AIVC
#13,703

# FINDINGS FROM TIBER PROJECT: ENERGY PERFORMANCES OF DIFFERENT ENVELOPE COMPONENTS

G. Fasano*, C. Romeo°, M. Zinzi*

* ENEA-SIRE-DINT, CR Casaccia - Via Anguillarese, 301 - 00060 Rome, Italy
Fax +39.06.30486315 E mail: gaetano.fasano@casaccia.enea.it – michele.zinzi@casaccia.enea.it

° Università "LA Sapienza"- Piazza San Pietro in Vincoli, 10 - 00100Rome, Italy
Fax +39.06.30486315 E mail: archromeo@libero.it

## 1. INTRODUCTION

This paper deals with preliminary studies carried on during the design phase on an office building to be built in Rome. The research is part of TIBER (Technologically Innovative Building with Energy Rational use), a Project financed by the THERMIE Programme.
TIBER is a project that strictly works with PTIR (Rome Industrial Technology Park), a consortium aimed to create a technology park in Rome [1]. The general aim of TIBER is to implement, promote and apply innovative energy conservation technologies, solar techniques, systems and standards an for office-laboratories building, to be used as reference construction for the other buildings of PTIR.
Specific objectives of TIBER can be summarised with the following:

- To prove and promote to the architects, engineers, developers and builders that energy conservation technologies and solar systems are technically and economically viable, safe and strategic. Thus they can be applied commercially.
- To demonstrate that it is possible to significantly reduce the existing energy consumption standards for office and laboratory buildings concerning heating, cooling, ventilation and lighting.
- To apply new research results on passive solar and ventilation systems and technologies inside a real building to reduce energy consumption, with an integrated approach to the design.
- To provide a low energy use and high quality indoor visual environment through an efficient and integrated use of daylight and artificial lighting, and dedicated control strategies.
- To combine efficiently advanced HVAC systems with the proposed passive ventilation and solar systems in order to integrate load management systems.
- To improve Indoor Air Quality through the use of innovative demand control and management of ventilation systems, microclimate parameters and ecology compatible materials.
- To use low cost maintenance materials and standardised construction techniques (concrete frame, low-brick, selective double glazing units, etc.).

A building is a complex energy system and its performances can be improved operating on different components, according to various parameters as: physical and geometrical characteristic of the building, air conditioning devices and strategies, climatic conditions, users behaviour and computer integrated building systems, a new important issue in retrofitting and new buildings.
The proposed architectural and technological components are an interesting example of innovative and efficient applications that can be promoted and taken up by the market. Moreover, the proposed combination and integration of solar technologies and other consumption-limiting measures are part of a whole innovative approach to the building design.
This report, in particular, deals with the energy performances advantages achievable improving the envelope characteristics. It must be noted that such operations (as adding insulating layers to the walls, mounting shading devices, etc.) often take place in building retrofitting, affecting the real efficacy of the operation. As a matter of fact, this limitation depends on operating on already

existing and degraded components. More over, the extra-costs and alteration of the initial aesthetic of the building are unavoidable consequences in retrofitting operations.
Conversely, consistent economical and technical advantages can be obtained if the performances of different envelope products are predicted and evaluated during the architectural design phase. A comparative analysis of performances of the building, equipped with different envelope components and materials, was carried out and in this report some significant results are summarised for the overall energy performance of the building to be constructed.
It is important to remind that the architectural and system designs were steered according to Italian legislation and standards for building and system performances, upgraded, when needed, with ASHRAE Fundamentals.

## 2. DESCRIPTION OF THE BUILDING

The building site is in a development zone on the north-east outskirts of Rome. The area of the site is 75 ha; this first building will have a volume of about 12.000 cubic metres out of the 1.5 million to be built on the same site. The schematic plan of the reference building is presented in Figure 1.
The project comprises four three-story office/laboratory blocks of different architectural design and one story block at the third level (block 4 in Figure 1). The subdivision of the whole building in five blocks was decided to permit a more flexible management of the five companies that will be hosted in the building. Table 1 describes the building and its five blocks. In next paragraphs the associated number will identify each block.
It must be reminded that the total area and volume do not coincide with the sum of the single block, because of collective spaces at ground level and stairs to upper levels.

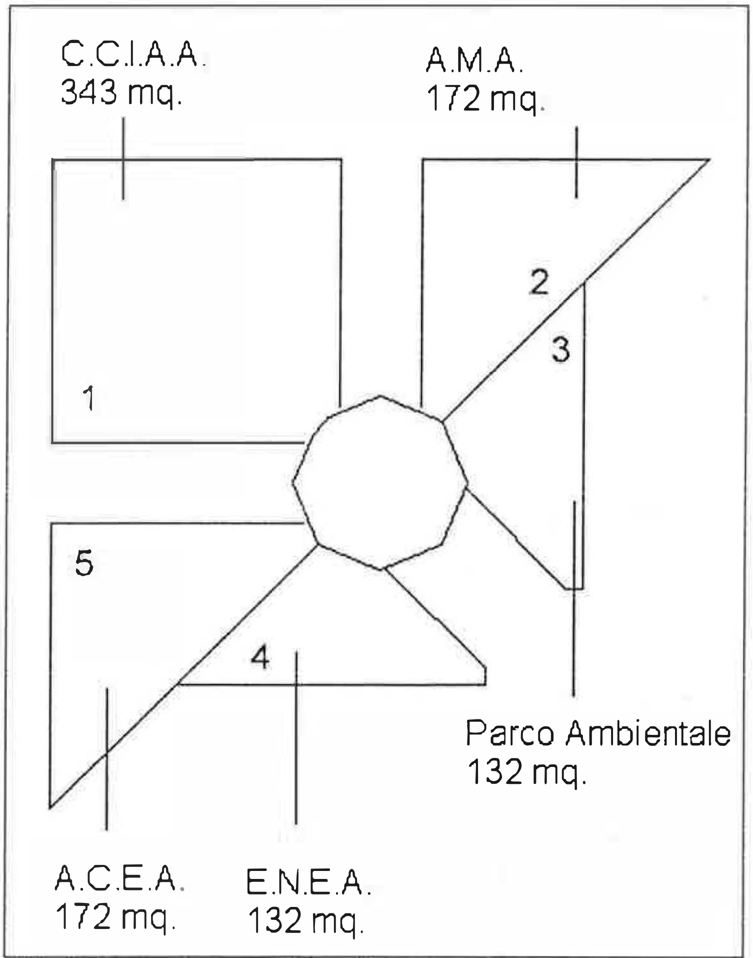


Figure 1: Schematic layout of the building

Table 1: Description of the building blocks

| Block | Floor Area [m²] | Volume [m³] | Occupants | Orientation |
|---|---|---|---|---|
| 1 | 343 | 3402 | 60 | NE-NO |
| 2 | 172 | 1468 | 25 | NE |
| 3 | 132 | 1101 | 45 | SE |
| 4 | 132 | 376 | 20 | SO |
| 5 | 172 | 1468 | 50 | NO |
| Total | 1200 | 12000 | 200 | NE-NO-SE-SO |

## 3. DESCRIPTION OF THE CLIMATE AND WEATHER

According to a correct way of conceiving a building, it is necessary to create a close relation in space and time between architectural objects and environmental conditions. Hence it is essential integrating the climatic component in making architecture. In order to consider climatic conditions of a particular site, a report covering the whole annual cycle is needed.
Weather local data, measured by weather stations, may give information, which will allow to direct towards the most favourable design choices. However, the main object must always sets out to achieve the best level of indoor comfort and air quality.
Specific site's weather data used in executing the building dynamic simulation involve various meteorological parameters. At every time step weather data appear in combination each to other and it's difficult to value their respective weight. Architectural and HVAC solutions to every single climatic problem should be taken side by side in a climaticaly well-balanced building.

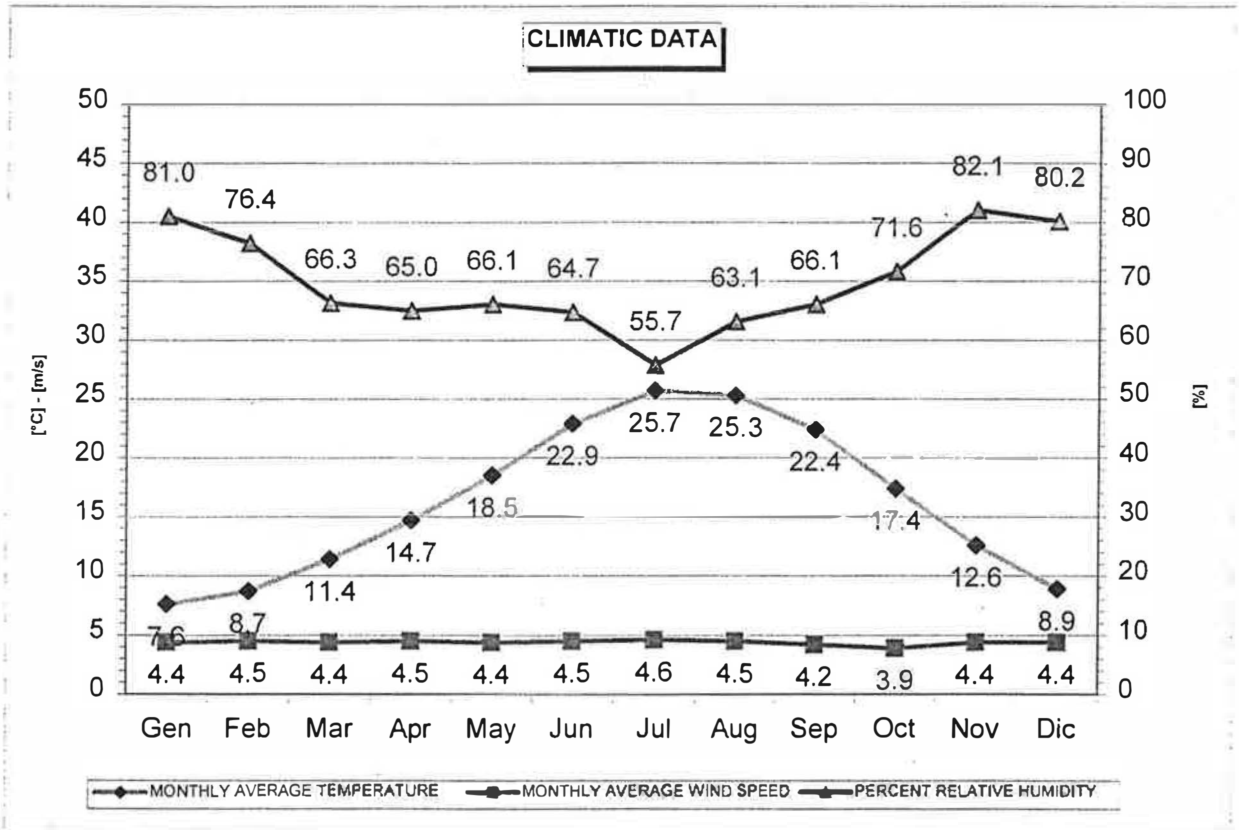



Figure 2: Monthly average daily air temperature, wind speed and relative humidity

An assigned site has a satisfactory climate characterisation when the following measured data are available:

- Monthly average *daily* global horizontal solar radiation
- Monthly average temperature

- Monthly average humidity ratio
- Monthly average wind speed and prevalent direction

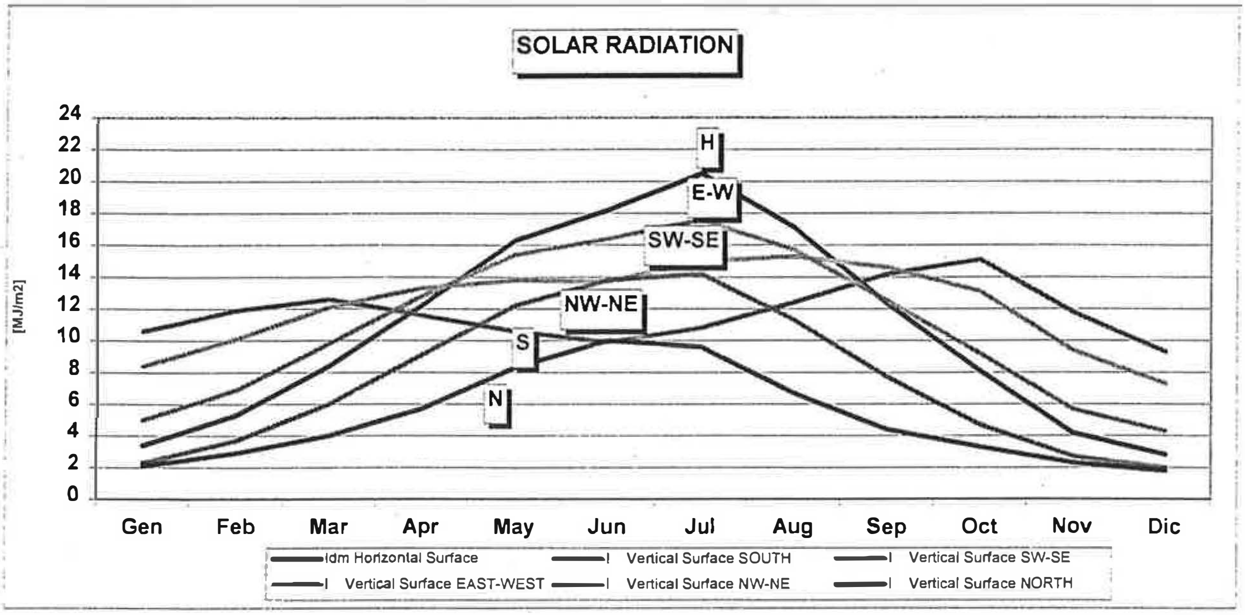



Figure 32: monthly average daily global horizontal solar radiation for different orientation

From UNI 10349 [2] standards, data concerning the outdoor air temperature, the relative humidity and the wind speed are acquired. Monthly average values are considered in this case. In Figure 2 the graphs of these weather parameters are plotted. In Figure 3 are reported the plots of the monthly average daily global horizontal solar radiation for different orientation, calculated starting from horizontal values. The above-cited standard UNI 10349 includes these values divided in beam and diffuse radiation for every month.
Monthly average values are used in this case too. All these parameters are used as input for running simulations with the building simulation tool.

## 4. DESCRIPTION OF COMPONENTS AND MATERIALS OF THE BUILDING ENVELOPE

In this section the criteria to select components and materials suggested for the building envelope is described. Since the aim of TIBER is the design and construction of a high-efficient energy building, the chosen materials must improve the performances obtained with traditional solutions. Such objectives can be mainly pursued by:

- Improving U-values of opaque components.
- Improving U-values and controlling g-factors of transparent components.

To check the efficiency of the selected materials it is necessary to verify the improving of building performances by the comparison of efficient versus traditional solutions. Neither this step is easily to carry out, since the thermal properties of building envelope components are widely influenced by the locality (different materials and technologies) and the age of the construction (different insulation properties). We selected four combinations of external opaque (walls and roofs) and transparent (windows) components distinguishing each to other by their average transmittance values. Their properties are summarised in Table 2. The reference components, solution A, represent average values for buildings in mid-Italy climate, without insulation in walls and clear double glazing unit without thermal break frame for windows. In the solution B, the opaque components are equipped with a thin insulation layer (2 cm.) and the windows have thermal break frames. In the solution C both the opaque (5 cm of insulation) and transparent (low emissivity coated double glazing unit) components are improved. Finally high insulation levels are adopted in solution D (12 cm of insulation for opaque components and low coating and argon filled windows).

These choices have been made in order to show how improved performances of the envelope components will allow energy saving politics in building design.

Table 2: U-values of building components

| Solutions | COMPONENTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | External wall | | | Roof and external floor | | | Window | | |
| | Thickness [m] | | Uvalue [W/m²K] | Thickness [m] | | Uvalue [W/m²K] | Thickness [mm] | Uvalue [W/m²K] | gvalue [%] |
| | Tot | Insul | | Tot | Insul | | | | |
| A | 0.24 | - | 1.06 | 0.25 | - | 1.23 | 4-6-4 | 4.50 | 75 |
| B | 0.26 | 0.02 | 0.75 | 0.26 | 0.02 | 0.97 | 4-12-4 | 3.50 | 75 |
| C | 0.29 | 0.05 | 0.60 | 0.30 | 0.05 | 0.74 | 4-12-4 | 2.50 | 67 |
| D | 0.36 | 0.12 | 0.41 | 0.37 | 0.12 | 0.47 | 4-16-4 | 1.50 | 59 |

As it can be inferred from above, the solar factor of windows was not considered as fundamental parameter because of the two following main reasons:

- On south-east and south-west facades, the solar control is achieved by means of external shading devices, meanwhile double glazing units low-emittance coatings improve thermal performances.
- On north-east and north-west facades, the influence of the solar radiation on cooling loads is not strong. For these orientations there is non need for controlling the solar radiation by means of expansive solar filter glazings or shading devices.

Table 3: Characteristics of the lamellae

| PARAMETER OF LAMELLAE | |
|---|---|
| Luminous reflectance | 0.85 |
| Length [cm] | 10 |
| Pitch [cm] | 10 |

The shading devices are realised with horizontal lamellae mounted just outside the window. The inclination of lamellae could be manually (season regulation) or mechanically (continuos regulation) operated, according to the requested level of control and the available budget. The system is designed for shading the direct radiation and redirects its visible component inside the building. To achieve satisfactory results, it is necessary to adopt high reflectance lamellae. In Table 3 are reported the main characteristics of the lamellae.

## 5. DESCRIPTION OF TRNSYS CODE

For accurate results in simulation analyses it is necessary to use advanced codes, able to consider all the parameters affecting the performances of the building. This necessity led to TRNSYS, a complex tool widely used for all the solar applications [3].
TRNSYS is a modular system simulation program. The modular structure of TRNSYS gives the program extreme flexibility. This code is well suited to detailed analyses of systems whose behaviour is dependent on the passage of time.
A system is defined to be a set of components, interconnected in such a manner as to accomplish a specific task. The performance of a system component (the building envelope in the case of study) will normally depend upon characteristic fixed parameters, the performance of other components, and time dependent forcing functions.
Once all of the components of a system have been identified and a mathematical description of each component is available, it is necessary to construct an information flow diagram for the system. An information flow diagram is a schematic representation of the flow of information into and out of each of the system components
One of the main features of the tool is to be a dynamic code, so transitory and capacitance phenomena, typical of energy balances in buildings, can be taken into account. Hence, even if

mean monthly values are inputted, the code has internal statistical functions, which give hourly outputs of energy needs. Integrated values can be used to obtain monthly, season or annual loads. TRNSYS is an open code, working through different routines linked together. Such routines are in the library of the code, or can be implemented *ad hoc*, this flexibility permits to cover exigencies typical of the single application.
The TRNSYS project implemented for this analysis consists of four main routines and some calculation blocks, the routines are the following:

- Weather generator
- Solar radiation processor
- Shading device routine
- Definition of characteristics of the building (Pre-Bid)

## 6. RESULTS OF SIMULATIONS

A first set of measurements was carried on block 1 only. The aim was to evaluate the energy savings that can be obtained using different levels of insulation. The results of this preliminary parametric analysis are summarised in Table 4. As partially expected, it was verified the decreasing of both heating and cooling loads from solution A to D. An energy approach would suggest that solution D is the best one. But it must be noted that the economy aspect of the problem should always be kept in mind.
The solution C resulted to be better than B, with limited extra-cost (3 centimetres of insulation added and adoption of low emittance glazings). Conversely the solution D even if best performing, is more expansive of C (7 centimetres of insulation added and adoption of low emittance glazings with argon in the gap). More over it must be reminded that a too *sealed* envelope can avoid the *breathing* of the building, when strong external and, often, internal cooling loads (people, lighting, appliances that in the design phase can be only partially considered) increase the indoor air temperature and pollutant emissions. Since in the design phase of TIBER, the approach was to consider all the following issues:

- energy saving,
- thermal comfort for the occupants,
- indoor air quality control,
- low construction and maintenance costs,

among the four solutions we took in account the best performing from an energetic and economical point of view resulted the solution C. So all the characteristics of the components simulated in this case of study were adopted in all the blocks of the building. In Table 4 the total heating loads for the four envelopes options and the relative percentage savings are reported.

Table 4: Block 1:Annual heating and cooling loads

| | BLOCK 1 ANNUAL LOADS [kJ] | | | | SAVINGS [%] | | | |
|---|---|---|---|---|---|---|---|---|
| | SOLUTIONS | | | | | | | |
| | A | B | C | D | A | B | C | D |
| HEATING | 3,53E+08 | 3,20E+08 | 2,81E+08 | 2,66E+08 | - | 9,2 | 20,4 | 24,6 |
| COOLING | 1,42E+08 | 1,36E+08 | 1,30E+08 | 1,21E+08 | - | 4,5 | 8,2 | 14,7 |

Table 5: Percentage savings for the single blocks

| BLOCK | HEATING SAVINGS [%] | COOLING SAVINGS [%] | ORIENTATION |
|---|---|---|---|
| 1 | 20.4 | 8.3 | NE-NO |
| 2 | 20.6 | 5.9 | NE |
| 3 | 15.9 | 49.5 | SE |
| 4 | 31.4 | 31.2 | SO |
| 5 | 24.4 | 12.3 | NO |

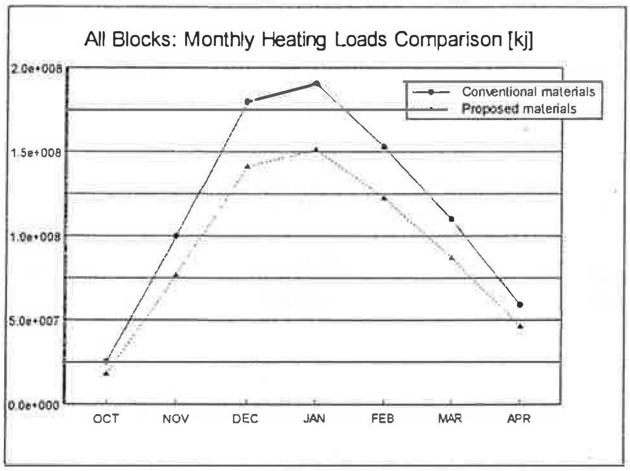
The second set of measurements was run for the whole five blocks. The simulations are performed for each block separately, since the control strategy for heating, cooling, ventilation and lighting will be different, according to different exigencies of the five companies, which occupy the five blocks. For each block the energy loads are calculated considering first the building equipped with traditional components and materials (solution A), then with innovative solutions (solution C). In Table 5 are reported the percent energy savings achievable in the single blocks during the hot and cold season, improving the envelope materials and components. It must be noted that the annual loads do not coincide with the sum of the selected months, since, even during the winter (summer) period, a small cooling (heating) demand could exist.

Table 6: Monthly heating loads

| Month | Heating loads old [kJ] | Heating loads new [kJ] | Savings [%] |
|---|---|---|---|
| OCT | 2.5E+07 | 1.8E+07 | 29 |
| NOV | 1.0E+08 | 7.7E+07 | 23 |
| DEC | 1.8E+08 | 1.4E+08 | 21 |
| JAN | 1.9E+08 | 1.5E+08 | 21 |
| FEB | 1.5E+08 | 1.2E+08 | 20 |
| MAR | 1.1E+08 | 8.7E+07 | 21 |
| APR | 5.9E+07 | 4.6E+07 | 21 |
| YEAR | 7.6E+08 | 6.4E+08 | 22 |

Table 7: Monthly cooling loads

| Month | Heating loads old [kJ] | Heating loads new [kJ] | Savings [%] |
|---|---|---|---|
| MAY | 2.0E+07 | 1.4E+07 | 33 |
| JUN | 5.8E+07 | 4.5E+07 | 22 |
| JUL | 1.2E+08 | 9.8E+07 | 18 |
| AUG | 1.2E+08 | 9.8E+07 | 17 |
| SEP | 5.6E+07 | 4.5E+07 | 20 |
| OCT | 2.6E+07 | 2.1E+07 | 19 |
| YEAR | 4.0E+08 | 3.2E+08 | 20 |



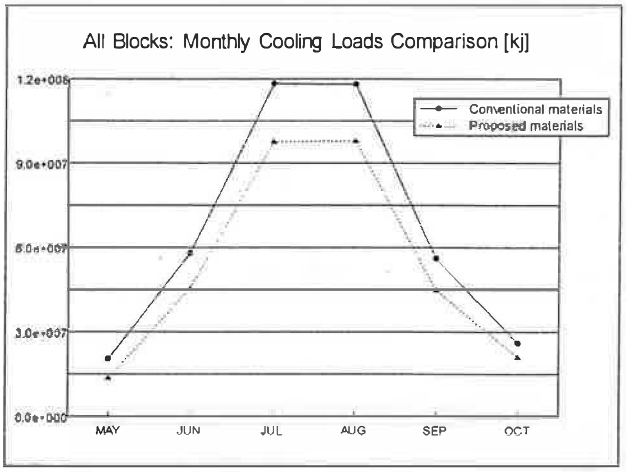




Figure 4: Monthly heating and cooling loads comparison for all blocks

More detailed analyses are presented in Tables 6 and 7, where the total heating and cooling needs are reported as a function of the month of the year. In Figure 4 the comparison plots are presented for both heating and cooling.

In Figure 5 the same kind of graph is reported for the heating season of block 1, facing north-east and north-west, where the energy savings are more significant, due to the better insulation of opaque and transparent component of the building envelope. Interesting results can be inferred from Figure 6 concerning block 3 simulations, facing south-east. In this case the shading effect of lamellae is important for reducing cooling loads, while the reduction of solar gains in winter is compensated by the better insulation properties of the windows.

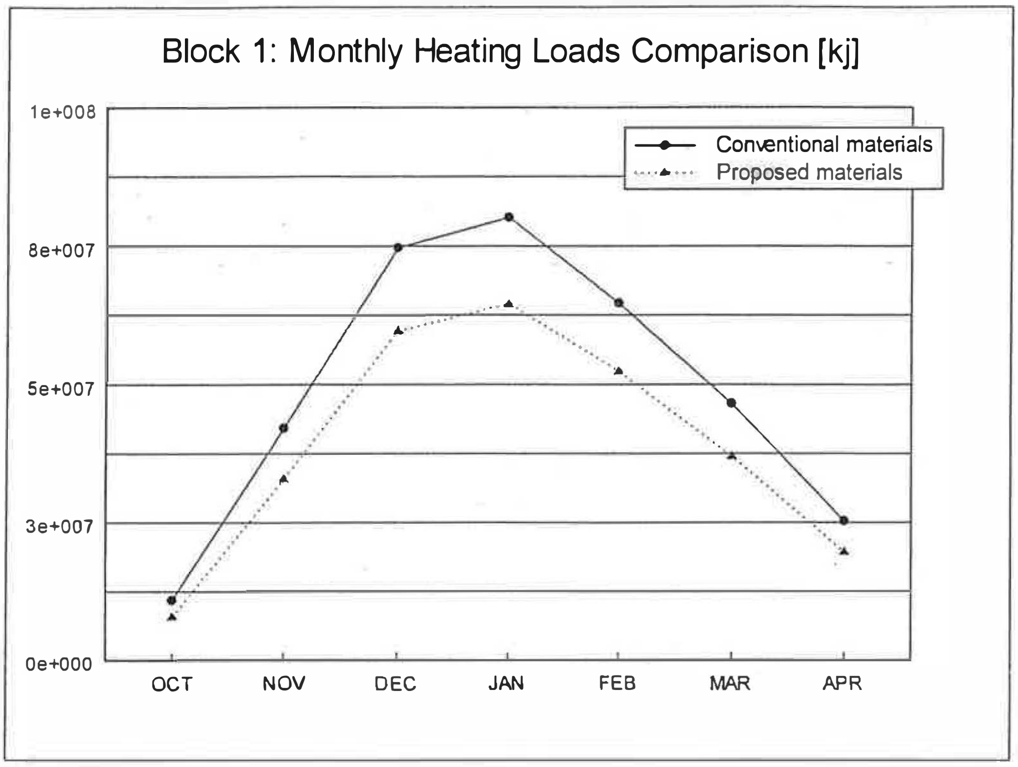



Figure 5: Monthly heating loads comparison for block1

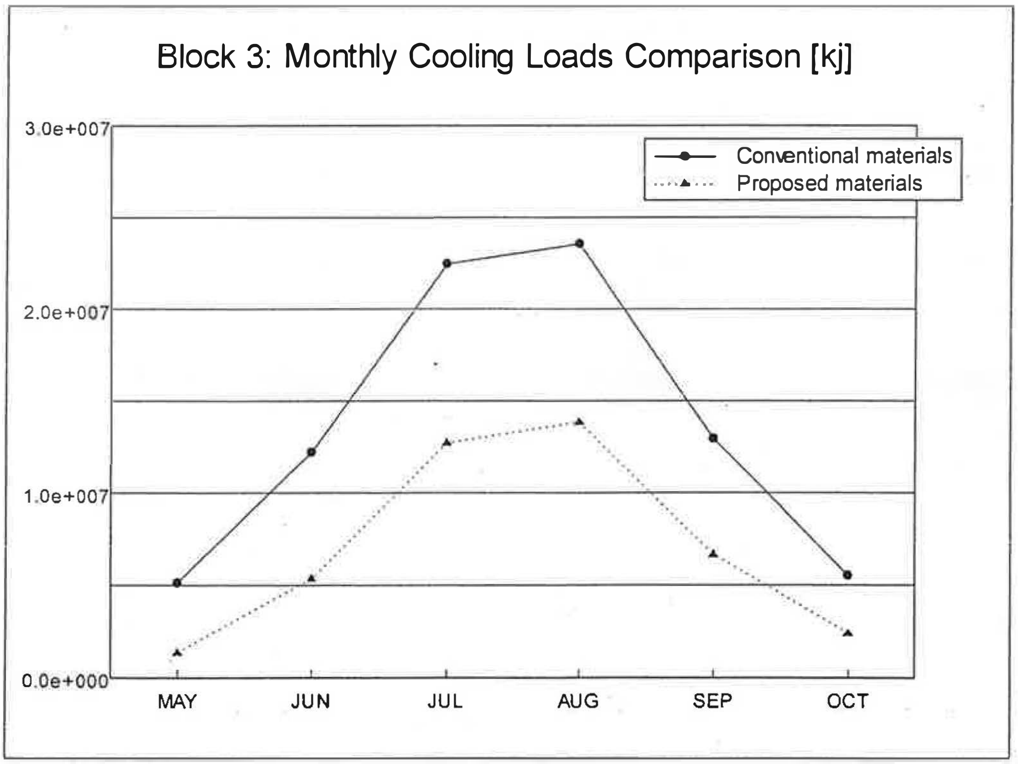



Figure 6: Monthly cooling loads comparison for block 3

## 7. CONCLUSION

The simulations, performed with two envelope options, allow verifying the efficacy of different materials and components selection. The results obtained and summarised at the precedent paragraph suggest the following conclusions:

- The parametric analysis showed that there is a limited level of insulation needed at Mediterranean latitudes. The adoption of high insulating opaque and transparent components leads to energy savings that do not justify the excessive first costs.
- During the winter season, improving the thermal loss properties of opaque and transparent components leads to energy savings of about 20%. Higher savings are obtained (about 35%) only for block three, because of the high ratio of the dispersing surfaces on the volume of the zone.
- During the cooling season only small savings (between 6 and 10%) can be obtained with the proposed components for block facing north-east and north-west. Conversely, for blocks facing south-east and south-west the savings are much higher, since the mounting of external shading devices can lead to savings of 40% or more. The average annual savings, as presented in the previous paragraph, are in the order of about 20%.
- The suggested solutions allow reducing the needs for heating, cooling and ventilation systems. Such reductions regard both the peak demand and the annual energy needs. This implies the reducing of the size of the conditioning system and the energy consumption throughout the year.
- The suggested solutions can be improved through the optimisation of user behaviour regarding, as an example, the regulation of the shading devices, according to weather conditions or the period of the year. In other cases the manual opening of the window by occupants can reduce the ventilation and cooling loads, this is typical for intermediate months, when the natural ventilation is an efficient substitute tomechanical devices.

The study, presented in this paper, stresses the importance of adopting advanced envelope components, by the way it must be noted that the amount of energy saved with these options is only a part of a wider strategy not considered in this analysis. Optimising the whole building-system, with advanced conditioning solutions (as ice storage for the cooling season, high performance boilers for the heating season) and control strategies by means of intelligent control systems, makes more consistent the annual energy savings to be achieved.

## REFERENCES


1. *Project T.I.B.E.R. (Technologically Innovative Building with Energy Rational Use): Activity Report n. 1 & 2.* Thermie Programme - Contract BU/163/98/IT, 2000.
2. *UNI 10249 – Riscaldamento e Raffrescamento degli edifici: Darti Climatici*, 1994.
3. *TRNSYS A Transient System Simulation Program - Release 14.2.* Beckman W. A. et al. Solar Energy Laboratory University of Wisconsin-Madison, 1996.