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Renewable Energy 23 (2001) 497–507

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**RENEWABLE  
ENERGY**

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# Effect of fixed horizontal louver shading devices on thermal performance of building by TRNSYS simulation

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## Abstract

Buildings in most countries around the world require large amounts of energy both for cooling and heating. In fact cooling loads due to solar gains represent about half of global cooling loads for residential as well as non-residential buildings. While solar gains through windows contribute largely to these loads, any method of decreasing these gains through shading should be applied with caution, since a balance is required; decreasing cooling loads by shading may increase heating loads drastically and vice versa. So the overall energy requirements both for heating and cooling should be considered. With this in mind a study was done on the thermal performance of a building by TRNSYS simulation, and a shading model for windows was incorporated in it. The shading devices adopted were external fixed horizontal louvers with different slat lengths and tilts. The study was conducted for four different cities in Italy. The optimization of the shading devices was done with respect to primary energy loads for the whole year, and the optimum design was found to depend on location and weather conditions. It was also found that shading factor varies with time of day and is different for summer and winter. For example, for Milan it was found that 70% of gain is cut off in summer, while only 40% is cut off in winter by using optimum shading, which is desirable. © 2001 Elsevier Science Ltd. All rights reserved.

*Keywords:* Passive cooling; Fixed external shading; Louvers; TRNSYS; Simulation

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## 1. Introduction

A building serves as a boundary between the outside environment the and inside environment. However, the inside of a building is influenced by outside weather

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conditions, like solar insolation, ambient temperature, wind speed, rainfall, humidity etc. To keep thermal comfort conditions inside, large amounts of energy are required for both heating and cooling depending on the location and weather conditions. In fact cooling loads due to solar gains represent almost half of global cooling loads in non-residential buildings and more than half in residential buildings [1]. One solution could be to develop a technique for excluding solar radiation selectively. On the other hand in some weather conditions both cooling in summer and heating in winter are needed. As such, while considering any method of decreasing solar gains through windows, the overall energy requirements, i.e. both for heating and cooling should be kept in mind, as a balance is required; decreasing cooling loads by shading may increase heating loads drastically and vice versa. So caution is needed when selecting a shading device.

With this in mind, a study was done to determine the thermal performance of a building by TRNSYS simulation [2,3] using PREBID [4] in IISiBat environment [5], in which a shading model for windows was incorporated which would demonstrate the effect of various shading devices on building performance. This was done for four different locations in Italy viz. Milano, Roma, Napoli and Palermo in order to optimize the best shading device for each location.

## 2. Shading devices and new routine for characterization of shading devices linked to TRNSYS

Fixed shading devices are generally used on the external face of glazing since they lower direct radiation from reaching the internal ambient, dissipating the heat to outside. They are more efficient than internal fixed shading devices which dissipate the heat to the air gap between the shading device and the glazing. The shading devices adopted in this study were external fixed horizontal louvers used on the south window as shown in Fig. 1

Three types of this shading device were used defined by,  $s/l$  ratios, where

$l$  length of slat  
 $s$  vertical distance between slats

They are:

- type  $s1$  where  $s/l=1$
- type  $s2$  where  $s/l=2$
- type  $s92$  where  $s/l=0.92$

Different tilts ( $\alpha$ ) of these shading devices with respect to the horizontal were considered:  $\alpha=30^\circ$ ,  $45^\circ$ ,  $60^\circ$  and  $90^\circ$ —i.e. slats closed.

The routine developed by the WIS group, LOUVER.DLL [6] was used to study the effect of shading by louvers on the south window of the building. The module performs the solar and thermal characterization of the shading device. The inputs

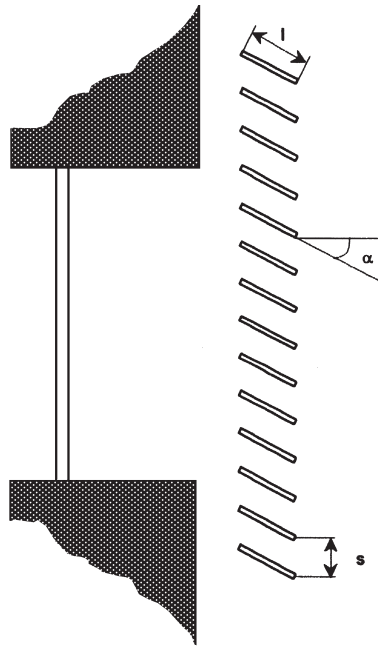


Fig. 1. Horizontal louver shading devices.

are: length of slats, distance between slats, tilt, absorption from back and front of slats, in this case assumed to be 0.2. This routine generates  $19 \times 19$  matrices for the primary and secondary transmittance of the shading device relative to the window coordinate system (relative altitude and relative azimuth). The diffuse transmittance is one value as it is hemispherical. This routine was linked to the TRNSYS program with a small subroutine to make it compatible with TRNSYS. TRNSYS converts the matrices w.r.t. azimuth and zenith angles and also interpolates the intermediate values.

### 3. Building details

A simple 2-zone building was considered as shown in Fig. 2. The salient details of the two zones are given below:

Zone 1 Volume  $150 \text{ m}^3$   
 Thermal capacitance  $180 \text{ kJ/K}$   
 Initial zone temperature  $20^\circ\text{C}$   
 Initial relative humidity 5%

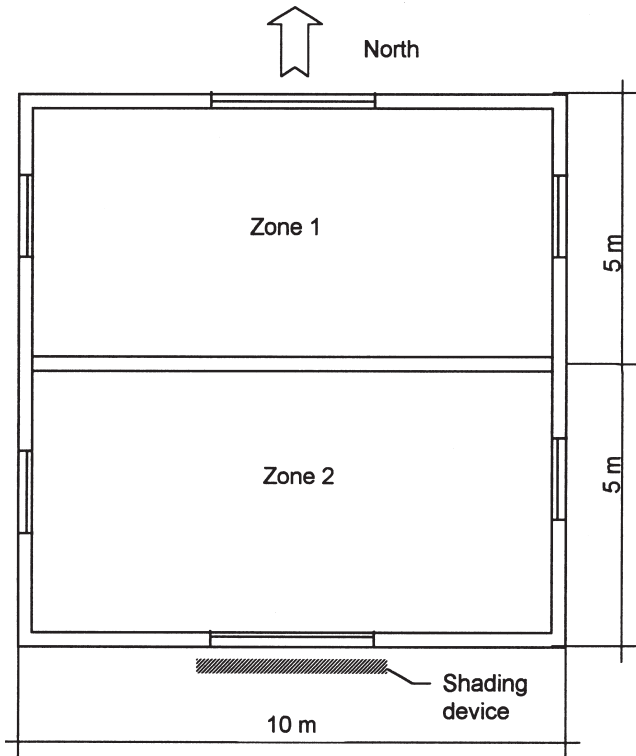


Fig. 2. Plan of the simulated building.

|           | Wall areas (m <sup>2</sup> ) | Window areas (m <sup>2</sup> ) |
|-----------|------------------------------|--------------------------------|
| North:    | 30                           | 5                              |
| East:     | 15                           | 2.5                            |
| West:     | 15                           | 2.5                            |
| Internal: | 30                           |                                |
| Roof:     | 55                           |                                |
| Floor:    | 50                           |                                |

The details of Zone 2 are identical to Zone 1 except it has a south wall and south window instead of north wall and north window.

| Composition of walls                          | Thickness (m) |
|---|---------------|
| Lime mortar                                   | 0.02          |
| Clinker                                       | 0.30          |
| Gypsum mortar                                 | 0.02          |
| Total thickness of wall                       | 0.34          |
| Overall wall U-value=1.691 W/m <sup>2</sup> K |               |

Windows were double glazing units having  
 U-value  $2.8 \text{ W/m}^2 \text{ K}$   
 g-value  $0.755$

The roofs are slanting N and S with a view factor of 0.8 to the sky.

The other details of each Zone are: Heating set-point temperature  $20^\circ\text{C}$   
 Cooling set-point temperature  $26^\circ\text{C}$

Gains

2 persons doing light work, equivalent to  $150 \text{ W/person}$   
 Lighting and other appliances  $500 \text{ W}$   
 Infiltrations  $0.6 \text{ vol/h}$

#### 4. TRNSYS simulation details

In order to carry out a TRNSYS simulation of the shaded building, the building blocks were defined, i.e. the individual components were defined, and then connected, so that they form an assembly with a flowchart of information from one component to the other. The output of one component might be the input of some other. This is done in the IISiBat environment graphically and is shown in Fig. 3

The different components of the assembly are briefly described below.

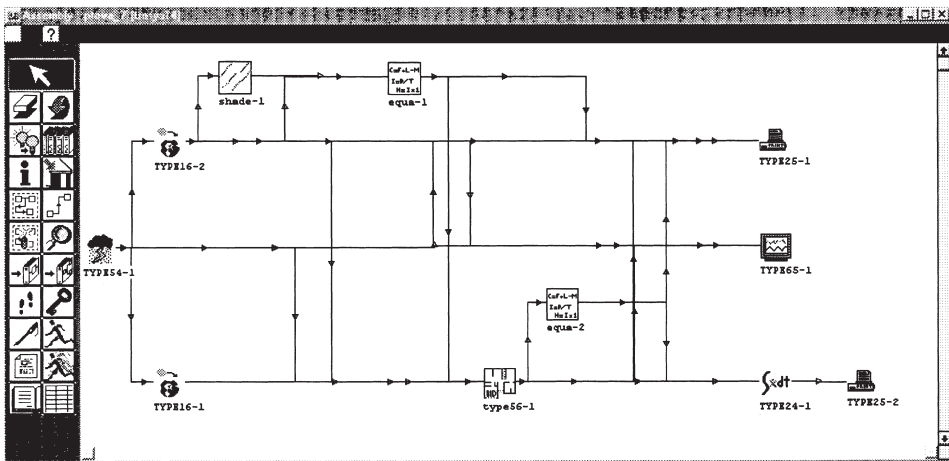


Fig. 3. Assembly panel window.

#### 4.1. Weather data generator: Type 54

This component generates hourly weather data given the monthly average values of solar radiation, dry bulb temperature, humidity ratio, and wind speed (optional). The purpose of this method is to generate a single year of typical data similar to a typical meteorological year.

#### 4.2. Solar radiation processor: Type 16

Weather generator generates radiation data on horizontal surface at one hourly intervals. The solar radiation processor calculates several quantities related to position of sun and estimates insolation up to four surfaces of either fixed or variable orientation. The component also interpolates radiation data if required at other than one hour interval. Since in the building developed there were six surfaces at different orientations, the four walls and two slanting roofs, two radiation processors were employed; the first for the walls and the second for the roofs.

#### 4.3. Shade 1: Type 67

This is the new routine for shading linked to TRNSYS to calculate the effect of shading factor on building performance.

#### 4.4. Equation 1 algebraic operations: Type 15

As has been mentioned shade routine produces 3 transmittances—primary, secondary and diffuse for the shading devices. These have to be supplied as inputs to the building. However TRNSYS takes only one transmittance value through window in building simulation. Therefore this component equation 1 was introduced to calculate weighted average of primary, secondary and diffuse transmittance, which is the shading factor.

#### 4.5. Building: Type 56

This component models the thermal behaviour of a building having up to 25 thermal zones. The interaction between two or more zones is calculated by matrix inversion. The effect of both short wave and long wave radiation exchange are accounted for with an area ratio method. The walls, ceilings and floors are modelled according to ASHRAE transfer function approach. In order to use this component, a separate pre-processing program must be first executed (BID), which generates two files which are used by Type 56 in the simulation.

#### 4.6. Equation 2 algebraic operations: Type 15

Type 56 generates many outputs. One of them is sensible energy demand=(−heating+cooling). The separation of heating and cooling loads was done by Equation 2.

## 5. Results and discussions

The first parameter of consideration was the solar gains through the windows and the effect of shading devices on these gains. Since the louvers are put only in the south window i.e. in zone 2, only this zone is considered.

Fig. 4 shows the variation of annual solar gains through the windows, (south, east and west) with the addition of different shading devices for Roma. The graph demonstrates quantitatively that the gains are maximum with no shading. With the slats closed the gains do not become zero as the east and west windows are still unshaded.

The situation is rather interesting when the case of slats closed is considered; while h1 and h92 closed show a large decrease in gains, as the south window is completely shaded; in the case of h2 gains increase with slats closed. This is because with the slats closed only one half of the south window is covered, through remaining half sunlight comes in, while for other tilts more of the window is shaded. The same pattern is followed in all four locations.

Figs. 5 and 6 demonstrate the annual total energy loads for the building for Milano and Palermo with and without shading, as also a break-up of the same i.e. the heat energy and cool energy loads for both zones 1 and 2. It was observed that the annual total loads are highest for Milano followed by Roma, Napoli and Palermo. This is due to the location of the four cities; Milano is at the highest latitude therefore coldest. So the energy for heating is maximum, although cooling loads are minimum for Milano, the sum total for the whole year is highest among the four.

As expected the influence of shading devices on cooling and heating loads is very small for zone 1, any slight variation in these loads is due to intermediate temperatures reached in zone 2, influencing temperatures in zone 1 during the season between summer and winter when heating and cooling systems do not intervene, since set

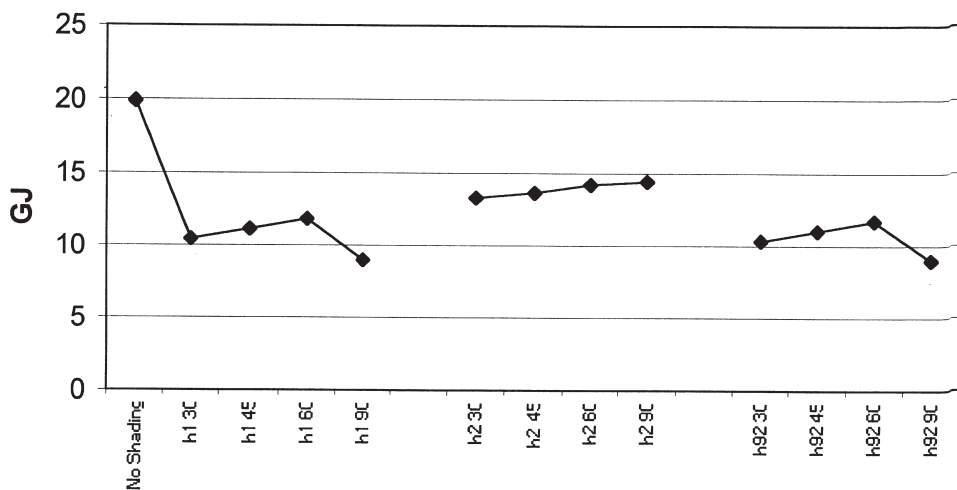


Fig. 4. Solar gains through windows in zone 2 Roma.

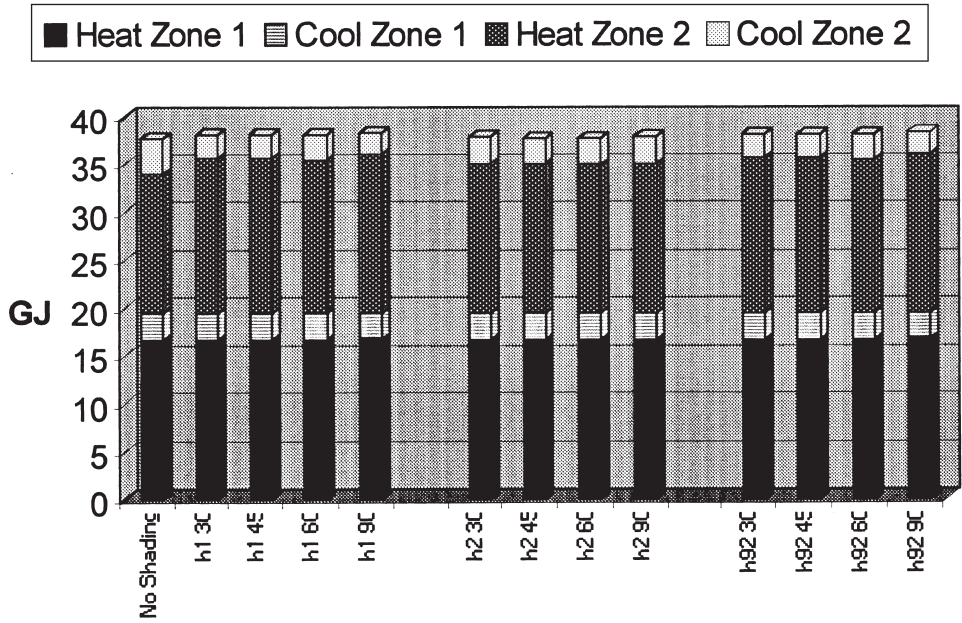


Fig. 5. Total energy loads, Milano.

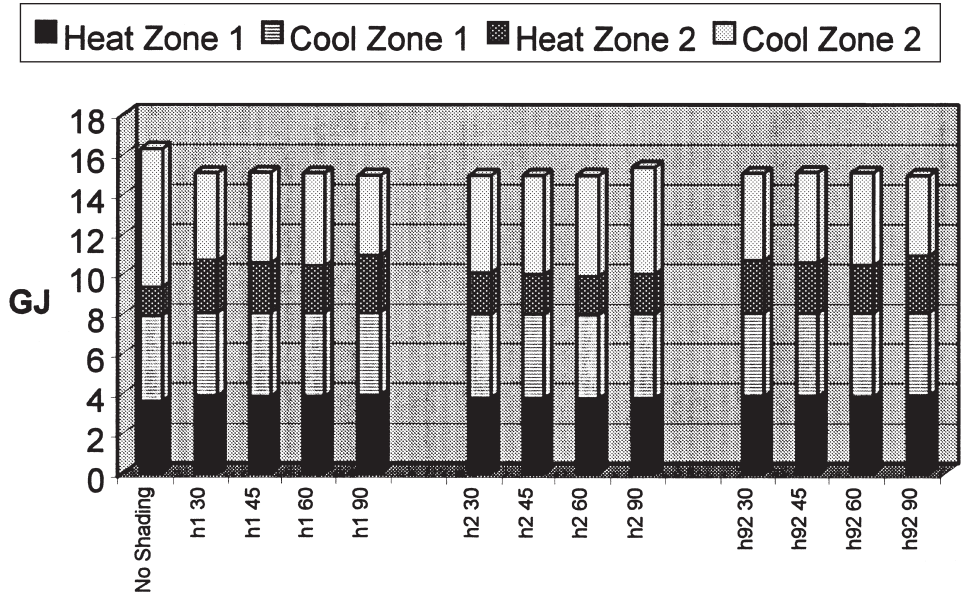


Fig. 6. Total energy loads, Palermo.



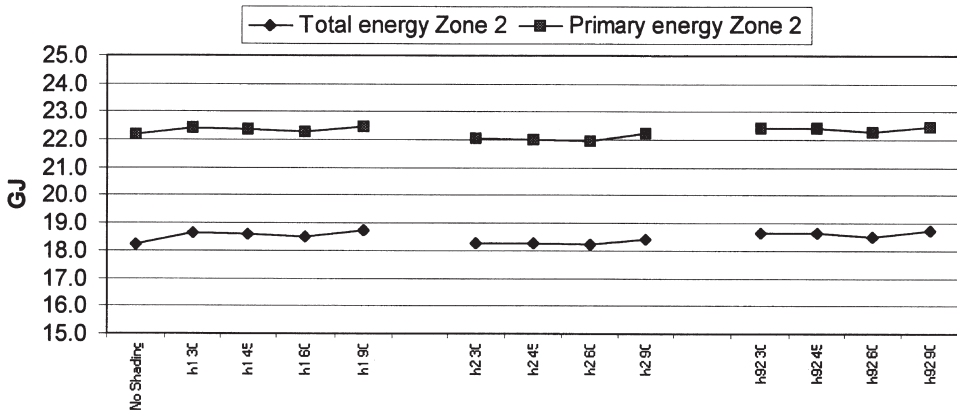


Fig. 7. Shading device optimization, Milano.

temperatures for heating is 20°C, while cooling is 26°C. So in further results zone 2 is highlighted.

It is observed for cooler climate like Milano no shading gives the lowest energy load, since heating has more weightage than cooling, while for warmer Napoli and Palermo the situation is reversed, i.e. no shading gives highest loads, because cooling loads are heavier here. For Roma, shading device h2 gives the lowest load. These bar charts also demonstrate the variation of the loads with different shading devices each tilted at specific angles and give an idea about which shading device to choose in which location.

Figs. 7–10 show the optimization of the shading device with respect to primary energy. These graphs also show the variation of total energy in zone 2 with different shading devices. The reason for choosing primary energy as an optimization index is that the efficiencies for heating and cooling are different. For heating by gas for

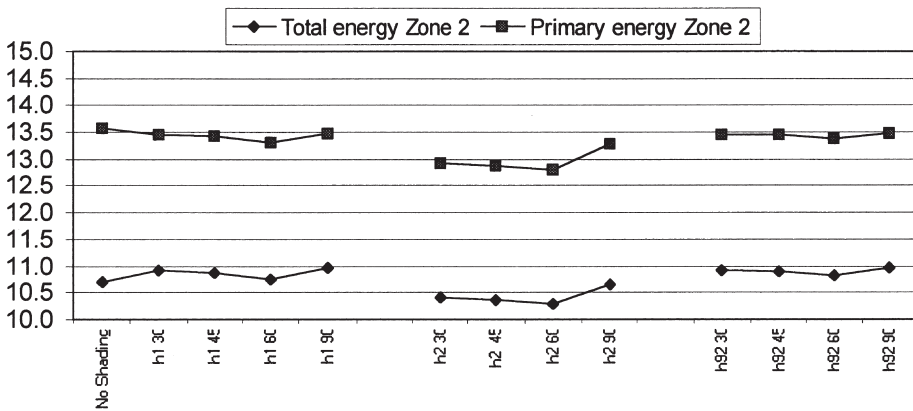


Fig. 8. Shading device optimization, Roma.

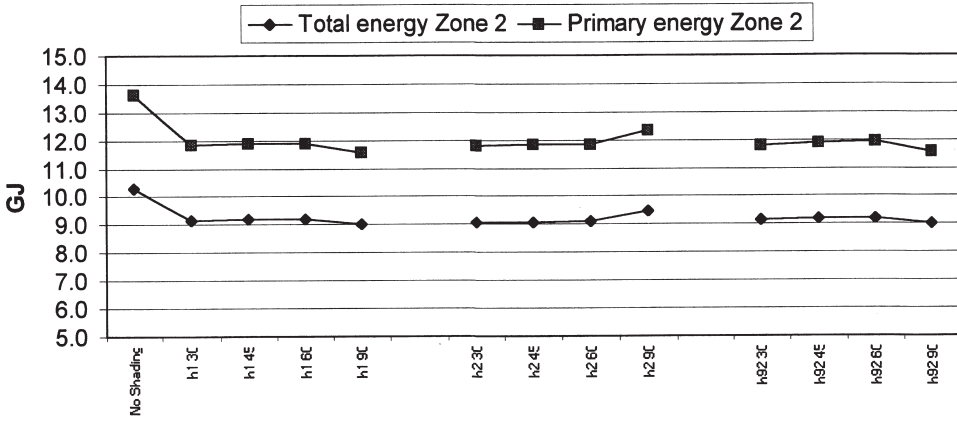


Fig. 9. Shading device optimization, Napoli.

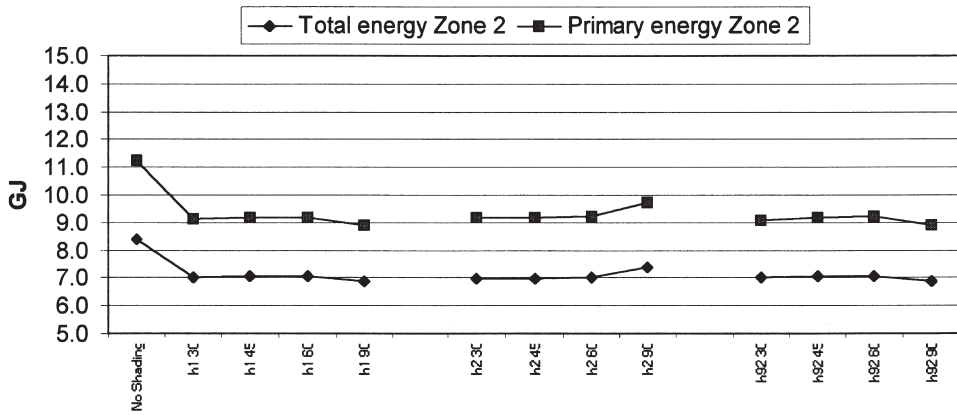


Fig. 10. Shading device optimization, Palermo.

example the efficiency of conversion may be taken as 85%. For cooling however air conditioning would be required, the coefficient of performance of the air conditioner is to be considered, here assumed to be 2.2 (a typical value). Therefore the primary energy = total energy load/C.O.P. \* efficiency of electrical generation = total energy load/2.2 \* 0.33 = total energy load/0.73.

It is seen that for Milano and Roma h2 60 gives best performance while for Naples h2 30 is the optimum, for Palermo h2 30, h1 30 and h92 30 are equally good.

### 6. Conclusions

It can be seen that external fixed horizontal louvers of proper design for south windows are effective in not only reducing cooling loads of a building in summer

but overall annual primary energy loads of a building. However care must be taken while choosing a particular louver shading system as the optimum shading system depends on the location and weather considerations in which it is to be used.

### **Acknowledgements**

The author would like to express her appreciation to ENEA–Cassaccia, Rome where this work was carried out, to Dr Augusto Maccari of ENEA for all help rendered, and also to ICTP Trieste, Italy for funding the Project.

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