

## The bioclimatic dimension of educational buildings in Greece

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### ABSTRACT

The architectural programme of educational buildings provides excellent opportunities for applying environmentally sustainable design strategies. This paper discusses the issues associated with this relationship and presents the conclusions of a research examining a number of historical and contemporary built examples in Greece. It highlights the design parameters which have an important effect on occupant comfort, indoor environmental quality and energy use.

### 1. INTRODUCTION

This research highlights the close relationship between the functional characteristics of educational buildings in Greece and the environmental design objectives. These objectives are providing thermal and visual comfort, as well as the required levels of indoor environmental quality by the minimum expenditure of non-renewable energy. Additionally, the architectural programme of educational buildings allows the designer to develop transitional spaces, exploring the relationship between inside and outside. Last but not least, environmentally sustainable design of school buildings contributes on raising the awareness of young users on environmental issues.

This relationship, though recognized and expressed historically, was ignored in many examples of educational buildings designed at the first part of the 20th century (Yannas, 1994). As is shown by this research, the bioclimatic dimension of architectural design consisted an integral part of the design process in the past (e.g.

at the school buildings of the 1930s). In recent years, these principles tend to be readopted by contemporary architects who redefine the elements of architectural conception on their projects.

### 2. METHODOLOGICAL APPROACH

#### *2.1 Field of study*

Fifteen educational buildings were selected to conduct the survey. Twelve of them are located in the southeastern region of Greece (climatic zone B) and three of them in the south insular region of Greece (climatic zone A). Their period of construction lies between the 1930s and the 2000s. Consequently, the buildings chosen function as a representative sample of the trends towards environmental design of each period.

#### *2.2 Description of the research process*

The study was conducted from mid March 2004 till mid September 2004. It consisted of a series of visits and discussion with the users wherever this was possible. The questionnaire consisted of several sections and asked the subject to evaluate their thermal environment, the interior air quality, the lighting quality to finish with a checklist on the use of different thermal environmental control means (windows, shading devices, passive heating and/or cooling systems). The observations on each example were compared to and enriched by bibliographic sources and results of existing surveys (e.g. by KAIIE). Hereafter, the general characteristics of each group of buildings are presented through the most representative examples.

Without a doubt, the present project func-

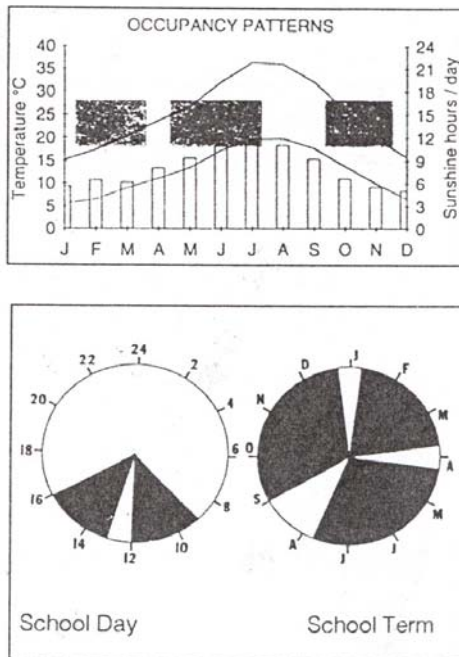


Figure 1: Occupancy patterns of school buildings at seasonal and daily level (Yannas, 1994).

tions as a preliminary stage of research which explores the environmental performance of educational buildings in Greece. It does not cover in any way the need for an organized collection of numerical data or numerical analysis that should take place in a second phase.

### 3. ENVIRONMENTAL DESIGN CONSIDERATIONS OF EDUCATIONAL BUILDINGS

#### 3.1 Thermal behavior

Each building should be regarded as a “live organism” that has to adapt to continuously changing conditions. Especially essential is this feature for educational buildings at seasonal and daily level (Fig. 1).

The majority of educational buildings operate from September through June, covering therefore a wide range of climatic conditions. On the first count, the emphasis is given on the heating needs during the cool period. Notably though, the cooling needs in Mediterranean countries such as Greece are increased. This situation is also compounded by the fact that temperatures rise significantly by May already, while the warm period expands until September and often October. Nevertheless, in comparison with other types of buildings, the educational buildings

present reduced heating and cooling needs during peak demand periods which usually coincide with school holidays (e.g. during December-January, July-August). As a result, educational buildings offer an excellent opportunity for the application of passive heating and cooling systems (Yannas, 1994).

In addition, the educational procedure is consisted by diverse levels of human activity (theoretical lessons, intervals, sports, workshops). Therefore, designers attach great importance to the control of the constantly changing internal heating loads. Each classroom presents multiple temperature fluctuations within the daily cycle. Thus, heating and cooling demands vary in a significant level. For example, schools remain closed during the evening hours when the building envelope radiates back the heat that has been stored into the building elements during the day. Thereby, there is a need of pre-heating in the morning before the students enter the classroom.

Internal heat gains from metabolic processes of students form an integral part of the thermal balance in a densely occupied classroom (100 W in average for each student). For instance, after the interval, students enter into the classroom after having intense body activity (e.g. during games). At this moment each student contributes to the total sum of internal heat gains with more than 100 W in average  $\times$  (25 students)  $>$  2,5 kW. However, cooling needs must be covered slowly and in an indirect way due to the young users’ sensitivity to quick temperature changes (Ευαγγελινός et al. 1978).

Just as important is the need for ventilation, both for providing passive cooling during the warm period and fresh air supply all year round.

#### 3.2 Lighting – visual comfort

Sufficient levels of natural lighting and uniform distribution of both natural and artificial lighting are an essential part of environmental design. They also improve significantly the students’ productivity. Beyond this, visual comfort is attained by glare control which should be taken into consideration from an early stage during the design process.

#### 3.3 Energy consumption

According to the Center of Renewable Energy Sources, the average energy consumption of

school buildings in Greece is estimated at 92 kWh/m<sup>2</sup>, but occasionally reaches 100 - 200 kWh/m<sup>2</sup> (KAΠE, 2002). This amount is regarded as particularly high, taking into consideration the temperate climate of Greece.

### 3.4 The contribution of environmental design to the educational procedure

School environment signals the transition from private to public space. Thus, it is a route to socialization. As the first image of public architecture one receives, school buildings could raise user awareness towards environmental issues.

## 4. EXAMPLES

### 4.1 1930s-1940s: Rationalism and conventional principles of environmental design

The "schools of the 1930s" was a school building construction program which built almost 3,000 schools in the pre-war period, the majority in modern style. During our research, we examined seven of them. As their designers aim at functionality, they tend to adopt simple principles of environmental design such as:

#### *Orientation – direct solar gains*

Wherever this is possible, the building envelope is oriented parallel to the west-east axis. A characteristic example is the Elementary School at Kallisperi str., Acropolis, designed by P. Karantinos in 1931 (Fig. 2). Instead of being oriented towards the view to Acropolis, the classrooms are oriented towards the south-facing courtyard.

#### *Thermal zoning*

Thermal zoning and buffer spaces are also widely used. We can see an example of this examining the space sequence at the Elementary School of D. Pikionis at the foothill of Lycabet-

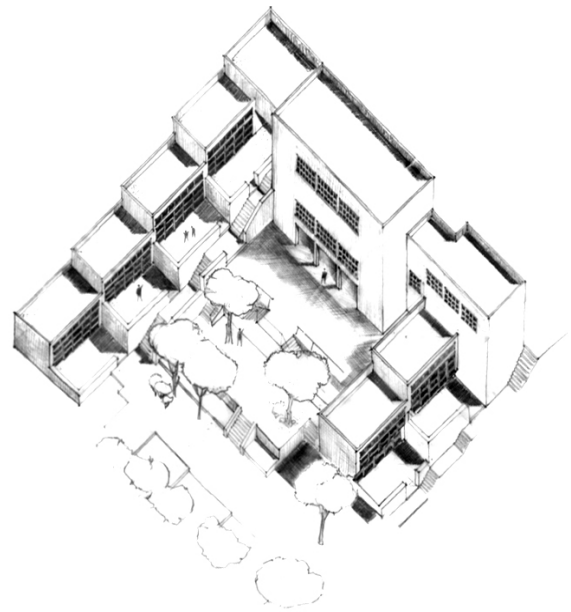


Figure 3: Axonometric view of the Elementary School at Lycabettus Hill, D. Pikionis, 1932-37.

tus (1932-37). The main feature of the architectural composition is the use of a unit that consists of a corridor at the north (buffer space), the main classroom and an outdoor space at the south. This principle is combined with the integration with the landscape, offering a unique example of design with nature (Fig. 3).

#### *Materials*

According to the users, a main difference between the school buildings of the 1930s and more recent built examples is the thermal behavior of the structural materials. In most cases, the schools are built of a reinforced concrete shell and brick masonry and the materials on the elevations are stucco surfaces, wooden window frames and iron railings.

Therefore, the use of materials of high heat capacity contribute to the total amount of the building's thermal mass. Heat is absorbed and stored during sunny periods when the heat is not desirable in the living space of the school, and then it is released during overcast periods when heat is desirable or during the night, when the school is closed. Admittedly, levels of thermal comfort tend to be higher in these schools during the warm period. Nonetheless, thermal loss is increased in schools built before the 1980s, due to the lack of thermal insulation.



Figure 2: Plan of the Elementary School at Kallisperi str., Acropolis, P. Karantinos, 1931.

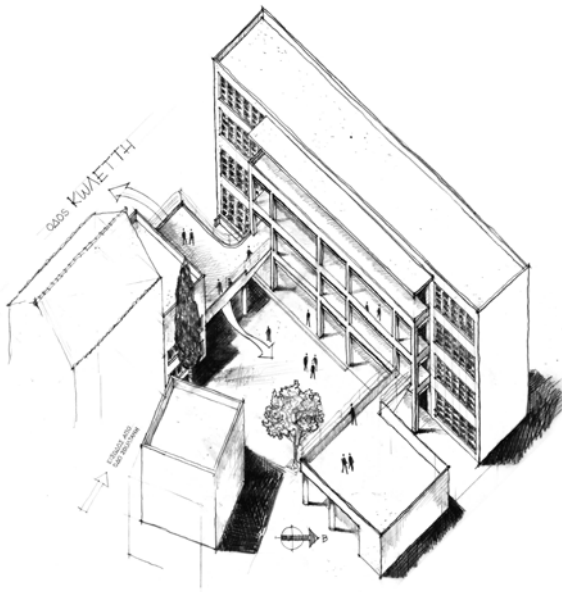


Figure 4: Axonometric view of the Elementary School at Exarheia, N. Mitsakis, 1932-37.

#### *Composition of volumes*

The synthesis of pure geometrical forms suggests another feature of the schools of the 1930s. In many cases, shading is provided by architectural elements e.g. at the Elementary School at Exarheia, designed by N. Mitsakis (1932-37). This kind of approach presupposes a deep knowledge of the solar route (Fig. 4).

#### *Urban tissue*

During our research, we emphasized on the comparison between the present and the current state of the urban tissue that surrounds the buildings. In the 1930s there was a wider choice of building sites and a large potential for exploiting landscape elements. Nowadays, the increase of the density in the urban environment has resulted in the radical change of these buildings' thermal behavior.

#### *4.2 1950s-1980s: The reality of the large state school buildings and visions of the future*

During the decades that followed, the contribution of the building activity to the greek economy raised significantly. This, in turn, led to the standardization of construction. Most schools are built by the Organization of School Buildings (OΣK) and designers tend to sacrifice quality aims for targets such as economy and speed of construction.

Nevertheless, there are some outstanding ex-

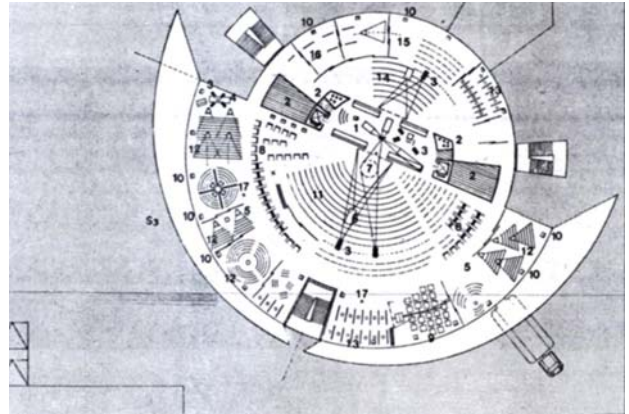


Figure 5: Plan of the Secondary School at Ag. Dimitrios, T. Zenetos, 1969-76.

amples of visionary architecture that seek new a new form of relationship between the architectural procedure and its environment. The most characteristic example of this trend is the Secondary School at Agios Dimitrios, designed by T. Zenetos in 1969.

A significant stylistic feature is the succession of louvred roofs surrounding the southern semi-circle of the building. Its width fluctuates according to the orientation so as to provide effective protection to the interior without wasting material. The users interviewed observed that despite the large number of alterations and expansions to the initial plan, environmental objectives such as natural lighting and glare control are achieved in the interior of the classrooms (Fig. 5).

#### *4.3 1980s – today: Working with climate – from theory to practice*

Passive systems that provide heating, cooling and lighting with the minimum expenditure of non-renewable energy have started to be applied in school buildings from the 1980s.

#### *Passive solar heating systems*

The Nursery School at Holargos, designed by A. Tombazis in 1980 is a characteristic example of the trend towards the integration of environmental design principles at school buildings in Greece (KAΠE 1992). Passive heating systems are integrated in its building envelope such as: direct solar gains through south openings, indirect solar gains through Trombe – Michel walls, isolated solar gains through thermosiphonic air panels (Fig. 6).

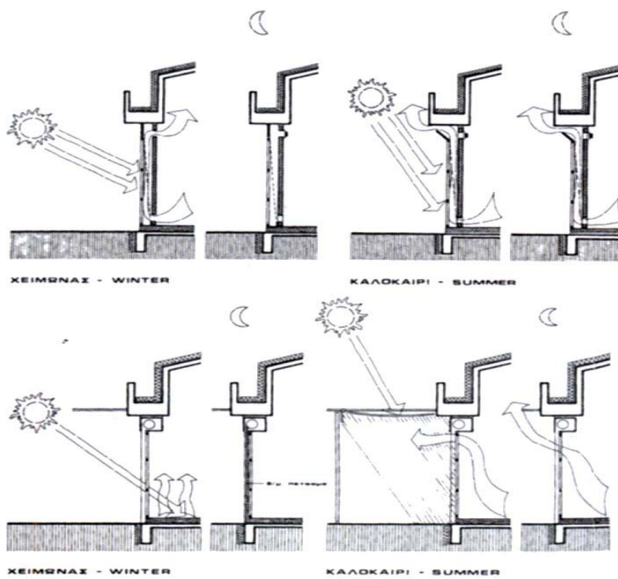


Figure 6: Passive solar systems at the Nursery School at Holargos, A. Tombazis, 1980-84, (KAIE 1992).

### Natural lighting

The need for natural lighting gives form to a series of architectural elements which characterize the buildings' elevations. For instance, the Kindergarten and Elementary School of I. Kalligeris at Rethymno (1985-87) introduces roof sheds at all of the classrooms. Glare control is achieved by movable shading devices that reflect the sunlight and diffuse it to the workspace (Fig. 7). Cross ventilation is also achieved. Unfortunately, a series of modifications to the initial architectural design (e.g. non-operable windows and shading devices) have led, according to the users, to poor environmental performance of the building (KAIE 1992).

## 5. CONCLUSIONS

The research on the bioclimatic dimension of the educational buildings in Greece, which was presented in this paper, constitutes a preliminary approach to the assessment of the potential of adoption of environmental design principles at school architecture. Flexibility is a fundamental basis of environmental design. Educational buildings need to be able to adopt to a wide series of changes, either of the educational procedure, or of the climatic conditions. Thereby, the users' observations demonstrate that conventional principles of environmental design seem more appropriate for the design of sustainable

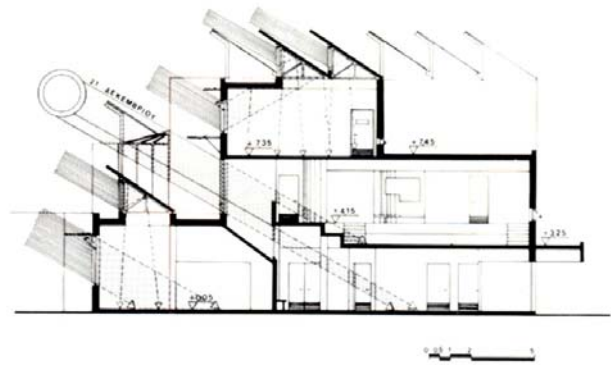


Figure 7: Roof sheds, School at Rethymno, I. K (KAIE 1992).

educational buildings. Instead, in many instances, sophisticated systems have not functioned as expected due to the inability of the users to interact with them. Therefore, just as important is the integration of systems that are simple and user-friendly. One thing to bear in mind is the young age of the users.

In addition, economy is particularly important for the public school buildings. This might prevent the designer from applying high-cost systems. However, the adoption of simple principles results in energy efficiency and high environmental performance in the long term. Furthermore, maintenance costs should be kept at a low level.

As a conclusion, there is no doubt that due to the occupancy patterns and the density of occupation, as well as the temperate climatic conditions, the needs for heating, ventilation, cooling and lighting of educational buildings in Greece could be covered by passive systems. As a result, the use of mechanical auxiliary systems could be eliminated.

Finally, this paper revealed the need for a more detailed environmental analysis of the educational buildings in Greece. It is imperative that the study should be extended to include more climatic regions.

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## REFERENCES

- Ευαγγελινός, Ε., Γ. Κοντορούπης και Ε. Μαΐστρου, 1978. Διερεύνηση μεθόδων θέρμανσης με ηλιακή ενέργεια: πρόταση εφαρμογής σε σχολικά κτίρια. Αθήνα: Εθνικό Μετσόβιο Πολυτεχνείο, Ανωτάτη Σχολή Αρχιτεκτόνων.
- Κέντρο Ανανεώσιμων Πηγών Ενέργειας (ΚΑΠΕ), 1992. Βιοκλιματική αρχιτεκτονική: εφαρμογές στην Ελλάδα. Πικέρμι: Κέντρο Ανανεώσιμων Πηγών Ενέργειας, Επιτροπή Ευρωπαϊκών Κοινοτήτων
- Κέντρο Ανανεώσιμων Πηγών Ενέργειας (ΚΑΠΕ), 2002. Οδηγίες για θερμική-οπτική άνεση και εξοικονόμηση ενέργειας σε δημόσια σχολεία. Πικέρμι: Κέντρο Ανανεώσιμων Πηγών Ενέργειας.
- Yannas, S., (ed.), 1994. Design of Educational Buildings, 1 Primer. London: European Commission Directorate – General XII for Science, Research and Development, Climate-Responsive Architectural Design, Environment & Energy Studies Programme, Architectural Association Graduate School.