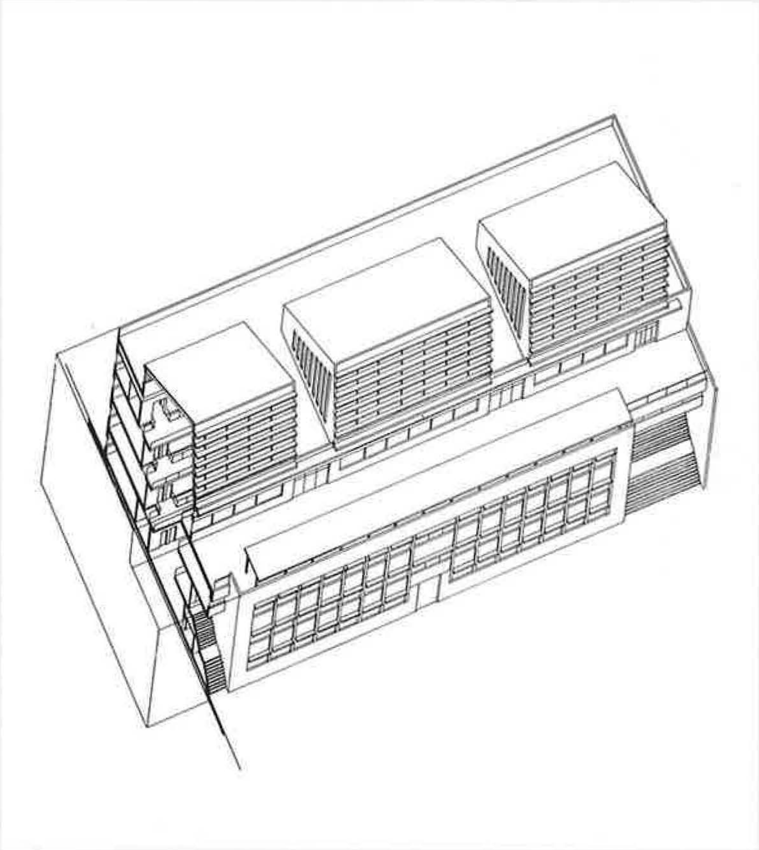
BUILDING 2000

Commission of the European Communities

- Modular faculty building for University of Seville's new campus to be built on Expo 92 site.
- Minimum energy consumption and low maintenance.
- Adequate daylighting of all rooms.
- Prevention of summer-time overheating and glare.

UNIVERSITY FACULTY BUILDING

SEVILLA/SPAIN



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. Site location

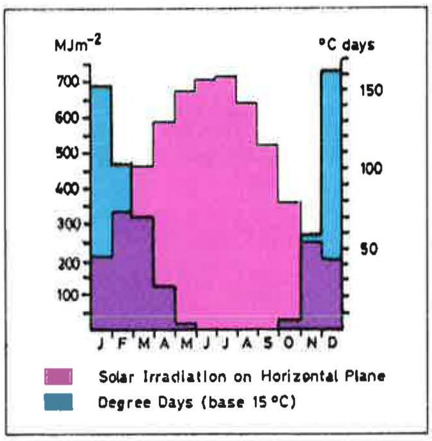


Figure 2. Solar irradiation and degree day data

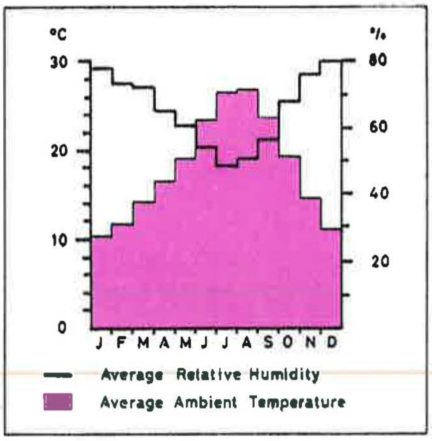


Figure 3. Relative humidity and ambient temperature data

Building Type

When the fair is over, the Expo 92 site will be transformed into a new campus for the University of Seville. This building is one of several being constructed initially as an office block for Expo 92 which will eventually be converted into accommodation for one of the university faculties. It contains teaching and administration accommodation, the usual service areas, shops and a bar and a room for use as a students' club.

Location

The site (which is 7 m above sea level) is to the west of the city of Seville (latitude 37 ° 25' N, longitude 6 ° W) in the Cartuja area by the Guardalquivir river (see Figure 1).

Site Microclimate

The climate is characterized by extremes. There are cold periods and periods of overheating. The differences between daily minimum temperatures and daily maximum temperatures are considerable. Solar irradiation and degree day data are given in Figure 2 and relative humidity and mean ambient temperature data in Figure 3. These data, together with those in Table 1, were collected some 3 km north-west of the site.

Precipitation	586.8 l/m^2
Relative humidity	65%
Ambient temperature	17.3 °C
Average maximum temperature (July)	30.0 °C
Average minimum temperature (January)	4.9 °C
Prevailing wind direction	SW
Wind speed	3.2 m/s
Global irradiation on the horizontal	
in kWh/m^2	1579 kWh/m^2
in MJ/m^2	5686 MJ/m^2
Degree days (base 15 °C)	580
Sunshine hours	1475

Note: These data are annual averages unless indicated otherwise

Table 1. Some key climate data

Design and Construction Details

The building design is a modular one which can be modified to meet the specific needs of individual faculties. The arrangement of the individual faculty buildings on the site is shown in Figure 6.

The main feature of each building is a central atrium which is divided into three independent units to facilitate control of heat and sound. The accommodation is arranged in two four-storey blocks on either side of the atria. The teaching block is on the north side and the administration and services block on the south side. Plans of the ground, first, second and third floors are shown in Figures 4, 5, 7 and 8. U-values of some key building elements are given in Table 2.

Because the teaching block requires better heating and lighting control than the administration block, it is arranged alongside the atria in a stepped fashion to give maximum exposure to the available solar radiation from the south (see Figure 9). The entry of the radiation into the rooms is controlled on a seasonal and daily basis by means of blinds and other shading devices. The ventilation system makes full use of the atrium. The classrooms have adequate daylighting with minimum glare.

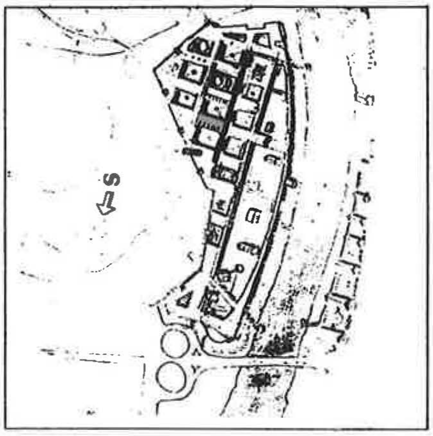


Figure 6. Arrangement of modular buildings on the site.

Roof	0.5
Wall	0.49
Glazing	4.0
Floor	0.35

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

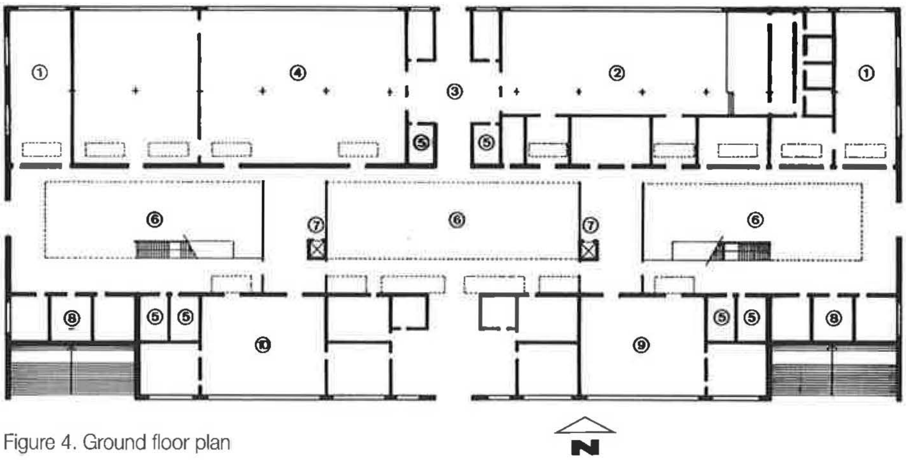


Figure 4. Ground floor plan

Key to ground floor plan:

1. Store
2. Auditorium
3. Hall
4. Library
5. Bathrooms
6. Atria
7. Elevators
8. Shops
9. Bar
10. Students' club

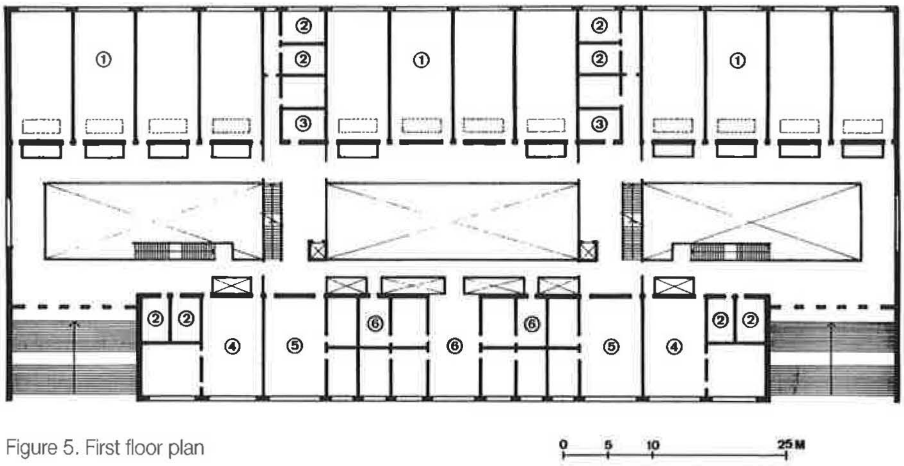


Figure 5. First floor plan

Key to first floor plan:

1. Classrooms
2. Bathrooms
3. Stores
4. Seminar rooms
5. Boardrooms
6. Manager and administration offices

Key to second floor plan:

1. Classrooms
2. Bathrooms
3. Stores
4. Seminar rooms
5. Research departments

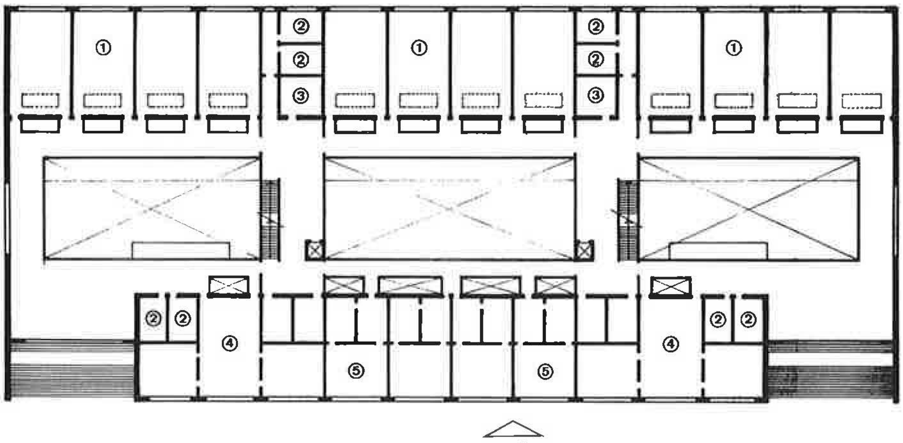


Figure 7. Second floor plan

Key to third floor plan:

1. Professors' offices and subject departments
2. Bathrooms
3. Stores
4. Terrace

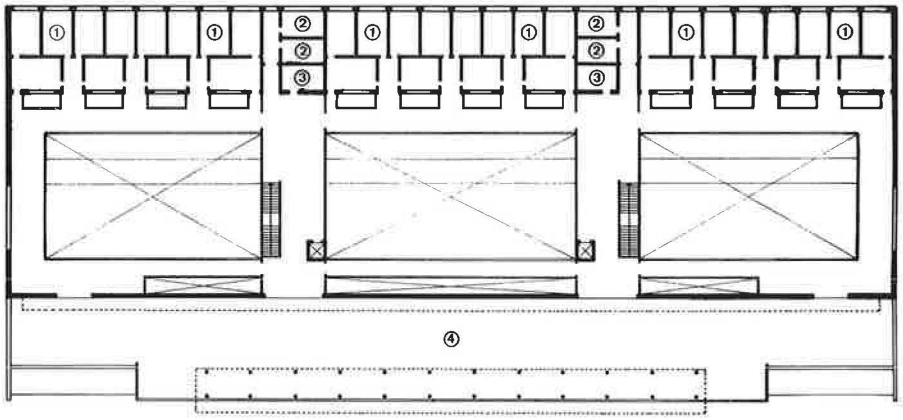


Figure 8. Third floor plan

Key to cross section:

1. Atrium
2. Professors' offices
3. Classrooms
4. Library
5. Research departments
6. Administration offices
7. Bar

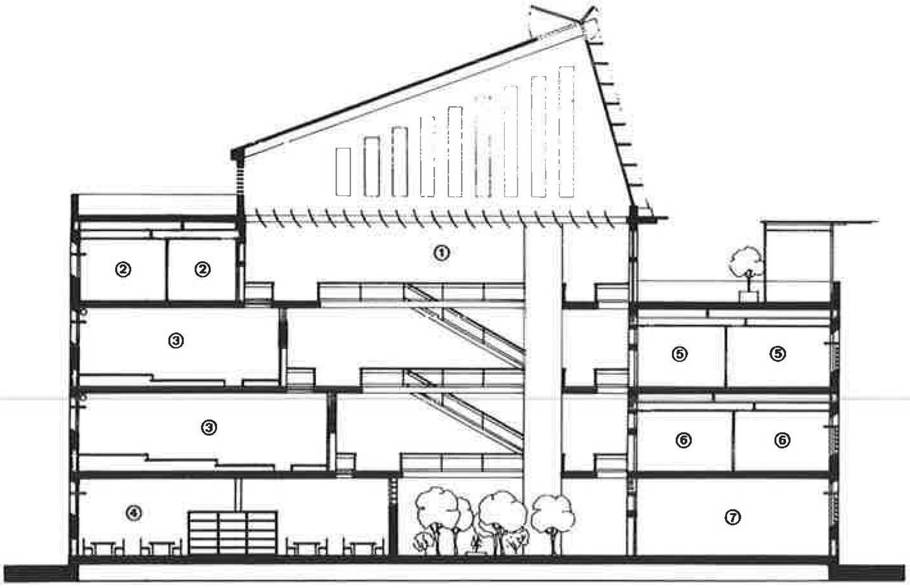


Figure 9. Cross section

DESCRIPTION OF PASSIVE SOLAR FEATURES/COMPONENTS

Introduction

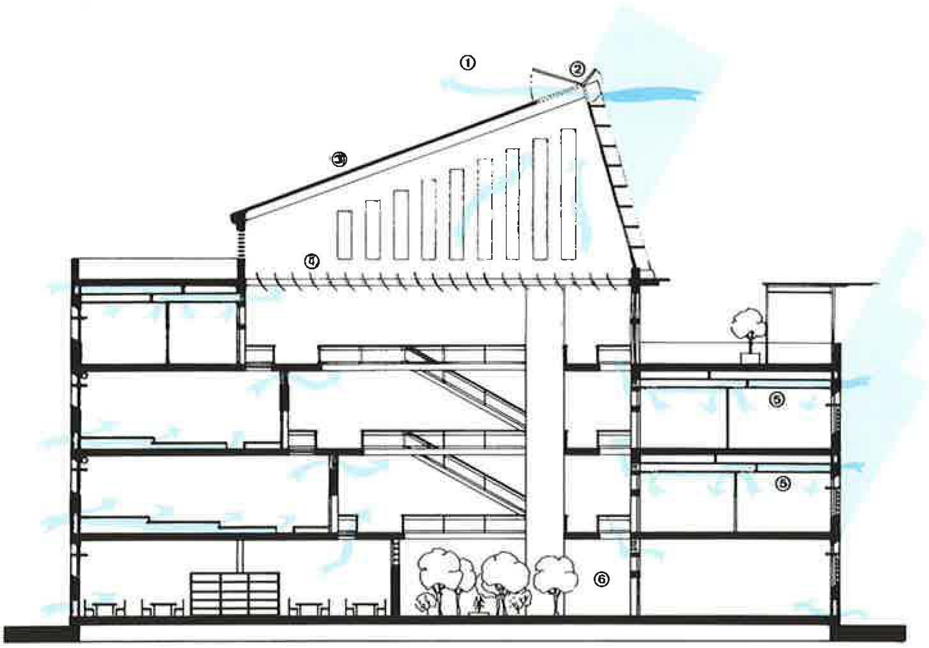
The object has been to create an energy-efficient building which is thermally, acoustically and visually comfortable and conducive to study and research. Public spaces have been arranged to favour relationships between users. Passive solar features have been used with the aim of providing each room with the appropriate amount of cooling in spring and summer, heating in winter and lighting throughout the year. Care has been taken to achieve a level of ventilation in each space which is right for its occupancy. Unwanted heat gains and losses have been reduced. A good level of daylighting has been provided in work spaces and recreation areas.

Control of Thermal Environment through Atria

The three independent atria are the main means of providing environmental control. Through them, the amount of solar radiation and ventilation inside the building can be regulated. Different devices enable the thermal needs of the building to be met whatever the weather.

Mode of Operation in Summer

In Seville, the extremely high temperatures reached in summer are the major problem. In this building, summer-time cooling is achieved by shading, planting on the ground floor and controlled ventilation. The fixed blinds on the atrium glazing prevent entry of direct radiation at this time of year. Good ventilation is achieved using the Venturi effect: hot air rises in the atrium because of density differences and a hatch at the atrium ridge helps create air flow throughout the building (see Figure 10).



Key:

1. Prevailing wind
2. Large opening at ridge
3. Opaque roof
4. In summer, the cloth mat is removed
5. Split ceiling void vent
6. Cool zone - planting and fountains

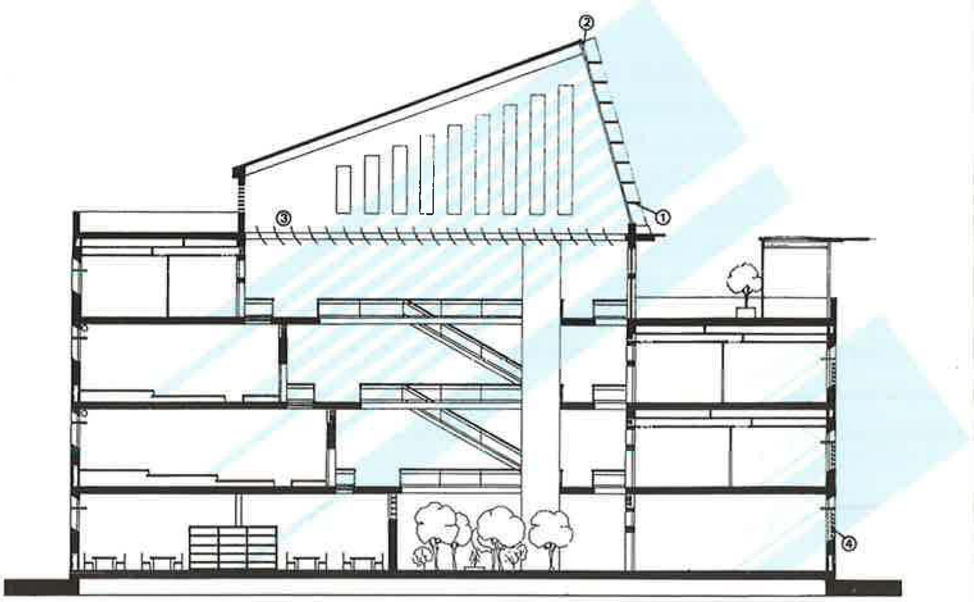
Figure 10. Mode of operation in summer

Mode of Operation in Winter

In winter, the fixed blinds on the atrium roof permit entry of direct solar radiation. The movable mat on the bottom of the atrium roof can, according to its angle of incidence, either allow this radiation to enter the teaching block when it is needed on cold winter days or serve as a light diffuser on milder days. The mode of operation in winter is shown in Figure 11.

Daylighting

The main problem has been to provide adequate lighting of the rooms in the north block. This has been achieved by means of diffuse light from the windows on the north facade and direct sunlight through the skylight at the south end of each room, above the lecturer's desk. Entry of the direct light is controlled to prevent glare. Above the windows, light shelves reflect light towards the ceiling and help provide uniform lighting throughout the room.



Key:

1. Fixed overhangs
2. Glazing
3. Removable cloth mat to diffuse light when needed
4. Light shelves and movable louvers

Figure 11. Mode of operation in winter

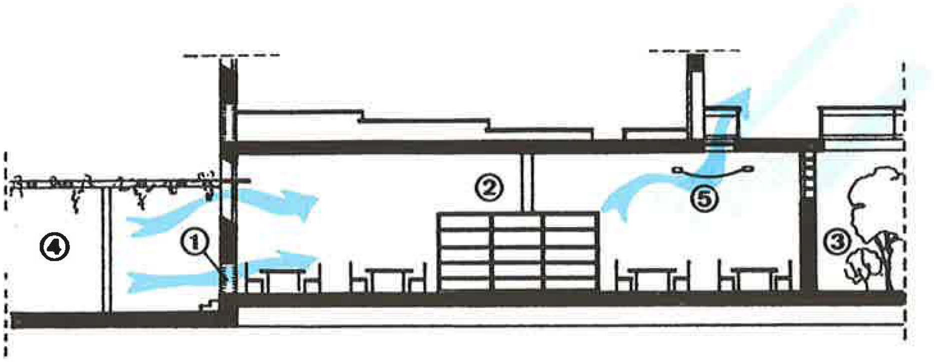
ENERGY CALCULATIONS PERFORMED AND DESIGN TOOLS USED

Design Tools

The ventilation and daylighting systems were designed with the help of various design tools. Air flow modelling and testing was carried out by Cambridge Architectural Research. Daylighting was studied using the split flux method plus direct sunlight and the results checked using a SERI protractor. Some of the results of these studies are given below.

Library

With maximum daytime temperatures in June around 31 °C, a high ventilation rate is needed in areas such as the library, lecture rooms and classrooms which are subject to direct sunlight. It was decided that the only feasible cooling strategy was to provide air flow rates of 0.5-1.0 m/s in these rooms in summer to give direct physiological cooling. The library, which is on the north side, receives a good level of daylight but does not require shading: the high ceilings (4.5 m) allow good light penetration. The solar radiation and air flows in that room are shown in Figure 12. The main seating and reading areas are arranged on the perimeter and are lit naturally. The book stocks are in the centre and are artificially lit only when and where it is necessary. The outdoor space to the north of the library can be made secure and developed as a study area. Pergolas and other landscape features can be used there to further minimize the risk of overheating in the library.



Key:

1. Louvers fixed for good ventilation
2. Bookstack
3. Cool zone
4. Secure open air reading area
5. Light diffusers

Figure 12. Ventilation and daylighting of the library

Lecture Rooms

Lecture rooms present a challenge to any architect wanting to use passive solar design - partly because they are densely occupied and therefore have high cooling loads and partly because they have to be blacked out sometimes for the showing of slides, etc., but still require ventilation. In this building, it was decided to bring fresh air in from the north wall under a raised, stepped floor and vent it into the atrium via light-proof louvers at the lecturer's end of the room (see Figure 13). In addition, there is glazing which are capable of being blacked out but which can be opened to provide extra ventilation when the blackout is not required. Bringing in air through the floor void has the advantage of providing fresh air where it is needed, close to the occupants, and creating perceptible air movement.

Calculations showed that, with an area of 4.05 m^2 at both the inlet and the outlet positions, the natural ventilation would be enough to keep the temperature in the lecture rooms down to 3 °C above ambient on the hottest June day when the ambient temperature is 31 °C but the relative humidity is 46% and the wet bulb temperature is 23 °C. This gives a corrected effective temperature of 29 °C at 0.5 m/s which is just 2 °C above the normal comfort level. As this represents the worst possible case (the building is not normally used in July and August), it is regarded as being just about acceptable.

In winter, ventilation rates can be much lower - the minimum required to provide enough fresh air.

Key:

1. Blackout when needed
2. Light-proof mechanical louvers
3. Light diffusers

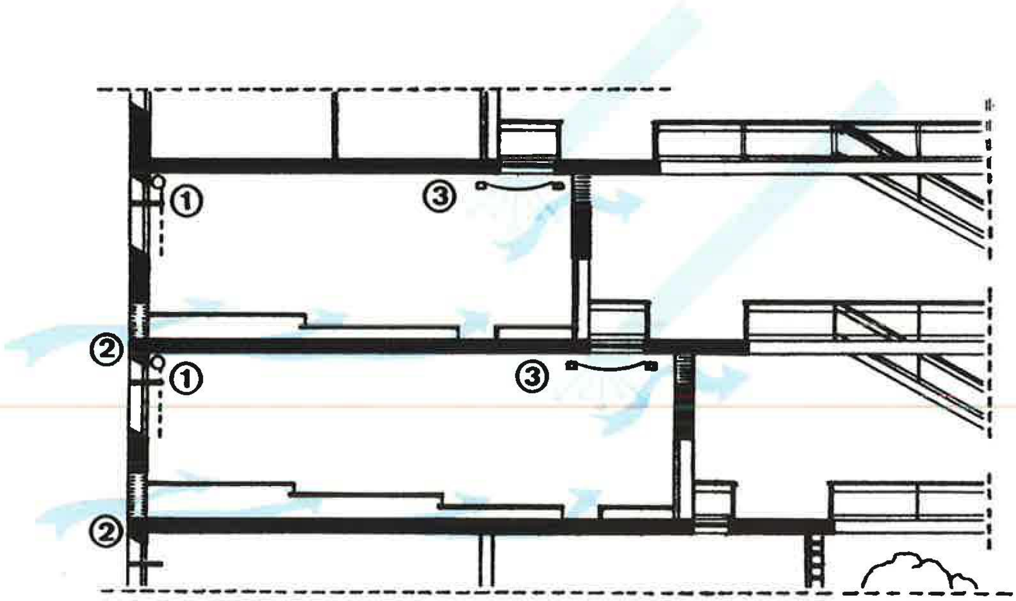


Figure 13. Ventilation and daylighting of the lecture rooms

Offices

The studies showed that the perimeter offices and other rooms on the south side of the building require effective shading and operable windows to create cross ventilation. It was found that a shading system which combines fixed light shelves with movable louvers was effective. The offices in this block which face the atrium needed no shading but did require openable windows. To achieve the cross ventilation, a false ceiling void (split as indicated in Figure 14) provides an exhaust for the perimeter offices and a means of supplying inlet air for those facing the atrium.

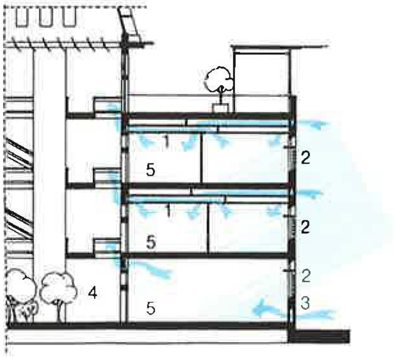


Figure 14. Ventilation and daylighting of the offices, club and bar in the south block

Key:

1. Split ceiling void vent showing supply of air to offices facing atrium
2. Light shelves and operable louvers
3. Restricted openings to maintain extraction from north rooms
4. Cool zone
5. Diffused light

Role of Atria in Ventilation and Cooling

The atria not only have an important role in daylighting but also have a part to play in driving ventilation air through the building. Each atrium will, however, only extract exhaust air from the adjacent rooms if the temperature of the air in the atrium is above ambient. Therefore the design is such that the unoccupied upper portion of the atrium is allowed to reach 5-7 °C above ambient and is vented at a relatively high rate. This enables it to serve as an exhaust for the used air from the library, lecture rooms and offices. The atrium floor is planted extensively and contains fountains to give a cooling effect. Solar gains are minimized by shading the atrium roof. This causes the ventilation rate in the bottom zone of the atrium to be relatively low. To stabilize the cool air in this zone, openings at the bottom of the south and north external walls are kept to a minimum. The vent openings to the library are at the first floor level and have been designed to direct air upwards. At the time of writing this brochure, no detailed analysis had been carried out. It seems likely, however, that it will be possible to reduce air temperatures at the bottom of the atrium to at least halfway to the wet bulb temperature and that there will be further cooling from the cold collected by massive surfaces during night-time ventilation. It is possible that the temperature will be maintained at a level at least 5 °C below maximum external daytime temperatures. The atrium is divided into three to avoid problems related to air flow stability, fire safety and noise. The provision of internal shades from cloth sails on mechanical rollers has obviated the need for movable shades on the south side of the atrium. Fixed overhangs give seasonal control.

Daylighting Analysis

The daylighting analysis was carried out for a point 2 m above floor level in the first-floor south gallery of the atrium (point P in Figure 15). This was chosen for the study because it was judged to have intermediate to bad daylighting compared with other places in the building. The daylight factor at this point due to the light entering through the south-oriented rooflight was 2.84% and that from the light from the east and west windows was 2.2%.

In December, January and February, the sky in Seville is overcast. For the winter months, therefore, the total illuminance on the vertical plane can generally be taken as 5,000 lux. In winter, the component for internal reflection is around 1%. Therefore the total lux at point P in winter would be (2.84 + 2.2 + 1)% x 5000 = 300 lux. When the transmittance of the glass and the dirt factor are taken into account, this reduces to 200 lux. In general, a figure in the range 300 to 200 lux can be said to be adequate. However, if the glass was not maintained in a clean condition a point in a classroom near P would probably be felt to have a fairly low lux. If direct sunlight enters the atrium, of course, values as high as 700 lux can be reached. Statistically, however, this is only likely to happen 56% of the working period and 200-300 lux should be taken as the "safe" winter figure. It is the result of a needed compromise because the building was designed to take advantage of sunny conditions but avoid overheating and over-illumination.

For the rest of the year, the sky in Seville is clear to very clear. The building, however, is designed so that it does not receive direct sunlight from April to September. A figure of 15,000 lux can therefore be taken on a south-oriented vertical plane and 12,000 lux on an east/west-oriented plane. The component from internal reflection at this time of year is 2%, mainly due to the ceiling. From these figures it can be calculated that the lux at point P from March to October/November is (2.84 + 2)% x 15,000 + 2.2% x 12,000 = 990 lux. This reduces to 631 lux when the transmittance of the glass and the dirt factor are taken into account. With this illuminance level, good daylighting is assured in the galleries and classrooms. In the upper galleries, indeed, there is a risk of over-illumination with glare and discomfort. Intelligent use of canvas or fabric louvers reduces this risk but care must be taken to ensure that, when these are used, enough light reaches the other parts of the building, particularly the north- facing galleries. To aid this, reflecting finishes and translucent fabrics are used within the building.

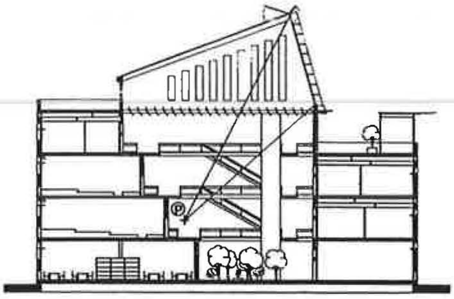


Figure 15. The subject of the daylighting study - point P

GENERAL DESIGN GUIDELINES/POINTS OF INTEREST RESULTING FROM THIS PROJECT

In warm climates the atrium is an excellent device for controlling indoor environments but it must be designed to induce ventilation by the stack effect in summer rather than heating by the greenhouse effect in winter.

The volume of the atrium must be kept small to ensure that environmental control takes place. It may sometimes be necessary to divide the atrium into several courtyards.

There must be a large volume of air above the upper walking level of the atrium which can be allowed to warm up above the comfort temperature to induce the stack effect.

In warm climates it is necessary to limit the amount of glazing in the atrium to prevent overheating in hot weather.

In the sloping lightweight roof used in this building, the aerodynamic design which generates positive and negative pressures at the ridge of the atrium and the openings to achieve a Venturi effect all improve air extraction.

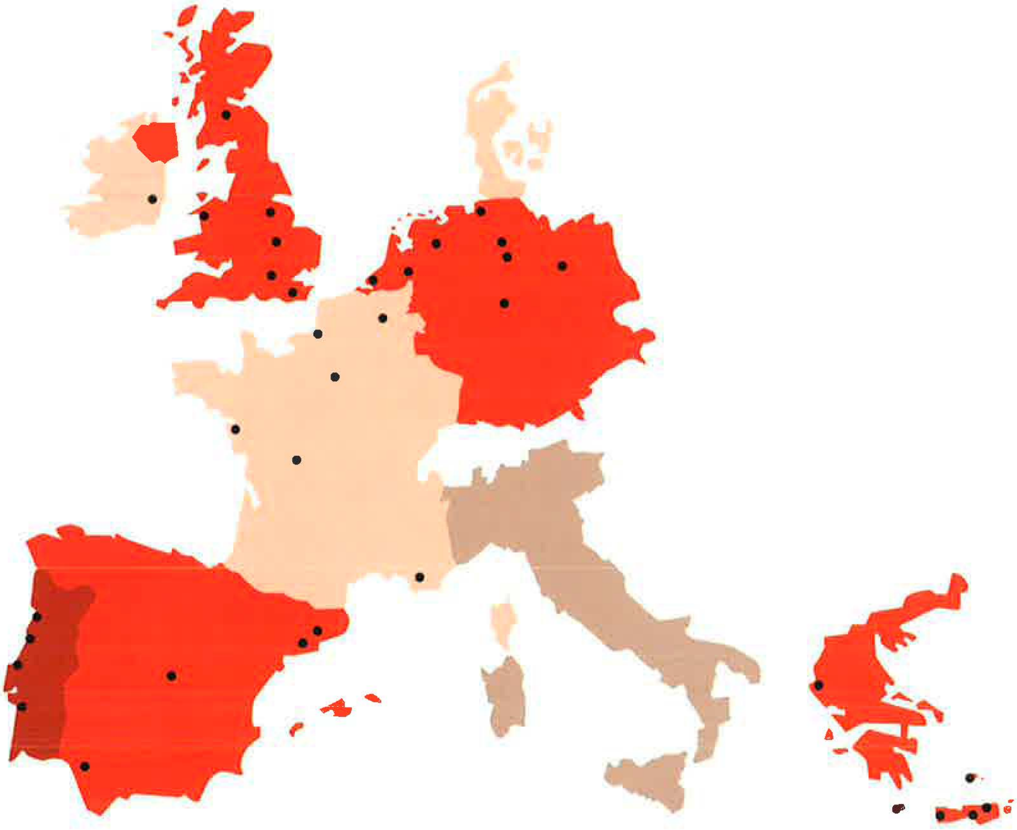
To control entry of solar radiation into the building, it is better in inaccessible positions on the outside of the building to use fixed light shelves designed to operate seasonally. Indoors, in accessible places, light blinds can be used for adjustment on a daily basis.

When rooms are deep and therefore difficult to illuminate, it is a good idea to create stepped building levels. With these, daylight penetrates deeply into the rooms and the volume of the atrium is increased so that the lighting performance is better.

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 of 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 Commision's research and development programme on solar energy applications to buildings.

Commission of the European Communities/Directorate-General for Science, Research and Development



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

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