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An Environmentally Friendly Approach towards the Conservation of Vernacular Architecture

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Abstract**—**Contemporary theories of sustainability, concerning the natural and built environment, have recently introduced an environmental attitude towards the architectural design that, in turn, affects the practice of conservation and reuse of the existing building stock. This paper presents an environmentally friendly approach towards the conservation of vernacular architecture and it is based on the results of a research program which involved the investigation of sustainable design elements of traditional buildings in Cyprus. The research in question showed that Cypriot vernacular architecture gave more emphasis on cooling rather than heating strategies. Another notable finding of the investigation was the great importance given to courtyards as they enhance considerably, and in various ways, the microclimatic conditions of the immediate environment with favorable results throughout the year. Moreover, it was shown that the reduction in temperature fluctuation observed in the closed and semi-open spaces, compared to the respective temperature fluctuation of the external environment -due to the thermal inertia of the building envelope- helps towards the achievement of more comfortable living conditions within traditional dwellings. This paper concludes with a proposal of a sustainable approach towards the conservation of the existing environment and the introduction of new environmental criteria for the conservation of traditional buildings, beyond the aesthetic, morphological and structural ones that are generally applied.

Keywords**—**Bioclimatic, conservation, environmental, traditional dwellings, vernacular architecture.

I. Introduction

THE theories and practices on the conservation of historic and traditional buildings have, over time, been enriched in order to be adapted to the contemporary perceptions and socio-economic patterns of each time. Contemporary theories on sustainability, in relation to the natural and built environment, have recently introduced an environmental approach towards the architectural design, thereby influencing restoration practices and reuse of the existing building stock. The reuse of traditional buildings is, by definition, a sustainable approach to the built environment based on the utilization of existing building shells, as opposed to erecting new structures, leaving, in the process, a significantly smaller environmental footprint.

An environmentally friendly approach, to the conservation of existing traditional buildings, aims to maintain and enhance their existing bioclimatic characteristics as well as to further improve their environmental status.

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This paper is based on the results of a research program, funded by the Republic of Cyprus and the European Regional Development Fund through the Cyprus Research Promotion Foundation, which investigates the implementation of sustainable design elements of vernacular architecture in the rehabilitation of traditional buildings in urban areas of the island [1]. The program has focused on the identification and preservation of the factors and elements that contribute to the improvement of thermal comfort within urban traditional buildings in the historic centre of Nicosia.

An environmentally friendly conservation approach of traditional buildings aims to preserve and reveal their existing bioclimatic characteristics, as well as to enhance their environmental character. The aim of the present paper is to propose a sustainable approach to the existing environment and to introduce a series of environmental criteria in the conservation and restoration process and practices of traditional buildings, which will benefit society as a whole.

II. Urban Vernacular Architecture of Cyprus

The vernacular architecture of Cyprus derives from the local lifestyle and socio-economic factors and is adapted to the surrounding environment by the use of local resources [2]. The original traditional building types of urban centres (e.g. Nicosia) were similar to those of typical rural houses of settlements in the plains [3]. Houses occupied a large area and were positioned in such a way that the longest façade of the house, or the main part of the courtyard, had the optimum orientation. Individual rooms (closed and semi-open spaces) were arranged around a large irregular yard [4], [5]. So long as the degree of urbanization, and the availability of the space, did not impose any restrictions, the criterion of orientating the buildings was primarily climatic; hence factors such as sun shading and cross ventilation additionally played an important role [3].

As a result of the development of urban centres in the 1920s and 1930s, there emerged the necessity of building in direct contact with the street which gradually undermined the importance of environmental criteria [6], [7]. The urban tissue acquired a more compact built form with dwellings following the continuous building system. Courtyards, located at the back of the plot, continued to play a very important social and environmental role in the arrangement of the house, as most of the everyday activities took place in this area, as a space of socialization, due to the warm Mediterranean climate.

The semi-open covered spaces, usually located along the south side of the building, locally referred to as *iliakos*, continued to be present as part of a cultural expression of the Mediterranean way of living [6].

With regard to the typology, the three main categories of building plans are: the I-shape, as a more compact and simple form of linear placement of the individual spaces, and the U and L-shape typologies, as the prime evolutions of the I-shape [3]. By consequence, the surrounding buildings occupy one, two or more sides of the yard. The L-shape is, in fact, the most common arrangement recorded at nearly half of the dwellings in the urban centre of Nicosia.

The central part of the building volume, in relation to its interior arrangement and subdivision, can be further differentiated into the single bay (monochoro), double bay (dimeres) and triple bay (trimeres) type. The triple bay prevails in the urban area of Nicosia and, by extension, in the sample under study, representing about 75% of the dwellings. This arrangement offers a very convenient solution to the entrance of the house through the central bay, which functions as an intermediate closed, or semi-open, space that crosses the dwelling. Through this space, called *portico*, access from the street to the courtyard is achieved. Additionally, this space gives access to the rest of the rooms arranged on its two sides [6].

III. Methodology of Research

In order to draw conclusions on the thermal performance of traditional buildings, two areas in the historic centre of Nicosia, i.e. Chrysaliniotissa in the walled city of Nicosia and Kaimakli, were investigated and an appropriate sample of 111 buildings has been selected for research and monitoring in relation to their environmental characteristics (Fig. 1).

Fig. 1 Kaimakli area in the historic centre of Nicosia

In particular, the buildings were selected taking into account the typology, construction, location, existence of specific topographical characteristics or subsequent interventions; all of which have allowed a comparative assessment of the buildings and thus the drawing of reliable conclusions (Fig. 2). The data collected were tabulated and encoded for comparative investigation and analysis [6]. These recordings defined the basis for the selection of a number of characteristic buildings for further detailed examination and research. Activities of the local occupants and human parameters (closed and open windows during the day and night, clothing, other activity etc.) were also examined and assessed with regard to the satisfaction of biological and psychological conditions. Questionnaire-based research provides valuable information regarding the way occupants use their houses in relation to heating, cooling and lighting, in order to achieve comfortable living conditions. The second stage of research included the selection of a smaller number of representative buildings (14) for an in-depth analysis. Quantitative data were collected through extensive recordings of climatic and environmental conditions for a period of an entire year. In the 14 buildings under investigation, data loggers were placed in selected indoor and semi-open spaces in order to record temperature and relative humidity levels. At the same time, weather stations were installed in the two areas under study in order to record the external environmental conditions. The objective of the research was to relate the architectural characteristics of the case-study buildings, as well as integrated bioclimatic principles, with the thermal performance of the buildings in question. More specifically, the analysis of the architectural and environmental data of the buildings under study enabled the identification of the number of factors affecting the thermal performance of each building, which are (i) the typology of the building, (ii) the current condition and the level of the building's maintenance, (iii) the building materials, (iv) the orientation of the building and (v) the living pattern and the users' contribution in obtaining thermal comfort.

The sample selected includes 12 residential buildings, one or two storey buildings, as well as two mansions, one of which is currently being used as a hostel and the other as a cultural centre of the University of Cyprus.

Based on the recordings of the environmental data in the selected sample, conclusions were drawn which demonstrate the environmental behavior of traditional buildings.

(a) (b) (c)

Fig. 2 Traditional buildings in the historic centre of Nicosia

IV. Research Results

The analysis of the data gathered showed that special emphasis in Cypriot vernacular architecture was given on the cooling rather than the heating strategies [7]. The hot climate of the area probably led to the enhancement of cooling strategies through cross ventilation and stack effect (appropriate location and size of openings) as well as shading (pergolas, shutters, iliakoi etc.). The great importance of the courtyards is further reinforced by this investigation.

These spaces offer a number of environmental advantages related to the microclimatic conditions of the immediate surroundings offering favourable results during all periods of the year; i.e. by ensuring direct solar gains and cross ventilation in the spaces around the courtyards, as well as by the presence of vegetation and water features. Moreover, the reduction in temperature fluctuation observed in the indoor and semi-open spaces (iliakos and portico), compared to the respective temperature fluctuation of the external environment, creates more comfortable living conditions within traditional dwellings [8].

At all periods of time during which temperature data recording was conducted, a much smaller temperature fluctuation within the interior space was recorded, compared to that of the external environment [8]. This demonstrates the thermal protection provided by the traditional building envelope in relation to diurnal temperature fluctuation of the external environment. The reduction of temperature fluctuation underlines the importance of the thermal inertia of the building envelope, as a result of high thermal capacity of the building materials used in traditional architecture [8], [9]. Indicatively, it is noted that, during the interim period (March 2013) the recordings in the building that is used as the University of Cyprus Hostel (A30), showed average diurnal temperature fluctuation of 2 ^{o}C for indoor spaces and 7 ^{o}C in the southern semi-open spaces (iliakos) while, at the same period, the temperature fluctuation in the external environment was 13.7^{o}C (Figs. 3 and 4). This is due to the large thermal mass of the traditional construction which reduces the diurnal temperature fluctuations, since thermal mass absorbs thermal energy when the surroundings are higher in temperature while it gives thermal energy back when the surroundings are lower in temperature than the mass of the structure [1], [10].

The outdoor and semi-open spaces of traditional buildings, i.e. courtyards and iliakos, contribute to higher average temperatures during the heating and interim period, compared to the temperatures of the external environment. Higher temperatures in open-air and semi-open spaces were recorded during the cooling period, resulting from insufficient shading and ventilation. The study regarding the contribution of semi-open spaces was conducted through a comparative study of two buildings in the region of Kaimakli i.e. B35 and B40 (Fig. 5). The investigation showed that the semi-open space which is adjacent to a pass-through semi-open space (iliakos in contact with a portico) of building B35 ensures reduced maximum temperatures in comparison with the semi-open space (iliakos) of building B40; a fact indicating the contribution of cross-ventilation in minimizing extreme temperatures. The reduction in the average maximum temperature in the semi-open space (iliakos) in question, compared to the corresponding temperature of the external environment for the recording period of August 2013 varies around 1°C. However, during the same time in this space, a higher average temperature was recorded during the 24-hour period compared to the corresponding temperature of the external environment.

Consequently, the research showed that the bioclimatic function of the semi-open spaces is related to the shading of the building's main areas, and by extension to temperature reduction of indoor spaces during the cooling period. In addition, a southern-oriented semi-open space (iliakos) contributes to a favorable microclimate during the heating and interim periods. Because of the thermal mass, it retains both the average minimum and average maximum temperature at higher levels than the corresponding values of the external environment.

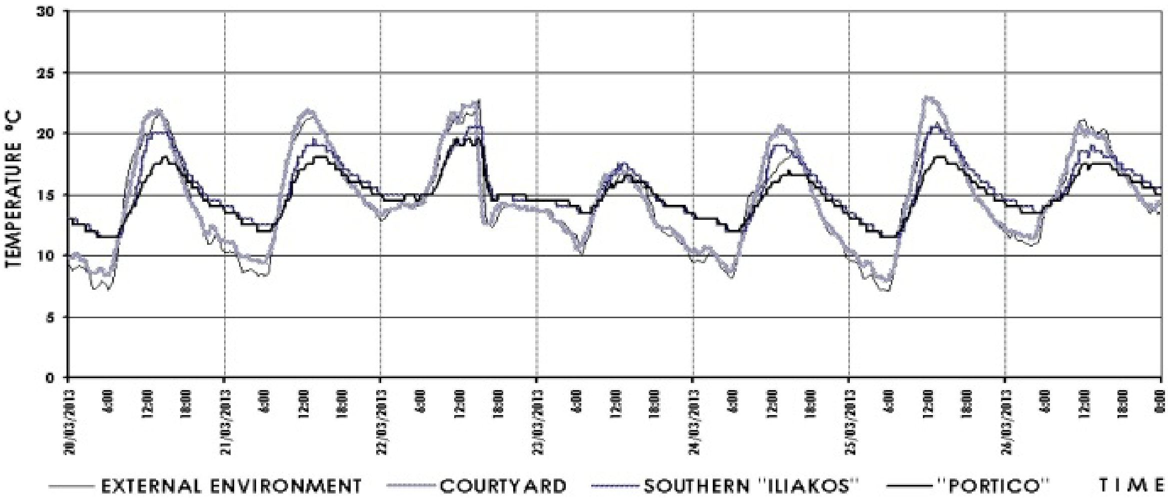

Fig. 3 Recorded temperature data of outdoor spaces i.e. courtyard, southern iliakos and portico of the University of Cyprus Hostel

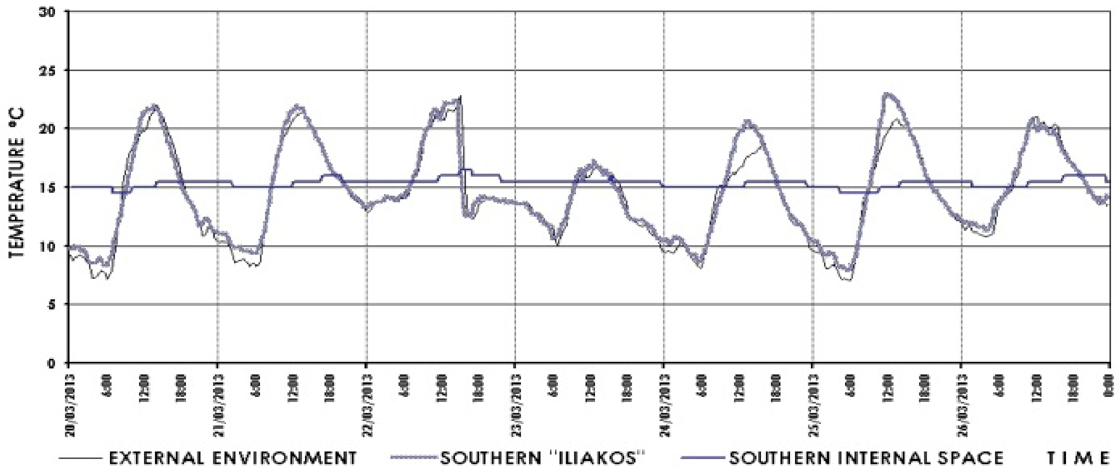

Fig. 4 Recorded temperature data of the southern iliakos and the adjacent internal space of the University of Cyprus Hostel

At the same time, the microclimatic conditions of the inner courtyard play a significant role in the thermal behavior of semi-open spaces [1], [11]. The courtyard of building B35 is covered by soil with many deciduous trees which provide shade during the cooling period and permit the entry of sunlight during the heating period.

Conversely, the inner courtyard of building B40 has minimal planting and is covered by hard surfaces of stone slabs and concrete; materials of high thermal capacity. The investigation showed over-warming phenomena in the open-air and semi-open spaces of building B40 during the hot summer months because of the high thermal mass materials of the courtyard.

Examining the role of the urban fabric and building density, it was established that there is a positive contribution of the continuous building (attached buildings) system that is applied in traditional urban tissues [1], [12]. The assessment of the continuous building system –as opposed to a free-standing building system– was made by comparing buildings B41 and B27 (Fig. 6). In the continuous building system, the surface of the building envelope exposed to the external environment is limited, which minimizes the heat flow to and from the external environment i.e. heat losses during heating periods and heat gains during the cooling periods respectively.

In particular, the thermal behavior of building B41, which is in a continuous building system, appears favorable compared to that of building B27 which is free-standing, recording a higher average temperature and less diurnal variation during the heating period. The recording made during the interim period, showed a difference of 1.5°C in the average temperature of the two buildings. During the cooling period, the building in the continuous building system (B41) showed a lower average temperature and lower diurnal fluctuation in relation to the free-standing building (B27). The recording made during this period showed the same difference of 1.5 °C in the average temperature of the two buildings.

The contribution of natural ventilation in shaping internal thermal conditions was investigated during the two extreme climatic periods in buildings B21 and B41 under study (Fig. 7). During the heating period, and in particular during the evening and night time, natural ventilation of the internal spaces of the buildings is not desired, as the temperatures of the external environment are far lower than thermal comfort temperatures, causing reduction of indoor temperatures and cooling of the building envelope.

Conversely, during the cooling period increased natural ventilation has a positive effect, especially during night-time, when the temperature of the external environment is lower than the temperatures of the internal environment. The utilization of night cooling as a passive cooling strategy through natural ventilation allows the escape of thermal energy, collected through solar gains and stored in the thermal mass of the building envelope during daytime.

Comparative recordings in buildings B21 and B41 under investigation, during the cooling period showed a decline of temperatures by 1.4°C in building B41, where the night cooling strategy was applied. However, ventilation during the cooling period days is not desired, as the temperature of the external environment is much higher than the temperature of the internal environment.

The proper application of the ventilation strategy discloses the significant role of the user of the building in ensuring adequate comfort conditions inside the traditional building shells. It is noted that, during the period of absence of the residents of building B41 (summer vacations during August) and by extension, during the absence of any form of ventilation of the traditional building, an increase by 0.6 °C in the average temperature of indoor spaces of the building was recorded.

The effect of contemporary interventions and alterations in traditional buildings has been a key axis of investigation in the present study. Initially, the effect of converting semi-open spaces into enclosed indoor spaces was investigated. The study was conducted through a comparative study of two south-oriented semi-open spaces (iliakos), one of which was closed by adding extensive glazing surface i.e. B30 while the other preserved its original state as a semi-open area i.e. B40 (Fig. 8).

Temperature recordings indicated the positive contribution of converting a south-oriented semi-open space into a closed indoor space during the heating period. Keeping glazing panels closed, direct solar gains enter the interior and are stored in the thermal mass of the building materials, thus ensuring higher temperatures in the indoor spaces (greenhouse effect).

On the other hand, during the cooling period, temperature recordings indicated the negative contribution of converting a south-oriented semi-open space into a closed indoor space, since the space suffered from overheating. During this period of the year, the removal of extensive glazing surface and the return of the space to its original semi-open state prevent undesirable overheating of the space.

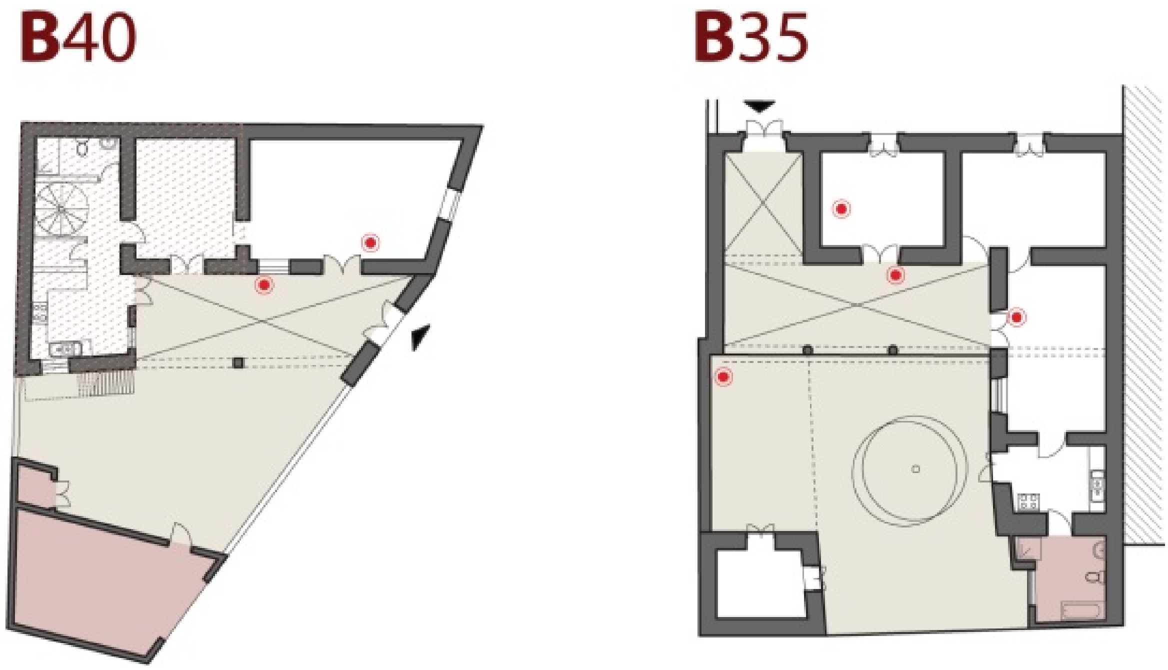

Fig. 5 Ground floor plans of buildings B35 and B40

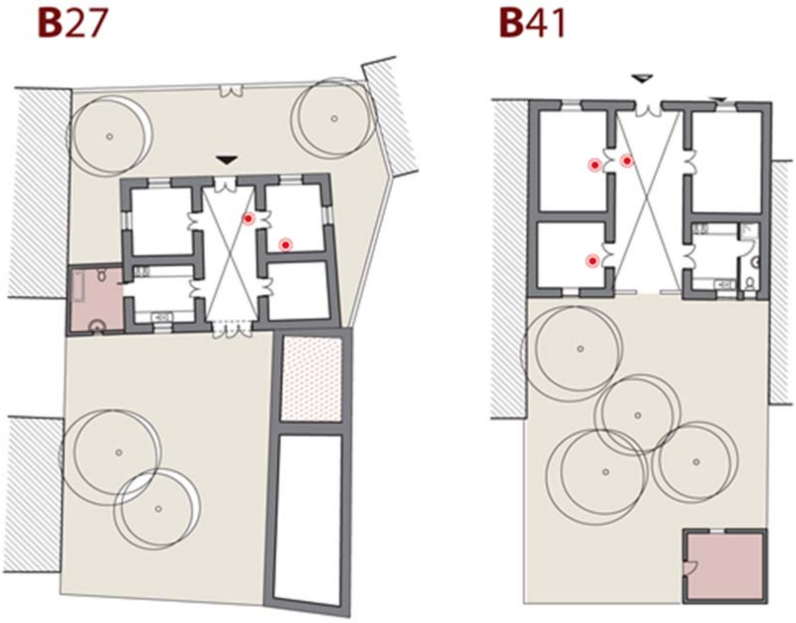

Fig. 6 Ground floor plans of buildings B27 and B41

The investigation of the conversion of the portico into a closed indoor space was conducted through a comparative analysis of the temperature data recorded in the porticos of buildings B24 and B55, south and north oriented, respectively (Fig. 9). The south oriented closed portico, (B24), exhibits a very positive attitude during the heating period. The existence of large glazing surfaces, facing south, results in the conversion of the space into a greenhouse and thus ensures significant potential for direct solar gain utilisation. In the cooling period, this space maximizes the collection and storage process of direct solar gains and, combined with the lack of shading and ventilation, results in space overheating. The north oriented closed portico (B55), exhibits lower levels of thermal comfort compared to the south-oriented portico (B24) during the heating period because of the lack of direct solar gains and of significant heat loss from the extensive glazing surface. In the cooling period, the portico facing north recorded lower temperatures compared to the portico facing south, while there appeared no overheating of the space.

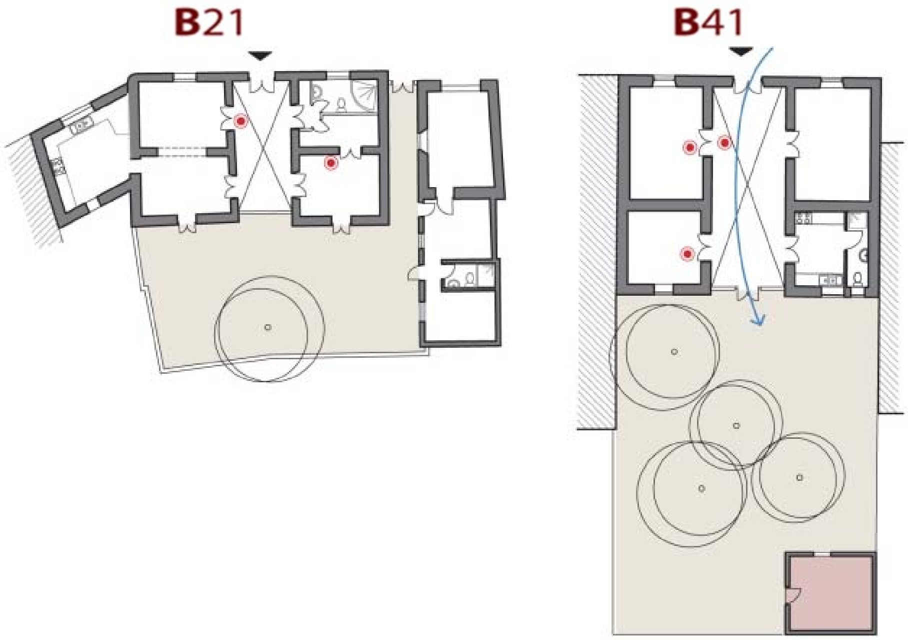

Fig. 7 Ground floor plans of buildings B21 and B41

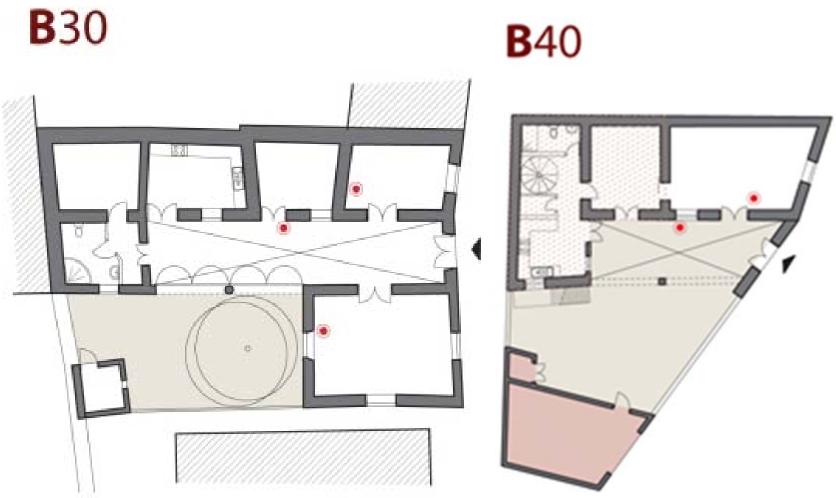

Fig. 8 Ground floor plans of buildings B30 and B40

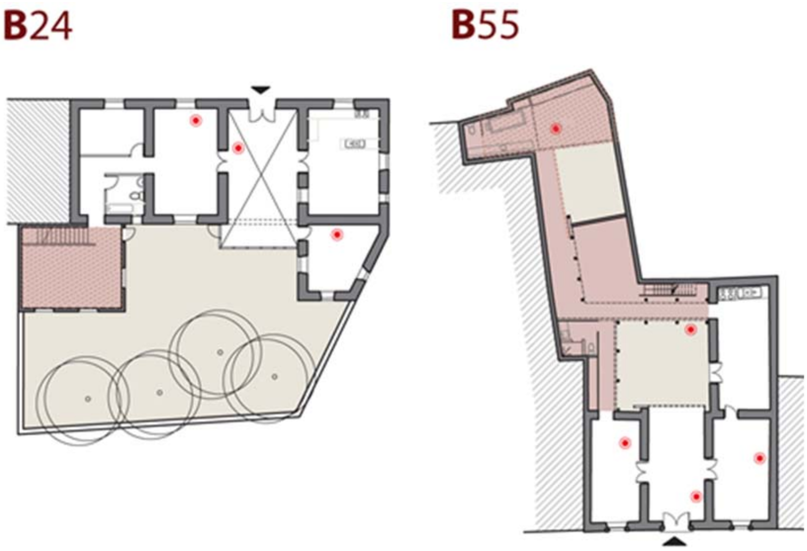

Fig. 9 Ground floor plans of buildings B24 and B55

V. Suggestions for the Maintenance and the Environmentally Friendly Restoration of Vernacular Architecture

The research carried out in the above mentioned program concluded with a series of suggestions for the maintenance and the environmentally friendly restoration of vernacular architecture and thus for the improvement of thermal comfort conditions and energy performance of traditional buildings. Proposals concerning the building envelope relate to the walls, the inclined and flat roofs and the openings.

Moreover, the interventions relate to individual spatial elements of vernacular architecture, such as semi-open spaces i.e. iliakos, porticos and courtyards.

A. Walls

The high thermal mass load bearing stone and mud-brick walls of a thickness of 50 cm ensures stable temperature conditions in the indoor spaces of traditional buildings (Fig. 10 (a)). The reduced temperature fluctuation recorded in indoor spaces of traditional shells, as opposed to a greater temperature fluctuation in the structures with lower thermal mass, as well as the temperature fluctuation of the external environment, is attributed to the high heat capacity of traditional masonry materials. This results to a time delay in the transmission of heat loads from the external environment to the indoor of the building. More specifically, during the heating period traditional masonry has the ability to delay the cooling of indoor spaces during the heating period nights when the temperature of the external environment is very low. This results in maintaining the indoor space often at a satisfactory thermal level during cold winter nights. During the cooling period, traditional masonry has the ability to delay heat of the indoor spaces, thereby maintaining, very often, sufficiently cool levels for the most part of the hot summer days. The maintenance of the heat capacity of the traditional building envelope during the restoration of a building is directly related to the maintenance of the original load bearing walls made of stone and mud-brick. The reconstruction of parts of the walls, where necessary, should be done using traditional building materials and techniques.

Apart from the high heat capacity of the masonry, substantial contribution to energy efficiency of traditional buildings derives from the exposure of the building envelope surfaces to solar radiation. In particular, the southern exposure of masonry ensures solar heat gains which are particularly desired during the heating period. Avoiding undesired heat gains –and therefore the overheating of indoor spaces during the cooling period– is ensured through the proper shading of southern surfaces. This can be achieved either through permanent shades, e.g. semi-open spaces (iliakoi) in front of southern walls or through, less permanent, devices such as lightweight structures with climbing deciduous plants.

B. Coatings and Plasters

The enhancement of the thermal performance of traditional constructions, in cases of coated masonry, can be achieved by using appropriate coatings with low thermal conductivity (Fig. 10 (a)). The use of lime coatings with suitable thermal properties in exterior surfaces ensures better thermal insulation characteristics of the wall and, by extension, improved energy efficiency of traditional buildings.

In interior surfaces, it is proposed that gypsum based coatings are used because of their compatibility with traditional materials; particularly with mud-bricks. The hygroscopic properties of gypsum coating; i.e. their capacity to absorb humidity from the environment, results in the reduction of relative humidity levels in the indoor environment, while further improving occupants thermal comfort, especially during the cooling period.

Addressing rising moisture is ensured through the use of appropriate hydraulic mortars, compatible with traditional materials, by creating, where necessary, moisture barriers in the construction, as well as by making suitable arrangements of the soil around the walls that allows the removal of soil moisture.

C. Flat and Inclined Roofs

The restoration of existing traditional flat and inclined roofs is achieved through the maintenance and reuse of original timber components that are in good condition and through the replacement of parts of the structure, where deemed necessary, with new ones, identical to the original (Fig. 10 (b)).

The integration of suitable insulating materials to the roof structure ensures the improvement of the energy efficiency of roofs of the traditional construction, with significant benefits during both the cooling and heating periods. Furthermore, the placement of traditional tiles on roofs and light-colored coatings on flat roofs ensures reflection of solar radiation.

Particularly widespread in the past was the shading of flat roofs with deciduous climbing plants in lightweight structures. Plant coverage gives protection to horizontal or slightly inclined roof surfaces from direct solar radiation during the cooling period, while ensuring insolation of roof surfaces and by extension providing indirect, solar gains during the heating period.

D. Doors and Windows

External shutters in the form of timber solid planks or movable louvers in the doors and windows of the traditional buildings constitute one of the main cooling strategies applied on vernacular architecture (Fig. 10 (c)).

The maintenance of these shutters during the conservation of traditional buildings ensures the partial control of natural ventilation and shading/insolation in accordance with the users' demands.

To improve the thermal performance of the building envelope, it is necessary to replace the single-glazed windows with double-glazed ones, placing them in more airtight frames than the original ones.

Moreover, the placement of a second glazed barrier on the interior side of external timber doors of the traditional building, leads to a reduction in thermal losses because it creates a more airtight frame. In the case of south oriented openings, the newly glazed surface enables direct solar gains which are particularly favorable during the heating period.

At the same time, appropriate shading of southern openings, by the use of external shutters, prevents overheating of indoor spaces of buildings during the cooling period. The existence of external timber shutters contributes favorably to appropriate shading in east and west oriented openings, while the presence of external shutters in north openings provides protection of the building shell from northern cold winds, prevailing during the heating period.

(a) (b) (c)

Fig. 10 (a) Load bearing stone and mud-brick walls, (b) Traditional flat roof, (c) External shutters in windows of traditional buildings

E. Semi-Open Spaces

Semi-open spaces, in the form of iliakoi and porticos, constitute an important environmental feature in traditional architecture as they create pleasant areas for everyday interaction for the most part of the year (Fig. 11 (a)). The closing of iliakos and porticos with glazed surfaces transforms semi-open outdoor into indoor spaces. Apart from the advantages relating to the functionality of the building, this transformation additionally affects the buildings' thermal performance.

The enclosed south-facing iliakoi and porticos offer significant heat gains, especially during the heating period, due to extensive southern glazing. To avoid overheating, the glazed surfaces should remain open throughout the daytime during the cooling period.

Furthermore, an external and/or internal, shading devise is necessary to be installed in order to minimize the undesired direct solar gains during the cooling period.

Appropriate shading may be achieved either by internal, movable shading systems, such as blinds and fabric panels, or by external lightweight structures such as blinds panels or pergolas.

On the other hand, enclosed north-facing iliakoi and porticos provide cooler and pleasant spaces throughout the cooling period. However, the conversion of a northern semi-open space into a closed one results in the creation of spaces with significant heat losses, due to the extensive glazed surfaces and therefore spaces with high energy requirements for heating during the winter.

F. Cross Arrangement of Spaces and Openings

A very common traditional cooling strategy is the cross arrangement of spaces and openings. The maintenance of the original cross arrangement of individual areas of traditional buildings can be achieved by preserving all original openings (Fig. 11 (b)).

Cross arrangement of spaces is of particular importance in achieving thermal comfort conditions during the cooling period, since cross-ventilation is an effective passive strategy for the cooling of the building shell. The preservation of the small operable openings placed high up on the walls (arseres) ensures the escape of hot air to the external environment.

In addition, it is not recommended to divide areas with cross openings, but if this is necessary for functionality reasons, a satisfactory solution is to reduce the height of wall partitions or to create openings on the internal partitions, thus maintaining the possibility of cross ventilation of the area.

G. Courtyards

The courtyard constitutes a very important environmental element in traditional buildings as it improves the microclimatic conditions of the building (Fig. 11 (c)). Maintaining the original soft surfaces in the courtyard of traditional buildings and avoiding hard surfaces with high thermal mass, has beneficial results in improving the microclimatic conditions of the immediate surroundings of the buildings, especially during the hot summer months.

In particular, soft surfaces, especially planting coverage, ensure reduction of courtyard overheating as well as of the surrounding spaces of the building, while reducing direct and reflected solar radiation. Moreover, courtyards – due to the transpiration of the plants and the evaporation of moisture retained in the soil or in pebble surfaces – ensure further reduction of the temperature of the intermediate environment. Conversely, hard surfaces lead to increased temperatures, even during the hours that the temperature of the external environment is reduced, as a result of the storage of thermal energy in building materials with high heat capacity.

The existence of water elements in the internal traditional courtyard, such as wells and water reservoirs, ensure cooling through evaporation, which is especially beneficial during the cooling period.

The creation of green surfaces by placing lightweight structures with climbing deciduous plants ensures the shading both of the traditional courtyard and the surrounding indoor spaces.

(a) (b) (c)

Fig. 11 (a) Semi-open spaces i.e. iliakos and porticos, (b) Cross arrangement of spaces, (c) Courtyard

VI. The Role of Users in Thermal Performance and their Interaction with the Building Envelope

An important role in improving comfort conditions and energy performance of traditional buildings is played by the users themselves, mainly through the implementation of cooling strategies i.e. ventilation by the proper use of openings, shading and insolation by the proper use of external shutters in openings, courtyard and plant watering etc.

Particularly important is the contribution of users in the cooling of traditional buildings. Night cooling is a key measure of passive cooling of the building envelope during the cooling period. More specifically, opening the windows of buildings during the night, when the temperature of the external environment is lower than the temperature of the indoor spaces, leads to the cooling of the building envelope and by extension to the reduction of indoor temperatures. The cooling of the building envelope leads to lower indoor temperatures even throughout the following day. Repeating this strategy for more than 24 hours leads to the maximization of the positive effects of night ventilation with further reduction of the temperature.

The proper use of external shutters of the openings in traditional buildings may contribute favorably to the thermal comfort conditions of users. In particular, closing external shutters during daytime in the cooling period, when high levels of solar radiation are observed, reduces undesired solar gains and prevents the overheating of interior spaces.

Conversely, the opening of external shutters during daytime in the heating period, especially when high solar radiation levels are observed maximizes direct solar gains, ensuring a positive contribution to the thermal performance of buildings.

Particularly important is the contribution of traditional external shutters with movable blinds, which ensure the appropriate inclination of the blinds according to users' demands. This arrangement of the blinds, apart from meeting issues of privacy and security of the indoor space, it enables insolation or shading and simultaneous ventilation of the building envelope.

The use of solid timber planks in the openings of traditional buildings –although it does not favor ventilation and precise control of insolation or shading– it ensures higher levels of thermal insulation of the building envelope against external environmental conditions. It should be noted that, all external shutters are made from timber; an environmentally friendly material with favorable thermal characteristics.

Finally, the users' habit to water plants and to wet soft and hard surfaces in traditional courtyards ensures cooling through evaporation and leads to improved microclimatic conditions of the immediate surroundings of the building.

VII. Concluding Remarks

An environmentally friendly approach towards the maintenance and restoration of traditional buildings is directly related to the preservation of the bioclimatic design strategies and the ecological principles that characterize them. The quantitative investigation carried out within the framework of this research has confirmed the environmental aspect of construction in vernacular architecture.

The application of basic principles of bioclimatic design, referring both to heating and cooling strategies of the building envelope, as well as to strategies for the improvement of the microclimatic conditions of the immediate environment, provides adequate comfort conditions in the indoor spaces of traditional buildings.

Additionally, the use of available local materials and construction techniques ensures beneficial effects in terms of thermal performance of the building envelope, and thus optimizing thermal conditions for the occupants.

Identifying and investigating the environmental features of traditional architecture has allowed the drafting of proposals which aim at an environmentally friendly restoration of traditional buildings and complexes.

The proposals refer to the incorporation of environmental criteria in the conservation and restoration practices of traditional buildings as well as in the construction of contemporary additions in buildings or new building units in traditional settlements, leading to a sustainable development of the built environment.

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