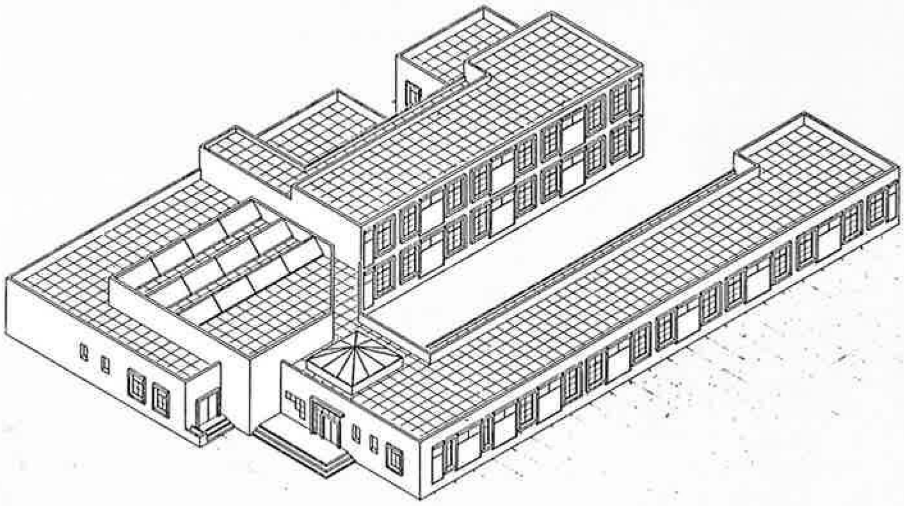
BUILDING 2000

Commission of the European Communities

HIGH SCHOOL

GAVRION, ANDROS ISLAND/GREECE

- High school with ten classrooms
- Passive solar heating in winter using direct gain through south-facing glazing and Trombe walls
- Prevention of overheating on warm days by shading and cross ventilation
- Adequate daylighting of classrooms through south-facing windows and north-facing skylights
- Heating of auditorium in winter using active solar system with air collectors



Building 2000 is a series of design studies illustrating passive solar architecture in buildings in the European Community.

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PROJECT DESCRIPTION

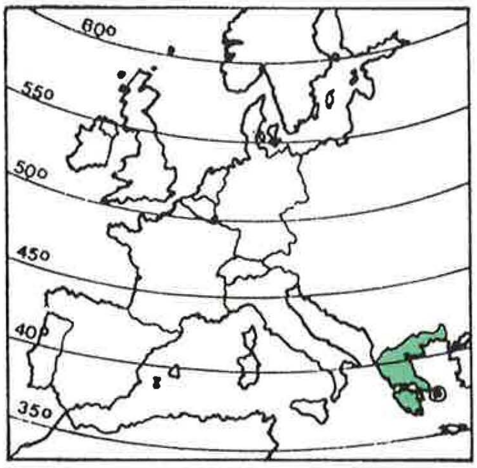


Figure 1. Location

Degree days (base 18° C)	1219
Sunshine hours	2895
Global irradiation on a horizontal plane	
Jan-Dec in kWh/m²	1639
(Jan-Dec in MJ/m²	5900)

Table 1. Some key climate data

Building Type

This is a high school with ten classrooms, a library, laboratory, auditorium, administration offices and the usual service areas such as storage spaces, warehouses, cloakrooms, corridors, etc.

Location

The building is at Gavrion on the island of Andros (latitude 37.3° N, longitude 24.8° E - see Figure 1), the most northerly island of the Cyclades archipelago. The 5 acre site is at sea level and perfectly flat which allows the school to be positioned away from shadows likely to be cast by other buildings constructed in the locality in future.

Site Microclimate

Andros is situated in the middle of the Aegean sea and the climate is typical of the Mediterranean marine area - temperate and humid. The annual amount of solar radiation falling on a horizontal plane is high - around 5700-6100 MJ/m² (1583-1694 kWh/m²). The winters are mild and the summers warm. The coldest month of the year is January, when the mean temperature is 10.3° C. In July the average temperature is 26.1° C. The prevailing winds are from the north and relatively strong, in the region of 3.5 m/s to 10.5 m/s. Some key climate data are given in Table 1 and Figure 2.

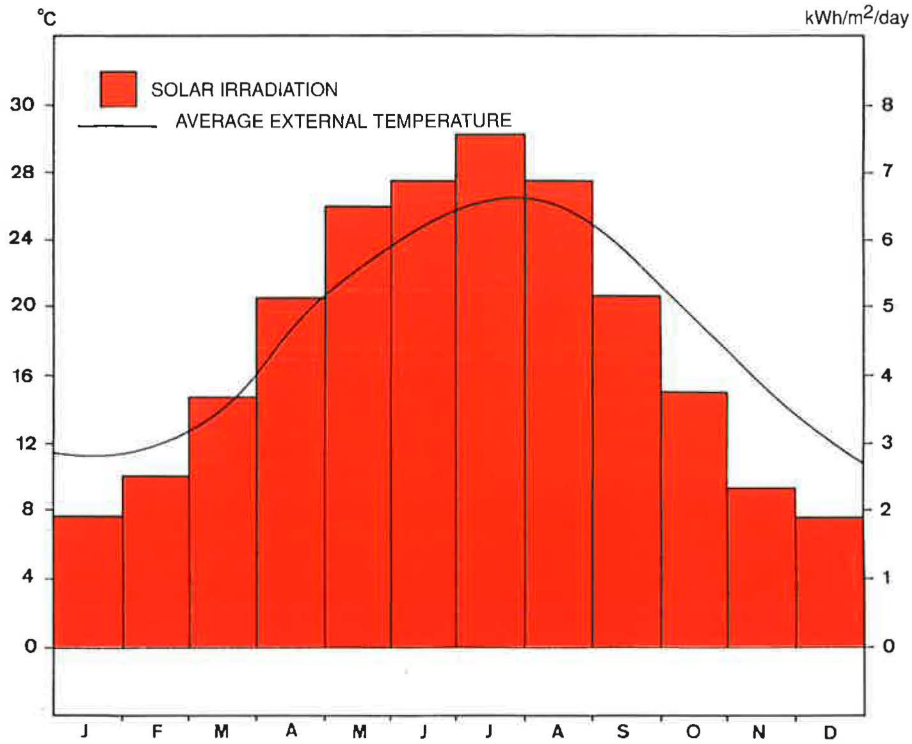


Figure 2. Solar irradiation and ambient temperature data (average values for 1960-75)

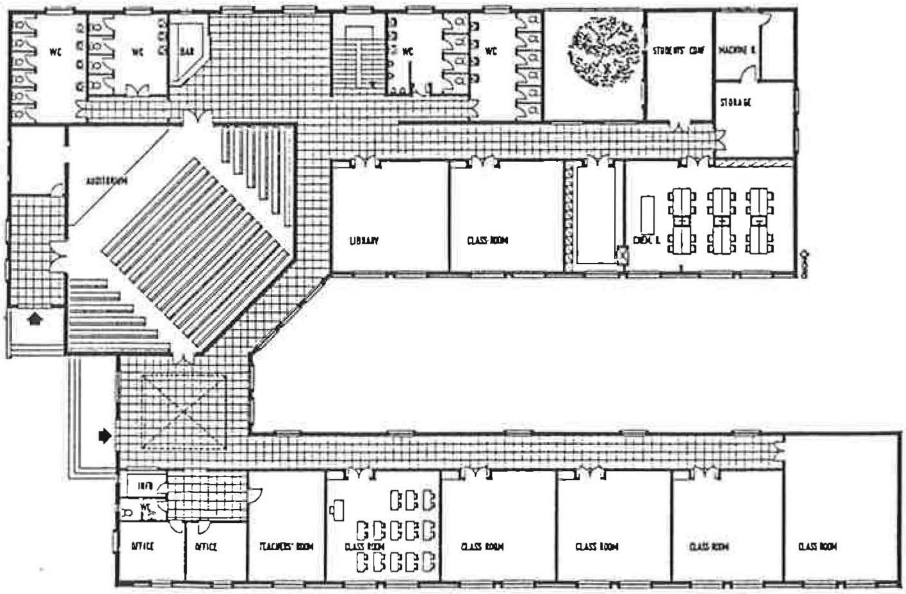


Figure 3. Ground floor plan

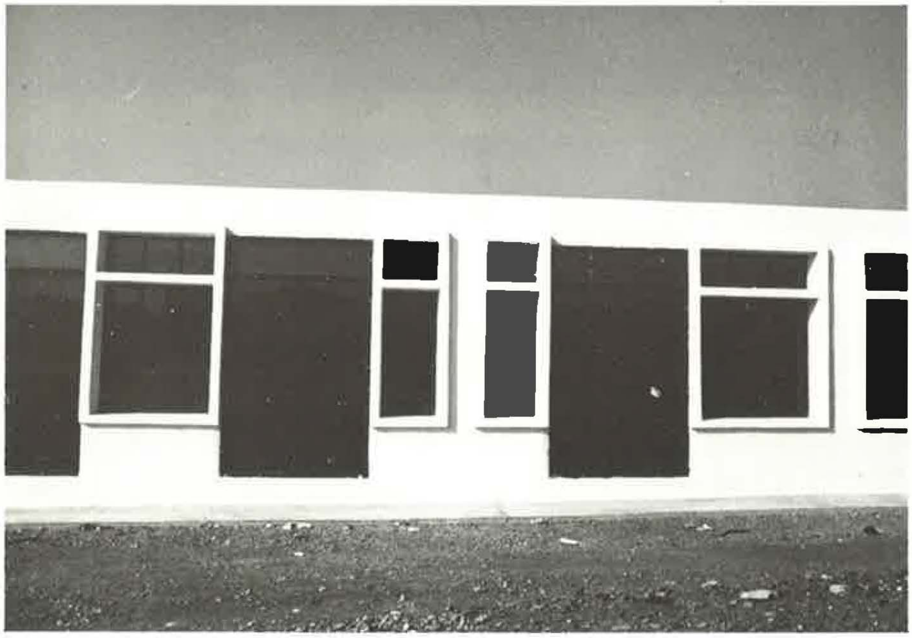


Figure 4. South facade

Design and Construction Details

The 1600 m^2 building has been designed to be in keeping with the traditional architecture of the island and yet to take into account bioclimatic principles and the needs of a school. It is arranged along an east-west axis with a slight veer towards the east and consists of two wings joined by the auditorium. It is on two floors. Six class-rooms, the library, laboratory, auditorium, administrative offices and services are on the ground floor. The other four classrooms are on the upper floor. The classrooms, library, laboratory and offices are on the south side of the building. The storage areas, warehouses, cloakrooms and corridors, etc., are on the north side. The ground floor plan is shown in Figure 3 and the south facade in Figure 4.

The entrance hall has been turned into a sunspace by addition of a glass pyramidal roof (Figure 11). The building is well insulated, the insulation being placed on the interior of the structure. Polystyrene panels have been used on the roof and external walls. Aerated perlitic concrete has been used for the floor. There is double glazing on all north-facing windows. The U-values of some of the building elements are given in Table 2.

external walls	0.44
roof	0.31
floor	0.65
glazing	
single	5.80
double	3.70

Table 2. U-values of some building elements (W/m^2 K)

Figure 10. Internal view of skylights on north side of classrooms

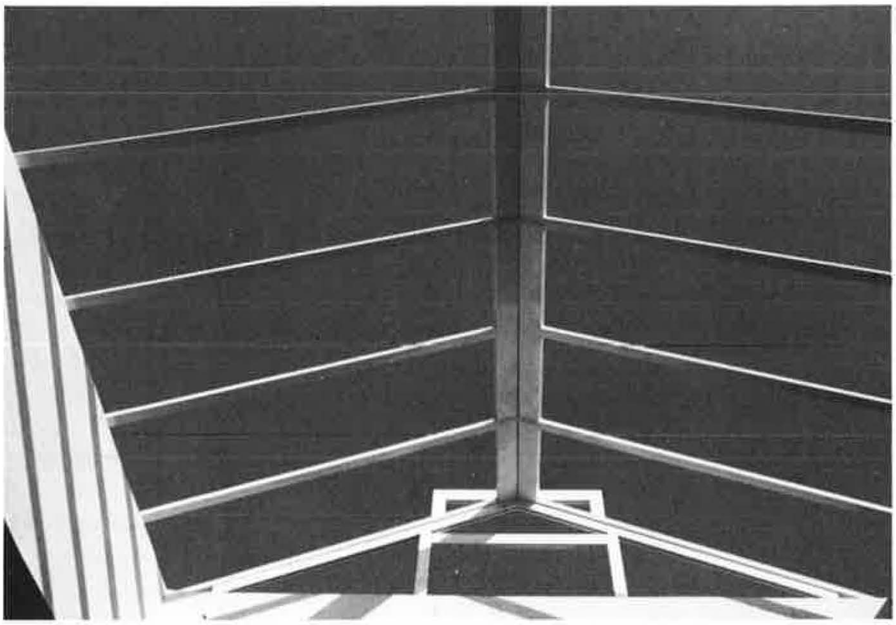


Figure 11. Internal view of glass roof in entrance hall

ENERGY CALCULATIONS PERFORMED AND DESIGN TOOLS USED

Design Tools

The heating, shading, ventilation and daylighting systems were designed with the help of a number of design tools.

Thermal Performance

The thermal performance was evaluated using the PASTEMP computer simulation model. This is based on a simplified thermal network method developed by Building Research Establishment in the UK. Daily internal temperature variations, heating or cooling loads and the passive solar contribution to heating or cooling are estimated using admittance factors. These indicate the extent to which heat enters the building materials over a 24-hour cycle of temperature variation. (Dense materials take up more heat and have higher admittance values than lightweight materials.) Various input parameters describe weather conditions, building structure and openings, etc., occupancy patterns and desired internal temperatures and ventilation rates.

Thermal Comfort

The thermal comfort of the building was estimated using the COMFORT 2.10 program developed by Bruel and Kjaer of the Technical University of Denmark. This calculates the predicted mean vote (PMV) index which indicates how close to comfort a space is taking into account air temperature, humidity and speed and the occupants' clothing, metabolic rate and activity levels. It also estimates the percentage of dissatisfied occupants (PPD).

Daylighting

Daylight factors and illuminances inside the building were determined from room, window and site characteristics using the MICROLITE 1.0 computer model developed in the USA.

	kWh	%
Energy losses		
fabric	17.1	56
infiltration and ventilation	13.6	44 +
Total losses	30.7	100
Energy gains		
casual	16.9	54
passive solar (direct gain and Trombe wall)	12.7	42
active solar (air collectors)	1.1	4 +
Total gains	30.7	100

Table 3. Annual energy balance

Results of Thermal Performance Analysis

The calculations showed that, because of the mild climate and relatively short occupancy period (9 am to 4 pm, September to June), the passive solar systems will supply almost all the heating needs of the building. They also indicated that the natural ventilation and shading systems would be sufficient to cool the building in the warmer months.

The energy balance of the building for a typical year is shown in Table 3. Figures 12 and 13 show the classroom temperatures over a cold sunny and a cold cloudy day in January and over a typical January and a typical June day. The curves show the effect of shading the Trombe wall.

Evaluation of the active solar system showed that the 15 m^2 array of solar collectors would provide around 90% of the auditorium heating require-ments. Use of the collectors is justified because the auditorium is large and has a low glazing area.

The building's high insulation levels and the low thermal mass of the floor lead to a rapid response to solar gains. Thermal comfort is highly dependent on ventilation rates. Because of the large number of openings in the building, the basic infiltration rate was assumed to be 2 air changes per hour (ACH). The required rate, which depends on the number of pupils in the building, is set at 3 ACH in winter and 5 ACH in the warmer months when cross ventilation can be induced in daytime through the Trombe walls. Ventilation is increased at night to cool the building structure.

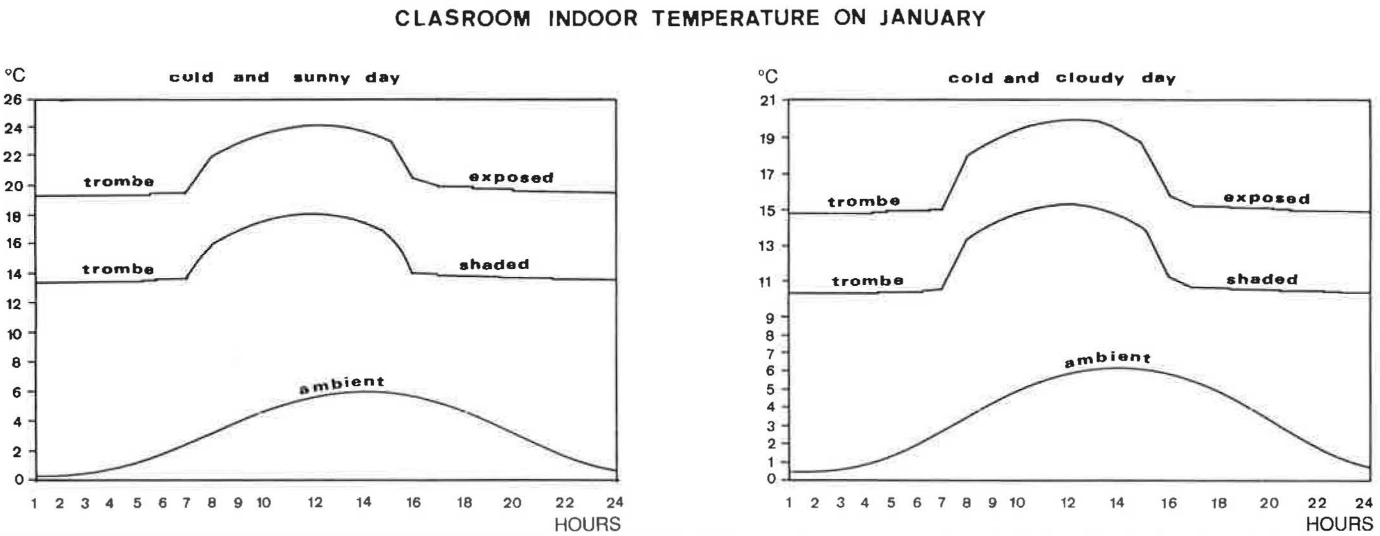


Figure 12. Variation in classroom temperature on a cold sunny and a cold cloudy January day. The curves show the effect of shading the Trombe wall. The occupancy period is from 8 am to 4 pm.

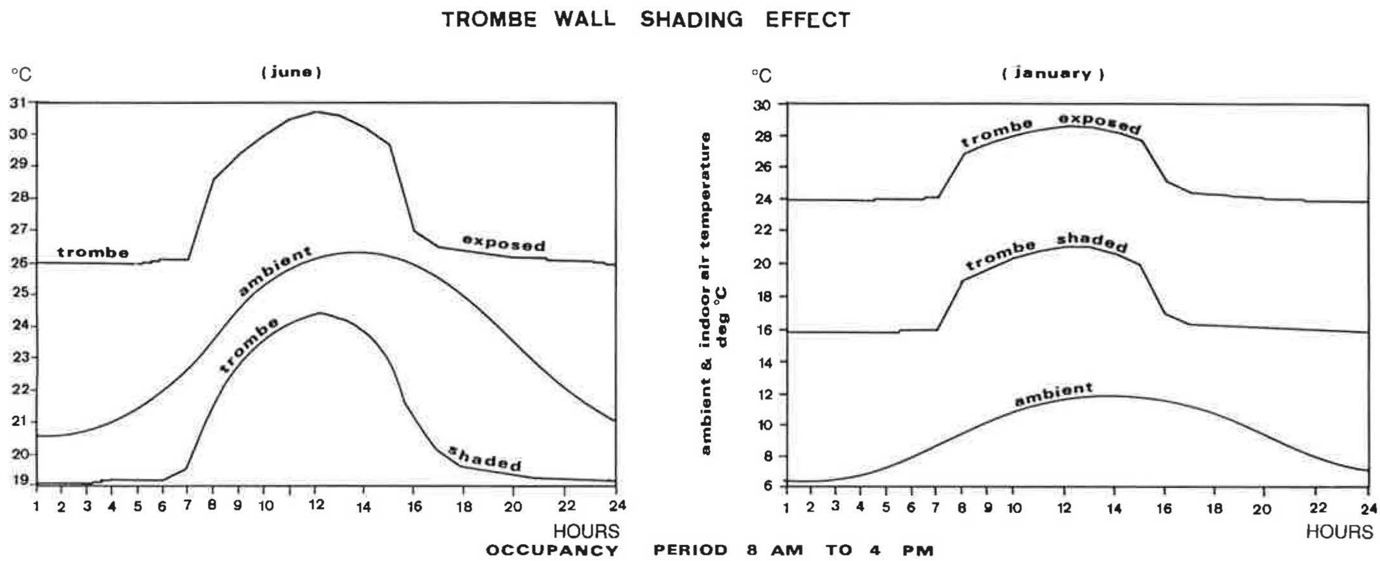


Figure 13. Variation in classroom temperature on a typical June and a typical January day. The curves show the effect of shading the Trombe wall. The occupancy period is from 8 am to 4 pm.

Results of Thermal Comfort Analysis

The comfort analysis showed that the PMV and PPD values vary considerably not only from month-to-month but over a single day. This is because thermal comfort depends on variables such as air temperature, mean radiant temperature, relative humidity and ventilation rate (i.e. air speed) as well as on clothing and activity levels. The results showed that the building will be comfortable without the use of auxiliary heating or cooling systems both in winter and in the warmer months of occupation: the PMV was always in the range - 0.5 to + 0.5 and the PPD in the range 5% to 10%. The actual figure depended on the ventilation rate and the use of the Trombe walls. The daily variation of the PMV in a classroom on a typical June and January day is shown in Figure 14.

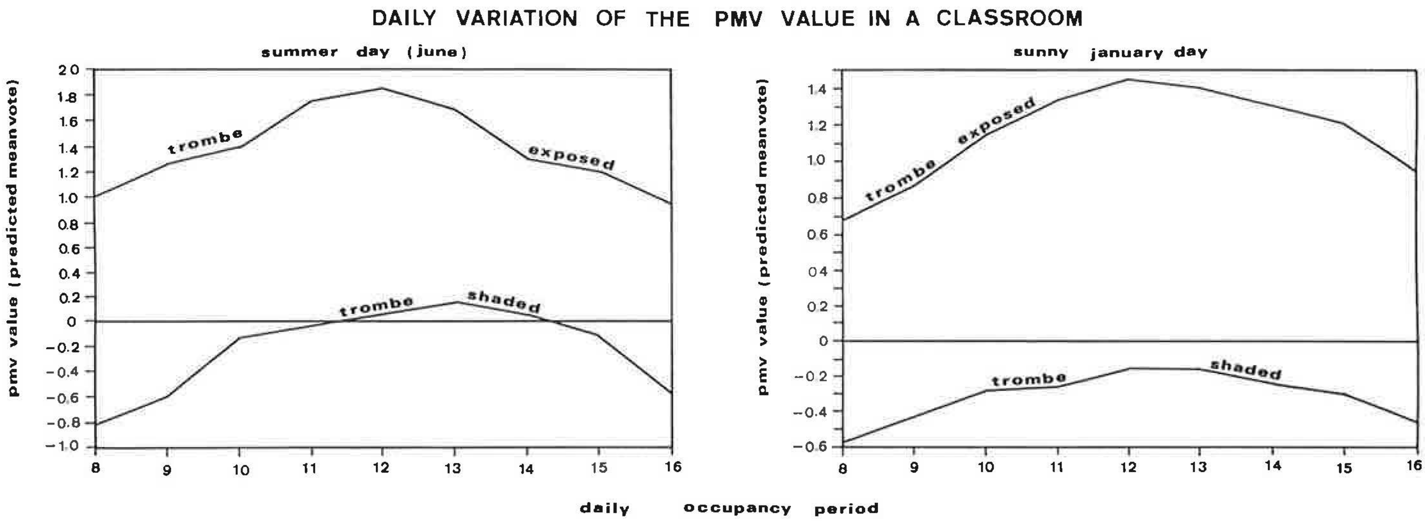
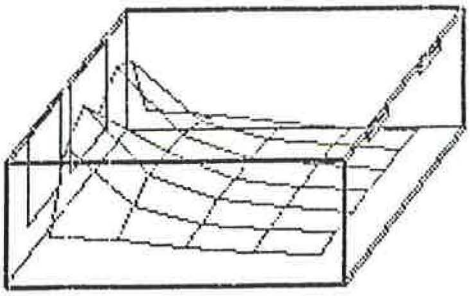


Figure 14. Variation of the PMV value in a classroom on a sunny June and a sunny January day over the period of occupancy

Results of Daylighting Analysis

The analysis was carried out for a classroom at a height of 1 m from the floor for different hours of the day on 21 December with an overcast sky. The results are given in Figure 15. The building has extensive areas of glazing and, as would be expected, produced average daylight factors of between 7% and 9%. At 12 noon, with a sky illumination of 24,000 lux, the minimum daylight factor was 2%. This is above the 300 lux required on average for a classroom. Glare arising from reflective surfaces (on, say, student desks) is prevented by the use of venetian blinds.



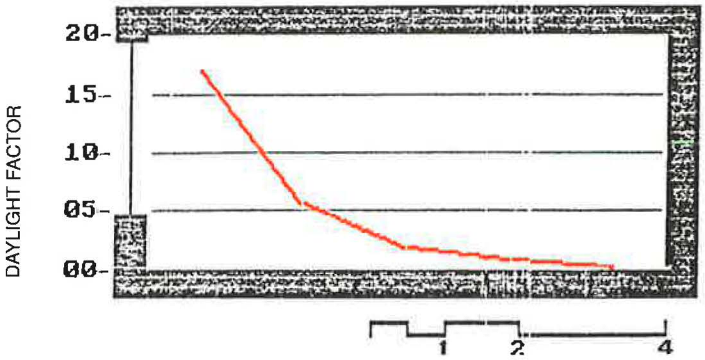


Figure 15. Daylight factors in classroom on 21 December

Figure 16. View from the south west

GENERAL DESIGN GUIDELINES/POINTS OF INTEREST RESULTING FROM THIS PROJECT

Bioclimatic design, in its broadest sense, was known to the island's early architects. Modern buildings on Andros, on the other hand, have ignored the climate factor. This project aimed to demonstrate that bioclimatic principles can be used effectively in modern buildings in the Cyclades region. A school building was chosen for the demonstration because, with its high internal gains and lack of summer use, it is particularly suitable for passive solar systems. Because the project is a demonstration, the systems used in the school needed to be simple to operate and cheap to install. Andros' regulations concerning building shape led to the choice of direct solar gain, Trombe walls and solar air collectors. The project has showed that these systems can fit into the local architectural environment. The studies carried out as part of the Building 2000 programme proved that:

- the chosen heating systems can provide assured thermal comfort conditions and supply the majority of the heating demands of buildings in the region;

- cross ventilation is a simple and effective means of providing cooling in this geographical area because there are cool northerly winds most of the year;

- high levels of insulation installed in a way which takes into account the building use are a decisive factor in the success of bioclimatic design.

Figure 17. Detail of Trombe wall

BUILDING 2000 Building 2000 brochures are published by Directorate General XII of the Commission of the European Communities to show how design studies can help architects and other building designers use passive solar principles to the best effect to produce attractive energy efficient buildings. Each brochure describes studies carried out with the support of the Commission during the design phase of one or thirty-six non-domestic buildings in the EC Member States. The studies were on such topics as daylighting, heating, cooling, ventilation, comfort, control systems and urban design. They were carried out with the help of acknowledged European experts in these fields and drew heavily on lessons learned and techniques developed through the Commission's research and development programme on solar energy applications to buildings.

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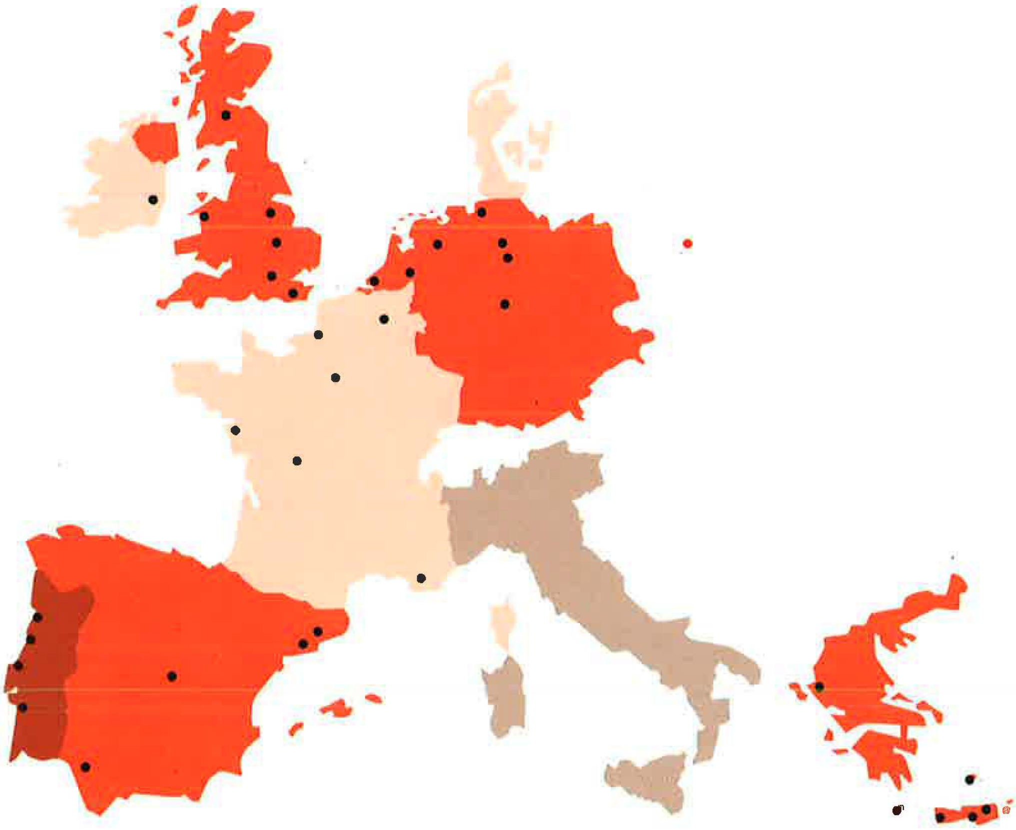

List of Design Team Participants and Advisers

Client
Prefecture of Cyclades
Greece

Architect
Alexander Kapon
Charilaou Tricoupi Str 146
Athens 11472
Greece

Energy Consultant
George Zannis

Structural Engineer
Savas Varthalitis

This set of **Building 2000** brochures illustrates how architects and other building designers can successfully apply passive solar principles to produce energy-efficient buildings.

BUILDING 2000
Participants

Project Director
Theo C. Steemers

Coordinator
Cees den Ouden

Technical Steering Committee
Dean Hawkes
Nick Baker
Alex Lohr
Jean P. Lepoivre

Regional Liaison Agents
(D) Jörn Behnsen
(E) Vicente Sifre
(F) Michel Raoust
(GB) Alan Hildon
(GR) Matheus Santamouris
(P) Eduardo Maldonado

Further information or copies of the brochures can be obtained from prof. ir. Cees den Ouden, EGM Engineering BV, P.O. Box 1042, 3300 BA Dordrecht, The Netherlands.