting strategies used, in order to achieve solutions of low environmental impact, well adapted to users’ needs and presenting high levels of air quality and comfort.

3.3 The role of transition spaces

Several examples of the use of atria as the base of a hybrid ventilation concept (Bensalem et al., 2002) are included in the case-studies.

In Bertolt-Brecht School in Germany (D2) two open courtyards were transformed into atria to be used as common rooms and as the heart of the ventilation concept (Figs. 1, 2). In spite of some problems with lighting reduction and winter comfort, mostly related to the change in use, the project achieved user satisfaction and high

Figure 1: One of the two courtyards of Bertolt Brecht School transformed into an atrium.

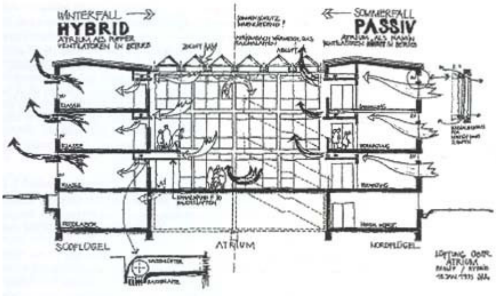

Figure 2: Ventilation concept as originally planned in Bertolt Brecht School.

levels of energy efficiency and comfort as an integrated design.

In fact, energy consumption for heating was reduced by 75%, while artificial lighting needs dropped up to 77% in several classrooms, according to monitoring results.

A similar concept was used in the Ioannina School of Philosophy in Greece (G2) where the atrium space (Trianti, 1996) was transformed into a winter garden and circulation space with occasional recreation uses (Figs. 3, 4).

Due to the combination of a specially designed solar roof and an array of earth pipes buried under the atrium surface, the atrium space is comfortable all year round and as such it is quite appreciated by the users.

Energy gains are estimated at 31% of annual heating requirements for this part of the building.

Figure 3: Ioannina School of Philosophy: View of the atrium roof from S.W.

Figure 4: Ioannina School of Philosophy: View of the atrium space.

3.4 Integration of innovative ventilation systems

Innovative ventilation systems have been used in several case-studies, where natural ventilation strategies have been integrated to the existing building structure, often entailing change in use, dimensions or openings.

In Egebjerg School in Ballerup, Denmark (DK1) modern heating and ventilation technologies were combined to achieve a healthy indoor climate at a reasonable cost, using ecological materials and natural ventilation of spaces. The integrated design concept developed from a close cooperation between architects, engineers and consultants, and the resulting innovative ventilation system profits from the existing crawl space and double height common assembly room, to achieve pre-heating of ventilation intake and operation of a ventilation chimney for extract air. Another innovative feature is a natural lighting and ventilation collector, integrated to the roof of each classroom (Figs. 5, 6).

In this project energy gains were also consid-

Figure 5: North view of Egebjerg School.

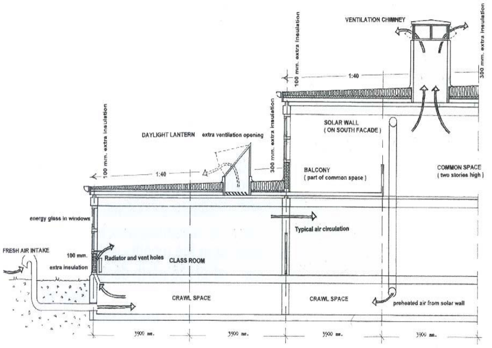

Figure 6: Technical section of the school.

erable, since annual energy consumption for heating was reduced from 181kwh/m^2 to 87kwh/m^2 while electricity for lighting and ventilation dropped to 22 kwh/m^2 from 36kwh/m^2 before retrofitting.

In another school in Denmark (Enghojskolen School, DK2) the retrofitting concept included a drastic change in the architecture, entailing the creation of a new roof with increased height for classrooms, replacement of all materials by ecological ones and reconstruction of windows in order to achieve a user-operated natural ventilation system (Fig. 7), which not only significantly reduced the building’s environmental impact, but also developed the students’ environmental conscience and ability to actively intervene in order to achieve high environmental standards.

In this project annual energy consumption for heating dropped from 284kwh/m^2 to 73kwh/m^2 while electricity consumption was reduced from 72kwh/m^2 to 39kwh/m^2 after retrofitting.

The hybrid ventilation system was also central for a school in Norway (Kampen School, N1) where existing air ducts and ventilation shafts in the building were combined with a new air intake tower and integrated wall system in each classroom to create a non-draft ventilation process (Figs. 8, 9).

In this case, energy conservation features are integrated to a general retrofitting of the school, including the construction of a new wing joining the two original buildings together and sheltering common spaces, a library, and the new air intake tower.


Figure 7: Photo showing the interior of a refurbished classroom.


Figure 8: Kampen School: The new façade.


Figure 9: An interior view of the new air intake tower.

Besides hybrid ventilation features, a new daylighting system includes window interventions to install light shelves at mid-height and glare control in the classroom as well as demand-controlled lighting, ventilation and heat recovery systems. Low-e and environmentally favorable building materials are employed throughout the renovation process, while L.C.C. analysis is used for the whole system.

As a result of the retrofitting strategy, energy consumption was reduced by 18%, of which electricity consumption dropped by 47% despite higher ventilation rates.

3.5 The holistic approach to retrofitting

A new natural ventilation concept fully integrated to the architecture of the building was also central to the energy retrofitting strategy of Grove House at Thames Valley University, UK (UK3). Renovation of the building included a change in use, from offices to classrooms and computer laboratories, while both the external appearance of the refurbishment and its energy retrofitting strategy were vital for project implementation: the first because the building lies in a conservation area, the second to help the University maintain its Energy Efficiency Accreditation (Fig. 10).

The building acted as a pilot for its integrated environmental retrofitting system. It includes a passive stack and façade-ventilation system, as well as night cooling, vacuum tube solar thermal panels, more efficient heating and lighting systems with BMS controls and waterless urinals.

The mixed-mode ventilation is well integrated to this heavy-mass building with no problems to its façade: windows have been replaced to include air inlet grilles and the suspended ceiling in each laboratory is altered so that an air plenum is formed between it and the existing building concrete slab, from where fresh air is supplied to the building. The air is then drawn across the rooms into the corridors through acoustically treated vents and finally to the stairwells used as passive stacks to draw stale air out via roof mounted terminals.

Night cooling works in the reverse way to lower the temperature of the large ceiling concrete mass, while wall transfer grilles are placed throughout the building to allow the flow of air. The system is very successful both from the point of view of environmental impact and water conservation and has low maintenance and running costs. Due to this combination of heavy mass building and cross and stack ventilation there is improved air quality, internal temperatures are substantially reduced in the summer, while large ventilation openings create no drafts in cooler periods.

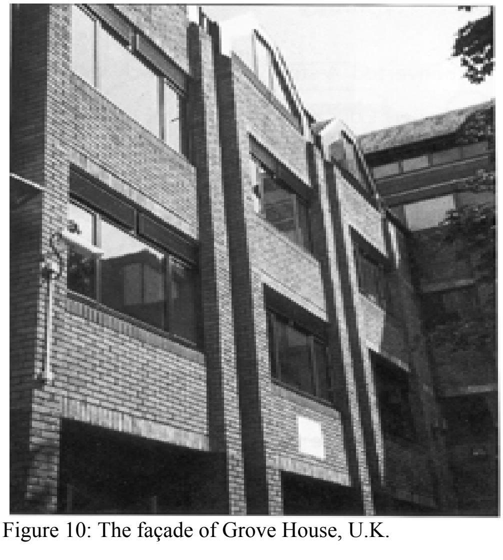
Figure 10: The façade of Grove House, U.K.

Finally in the Chemical Engineering Building in Greece (GR1) the retrofitting concept included an integrated design combining standard as well as innovative energy conservation measures. They include a double skin hybrid ventilation system using a combination of passive and PV technology (Fig. 11), the conversion of existing light shafts into light and ventilation ducts for the laboratories (Fig. 12), the combination of natural and artificial lighting, including the creation of light shelves and new shading to increase visual comfort in offices, the design of a new covered atrium to create an additional meeting space and the use of attached sunspaces for some laboratories in order to integrate existing catwalks (Spyrellis et al., 2001).


Figure 11: View of the Chem. Eng. building after retrofit.

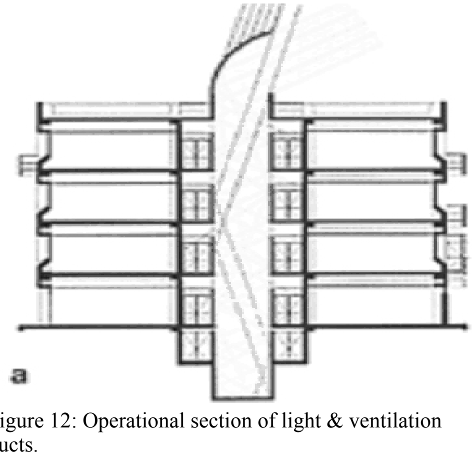

Figure 12: Operational section of light & ventilation ducts.

The energy retrofitting strategy was well integrated to this heavy mass building, where ample transition spaces occupied the majority of covered spaces presenting particular problems of comfort due to their lack of heating and natural lighting.

As calculated using TRNSY'S software, energy consumption for heating is reduced by 34,5% and this for cooling by 68,6% using a combination of simple energy conservation measures (Trianti et al., 2000).

4. CONCLUSIONS

As a result of the above analysis and the comparison of the resulting energy conservation and user evaluation features of the case-studies presented, it follows that the inclusion of architectural characteristics of the building to be refurbished, both as a space system and as a material configuration is essential to the successful integration of environmental retrofitting strategies in educational buildings (Trianti, 2000). Besides high energy savings, lower environmental impact and improvement of indoor climate, integrated projects include better use and appreciation of improved or extended spaces in the building or around it and increased involvement of students and teachers in the operation of the system, so that high environmental standards are achieved.

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