637: Low energy dwellings in Greece according to the Passivhaus Standard

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Abstract

The main research objective of this paper is to examine if the Passivhaus institute Standard for the construction of Low Energy dwellings can be applied in Greece, and how does this specification interacts with the architectural form. The various barriers technological and non will be introduced, with a preliminary assessment. The starting point of this research is the lack and the need of a National or NGO strategy - legislation for low energy consumption in residential buildings. The paper focuses on the evaluation criteria of the specific standard and the identification of determinative parameters of low energy strategy design in sub urban areas of Greece. For this scope, a house model is designed, according to the Greek Building Code for sub urban areas. The design represents our overall architectural approach for the relation of the house and its surrounding environment. We perceive the unification of the exterior and the interior through transitional multifunctional spaces. Dynamic simulations were performed using the TAS software compared with the results of PHPP. The study showed that the Passsivhaus Standard, with appropriate bioclimatic design, performs well at Greece regarding the buildings envelope and Life Cycle Energy consumption. However, further enhancement of the Standard is necessary to address the overall environmental impact of the buildings and the climate change consequences.
This study evaluates only the specific design. Detailed calculations are necessary for further evaluation.

Keywords: Passivhaus, Greece, Low Environmental Impact Homes, Bioclimatic Design

1. Introduction

The last years the increasing climate change mainly due to CO_2 emissions has driven for the discovery of new energy concepts in the building housing sector. The Energy Performance Directive supported these actions and promoted the construction of Low Energy Housing.
Northern and Central Europe made a lot of progress in the housing sector regarding carbon dioxide emissions. This is obvious not only by the Low Energy existing building stock, but also by the national legislation. In addition various voluntary standards are issued that are even higher from what is obligatory as minimum requirement. In Greece the situation is different. The dissemination of the Low Energy building concept is in a minor level. Further to that, the implementation of a Northern European Standard is faced with scepticism regarding the performance in a warm climate like Greece. This case study attempts to explore the potential and the necessary modifications for the implementation of Passivehaus as a Low Energy Consumption Standard in Greece.
For this, a design concept is introduced with maximum F/V ratio, extensive use of glazing and transitional multifunctional spaces.
This study attempts, through the specific case, to identify the interaction of the energy standard with the architectural form, and the necessary elements for the minimization of the overall environmental impact of the dwelling.

2. The Passivhaus standard

The Passivhaus Standard [1] is a widely recognized concept-method for designing and building low energy houses mainly in Northern and Central Europe. Furthermore, it is versatile, flexible in its implementation and easily adaptable. It allows freedom in architectural expression and therefore has good potential for a wide recognition by architects. Many examples exist already in Northern Europe and some also in the Southern parts and the Mediterranean. This gained experience and the available data [2] is insurance for the low energy performance of these buildings.

The main Evaluation Criteria for the certification of a Passivhaus are:

- Specific Space Heat and Cooling Demand max. 15 kWh/(m2a).
- Pressurization Test Result n50 max. 0,6 h-1.
- Entire specific Primary Energy Demand max. 120kWh/(m2a).

This study is concentrated on the evaluation of the first and second criteria.

3. Thermal Comfort.

3.1 Climate in Athens - Case study Site.

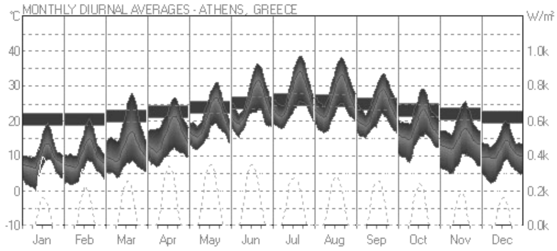

Fig 1. Monthly Diurnal Averages in Athens (produced in Meteonorm)

The site of this case study is assumed to be located at the outskirts of Athens. As shown in fig. 1, the climate of Athens is typical Mediterranean with short, mild winters and long hot summers. Average daily maximum temperatures exceed 30 °C for more than three months. Mean diurnal temperature differences in peak summer are often over 10 °C, thus providing a potential for night-time cooling. The solar radiation levels are high, both in winter and summer.

3.2 Comfort Zone

The definition and the limits of the comfort zone are essential in order to assess the performance of the dwellings and the results of the simulations. Looking at the annual temperatures range (fig. 1), it is evident that the main concern when designing low energy buildings in Greece is to minimize the excess heat gains during summer when outdoors temperatures go beyond 30 °C for a significant time period. Therefore, the upper limit of the comfort zone should be cautiously determined.

For the specific project, the comfort model used is the Adaptive Model. Contrary to the Fanger Model, the Adaptive Model is recommended for spaces where passive cooling strategies are applied.

One of the initial concepts for the design of the dwellings was the interaction between the interior and the exterior space and ideally their unification at certain periods of the year. This obviously leads to the introduction of passive cooling techniques for the summer comfort of the users. In addition to that, the Adaptive Model takes into consideration not only the physical aspects of comfort but also the psychological. It is most suited for purposes where the users interact with the building environment, and they have the ability to change the conditions of the space in order to feel more comfortable. Besides, case studies and research have shown that people are more tolerant to temperature swings when they are aware that they have the opportunity to change the conditions, even if this opportunity is not finally taken. (Yannas, et al. 2000). This is exactly what the conditions in the dwellings are intended to be. An environment with adaptive opportunity to the external conditions and user friendly building controls. The adjustments that can be done by the users in this dwelling in order to feel more comfortable are quite plentiful:

- Solar Control with the implementation of a second skin. Adjustment of the external louvers for sun protection or sun allowance.
- Ventilation levels control by opening or closing the windows, since windows are carefully designed and dimensioned for such purposes.
- Occupy parts of the house or outdoor space where, according to the time or season, conditions are more comfortable
- Use fans to enhance ventilation. Choice of clothing according to the weather conditions.
- Apply simple cooling techniques (e.g. evening watering of exterior spaces) to moderate the microclimatic conditions of the courtyard and semi exterior space at hot summer days and thus, affecting indoor conditions.
- Have cold or hot drinks anytime needed.

The close relation and response to the external conditions is also beneficial because it's been observed that in free running buildings the comfort temperature is strongly related to the past outdoor temperature (Humphreys, 1978).

Previous research (Givoni, 1998) shows that for dry summers under still air conditions (i.e. spaces with windows closed) people can feel comfortable even at 28°C. In addition, when roof fans are installed instead of air-conditioning systems, the limit of 28° C can be extended even to 29 °C. (Rohles 1983). With the use of fans temperatures of 29°C can be perceived as 24 °C.

Although ceiling fans are a low energy cooling method, the definition of the upper limit comfort zone was done without taking their performance into consideration. Therefore, taking as a fact that during the summer the relative humidity is rather low in Athens, the upper limit of the comfort zone is chosen to be 28 °C.

4. Case Study

4.1. Design principles and objectives.

The proposed Passivhaus design goes beyond the current practice demands and trends. It aims to redefine contemporary housing in Greece by introducing an alternative approach of luxury through an overall Low Environmental Impact attitude.

The "house" is perceived as a fold of Earth, the continuation of its surroundings. The design pursuits the unification of the interior and the exterior space, through transparency and versatility.

The minimalist approach of the design is integral and extends beyond the form. It covers all aspects of environmental footprint including energy demand for construction, life cycle energy consumption, water and waste management, reuse and recycle of materials.

The design objectives are:

To establish a sustainable level for the rational use of natural resources, materials, energy and water.
To provide an affordable and accessible home with high environmental values and high levels of human comfort.
To respond to the increasing demands of a high environmentally aware society.

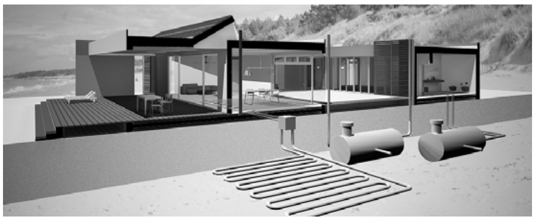

Fig 2. Perspective section of the case study house.

4.2 Buildings Layout

The case study is a single storey residential building of 198 m2 occupied area. This is the max allowed built area in plots of 4000 sq m. in suburban areas according to the Greek Building Code. Nearby buildings are assumed not closer than thirty meters radius.

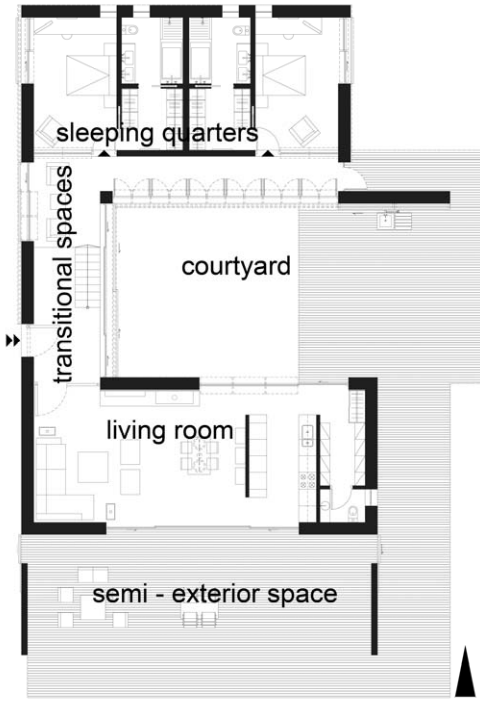

Fig 3. Organization of the plan

The house consists of three volumes: the sleeping quarters, the living area and the transitional space. They are placed at the perimeter of an open air courtyard facing east. A semi-exterior space facing south is positioned in front of the living room.

The percentage of glazing (glazing to wall ratio) on the facades is as following: 60% on the south façade, 20% on the north façade, 15% on the East façade and 10% on the west façade.

4.3 Incorporated Material

The incorporated materials are chosen according to market availability, common practice techniques and Life Cycle Assessment for minor environmental impact.

Table 1: Materials Used for Tas Simulations

ROOF	
layer	**thickness**
concrete	200 mm
insulation	300 mm
pebbles	100 mm
u-value: 0.103 W/m2K	

EXTERNAL WALLS	
layer	**thickness**
insulation	110 mm
plaster	5 mm
concrete	200 mm
u-value: 0.26 W/m2K	

GROUND FLOOR	
layer	**thickness**
wood	20 mm
concrete	150 mm
insulation	0mm
u-value: 0.5 W/m2K	

GLAZING	
low-e	6 mm
space	16 mm
clear float	4 mm
space	16 mm
low-e	6 mm
g-value: 0.5 u-value: 0.53W/m2K	

5. Low Energy Strategy

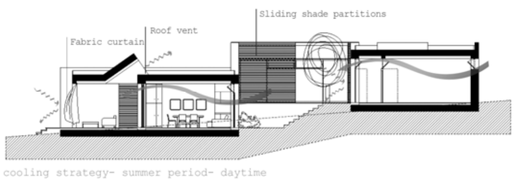

Fig 4. Cross section at the N-S axis

The defining strategies that contribute to the Low Energy Consumption of the dwelling are:

- Layout Organization
- Fabric Qualities
- Ventilation and Solar Control strategy
- Active / Hybrid Systems

5.1 Layout organization strategy

The proposed layout consists of a main courtyard with the circulation zone set on the perimeter. Living areas are placed around the courtyard with a semi exterior space facing South in front of the living room. The main organization of the dwelling was decided upon the shadow patterns and solar access. At summer period, during morning, the south part of the courtyard is in the shade creating a cool space for the occupants to take their breakfast. After 12.00 o'clock the shadows moves to the semi exterior space, at the South and the occupants can move there for lunch and evening siesta.

The main area of the courtyard is exposed to direct solar radiation for most part of the year and so are the transitional spaces at the perimeter. These multifunctional spaces act as buffer zones.

During heating period the glazed buffer zone collects heat gains and the hot air is transferred to other areas of the house. During summer period, the glazed partitions are parked on the side and the external louvers form a second skin providing shaded transitional spaces, promoting air circulation.

The layout promotes rain water collection from the roofs and the installation of biochemical treatment for human waste.

5.2 Fabric Qualities

The buildings envelope behaviour with respect to the thermal performance and air tightness is of significant importance to meet the Passivhaus criteria. Therefore, at this case study, the incorporated materials and the construction techniques respond to these requirements.

The main deviations of the proposed construction system, from the current practice, as identified by this study, for the various building elements are:

- Roof construction

Thermal insulation increased thickness from 80mm to 300 mm.

- Walls

Thermal insulation installed at the exterior of the building, instead of the brick wall cavity with increased thickness from 25mm to 110mm. Exposed concrete walls instead of brick cavity walls for increased thermal inertia, faster construction times and cost reduction.

- Floor slab

Positioned on the ground without insulation, to utilize ground as a heat sink.

- Window frames and glazing

Triple glazing, where a double glazing is the most common practice. Window frames placed directly on the concrete frame instead of windows sliding in the wall cavity

- Solar Control elements as a second skin

Solar control blinds are installed at the external skin avoiding the penetration of the building. The current practice dictates the installation of aluminium roller blinds at the inside of the building over the opening, while the blind slide to the outside. This practice generates thermal bridges and very high infiltration rates.

The above mentioned measures, accompanied by the appropriate detail design, improve the overall performance of the building, leading to thermal bridge-free construction with improved air tightness. In addition, the initial cost of these deviations from current practice, estimated at less than 2%, is of no significance.

5.3 Ventilation and Solar Control Strategy

For the reduction of heating and cooling loads the applied method is the extensive exploitation of the local climatic conditions through appropriate architectural design. The following elements are implemented:

Solar Control Elements

- Double skin façade composed by sliding external louvers.
- Deep overhangs south oriented for summer shading. Length/height ratio>1.
- Extend use of glazing, South oriented to enhance solar heat gains at winter period.

Cooling Elements

- Appropriate window design and dimensioning to promote cross ventilation and night cooling.
- Roof openings at semi exterior space for the dissipation of excess hot air.
- Thermal inertia of interior skin.

5.3.1 Cooling Strategy

Passive cooling is the primary cooling technique for the dwellings. Natural ventilation is achieved by opening the perimeter windows at the buffer zones and the tilt windows at south and north facades. This way cross ventilation occurs. During summer, the glazed areas of buffer zones are covered by the sliding louvers partitions, while glazed elements remain open all day. The moveable external partitions are shading East and West facades for 90% of the day.

According to the climatic data, two different cooling strategies are applied in two different summer periods.

Looking at the mean monthly temperatures in figure 1 it is clear that, for a long period of the year, the outdoor temperatures are within the comfort zone (i.e. between 20-28 °C), This is the summer period A (in general April, May, June, September, October) when natural ventilation is used in order to remove excess heat gains.

In summer period B (mainly July, August) it is evident that during daytime, temperatures go beyond 30 degrees, whereas night-time temperatures are often within the comfort zone. For this summer period, night cooling is applied. By utilizing the Fabric energy storage of the interior exposed concrete the buildings mass cools down during night time so that the next day radiant temperature is significantly lower. Inner ambient temperature is kept within the thermal comfort zone most of the summer period (figure 7). At this period, when air changes during daytime have to be reduced, glazing panels and shading louvers are both closed, thus maintaining lower radiant temperatures.

5.3.2 Heating strategy

The exploitation of solar heat gains through the extensive South oriented glazing is the main heating strategy.

Sun beams are penetrating deep into the core maximizing solar gains. The high thermal inertia of the interior exposed concrete promotes passive solar gains.

The super insulation of the external fabric minimizes heating and cooling losses.

The hot air from the buffer zones is redirected to the bedrooms and living room rising the resultant temperature of the rooms.

6. Performance

The performance of the dwelling is simulated with TAS and PHPP software. The model is divided to three thermal zones, buffer zone, living room, and sleeping quarters.

For winter period (Fig. 5) the results show that the temperature for the rooms ranges between 19 and 24 °C, while the temperature in the buffer zones range between 23 and 32 °C. The affect of the buffer zones in the resultant temperature of the other two zones was not calculated at this stage.

For summer period A (Fig. 6) the resultant temperatures are within the comfort zone for the whole period.

TAS simulations show that for summer period B inner temperature rises to a maximum of 29.5 °C, while the exterior rises to 40 °C (fig 7).

Ceiling fans are necessary only for a few hours during midday.

The preliminary results are satisfactory. Further dynamic simulations will follow to finalize outstanding issues.

However, as the analysis shows the heating demand of this case study is at least 80% less from the current practice. It remains in the future (after the completion of the first buildings) to verify on situ through detailed analysis the actual performance of these buildings.

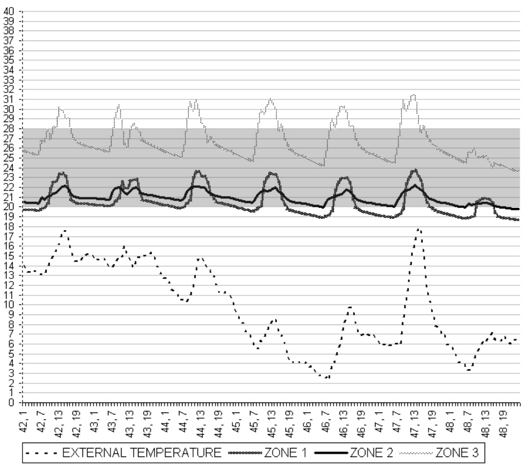

Fig 5. Daily temperatures for a typical week in February (11-17 Feb)

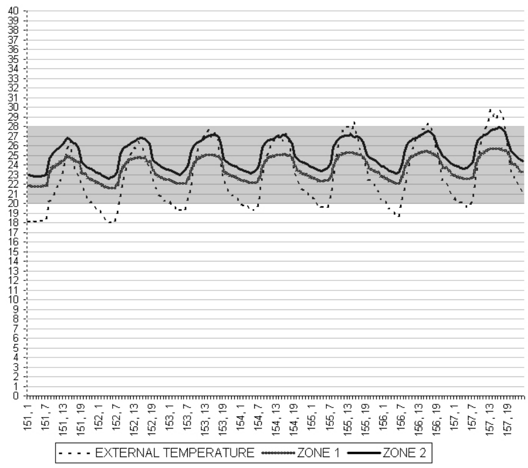

Fig 6. Daily temperatures for a typical week in June (31 May – 6 June)

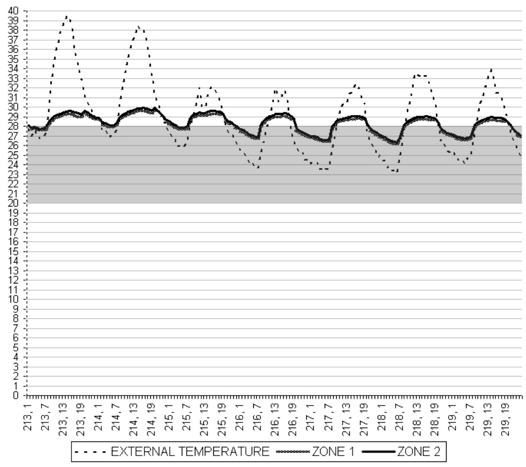

Fig 7. Daily temperatures for a typical week in August (1-7 Aug)

7. Barriers- Infiltration and Air Tightness

The calculations were performed with the assumption that controlled infiltration is possible with natural ventilation and without the use of a mechanical system. Values were defined at 0.6ACH-1 during Winter period, at Summer B period 0.6ACH-1,during daytime and 6ACH-1 at night time, while at summer A period infiltration was set at 1,3 ACH-1.

To evaluate the Passivhaus Air Tightness requirement of n50 max. 0, 6 h-1, in respect with the case study, the current status of the Greek Market was examined.

However very few data are available for the air tightness of the building stock in Greece. A minor sample, from a research conducted by the University of Athens on forty residential houses in Athens using fan pressurization method, showed that Air Tightness (ACH50) value varied from 2 to 13 ACH50 with the highest concentration between 5 and 10 ACH50. The research showed no correlation between Infiltration and Air Tightness. [3]

At this point the Passivhaus Standard requirement of 0.6 ACH50 is considered a barrier. Further to that extreme air tightness without a mechanical ventilation system run the risk of bad indoor air. A more moderate value should be established.

8.0 Low Environmental Impact Homes.

Scientific evidence show that the environmental issues arising from the housing sector go well beyond the energy performance of the buildings. Carbon dioxide emissions are associated not only with buildings energy consumption but also with the incorporated materials and the overall eco impact of the building (excavations for basement construction, waste management etc).

The emissions from the incorporated materials, and the overall Eco-Impact of the building should also be taken into consideration and implemented by the Passivhaus standard [4]. The amount of the reduced CO2 emissions during the buildings' service life should balance the CO2 emissions, during the production and installation phase, of the incorporated materials.

Therefore, the evaluation and quantification of these factors is essential. To do so, the right tools must be easy handed to the architects and engineers.

On the other hand, Water management is becoming a major concern, not only for Greece, as a consequence of the climate change and the irrational domestic usage.

Disposal of human waste in the sea at the coastal area of Attica, as a result of uncontrolled urbanization and hotel establishment, has created an infectious environment for human activities.

With simple and applicable solutions like rain water collection and biochemical treatment of human waste, the study attempts to confront these issues.

Building Low Environmental Impact Homes requires that all factors, in addition to low energy consumption, are minimized and taken into consideration from early design stages.

The transition from The Passivhaus Standard to the enhanced Eco-Passivhaus Standard is of vital importance to address Climate Change effectively.

9. Conclusion

The study demonstrated that the Passivhaus Standard criteria for heating and cooling performance in Greece could be achieved under certain circumstances. The low tech, high concept requirements, as an entry level to Passivhaus, are of significant importance for the end user, who is called to make decisions for the implementation of these measures.

10. Acknowledgements

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